Public Debt and Economic Growth nexus: A Dynamic Panel ARDL approach

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1 Introduction

In the aftermath of the 2007 global financial and economic crisis, the level of global public debt has increased significantly. According to the Bank for International Settlements (BIS), by mid-2017 global government debt reached $60 trillion, which is more than double the debt registered in 2008. The post-2007 worldwide economic turmoil also instigated the European sovereign debt crisis, where several countries across Europe experienced record high levels of government debt, the collapse of financial institutions and an increase in government bonds yield spreads.

This upsurge in global public debt has led to the revival of the academic debate on public debt and economic growth nexus. In fact, the sustainability of debt dynamics has gained significant importance and has been at the heart of the economic policy debate over the last decade. With global debt levels well above those registered in 2008, it is vital to analyse the repercussions that government debt has on growth. Empirical research in this area is key to identify the policy recommendations needed to avoid another economic crisis.

As highlighted by Checherita and Rother (2012), Baum *et al.* (2013) and Woo and Kumar (2015) there is a limited number of empirical studies that discuss the debt and growth nexus. This is explained by Abbas and Christensen (2010) as they identified several factors which led to the lack of interest in analysing the impact of debt on growth. The primary reason is the fact that researchers faced data availability constraints as time series data on public debt for a panel of countries is scarce. Also, prior to the global economic crisis, debt was not considered as problematic since debt levels in most developed countries were quite low. As a result, prior to the crisis, empirical literature focussed on the issue of external debt in low income countries and emerging economies (Krugman (1988), Clements *et al.* (2003), Schclarek *et al.* (2004)).

Given that the situation has changed globally and high levels of public debt are prevalent, research in this field has gained momentum in recent years. Following Reinhart and Rogoff's (2010) analysis on how high levels of debt negatively impact growth, subsequent empirical literature mainly discussed whether public debt accumulation beyond certain levels stifles growth. As a result, the economic debate centred around the nonlinear concept between debt and growth. This is often referred to as the inverted U-shape relationship where beyond a certain tipping point, higher levels of public debt impact economic growth negatively. However, most literature has failed to address other important questions. Firstly, there is lack of empirical evidence on whether public debt hinders or stimulates growth over the short- and long-term. Secondly, there is limited literature on the direction by which the implicit causality between debt and growth runs. Finally, even though European countries were severely affected by the European sovereign debt crisis, few empirical studies analyse individual European Union member states or the European Union as a whole.

This study uses data from 25 European Union member states over the 1996-2017 period. The contribution of this analysis is threefold. Firstly, this empirical analysis differs from previous literature in its methodological approach as it uses a panel time series autoregressive distributed lag (ARDL) model as proposed by Pesaran and Shin (1998) and Pesaran, Shin and Smith (2001). Hence, the model is data-driven and therefore is appropriate in analysing the relationship between the variables under study. Through a panel ARDL model the short- and long-run impact of public debt on economic growth are determined. The panel ARDL model is estimated for the full sample and also for two subgroups; one consisting of countries with high average levels of debt and the second consisting of those with and low average levels of debt. Secondly, a sensitivity analysis is carried out to identify whether this relationship changes across time due to major economic events. Finally, unlike most of the empirical literature, this study does not assume a unidirectional causality between debt and growth. Therefore, the Dumitrescu Hurlin panel causality test is used to test for bidirectional causality between the two variables.

The rest of the paper is organized as follows. The second section discusses the relevant theoretical and empirical literature as well as its limitations. Section 3 explains the data used and provides a brief overview of the main stylized facts. The fourth section discusses the methodology used. The penultimate section presents the empirical results of the panel ARDL estimations, sensitivity analysis and the panel granger causality test. Finally, the conclusion gives a brief discussion of the findings and provides some policy recommendations.

2 Literature Review

2.1 Theoretical Literature

There are three theoretical viewpoints that explain the public debt and economic growth nexus. The first school of thought is known as the Keynesian hypothesis. Through an Investment Savings-Liquidity Preference Money Supply (IS-LM) model Keynesian economists illustrate that there is a positive association between debt and growth. They demonstrate that public debt induced by a debt-financed fiscal policy leads to an expansionary effect on the economy. In fact, these theorists argue that budget deficits lead to an increase in aggregate demand. This in turn generates higher levels of income and transactions demand for money and prices. In light of these economic factors, interest rates rise prompting higher levels of savings and investment (Van and Sudhipongpracha, 2015). Nevertheless, this positive impact can only be triggered if the finance obtained from public borrowing runs in parallel with productive government spending including investing in infrastructure, health and education.

The second school of thought is associated with neo-classical and endogenous growth models (Modigliani, 1961; Diamond, 1965; Saint-Paul, 1992; Aizenman *et al.*, 2007). These theorists suggest that high levels of public debt are detrimental to growth. Contrary to the Keynesians, these theoretical models show that public debt crowds out private investment through higher levels of interest rates. The hypothesis of these theorists is that budget deficits hinder personal savings as private consumption increases, generating a decline in economic growth. In addition, the 'debt overhang' (Krugman, 1998) and the liquidity constraint hypothesis also provide theoretical evidence that public debt hinders economic growth. The Krugman (1988) debt overhanging theory suggests that if future debts gradually increase beyond the country's repayment ability, then it discourages the incentive for savings and investment. Meanwhile, the liquidity constraint hypothesis (Moss and Chiang, (2003)) states that a binding liquidity constraint on debt restrains investment. Also, Cochrane (2011) argues that higher levels of debt could amplify the negative impact of debt on growth. He explains how higher debt levels may increase uncertainty which may lead to future inflation and financial repression. This implies that the negative effect of debt on growth will also be reflected in the short-run.

Finally, the third theoretical viewpoint is associated with the Ricardian equivalence theory as discussed by Barrow (1989). The hypothesis behind this school of thought is that public debt and economic growth nexus is neutral. Advocates of this theory state that the acquired level of government debt is repaid through future taxes. Hence, a rational individual would be more inclined to save at present by purchasing government issued stocks, and sacrifice consumption in order to be able to pay for future taxes. As a result, the aggregate demand would be identical whether the government chooses to increase taxes at present or in the future. Therefore, the effect of debt on growth is neutralised as interest rates and private consumption are unaffected (Mosikari and Eita, 2017).

2.2 Empirical Literature

Reinhart and Rogoff (2010) published an influential article on sovereign debt and economic growth. This paper offers a good starting point in analysing the impact of public debt on economic growth. It illustrates that high levels of debt are negatively correlated with growth. In fact, this empirical study shows that when debt-to-GDP ratio is more than 90% it will negatively and substantially impact economic growth. However, there seems to be no correlation whatsoever when the debt-to-GDP ratio is less than 90%. The controversial results of this study prompted other economists to look at whether there is a universal fixed point at which debt-to-GDP ratio hinders economic growth. Thus, this influential paper triggered a new area of debt-growth literature that discusses and assesses the main findings of this study.

Herndon *et al.* (2013) provide a strong critique to the results found by Reinhart and Rogoff (2010). The authors point out some coding errors and criticise the methodological techniques used. They state that public debt and economic growth nexus varies significantly across countries and time periods, contradicting the idea that there is a single fixed threshold for every country. Moreover, they found an average annual GDP growth rate of 2.2% for countries with a debt-to-GDP ratios exceeding 90%, which challenges the -0.1% average growth rate indicated by Reinhart and Rogoff. Other studies such as Irons and Bivens (2010), Ghosh *et al.* (2013) and Égert (2015) have also contradicted Reinhart and Rogoff's findings as they explain that there is no evidence showing that there is a universal fixed point that applies to all countries. Pescatori *et al.* (2014) also rejects the idea of a valid threshold level above which growth is hindered. In fact, they demonstrate that countries with high but declining debt appear to grow at the same rate as countries with low levels of debt. Moreover, Eberhardt and Presbitero (2015) state that there are several factors affecting the debt and growth nexus and not just the debt-to-GDP ratio. These factors include production technology, the capacity to tolerate high levels of debt and the composition of the debt itself.

Reinhart and Rogoff admitted to a data coding error and revised it in subsequent papers (Reinhart *et al.*, 2012). However, they still provided evidence that economic growth in high debt regimes is lower than that obtained by low debt regimes. Although the general consensus among empirical studies concludes that there is no universal threshold level above which debt influences growth negatively, there are some recent empirical papers that broadly support the findings of Reinhart and Ragoff. Using a sample of 18 OECD countries, Cecchetti *et al.* (2011) assert that if debt-to-GDP exceeds the threshold of 86% it will have significant repercussions on economic growth. Similarly, Checherita-Westphal and Rother (2012) analysed the impact of debt on growth for 12 euro area countries over a 40-year period. Their results illustrate a non-linear (inverted U-shaped) relationship between debt ratio and per capita GDP growth. Overall they found that debt impacts growth negatively when it exceeds the 90%-100% threshold. Baum *et al.* (2013) report similar results for euro area countries using a dynamic threshold panel for 12 euro area countries over the 1990-2010 period. The results show that over the short-term, public debt impacts economic growth negatively, particularly when exceeding 95% of GDP. However, this impact becomes insignificant below a debt-to-GDP ratio of around 67%.

The empirical studies mentioned above focus on the threshold level of debt, use different methodologies, sample sizes and time periods which led to inconsistent results. However, the majority of these studies indicate that overall, public debt hinders economic growth. In fact, Woo and Kumar (2015) highlight that the magnitude of the negative effect of debt on growth is similar across studies. On average, a 10-percentage points rise in the ratio of debt-to-GDP will result in an immediate drop in economic growth of around 0.1 to 0.2 percentage points.

Although the consensual view among empirical studies is that overall public debt hinders growth there are a number of studies that contradict this general view and suggest a positive association between debt and growth. Abbas and Christiansen (2010) state that public debt impacts economic growth positively if the level of noninflationary domestic debt is moderate. They argue that adequate levels of debt enhance private savings and financial intermediation. Also, DeLong and Summers (2012) illustrate that under situations of a severely depressed economy, where interest rates are constrained by the zero nominal lower bound, expansionary fiscal policies will lead to a positive impact on short- and long-run growth.

The empirical literature discussed thus far assumes that the causal relationship between public debt and economic growth runs only in one direction: from public debt to economic growth. Yet, a few studies have considered the possibility of bidirectional causality between these two variables. Using 20 OECD countries over a 14-year period between 1998 and 2001, Ferreira (2009) identifies a two-way causality between economic growth and public debt. De Vita *et al.* (2018) suggest that bidirectional causality between debt and growth is weak at best. While a bi-causal relationship was detected for Austria, results for several European countries were ambiguous. Di Sanzo and Bella (2015) also present ambiguous results as they tested for causality for 12 euro area countries over the 1970-2012 period. The causality tests show that for Belgium, Germany, Greece, Ireland and Italy there is evidence of a one-way causality from debt to growth. Meanwhile, for France the unidirectional causality was in reverse: from growth to debt. Finally, there was no evidence of any causality for Austria, Finland, Luxembourg and the Netherlands. Lof and Malinen (2014) analyse the bidirectional causality effect of these two variables over 20 developed countries from 1954 to 2008. The study rejects the hypothesis of bidirectional causality as results only present robust evidence for a unidirectional causality that runs from debt to growth. Similarly, Gomez-Puig and Sosvilla Rivero (2015) reject the hypothesis of a bidirectional causality between debt and growth.

2.3 Gaps in Literature

Checherita and Rother (2012), Baum *et al.* (2013) and Woo and Kumar (2015) highlight that empirical literature on the debt and growth nexus is scarce. Moreover, the majority of studies referred to in the previous section focus on whether there is a public debt tipping point beyond which debt hinders economic growth. By focussing on the potential existence of a universal debt threshold, the existing literature uses econometric models that are limited to either explain the short- or long-term impacts of debt on growth and not both.

In addressing these gaps in literature, more recent studies have attempted to establish the short- and long-term impact of debt on growth rather than trying to identify the debt threshold. In doing so they apply a methodological approach that differs from previous studies. These studies use a production function that is augmented with debt stock and then estimate such equation using the recently developed ARDL approach. Gomez-Puig and Sosvilla-Rivero (2018) investigate the debt and growth relationship for 11-euro area countries. By estimating an ARDL regression for each of the eleven countries, the authors show that overall debt hinders growth over the longer-term while in the short-run this impact may be either positive or negative, depending on the country. Other studies, including Pegkas (2018) and Mhambla and Phiri (2019) use a similar methodology, however, they focussed their analysis on one country only, namely Greece and South Africa respectively. The two studies show that public debt hinders economic growth both over the short- and long-run.

