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Filip Ostrihoň
Corresponding author

Institute of Economic Research,
Slovak Academy of Sciences,
Slovakia
✉ filip.ostrihon@savba.sk

Maria Siranova

Institute of Economic Research,
Slovak Academy of Sciences,
Slovakia
✉ maria.siranova@savba.sk

Menbere Workie Tiruneh

Institute of Economic Research,
Slovak Academy of Sciences,
Slovakia

Webster Vienna,
Private University,
Austria
✉ menbere.workie@savba.sk
✉ menbere.workie@webster.ac.at

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Reassessing the Public Debt Threshold in the EU: Do Macroeconomic Conditions Matter?

Summary: This paper explores the relationship between debt and growth in the 28 EU member states over the 1995-2014 period using an interacted panel data estimator in standard augmented Solow growth regression. The nonlinear nature of the debt-growth relationship allows for computation of the optimal turning point given the set of four conditioning variables. Additionally, the heterogeneity in EU members' growth rates is explored by a panel data quantile regression estimator with nonadditive fixed effects. The results suggest that while additional government consumption decreases the level of growth-maximizing debt, the level of private debt has a positive impact on the optimal turning point. On average, estimated optimal debt thresholds are located in the vicinity of the policy-set 60% debt-to-GDP ratio; however, the observed high heterogeneity in the underlying data results in wide confidence intervals.

Keywords: Debt overhang, Debt threshold level, Panel data, Interaction effects, Quantile regression.

JEL: F34, F43, H63.

The adverse effects of excessive public debt on economic growth have been the subject of both theoretical and empirical research for over four decades. The departure of our paper from previous valuable studies is our focus on members of the EU before, during, and after the period of the Great Recession. The discussion on examining the threshold level of public debt is all the more important in the context of the EU because of the existing binding fiscal rules (i.e., Fiscal Stability Treaty, Maastricht criteria, Macroeconomic Imbalance Procedure) where all member states are under pressure to sustain a public debt-to-GDP ratio below 60 percent in the presence of substantially different economic conditions for both advanced and emerging economies. While the severity of public debt in the EU is relatively less dramatic than in other parts of the world, as indicated by Carmen M. Reinhart and Kenneth S. Rogoff (2010), the recent experience raised concerns about the sustainability of public debt with reference to the

mounting debt of some European countries that created the overall uncertainty for the EU as a whole.

Our paper represents the first step in this direction by allowing the growth-maximizing level of public debt to vary, given the set of four key determinants: (i) being part of the euro area common market; (ii) rising government consumption; (iii) the potentially harmful effect of financial sector development; and (iv) the mounting private sector debt. Overall, the findings of this study contribute to the current discussion in three directions. First, we show that the average point estimate of the optimal debt-to-GDP ratio at 70 percent is relatively near the official threshold set by EU governance fiscal rules. Second, the wide confidence intervals for the estimated optimal threshold indicate that it was not possible to precisely specify the interval of the actual value or unambiguously disqualify the officially set threshold of 60 percent. This also may be a sign of significant cross-country variation in public debt threshold values. Last, among the set of conditioning variables, government consumption matters the most, as it negatively affects the optimal turning point level and, with it, the amount of sustainable debt that a country can accumulate. All of these findings may be seen as supportive arguments for a more differentiated approach in the future design of EU-wide fiscal governance.

The remainder of the paper is structured as follows. Section 1 provides an overview of the theoretical background behind the debt-growth nexus and presents a discussion of the choice of conditioning variables. This section also reviews notable studies undertaking empirical research on the impact of public debt on economic growth. Section 2 describes the model design and construction of the database. In Section 3, we present the empirical results and discuss potential policy implications. The last section concludes the paper.

1. Debt-Growth Nexus and Channels of Transmission

The link between debt and growth has been explored from various perspectives. Generally, public debt can serve to enhance economic growth if additional resources are efficiently allocated and if there is strong governance (Ben Ali Tarek and Zidi Ahmed 2017). The behavior of government in public debt consolidation, in terms of fiscal space, is pivotal for the subsequent need for fiscal reform (František Hajnovic and Juraj Zeman 2012). While there is a general understanding that debt, to a certain extent, can serve as a vehicle to economic growth, there also is a recognition that if debt exceeds a sustainable level, it may become a major source of uncertainty and an obstacle to growth. Alberto Alesina and Guido Tabellini (1992) discuss the theoretical framework of public debt and economic growth as well as cross-country empirical evidence for various regions. One of the heated debates in this regard is determining the optimal level of public debt that is both sustainable and productive in terms of its contribution to economic growth.