Through an ARDL model these studies provide a different way to analyse the debt and growth nexus as they consider both the short- and long-term. However, the studies discussed above are either based on a single country or a group of countries with separate individual ARDL regressions. Therefore, the approach taken in these studies focuses on individual countries and there is no global approach. Given the cross-border rise in public debt across Europe following the economic crisis, it is vital to study the holistic impact that debt has on growth for a panel of EU countries rather than focussing on a single country. This will investigate the cumulative effect of the relationship between debt and growth across EU member states.

3 Data

3.1 Data Analysis

The study uses annual data from 1996 to 2017 for 25 advanced and emerging economies within the European Union: Austria, Belgium, Croatia, Cyprus, Czechia, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and UK[1]. The selection of the period and the set of countries is based on the availability of data. The data was obtained from Annual Macroeconomic Database of the European Commission (AMECO) and World Bank (World Bank Indicators). The variables used in this study include real gross domestic product (GDP), public debt, labour, physical and human capital.

Table 1: Definition of variables and data sources

Variable	Definition	Source
GDP	GDP measured at 2010 market prices	AMECO
Public Debt	General Government Gross debt as % of GDP	AMECO
Labour	Measured by the total number wage and salary earners	AMECO
Human Capital	Approximated by life expectancy at birth	World Bank
Physical Capital	Gross Fixed Capital Formation as a % of GDP	AMECO

[1] The UK is considered as a member state as at the date of analysis the UK still forms part of the European Union.

GDP is measured at 2010 constant prices and physical capital is the gross fixed capital formation as a percentage of GDP. Public debt is the general government consolidated gross debt as a percentage of GDP. Labour is the total number of individuals in employment. Human capital is approximated using life expectancy. Other human capital approximations such as Secondary School enrolment were considered, however, data was not available for all the countries in the sample. Human Capital Index as measured by University of Groningen Pen World Tables was also considered. However, when conducting unit root tests the human capital variable was integrated of order two (I(2)). Since the model used requires a maximum of integrated of order one (I(1)) variables such approximation could not be used.

Nevertheless, life expectancy is a suitable approximation of human capital as it is often considered as one of the main indicators that captures the overall effect of health on human capital. In fact, the general consensus among economists is that there is a strong positive association between life expectancy and economic growth. An increase in life expectancy means a healthier productive workforce. Extended longevity is also associated with better levels of health and lower mortality levels over the working years. Lorentzen (2008) demonstrate that an increase in longevity stimulates economic growth while Lindth (2004) establishes a positive relationship between higher life expectancy and GDP per capita. Moreover, Bloom and Canning (2001) argue that higher life expectancy can increase labour force as people are expected to work longer. Becker (2007) explains how better health and education are complimentary to life expectancy. Hence, despite the limitations in available data, life expectancy is a good approximation of human capital.

Table 2: Descriptive and Summary Statistics

	Observations	Mean	Standard Deviation	Minimum	Maximum
			Variable Levels		
GDP	550	478.83	694.91	4.49	2932.50
Debt	550	58.71	32.44	3.70	178.90
Labour	550	8370.88	10335.10	129.08	44155
Human Capital	550	77.57	3.40	68.77	83.33
Physical Capital	550	22.53	4.11	11.54	37.29
			Variable Growth Rates		
GDP	550	2.66	3.52	-14.80	25.1
Debt	550	2.97	14.21	-26.22	127.5
Labour	550	0.69	2.26	-13.91	7.90
Human Capital	550	0.33	0.43	-0.98	3.59
Physical Capital	550	0.20	8.43	-34.30	47.87

Source: Author's Calculations

Table 2 provides the descriptive statistics of the variables employed in the study. The annual average growth rate of GDP across EU countries was 3.52% in real terms. The highest life expectancy rate was registered in Spain while the lowest was recorded in Latvia. Labour and physical capital grew by an average annual rate of 0.69% and 0.2% respectively over the analysed period. Debt-to-GDP ratio varies considerably across EU member states as shown by the minimum and maximum amounts of debt-to-GDP ratio in Table 2. Countries including Greece, Italy and Belgium are associated with high levels of debt while Central Eastern and Southern Eastern Europe (CESEE) countries such as Estonia, Latvia and Romania tend to have lower debt ratios.

The Stability and Growth Pact obliges European Union member states to move towards a more sound debt balance of less than 60%. However, as shown in Table 2 there is a significant divergence in debt ratios across EU member states and not all countries are in line with the debt requirements imposed by the Stability and Growth Pact. Therefore, this study makes a distinction between two sets of countries with a high and low average debt-to-GDP ratio. The first group of countries consists of member states that over the examined period had an average debt-GDP ratio that exceeded the 60% mark. This group is referred to as countries with higher levels of debt (HDC). Meanwhile, the other group, represents the set of countries with an average debt-to-GDP ratio which is less than that stipulated by the Stability and Growth Pact, hence the group of countries with lower levels of debt, referred to as LDC. Table 3 provides a list of the two sets of countries that form part of the HDC and LDC groups. For each sub-group, countries are listed according to average levels of debt throughout the analysed period, from highest to lowest.

Table 3: Sample Description of Debt Regimes

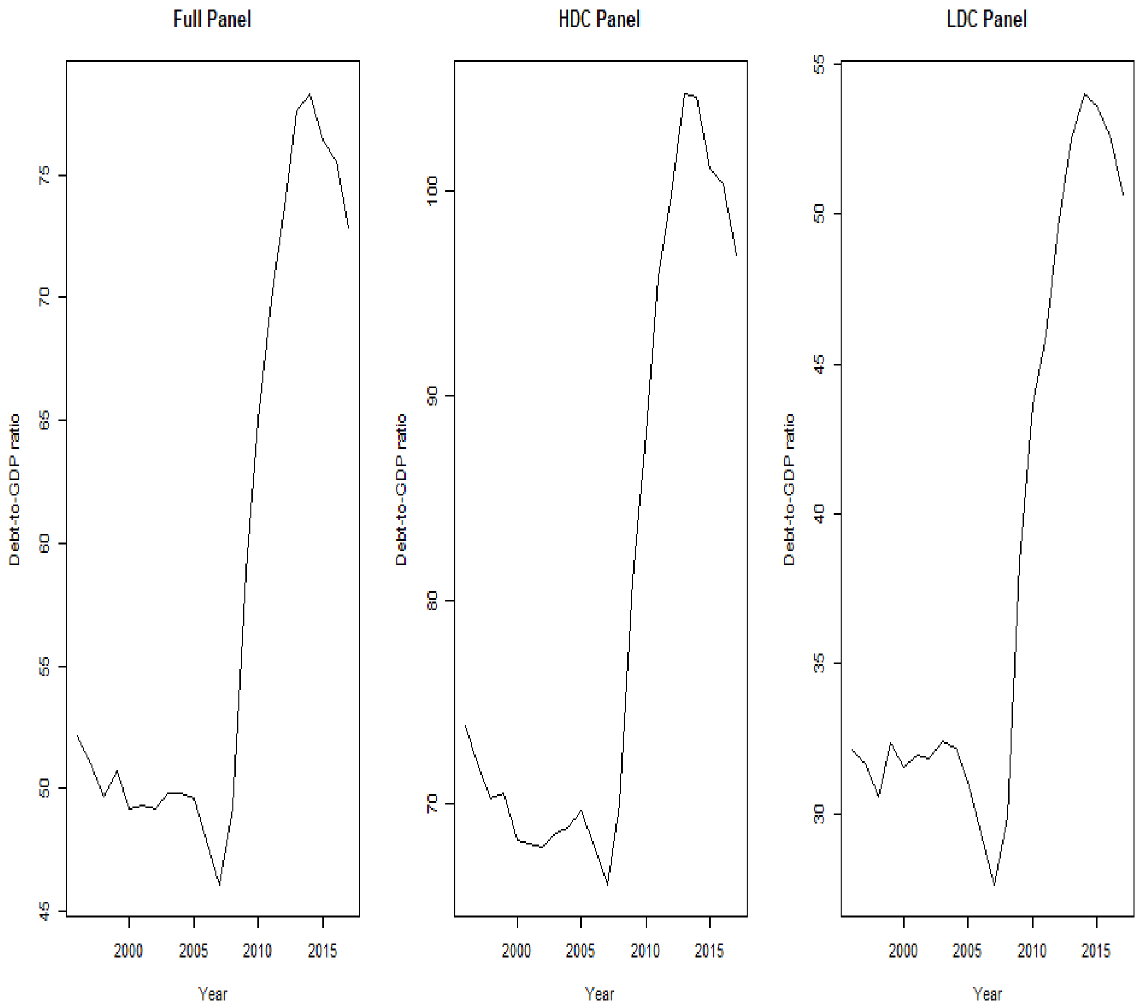
Average >60% (HDC)	Average <60% (LDC)
Greece	Netherlands
Italy	UK
Belgium	Sweden
Portugal	Croatia
France	Finland
Austria	Poland
Hungary	Slovakia
Cyprus	Slovenia
Germany	Czechia
Spain	Lithuania
Ireland	Romania
Malta	Latvia
	Estonia

Source: Author's Calculations

However, debt-to-GDP ratio does not only vary across countries, but it also varies across time and as a result of major economic events. During an economic crisis it is reasonable to expect higher government debts due to lower tax revenue and higher public spending.

As shown in Figure 1, the 2007 financial crisis and the subsequent economic crisis intensified the pressure on public finances. This led to a significant increase in government debt across all 25 EU member states in this panel, irrespective of their initial debt-to-GDP ratio[2]. In fact, on average, government debt-to-GDP ratio across the full panel of 25 EU member states increased by 12.1% in 2008. This was followed by an increase of 29.6% and 11.8% in 2009 and 2010 respectively.

Figure 1: Average debt-to-GDP ratio across panels



As a result, some countries including Greece, Spain, Ireland, Portugal and Cyprus faced significant problems and by the end of 2009 they were unable to refinance their debt. Also, countries with initially low levels of debt experienced significant debt growths. As

[2] Refer to the Appendix for a graphical representation on individual countries' debt data.

an example, Latvia, which is one of the member states with the lowest amount of debt-to-GDP ratio in the panel, had the highest increase in public debt over the examined period. In fact, its debt ratio increased by 127.5% from 2007 to 2008. On average, the debt-to-GDP ratio peaked during the 2013/14 period and started to decline slowly thereafter. For the full panel, the average debt-to-GDP ratio rose from 46.1% in 2007 to 78.3% in 2014. Also, during the same time period, the average ratio for LDC countries rose by 26.4% as it reached its highest average level of 54% in 2014. Meanwhile, the average debt-to-GDP ratio of HDC countries reached its highest level in 2013 with an increase of 38.6% when compared to the average ratio registered in 2007.

3.2 Stylized Facts

A simple graphical representation of public debt and economic growth clearly illustrates the relationship between the level of government debt and the real GDP growth. Figures 2 to 5 are a graphical representation of the initial level of debt and the subsequent growth of real GDP over five-year periods for the full panel, the HDC and LDC panels respectively.

Figure 2: Debt-to-GDP ratio and economic growth over subsequent five-year periods

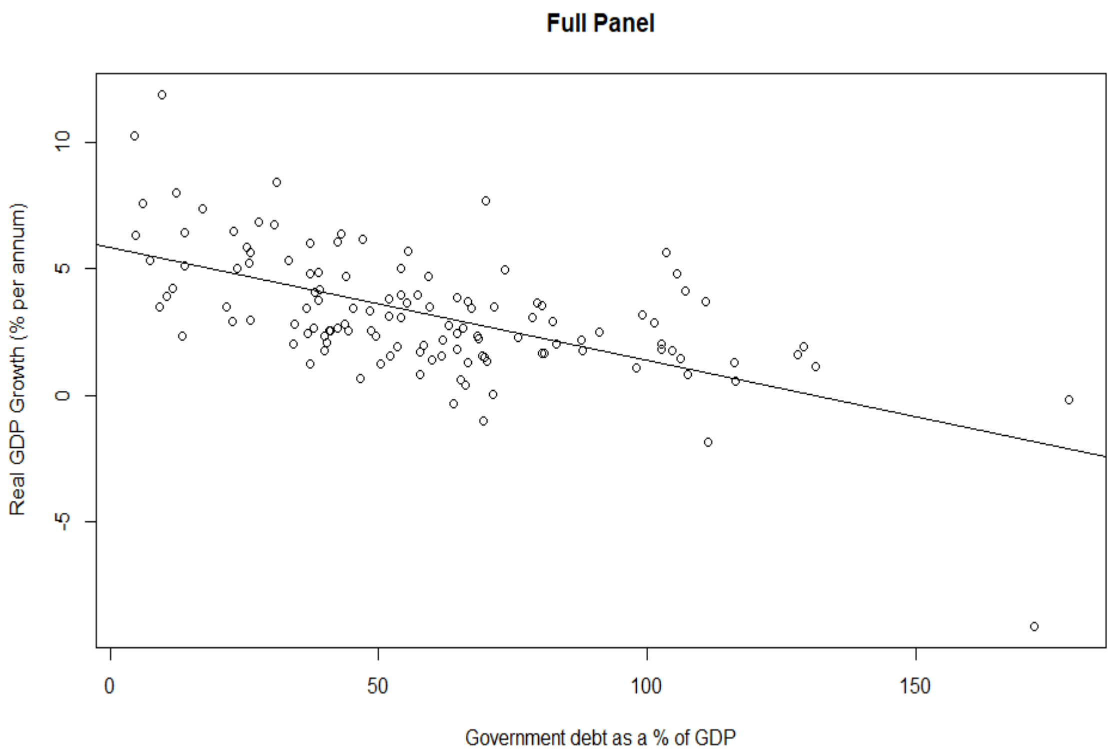


Figure 3: Debt-to-GDP ratio and economic growth over subsequent five-year periods

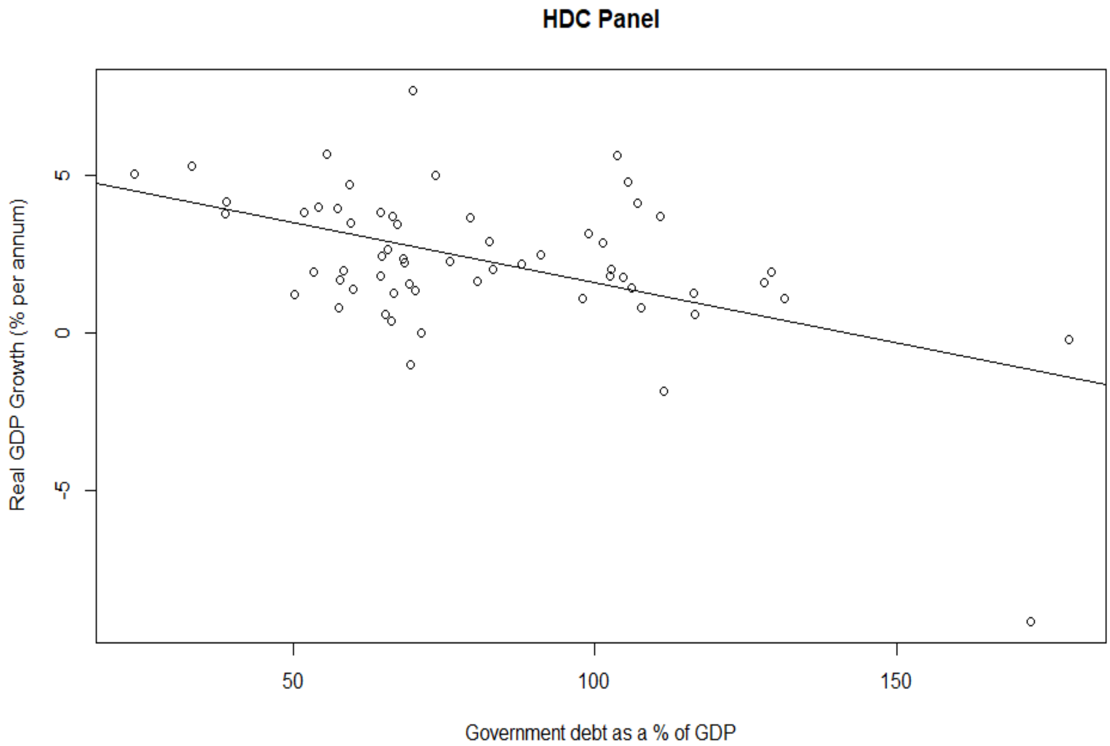
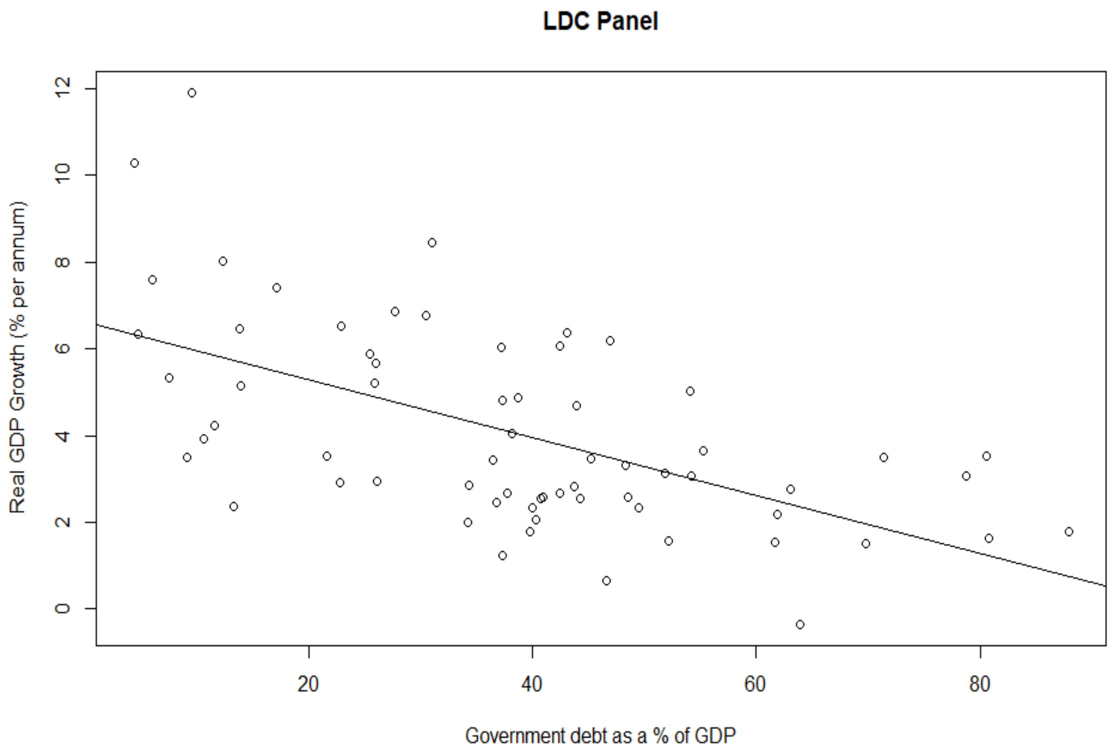


Figure 4: Debt-to-GDP ratio and economic growth over subsequent five-year periods



Taken at face value, and hence excluding other controlling growth determinants and ignoring the endogeneity problem, the scatterplot for all the three panels illustrates an inverse relationship between the initial level of government debt and the subsequent economic growth. Therefore, this indicates that public debt is detrimental to economic growth. In fact, the coefficient of initial debt to GDP ratio is -0.045 for the full panel of countries. This suggests that a 10-percentage point increase in debt ratio will lead to a slowdown of 0.45% in economic growth. Similarly, the OLS coefficient of the HDC and LDC panels are -0.038 and -0.067 respectively. Hence, data shows there seems to be an inverse relationship between debt and growth irrespective of the initial debt-to-GDP ratio. Although, these results provide an indication as to what the actual data shows they are not to be considered in isolation.

4 Methodology

The empirical approach applied in this study explores the relationship between public debt and economic growth through an extension of the standard production function. This framework is able to examine the impact of public debt in addition to the basic drivers of growth mainly labour, physical and human capital.

Solow's classical model (1956) explains how a variation in the accumulation of factors of production, labour and physical capital, lead to a steady economic growth. Following Solow's framework, several empirical studies have identified labour and physical capital as two key determinants of economic growth. Meanwhile, Lucas (1988) emphasizes the significant effect that human capital has on economic growth. Following this important contribution, the number of empirical studies that consider human capital as a vital determinant of growth has significantly increased over the last few decades. In their augmented Solow growth model Mankiw *et al.* (1992) include human capital as a third factor along with labour and physical capital. The study shows that investment in human capital leads to higher levels of economic growth. Other studies such as Bloom *et al.* (2004), Kelly and Schmidt (2005) and Baldacci *et al.* (2008) acknowledge that better quality of human capital enhances growth.

Therefore, the function used in this study includes government debt as an additional growth variable to the three control variables that are synonymous with economic growth, which leads to the following extended production function;

$$Y = f(Physical\ Capital,\ Labour,\ Human\ Capital,\ Debt)$$

For the sake of simplicity, the production function is assumed to be Cobb-Douglas form,

$$Y_{it} = A_{it} K_{it}^{\alpha_1} L_{it}^{\alpha_2}\ H_{it}^{\alpha_3}\ D_{it}^{\alpha_4} \tag{1}$$

where *i* denotes country, *t* denotes time, Y represents GDP, A is the index of technological progress, K and H are the physical and human capital respectively, L is the labour input and D is government debt. Also, α_1, α_2, α_3, and α_4 are the elasticities of physical capital, labour, human capital and public debt respectively. When taking logs of equation (1), the following linear multivariate regression is produced,

$$lnY_{it} = \alpha + \alpha_1 lnK_{it} + \alpha_2 lnL_{it} + \alpha_3 lnH_{it} + \alpha_4 lnD_{it} \tag{2}$$

Equation (2) is estimated using a time series autoregressive distributed lag model (ARDL) as proposed by Pesaran and Shin (1998) and Pesaran, Shin and Smith (2001). This framework helps in mitigating the limitations of previous literature as it distinguishes between short- and long-term impacts. Also, due to a small sample time period, estimating a separate empirical equation for each country in the sample is not optimal. As a result, it is more appropriate to use a panel estimation as it is more suitable where data availability is limited. A panel estimation uses both time and cross-sectional dimensions and so increases the total number of observations and their variation. Moreover, a panel estimation decreases the noise that comes from an individual time-series estimation. This leads to a more reliable inference.

4.1 Panel first- and second-generation unit root tests

The initial step in this empirical approach is to identify the order of integration in the data. This is important since in order to estimate an ARDL model it needs to be ensured that the variables in the regression are either integrated of order zero I(0) or at most integrated at order one I(1). This is because in the presence of integrated of order two I(2) variables the ARDL bounds testing approach fails to provide robust results. Thus, I(2) variables should be eliminated from the data set. To test for unit root in the group of panel series, the IPS and LLC tests panel unit root tests are used. These tests were proposed by Im, Pesaran, Shin (2003) and Levin, Lin, Chu (2002) respectively. The baseline framework of these two tests is an ADF regression for panel data and is specified as follows:

$$\Delta y_{it} = \gamma_i \, y_{i,t-1} + \sum_{j=1}^{P} \varphi_j \Delta y_{i,t-j} + \varepsilon_{it}, \text{ where } \gamma_i = \rho_i - 1$$

Both tests assess the null of unit root $H_0: \gamma_i = 0$ ($\rho_i = 1$) against the alternative of stationarity $H_1: \gamma_i < 0$ ($\rho_i < 1$). The LLC test assumes that the parameters tested are equal across all the panels and thus $\rho_i = \rho$ for all i countries in the panel. Meanwhile, the IPS test is less restrictive than the LLC test and is obtained as an average of the ADF statistic and allows the parameters to vary across panels.

However, both the IPS and LLC tests are considered as first-generation unit root tests as they do not consider the cross-section dependency problem that could emerge due to macroeconomic linkages, unaccounted residual independence and unobserved common factors. Therefore, second-generation unit root tests are carried out to check for cross-section dependence between the variables in this study's model. Firstly, the cross-section dependency (CD) test as proposed by Pesaran (2004) is carried out. The CD test identifies whether there is any cross-sectional dependency amongst the variables and can be applied when N is larger than T. The CD test is based on the average of the pair correction coefficients of OLS residual regressions. Once the presence of cross-sectional dependence is determined through the CD test, the Pesaran's (2007) cross-sectional Augmented Dickey-Fuller (CADF) test is conducted. The CADF test considers cross-section dependence among the variables and tests the null hypothesis of cross-sectional dependency among a panel of countries. This is done to ensure that even when there is cross-sectional dependency among the group of countries the variables are still either I(0) or I(1).

4.2 Panel cointegration tests

After confirming the order of integration, the second stage of the analysis tests for evidence of long-run cointegration among GDP growth and the independent variables by conducting the Pedroni (1999, 2004) and Kao (1999) panel cointegration tests. Other panel cointegration tests include Westerlund (2007). However, this test is not valid for the purposes of this study as Westerlund himself stated that such test is often subject to distortions when the T sample size is less than 100. The Pedroni (1999, 2004) and Kao (1999) tests are based on the panel-data model for an I(1) dependent variable y, and tests the null hypothesis of no cointegration against the alternative of cointegration:

$$\mathrm{y}_{it} = x_{it}^{'}\beta_i + z_{it}^{'}\tau_i + e_{it}$$

where for each panel i, the covariates in x_{it} is an I(1) series and both tests require the covariates to not be integrated amongst themselves. The Kao test assumes a common cointegration vector across all countries in the panel and thus restricts $\beta_i = \beta$. Although both tests have the same null and alternative hypothesis, there are some differences between them. In fact, the Pedroni test allows for panel-specific cointegrating vectors and such heterogeneity distinguishes it from the Kao test.

4.3 Panel Autoregressive Distributed Lag Model

After carrying out unit root and cointegration tests, the ARDL model is estimated. The ARDL model distinguishes between short- and long-run coefficients and can be reliably used on short sample periods. In fact, Pesaran and Shin (1998) illustrate that even if the sample size is small, the long-run parameters are super-consistent while the short-run parameters are $\sqrt{T}$ consistent. Thus, equation (2) is formulated into a panel ARDL (p, q_1, q_2, q_3, q_4) equation where p represents the lags of the dependent variable and q represents the lags of the independent variables. The panel ARDL equation is represented as follows:

$$
\begin{aligned}
lnY_{it} = \ \alpha_i + \ \sum_{j=1}^{p} \alpha_{1,ij} lnY_{i,t-j} + \sum_{j=0}^{q_1} \alpha_{2,ij} lnD_{i,t-j} \\
+ \sum_{j=0}^{q_2} \alpha_{3,i,j} lnL_{i,t-j} + \sum_{j=0}^{q_3} \alpha_{4,ij} lnH_{i,t-j} + \sum_{j=0}^{q_4} \alpha_{5,ij} lnK_{i,t-j} + \ \varepsilon_{it}
\end{aligned} \tag{3}
$$

where $i = 1, 2, 3, \ldots N$ and $t = 1, 2, 3, \ldots T$, α_i represents the fixed effects, $\alpha_1 - \alpha_5$ is the lagged coefficients of the independent variables and the regressors and ε_{it} is the error term which is assumed to be white noise and varies across countries and time. In a panel error correction (ECM) representation equation (3) is formulated as follows:

$$
\begin{aligned}
ln\Delta Y_{it} = \ \alpha_i + \ \sum_{j=1}^{p} \alpha_{1,ij} ln\Delta Y_{i,t-j} + \sum_{j=0}^{q_1} \alpha_{2,ij} ln\Delta D_{i,t-j} + \sum_{j=0}^{q_2} \alpha_{3,i,j} ln\Delta L_{i,t-j} \\
+ \sum_{j=0}^{q_3} \alpha_{4,ij} ln\Delta H_{i,t-j} + \sum_{j=0}^{q_4} \alpha_{5,ij} ln\Delta K_{i,t-j} + \beta_{1,ij} lnY_{i,t-1} \\
+ \beta_{2,ij} lnD_{i,t-1} + \beta_{3,ij} lnL_{i,t-1} + \beta_{4,ij} lnH_{i,t-1} + \beta_{5,ij} lnP_{i,t-1} + \varepsilon_{it}
\end{aligned} \tag{4}
$$

where Δ is the first difference of variables. Also $\alpha_1 - \alpha_5$ are the short-run coefficients while $\beta_1 - \beta_5$ are the long-run coefficients of GDP, debt, labour, human capital and physical capital respectively. To estimate the short-run relationship, the Hendry's (1995) suggestion is followed. The short-term impact of debt on growth is calculated by $\frac{\sum_{j=1}^{q_1} \alpha_{2,ij}}{(1 - \sum_{j=0}^{p} \alpha_{1,ij})}$ for significant coefficients.

Once, a long-run relationship is established between the dependent variables and the regressors, the panel ECM model (equation (4)) can de expressed as follows:

$$
\begin{aligned}
ln\Delta Y_{it} = \ \alpha_i + \ \sum_{j=1}^{p} \alpha_{1,ij} ln\Delta Y_{i,t-j} + \sum_{j=0}^{q_1} \alpha_{2,ij} ln\Delta D_{i,t-j} + \sum_{j=0}^{q_2} \alpha_{3,i,j} ln\Delta L_{i,t-j} \\
+ \sum_{j=0}^{q_3} \alpha_{4,ij} ln\Delta H_{i,t-j} + \sum_{j=0}^{q_4} \alpha_{5,ij} ln\Delta K_{i,t-j} + \ \theta_i ECM_{i,t-1} + \ \varepsilon_{it}
\end{aligned} \tag{5}
$$

where θ_i represents the coefficient of the ECM which measures the speed of adjustment that is made every year towards long-run equilibrium. The optimal lag length of the ECM model (5) is determined through the Akaike's lag selection criteria and a maximum lag length of three is chosen given the limited number of annual observations.

The panel ECM model is estimated for different panels within the dataset. Firstly, to establish a baseline, a panel that consists of all the countries in the sample is considered. This provides a general overview as well as a platform of the relationship between debt and growth across European member states. However, as highlighted in the literature review, the debt and growth nexus depends on several characteristics including the debt level and the capacity to tolerate high levels of debt. Thus, a distinction is made between countries with high and low levels of debt. The available observations on debt-GDP ratio is averaged over the analysed period and then the 25 countries are ranked accordingly to form two groups of roughly equal size (12 and 13 respectively). These two subgroups are the HDC and LDC panels outlined in the data section. This enables a comparative analysis between countries with high and low levels of debt.

To estimate the panel ARDL regression the pooled mean group (PMG) technique is used. This estimation technique is discussed by Pesaran, Shin and Smith (1997, 1999) and combines both averaging and pooling of coefficients. This panel method allows the intercepts, short-run coefficients and error variances to differ freely across groups. Meanwhile, the likelihood-based PMG estimator constrains the long-run coefficients to be identical across groups. As a result, this leads to consistent estimates when homogeneity restriction is indeed true. Also, in instances where the number of cross-sectional (N) is rather small, as is in this study, the PGM estimator is less sensitive to outliers and can simultaneously correct the problem of serial autocorrelation. Moreover, this likelihood-based estimation corrects the endogenous regressors problem by choosing appropriate lag structure for both dependent and independent variables.

4.4 Sensitivity Analysis

As highlighted by empirical literature the relationship between debt and growth varies over time periods and economic events. Therefore, given the increase in the overall level of government debt across EU member states following the 2007 financial crisis, the dataset is split into two sub-sample periods; the pre- and post-financial crisis periods. Firstly, this ensures the reliability of the first set of results. Moreover, this helps in identifying whether the relationship between debt and growth varies across time periods as a result of major economic events such as the 2007 financial crisis and the subsequent economic crisis. The Pedroni and Kao cointegration tests are repeated for the two sub-periods to ensure that there is a cointegrating effect before and after the crisis. Due to fewer time series observations the lag selection is set at a maximum of one lag.

4.5 Panel causality test

The final step in this empirical analysis is to test for bidirectional causality between public debt and economic growth. In a seminal article, Granger (1969) develops a method that analyses the causal relationship between time series. The Granger representation theorem illustrates that if the two-time series are cointegrated, then there must be at least a unidirectional causality between. This framework is extended by Dumitrescu and Hurlin (2012) which allow it to detect causality in panel data. Thus, the Dumitrescu and Hurlin (2012) causality test is employed to determine whether there is bidirectional or unidirectional causality between the two variables. To investigate the direction of causality a two-way Granger test is carried out as follows;

$$Y_{i,t} = \alpha_i + \sum_{k=1}^{K} \delta_{ik} Y_{i,t-k} + \sum_{k=1}^{K} \pi_{ik} D_{i,t-k} + \varepsilon_{i,t} \tag{6}$$

$$D_{i,t} = \alpha_i + \sum_{k=1}^{K} \delta_{ik} D_{i,t-k} + \sum_{k=1}^{K} \pi_{ik} Y_{i,t-k} + \varepsilon_{i,t} \tag{7}$$

with $i = 1, \dots, N$ and $t = 1, \dots, T$

where $D_{i,t}$ and $Y_{i,t}$ are the observations of public debt and GDP variables for country i in period t. Basically, equation (4) tests for significant effects of D on the present values of Y while (5) tests for the effect of Y on the present values of D respectively. Thus, the null hypothesis is:

$$H_0: \; \pi_{i1} = \cdots = \pi_{iK} = 0 \forall i = 1, \dots, N$$

which resembles the fact that there is no evidence of causality for all the countries in the panel. Also, an important assumption in this test is that there can be causality for all countries in the panel but not necessarily that there is such causality across all countries. Hence, the alternative hypothesis is,

$$H_1 : \pi_{i1} \neq 0 \; or \ldots \; \pi_{iK} \neq 0 \forall i = N_1 + 1, \ldots, \; N$$

If $N_1 = 0$ there is causality for all individuals in the panel. On the other hand, if N_1 is not strictly smaller than N than there is no causality for all countries and H_1 reduces to H_0.

5 Results

5.1 Panel unit root and cointegration tests

The first step in this empirical analysis is to carry out unit root tests. Stationarity tests are very important in this analysis as the order of integration for all the estimated variables should either be I(0) or I(1). The IPS and LLC first-generation unit root tests are conducted to test for evidence of stationarity. These tests are carried out for the three panels in the analysis which are the full panel and the HDC and LDC panels. The results of these two first-generation unit root unit tests are presented in the Appendix. Overall, the results show that the order of integration of GDP, debt, physical capital, labour and human capital are either I(0) or I(1) across all the three panels. In fact, in general the null of unit root in level terms is strongly rejected for physical capital and thus such variable is I(0). Meanwhile, all the other four variables are I(1) as the null of unit at first difference is rejected.

The next step is to check for cross-section dependence between the variables in the model through second-generation unit root tests. Firstly, the Pesaran (2004) CD test is conducted. This test can only be applied when cross-sectional data (N) is larger than the time period (T). Therefore, the CD test is only carried out for the full sample (N=25 and T=22). The CD test, presented in the Appendix, shows that there is evidence of cross-dependence between the variables as the null hypothesis of no cross-dependence is strongly rejected.

Therefore, in the presence of cross-sectional dependence, the Pesaran's CADF (2007) second-generation unit root test is carried out for all the three panels. The results in the Appendix show that overall, the null hypothesis of cross-sectional dependence is strongly rejected either in levels or first difference for all the five variables across the three panels. Hence, from the first- and second-generation unit root test it can be concluded that all the variables are stationary at first difference and so they can be used to estimate an ARDL model.

Given the strong support of first difference stationarity in all the variables and across all panels, the second stage of the analysis is to test for cointegration between the dependent variable and the four regressors. The Pedroni and Kao residual based cointegration tests are used to test the hypothesis of no cointegration in all three panels. Both cointegration tests presented in the Appendix strongly reject the null hypothesis of no cointegration in the three panels. Thus, there is evidence of a long-run relationship between the dependent and the explanatory variables for all three panels. This suggests that an estimation of equation (5) will provide reliable short- and long-run results.

5.2 Panel ARDL estimation

5.2.1 Full Panel

After confirming that the five variables are not integrated of an order equal or greater than I(2) and that the series are cointegrated, the next step is to estimate the panel ARDL regression as specified by equation (5) through a Pooled Mean Group (PMG) estimation. The suitable lag length is selected based on the AIC lag selection criteria and all insignificant variables are eliminated. Table 4 presents the empirical results on public debt and economic growth nexus conditioned on other explanatory variables for the full panel of 25 EU member states and for the full sample period, 1996-2017.

Table 4: ARDL estimation of full panel

	Pooled Mean Estimator	
	Coefficient	Standard Error
	Long-Run Coefficients	
D_t	-0.128***	0.009
L_t	0.466***	0.063
H_t	0.446***	0.174
K_t	0.118***	0.021
	Short-Run Coefficients	
ΔD_{t-1}	-0.055***	0.015
ΔD_{t-2}	0.020**	0.011
ΔL_t	0.251***	0.086
ΔK_t	0.050**	0.021
ECM_{t-1}	-0.683***	0.067
Constant	1.642***	0.267
Short-Run Effect of Public Debt	-0.034***	0.012

*Notes: **, *** indicate significance at 5% and 1% confidence levels respectively. Author's own calculations.*

The error correction coefficient ECM_{t-1} represents the speed of adjustment to restore equilibrium in the dynamic model following a disturbance. This coefficient in the full panel ARDL regression is -0.683 which implies that equilibrium is reached in less than two years. This highly significant and negative ECM coefficient also supports evidence that there is a stable long-run relationship between the dependent variable and the regressors. All coefficients of the explanatory variables are in line with expectations of economic theory. Labour, human and physical capital all have a positive association with economic growth over the longer-term. Also, labour and physical capital impact economic growth positively over the short-run while there seems to be no statistically significant short-run relationship between human capital and economic growth.

Meanwhile, the PMG estimation illustrates that government debt hinders economic growth both over the short- and long-term although the impact is more evident over the longer-term. The magnitude of coefficients is comparable to that obtained in previous empirical literature including Gomez-Puig and Sosvilla-Rivero (2018) and Pegkas (2019). The long-run multiplier shows that a 10% growth in debt-to-GDP ratio leads to an average drop of 1.28 percentage points in economic growth across EU member states. Meanwhile, government debt also impacts economic growth negatively in the short-run. In fact, a 10% rise in debt-to-GDP ratio leads to an immediate drop of 0.34% in economic growth across EU countries in the panel.

5.2.2 HDC and LDC Panels

In the next part of the analysis, the full panel is split into two sub-groups that distinguish between countries with high and low average debt-to-GDP ratio. This examines whether the impact of debt on economic growth varies across high and low levels of debt. A PMG estimation is carried out for these two sub-samples. Once again, the lag length of the two estimations is determined by the AIC lag selection criteria and any statistically insignificant variables are removed. The results of the two estimations are presented in Table 5.

Firstly, the ECM coefficient is similar across the two panels although the speed of adjustment of the LDC panel is slightly quicker than that of the HDC panel. Once again, the coefficients of labour, human and physical capital mirror economic literature, as although their magnitudes differ across panels, they have a positive impact on economic growth.

Table 5: Panel ARDL estimation of sub-samples

	Pooled Mean Group Estimator				
	HDC Panel			**LDC Panel**	
	Coefficient	Std. Error		Coefficient	Std. Error
			Long-Run Coefficients		
D_t	-0.100***	0.026	D_t	-0.133***	0.012
L_t	0.714***	0.124	L_t	0.281***	0.093
H_t	0.456**	0.235	H_t	0.546*	0.328
K_t	0.072*	0.041	K_t	0.128***	0.028
			Short-Run Coefficients		
ΔD_t	-0.072**	0.022	ΔD_{t-1}	-0.026**	0.012
ΔL_{t-1}	0.287**	0.128	ΔL_t	0.268***	0.094
ΔL_{t-2}	-0.104*	0.057	ΔK_t	0.054*	0.032
ΔK_t	0.044*	0.026	ΔECM_{t-1}	-0.705***	0.071
ΔECM_{t-1}	-0.679***	0.091	Constant	2.19***	0.309
Constant	0.904***	0.525			
Short-Run Effect of Public Debt	-0.072***	0.022		-0.026**	0.012

*Notes: *,**, *** indicate statistical significance at 10%, 5% and 1% respectively. Author's own calculations.*

Some interesting results on the debt and growth nexus can be drawn from the empirical evidence presented in table 5. Firstly, in the short-run, a rise in government debt has a more substantial impact on the countries with high levels of debt. In fact, a 10% rise in government debt leads to an immediate negative effect on growth of 0.72% for the HDC panel, 0.46 percentage points higher when compared to the LDC group. These results are in line with previous empirical studies including Gomez-Puig and Sosvilla-Rivero (2018) and Baum *et al.* (2013). The former claim that the short-run negative effect of growth is stronger for countries with higher levels of debt, including Italy, Belgium and Austria than those with lower levels of debt such as Finland. Baum *et al.* (2013) demonstrate that the short-run negative impact of debt on growth is more powerful for countries with high levels of debt than with those with low levels of debt.

A negative long-term relationship between debt and growth is also established across the two panels. However, this time, the magnitude of the panel of countries with low levels of debt is slightly higher than that of the HDC panel. Hence, on average, the long-run negative impact of debt on growth is more prevalent for countries with a low debt-to-GDP ratio. In fact, a rise of 10% in the ratio of debt-to-GDP leads to a 1.32 and 1.00 percentage point drop in the LDC and HDC panels respectively.

Therefore, the results illustrate that higher levels of government debt in countries with an initial high level of debt will hinder economic growth immediately. On the other hand, for countries with low levels of debt, this negative impact develops over time. Overall, when considering both the short- and long-run effects, the impact of government debt on HDC countries is slightly higher than that of LDC countries. However, the main message here is that irrespective of its initial level, public debt has a negative impact on growth both over the short- and long-term periods.

5.3 Sensitivity Analysis

The estimated short- and long-run coefficients presented in Table 4 are average values of the entire sample period (1996-2017). Therefore, this does not take into consideration the possibility that debt-growth relationship can change over time. As highlighted in the data section, the 2007 financial crisis and the subsequent economic crisis led to significantly higher levels of debt across EU member states. Therefore, by splitting the pre- and post-financial crisis into two sub-periods, the study examines whether the global financial crisis has altered the relationship between debt and economic growth. Once again, the Kao and Pedroni cointegration tests are carried out to check for cointegration in the two sub-periods. The results of these tests are found in Table E of the Appendix. The results illustrate that there is a long-run relationship between the explanatory variable and the regressors across both periods as the null of no cointegration is strongly rejected.

The aim of the estimation results in Table 6 is not to establish the short- and long-run impacts but to determine whether there is a change in the relationship between economic growth and the regressors over the two periods. Therefore, for the explanatory variables only the long-run multipliers are obtained, as short-run coefficients in such a small time period might not lead to optimal results.

Table 6: Panel ARDL estimation of pre- and post-crisis

	Pooled Mean Group Estimator				
	Pre-crisis (1996-2007)			**Post-crisis (2008-2017)**	
	Coefficient	Std. Error		Coefficient	Std. Error
			Long-Run Coefficients		
D_t	-0.095***	0.012	D_t	-0.068***	0.007
L_t	0.450***	0.053	L_t	0.771***	0.039
H_t	0.384**	0.183	H_t	0.276**	0.137
K_t	0.107***	0.015	K_t	0.104***	0.012
			Short-Run Coefficients		
ΔECM_{t-1}	-0.907***	0.063	ΔECM_{t-1}	-1.201***	0.062
Constant	2.848***	0.376	Constant	1.605***	0.304

*Notes: **, *** indicate significance at 5% and 1% confidence levels respectively. Author's own calculations.*

The long-run multipliers of human and physical capital do not substantially differ across the two periods and are comparable to those of the previous part of the analysis. However, an interesting conclusion regarding the impact of labour on economic growth can be drawn. This is because the post-crisis long-run multiplier is much higher than that registered during the pre-crisis period. This can be explained by the fact that the great recession and the subsequent sovereign debt crisis, have had a long-lasting effect on the real economy of several EU countries mainly because of rising and persistent levels of unemployment. Hence, during this rough economic period, it was far more difficult to increase employment rates given low aggregate demand. As a result, the long-term effect of an increase in employment is more evident after the crisis rather than before, when the economic situation was much better. Hence, the countries that managed to increase employment rates during this turbulent economic period had a significant positive impact on economic growth. In fact, a 10% growth rate in the number of individuals employed results in a positive long-run impact of 7.71% in economic growth. This is far more significant than the 4.5% that would be obtained before the crisis.

The debt multipliers in Table 6 suggest that the impact of public debt on economic growth varies across the two distinctive periods. This mainly occurs due to the different fiscal policy adopted over the two periods. During a period of economic distress, the role of government intervention increases in order to enhance confidence in the system and promote aggregate demand. As a result, several EU countries had to implement a variety of fiscal measures to stabilise the financial sector and cushion the negative consequences on their economies. Consequently, despite the substantial rise in government debt, the implementation of said fiscal policies in a period of recession have diminished the negative impact of debt on growth, as substantiated by the results in this study. In fact, the post-crisis debt long-run coefficient is lower than that of the pre-crisis as a 10-percentage point rise in debt-to-GDP ratio leads to a slowdown of 0.68% in economic growth, 0.27 percentage points lower than that of the pre-crisis period. However, although there is a lower impact on economic growth for the post-crisis period this impact is still negative. Therefore, these results contradict the suggestion of DeLong and Summers (2012) that the impact of debt on growth is positive in a period of economic distress.

5.4 Causality

There is limited number of empirical research that tests for a two-way causality between debt and growth and existing studies found ambiguous results. In fact, the results vary across countries and time periods considered in these studies. This is why a panel Granger causality test is conducted in the final part of the analysis. A pre-requisite of the Granger causality test is that the two-time series should have a long-run association between them or in other words, they should be cointegrated. In the previous parts of the analysis, through panel cointegration tests it was established that there is a long-run relationship between debt and economic growth across all panels. This shows that there must be at least a unidirectional cause between debt and growth.

Table 7: Dumitrescu and Hurlin panel causality test

Null hypothesis	W-statistic	Zbar-statistic	P-value
		Full Panel	
Y does not Granger cause D	1.72	2.54	0.01
D does not Granger cause Y	3.59	9.15	0.00
		HDC Panel	
Y does not Granger cause D	1.25	0.60	0.55
D does not Granger cause Y	2.44	3.52	0.00
		LDC Panel	
Y does not Granger cause D	2.15	2.94	0.00
D does not Granger cause Y	4.65	9.30	0.00
		Pre-crisis	
Y does not Granger cause D	1.87	3.09	0.00
D does not Granger cause Y	4.55	12.57	0.00
		Post-crisis	
Y does not Granger cause D	5.33	15.29	0.00
D does not Granger cause Y	2.03	3.63	0.00

Author's own calculations.

To test for the direction of causality the pairwise Dumiterescu and Hurlin Panel causality test (2012) is used. The test examines the null hypothesis of no homogenous Granger causality against an alternative indicating causality for at least one cross-sectional unit of the panel. The results of the pairwise Dumitrescu-Hurlin panel causality tests are presented in Table 7. For robustness of the results, the full panel, HDC and LDC panels are considered. Also, the pre-crisis and post-crisis subperiods are considered to check whether causality changes over time and economic events. The results reveal that for the full group of countries, there is a bidirectional causality between economic growth and public debt at a 95% confidence level. Hence, public debt restrains economic growth while economic growth also impacts the level of government debt. This is also consistent across time as evidence of bidirectional causality is found for both pre- and post-crisis periods. Moreover, a bidirectional relationship is also found for the set of countries with a low debt-to-GDP ratio. However, for the HDC group of countries there is evidence of unidirectional causality. In fact, there is evidence of a one-way causality that runs from debt to GDP but not the other way round.

6 Conclusion

Despite the European sovereign debt crisis, few empirical studies have examined the debt and growth nexus for European economies, particularly on a holistic European level. This study sets out to address this gap by using data for 25 European Union member states to carry out a comprehensive analysis of the impact of debt on economic growth.

Using a panel ARDL approach the empirical results in this study identify the short- and long-run impact of debt on growth. Overall the results substantiate the findings of empirical literature that government debt hinders economic growth. The study establishes that debt negatively impacts economic growth both over the short- and the long-term. This negative effect is also evident across different debt levels, suggesting that the relationship between debt and growth is not influenced the initial level of debt-to-GDP ratio. Moreover, even if to a lesser extent, during the post-crisis period, government debt still has a negative relationship with growth. Therefore, major economic events such as the European sovereign debt crisis did not alter the inverse relationship that exists between debt and growth. Apart from a panel ARDL analysis this study also tests for bidirectional causality between debt and growth. The results indicate that the causal relationship between debt and growth is ambiguous and varies across panels. For the full panel there is evidence of a two-way causality which is also significant across the pre- and post-crisis sub-periods. Also, there is evidence of bidirectional causality for countries with the lowest levels of public debt. Meanwhile, in economies with high average levels of public debt the causal relationship runs only from debt to growth and not the other way round.

Apart from highlighting the inverse relationship between debt and growth the results manifest the importance of designing policy frameworks that increase labour and human capital and encourage investment. This is because all the estimated panel ARDL regressions illustrate the reliance of growth on labour, human and physical capital. In fact, in all the estimations, labour has a significant impact on growth both over the long- and short-term. This is more evident in periods of recession and austerity. Although there is no statistically significant evidence of the short-run impact of human capital on growth, over the long-run the impact is substantially high. Higher levels of physical capital are also important in enhancing economic growth, although the impact is less than that observed for labour and human capital.

The policy implications derived from this analysis are twofold. Firstly, policy makers should be cautious in acquiring unsustainable high levels of debt. Although the negative impact of debt did not vary considerably between countries with an average of high and low levels of debt, this does not imply that moving to higher levels of debt is encouraged. This is because debt limits and fiscal space are country specific, as it often depends on the country's ability to tolerate higher levels of debt. Hence policymakers should to strive to lower public debt within the 60% GDP ratio as stipulated by the Stability and Growth Pact. Secondly, policymakers should focus on policies which enhance labour, health and education services and that promote private investment. These include: an educational system that provides a technical workforce that meets the needs of the labour market; a labour-engaging system that decreases frictional unemployment; a fiscal policy that incentivises work; providing government guarantees to enhance investment.

One of the main aims of this study is to fill some of the empirical gaps that exist vis-a-vis the debt and growth nexus. The approach used gives a different dimension compared to existing empirical literature that focusses on debt threshold levels since this study focusses on short- and long-run impact over different panel samples. This means that this study does not analyse the possibility of a nonlinear relationship between debt and growth. Hence this study could be extended to examine possible nonlinear effects. Another limitation is that due to data constraints, the study uses short time series data of over 22 years. In terms of further research, it would also be interesting to split public debt into local and foreign currency denominations. Using a similar methodological approach to that used in this study, further research could analyse the impact that local and foreign debt have on growth and whether there is any difference between them.

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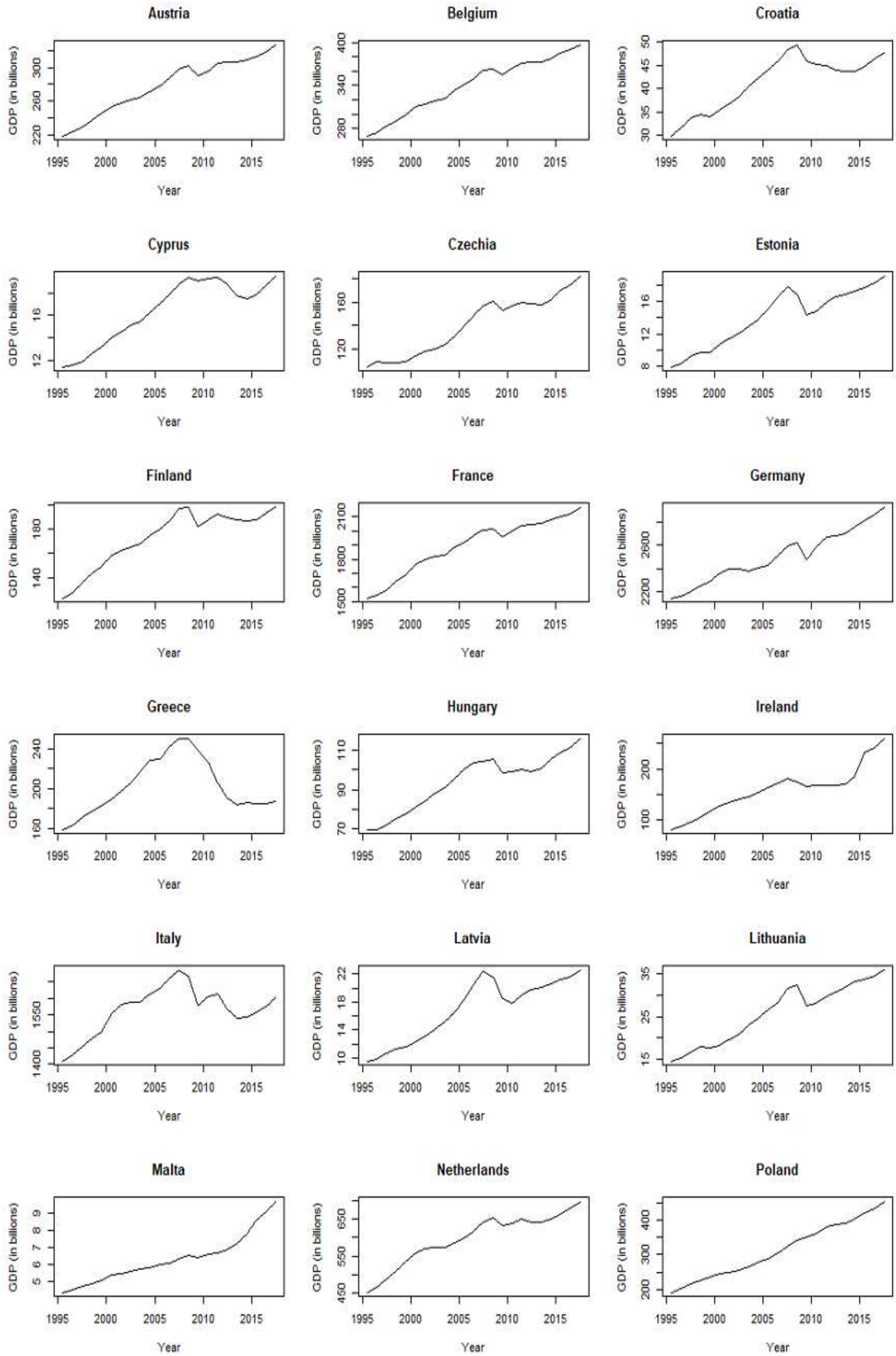
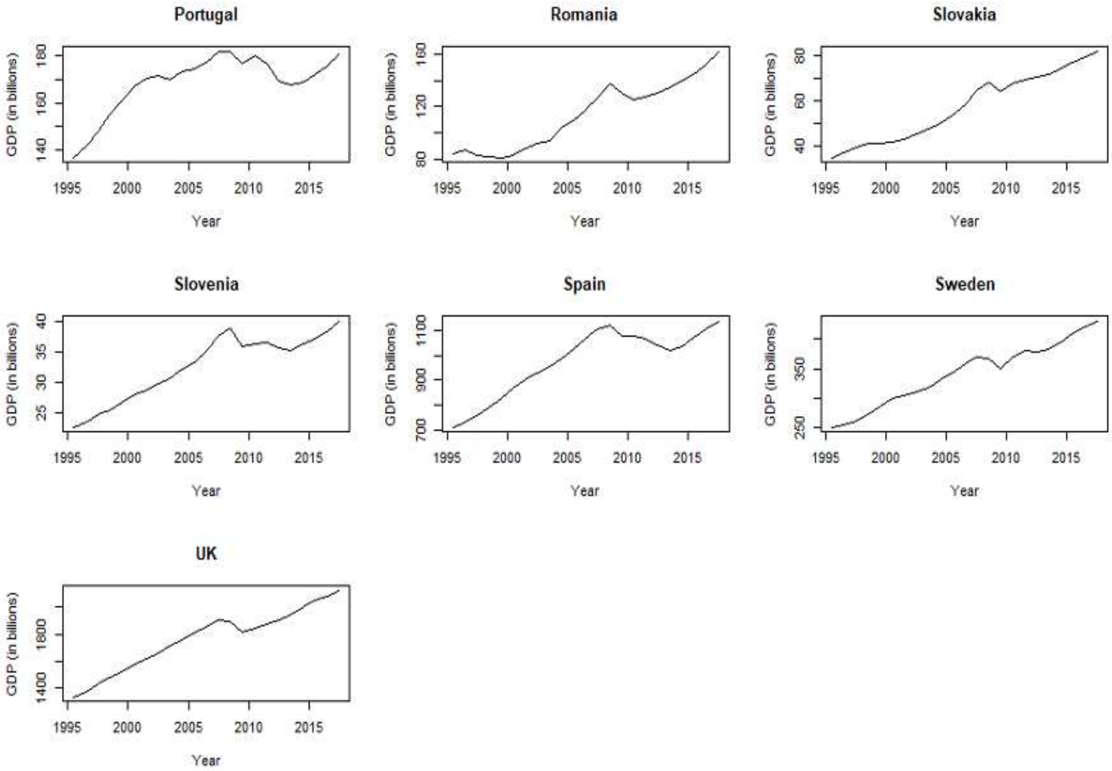
7 Appendix

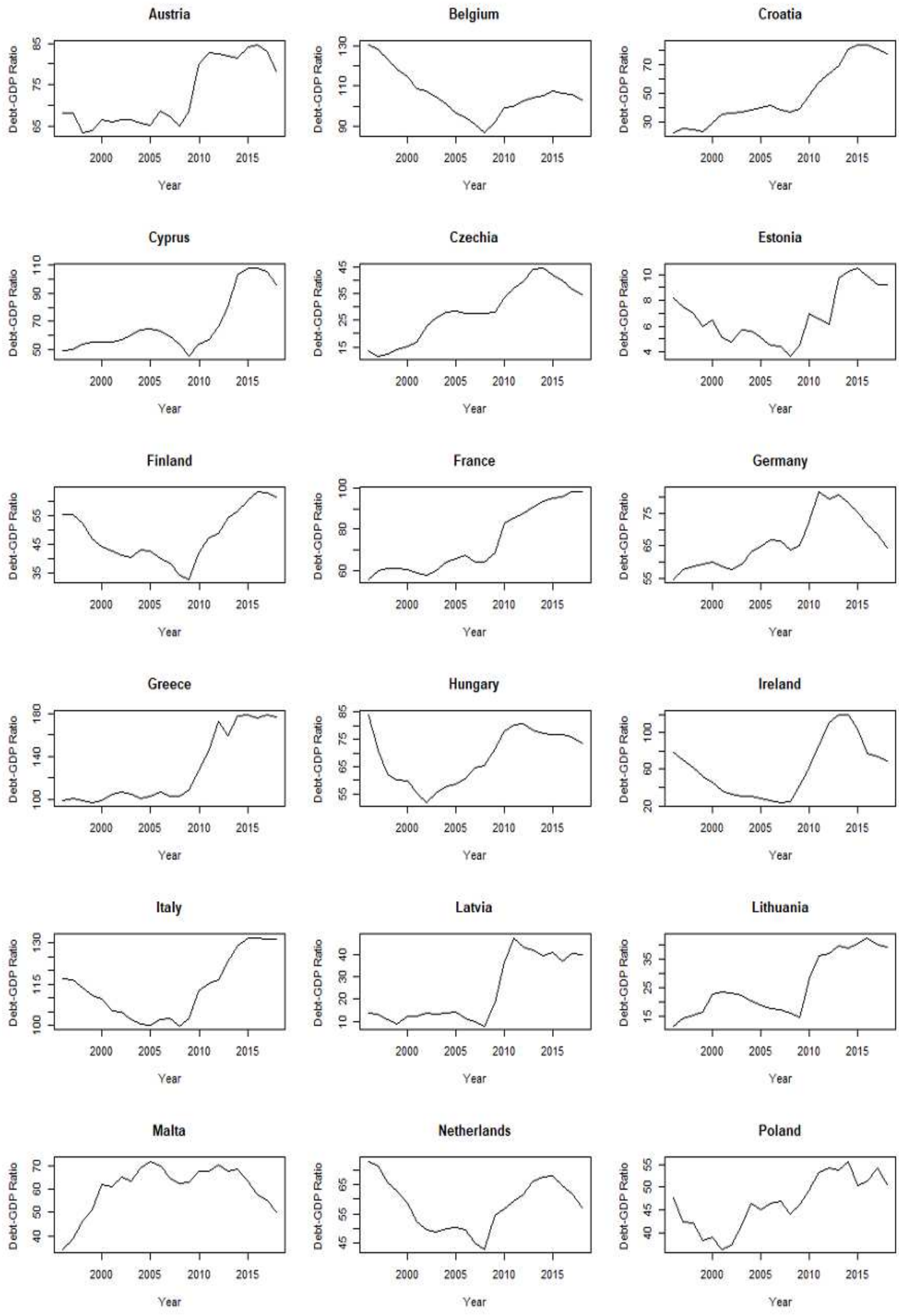
Figure A: Individual Countries' GDP

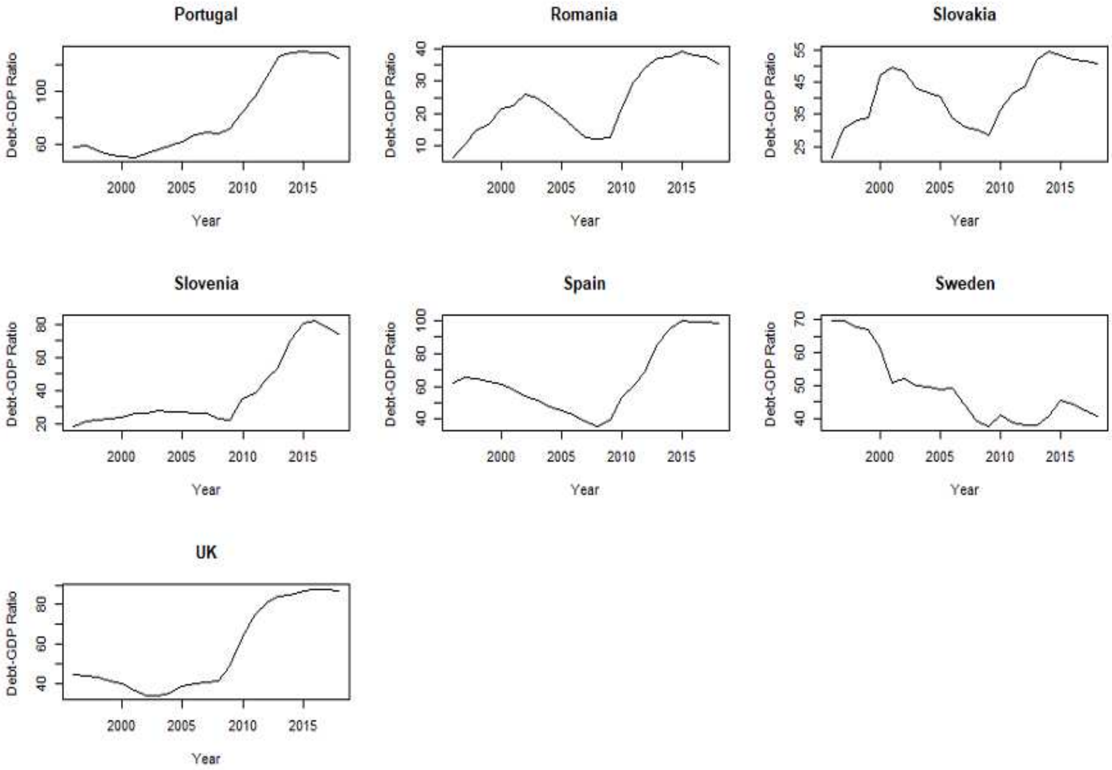




Source: Author's Calculations

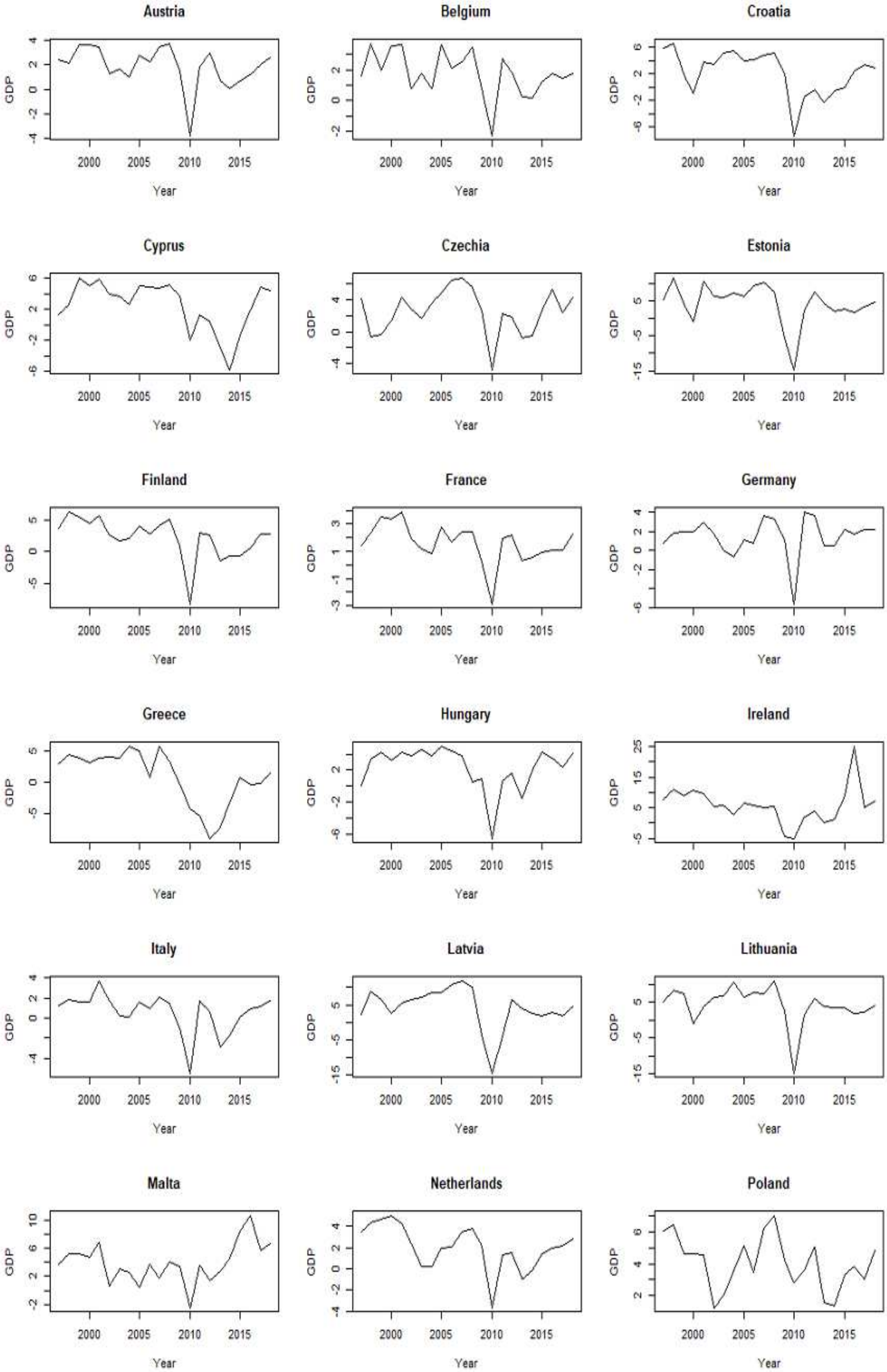
Figure B: Individual Countries' Debt-to-GDP ratio

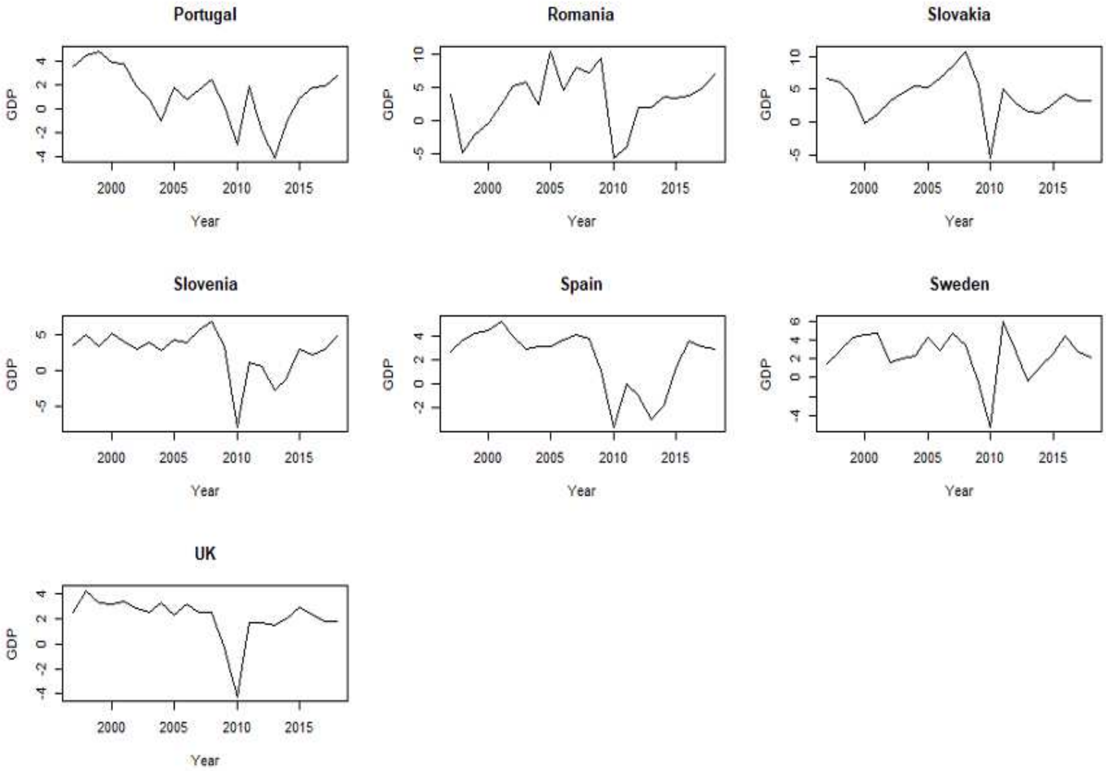




Source: Author's Calculations

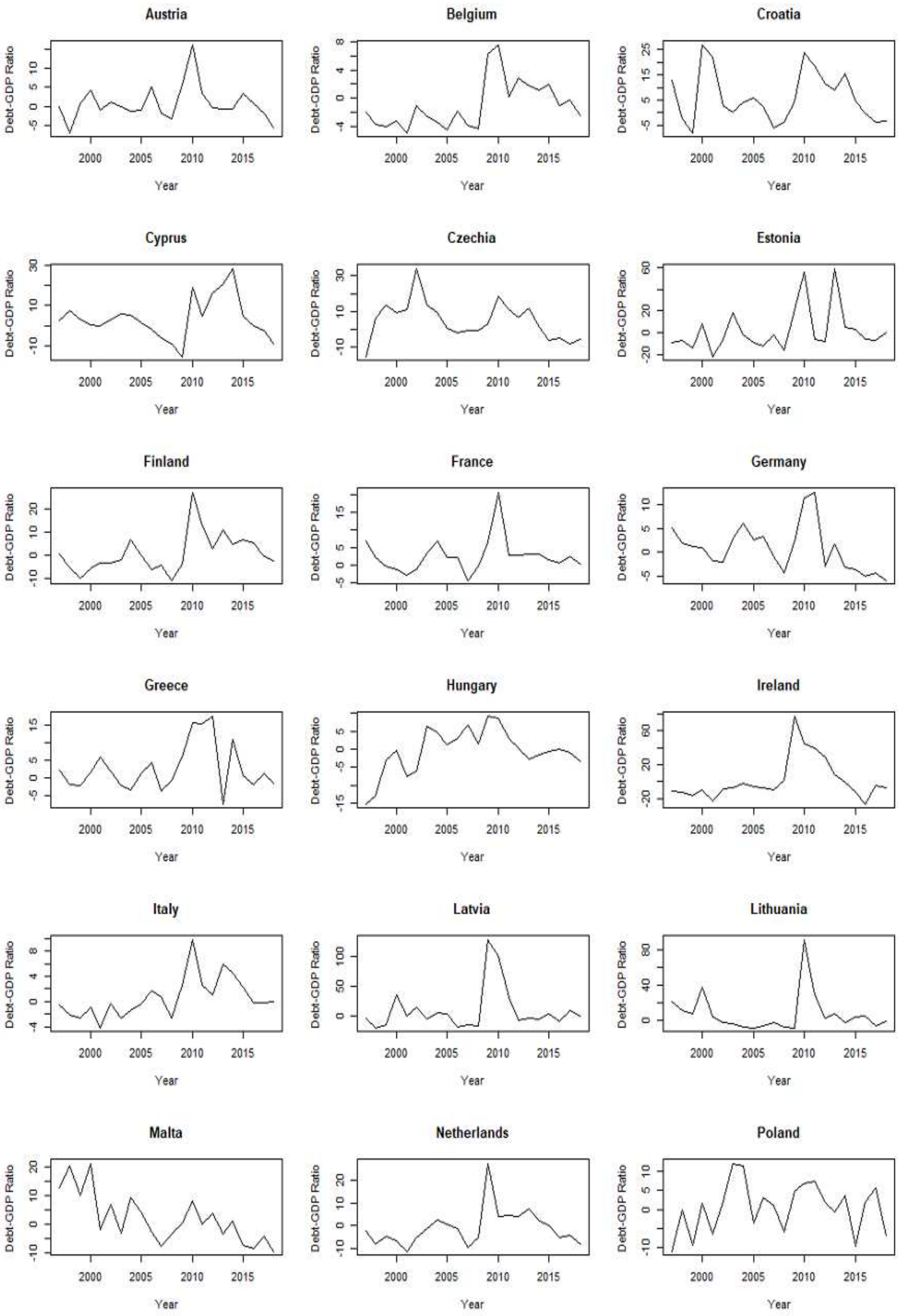
Figure C: Individual Countries' GDP Growth Rate

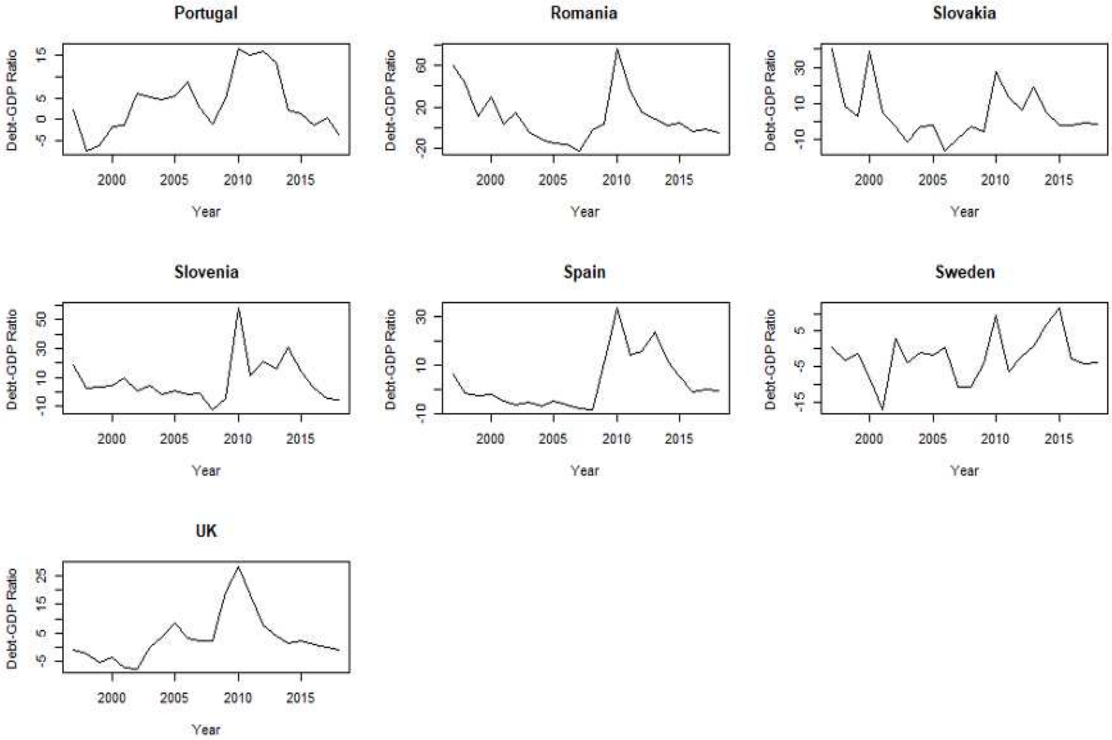




Source: Author's Calculations

Figure D: Individual Countries' Debt Growth Rate





Source: Author's Calculations

Table A: First-generation Unit Root Test

	IPS test		LLC test		IPS test		LLC test	
	Constant	Constant, trend	Constant	Constant, trend	Constant	Constant, trend	Constant	Constant, trend
	Level				First Difference			
Global Panel								
GDP	3.45	-0.029	-0.77	-4.02***	-6.96***	-4.53***	-7.42***	-5.16***
Debt	-0.06	-0.52	-2.98***	-4.12***	-6.00***	-2.81***	-6.04***	-4.02***
Labour	0.65	-2.14**	-1.68**	-5.15***	-5.97***	-3.73***	-6.62***	-5.00***
Human Capital	3.98	-0.59	-0.92	-6.45***	-11.59***	-9.81***	-4.61***	-5.10***
Physical Capital	-2.68***	-2.42***	-4.12***	-5.27***	-9.59***	-6.38***	-9.11***	-6.83***
HDC Panel								
GDP	1.94	0.74	-1.36*	-2.49***	-3.94***	-2.53***	-3.70***	-2.33***
Debt	0.07	0.14	-1.62*	-2.43***	-3.48***	-1.03	-3.85***	-2.13***
Labour	1.69	-0.17	-0.45	-2.53***	-2.99***	-1.71**	-3.24***	-2.34***
Human Capital	2.63	-2.16**	-0.32	-6.45***	-9.41***	-8.89***	-3.59***	-4.30***
Physical Capital	-1.38*	-0.73	-2.33***	-2.87***	-5.10***	-2.97***	-4.09***	-2.61***
LDC Panel								
GDP	2.92	-0.75	0.06	-3.44***	-5.86***	-3.85***	-6.97***	-4.96***
Debt	-0.15	-0.86	-2.60***	-3.47***	-4.97***	-2.91***	-4.77***	-3.58***
Labour	-0.72	-2.80***	-2.43***	-5.36***	-5.40***	-3.52***	-6.21***	-4.74***
Human Capital	2.99	1.26	-2.07**	0.67	-7.04***	-5.06***	-4.51***	-3.01***
Physical Capital	-2.40***	-2.66***	-3.86***	-4.86***	-8.40***	-5.99***	-8.68***	-6.91***

*Notes: IPS is Im-Pesaran-Shin test; LLC is Levin-Lin-Chiu test; Δ is the first difference, *, ** and *** indicate rejection of the null hypothesis at 10, 5 and 1 percent level of significance. Newey-West bandwidth selection with Bartlett kernel is used for both IPS and LLC.*

Table B: Cross sectional dependency test

	Pesaran Cross-Sectional Dependency test	
	Statistic	P-value
Global Panel	4.971	0.000

Table C: Second-Generation Unit Root Test

	CADF test			
	Constant	Constant, trend	Constant	Constant, trend
	Levels		First Difference	
Global Panel				
GDP	-0.81	-1.31	-2.84***	-2.87***
Debt	-2.08*	-2.17	-3.26***	-3.67***
Labour	-1.13	-1.57	-2.35***	-2.68**
Human Capital	-2.36***	-2.30	-4.61***	-4.64***
Physical Capital	-1.98	-2.38	-3.85***	-3.89***
HDC Panel				
GDP	-0.26	-0.97	-2.95***	-2.97***
Debt	-2.08	-2.19	-3.17***	-3.71***
Labour	-0.48	-1.33	-2.14*	-2.66*
Human Capital	-2.56***	-2.41	-4.58***	-4.59***
Physical Capital	-2.22*	-2.67*	-3.80***	-3.97***
LDC Panel				
GDP	-1.57	-2.01	-2.89***	-3.02***
Debt	-2.03	-2.21	-3.52***	-3.70***
Labour	-2.28**	-2.06	-2.87***	-3.22***
Human Capital	-2.10	-2.07	-4.82***	-4.83***
Physical Capital	-2.05	-2.48	-4.11***	-4.08***

*Note: ***denotes the rejection of null hypothesis of unit root at 1 percent level of significance, ** denotes the rejection of the null hypothesis of unit root at 10 percent level and * denotes the rejection of the null hypothesis of unit root at 10 percent level*

Table D: Cointegration Tests

	Global Panel		HDC Panel		LDC Panel	
	Pedroni Cointegration Test: AR Parameter Specific in Panel					
	Without trend	With trend	Without trend	With trend	Without trend	With trend
Modified Phillips-Perron t-	0.87	1.49*	0.63	1.01	0.64	1.58*
Phillips-Perron t-	-8.14***	-10.62***	-5.61***	-7.30***	-5.85***	-8.06***
Augmented Dickey-Fuller t-	-8.29***	-11.00***	-5.40***	-7.74***	-6.31***	-7.82***
	Pedroni Cointegration Test: AR Parameter Same for all Panels					
	Without trend	With trend	Without trend	With trend	Without trend	With trend
Modified variance ratio	-3.24***	-5.13***	-2.47***	-3.83***	-2.96***	-4.34***
Modified Phillips-Perron	-1.20	-0.83	-1.22	-0.96	-0.41	0.21
Phillips-Perron	-8.55***	-12.10***	-6.82***	-9.45***	-4.87***	-7.95***
Augmented Dickey-Fuller	-8.90***	-12.78***	-6.88***	-10.11***	-5.37***	-8.04***
	Kao Cointegration Test					
Modified Dickey Fuller	-12.55***		-10.45***		-6.73***	
Dickey-Fuller	-13.11***		-9.07***		-8.89***	
Augmented Dickey-Fuller	-6.78***		-5.16***		-4.32***	
Unadjusted Modified Dickey-Fuller	-21.58***		-14.10***		-16.49***	
Unadjusted Dickey-Fuller	15.01***		-9.66***		-11.59***	

*Note: * and *** indicate rejection of null hypothesis at 10, and 1 percent level of significance.*

Table E: Cointegration Tests

	Pre-Crisis Panel		**Post-Crisis Panel**	
	Pedroni Cointegration Test: AR Parameter Specific in Panel			
	Without trend	With trend	Without trend	With trend
Modified Phillips-Perron t-	4.36***	5.96***	6.29***	7.80***
Phillips-Perron t-	-7.93***	-13.25***	-6.42***	-5.14***
Augmented Dickey-Fuller t-	-10.34***	-12.27***	-9.63***	-7.62***
	Pedroni Cointegration Test: AR Parameter Same for all Panels			
	Without trend	With trend	Without trend	With trend
Modified variance ratio	-5.39***	-7.54***	-5.51***	-7.05***
Modified Phillips-Perron	1.34*	3.32***	3.83***	5.78***
Phillips-Perron	-10.69***	-21.35***	-3.16***	-4.92***
Augmented Dickey-Fuller	-12.74***	-18.14***	-4.29***	-7.09***
	Kao Cointegration Test			
Modified Dickey Fuller	-7.77***		-3.75***	
Dickey-Fuller	-12.33***		-7.91***	
Augmented Dickey-Fuller	-11.29***		-2.92***	
Unadjusted Modified Dickey-Fuller	-11.25***		-9.45***	
Unadjusted Dickey-Fuller	-13.20***		-10.20***	

*Note: * and *** indicate rejection of null hypothesis at 10, and 1 percent level of significance.*