The economic literature provides a number of channels through which public debt may be harmful to economic growth. The first line of argument addresses the adverse impact of excessive debt on economic growth *via* so-called debt overhang (Paul R. Krugman 1988; Jeffrey D. Sachs 1989; Eduardo Borensztein 1990; Catherine Pattillo, Helene Poirson, and Luca Ricci 2002; Cristina Checherita-Westphal and

Philipp Rother 2012). The effect of a debt overhang manifests by various means. One aspect is linked to the degree of uncertainty that high debt may generate and how it may ultimately lead to higher risk premiums and consequently a higher cost of financing. As noted by Krugman (1988), debt overhang refers to a large amount of debt held by borrowers who are not trusted by creditors to fulfill their debt contractual terms.

The second transmission channel operates through the disincentive mechanism. As argued by Stijn Claessens and Ishac Diwan (1990), a debt overhang occurs if the effects arising from the lack of liquidity and incentives discourage growth under the circumstances where creditors are unwilling to renegotiate the terms of loans. Similarly, John E. Serieux and Yiagadeesen Samy (2001) argue that a debt overhang creates a disincentive environment for private investment that, through lower investment spending, leads to a slowdown in the rate of economic growth, which further reduces future investment. As growth slows, the debt-to-GDP ratio increases, as does the risk premium for future borrowing, further reinforcing the disincentive effect.

The third transmission channel links the adverse impact of debt to economic growth through a crowding-out effect (Sachs 1989), where a high level of debt increases the market interest rate, making it difficult for the private sector to invest, which eventually reduces economic growth. In accordance with Claessens and Diwan (1990), high public debt may depress capital formation and economic growth through the illiquidity effect, as limited resources should be distributed among consumption, investment, and external transfers to service existing debt. A reduction in investment should obviously be interpreted broadly to encompass both physical and human capital accumulation, which ultimately undermines growth and development (Menbere Workie Tiruneh 2005).

The post-2008 crisis literature has addressed the debate on the optimum public debt level from various perspectives, partially acknowledging that not only is the optimal debt level highly country-specific (Markus Eberhardt and Andrea F. Presbitero 2013; Balázs Égert 2015) but also, more importantly, is affected by the individual economic conditions with reference to the fiscal space available to policy-makers in troubled times (Andros Kourtellos, Thanasis Stengos, and Chih Ming Tan 2011; Atish R. Ghosh et al. 2013). While recent studies show that fiscal multipliers tend to be conditioned on the business cycle and the fiscal position of a government (Raju Huidrom et al. 2016), to date, no study has investigated how the optimal debt-to-GDP ratios differ given the heterogeneity of individual countries and their varying economic conditions. In one of the rare studies, Marta Gómez-Puig and Simón Sosvilla-Rivero (2017), using dynamic conditional correlation (DCC) and a longer period of time (1961-2015) for selected euro area countries, show the time-varying conditional correlation between public debt to GDP and growth. Their findings suggest that the bidirectional relationship between public debt and growth varies both across time as well as across countries.

1.1 Empirics of Debt and Growth: Literature Review

Most empirical studies have examined the impact of public debt on the growth of developing and emerging economies (Claessens and Diwan 1990; Daniel Cohen 1993, 1997; Ashwini Desshpande 1997; Ibrahim A. Elbadawi, Benno J. Ndulu, and Njuguna

Ndung'u 1997; Abdur R. Chowdhury 2001; Maureen Were 2001; Pattillo, Poirson, and Ricci 2002). These studies generally showed the negative impact of high external (public) debt on the economic growth of developing or emerging countries in the 1980s and the 1990s and served as a powerful argument in favor of debt reduction and debt relief for heavily indebted poor countries during those periods.

In recent times, the seminal work of Reinhart and Rogoff (2010) has sparked the debt-growth nexus debate by emphasizing the nonlinear relation between public debt and economic growth. Using the episodes of public debt and economic growth for twenty advanced and twenty-four emerging economies using a long data period, Reinhart and Rogoff (2010) showed that a debt-to-GDP ratio of above 90% is associated with slower growth, regardless of the state of the economic development of the considered country. Naturally, the results triggered not only a series of empirical studies but also policy adjustments toward reducing the level of debt.

The results of further empirical papers are mixed, depending on the set of countries and the time period investigated, as well as on the type of empirical strategy implemented to examine the relations between public debt and growth. Such a potential nonlinear relationship between debt and growth stands in the center of several recent empirical studies (Manmohan S. Kumar and Jaejoon Woo 2010; Anja Baum, Checherita-Westphal, and Rother 2012; Checherita-Westphal and Rother 2012). The literature using the panel-threshold methodology to specify the debt turning point includes (Tsangyao Chang and Gengnan Chiang 2009; Stephen G. Cecchetti, Madhusudan Mohanty, and Fabrizio Zampolli 2011; Baum, Checherita-Westphal, and Rother 2012). The first attempt to theoretically find the concept of a growth-maximizing steady state of debt has been studied in Checherita-Westphal, Andrew Hughes Hallet, and Rother (2012).

To date, the results of empirical studies have not offered clear evidence on the common threshold of the public debt level. In contrast, the upper threshold level of public debt (the turning point) fluctuates wildly depending on the methodology employed, as well as period and country coverage. Studies deliver debt threshold levels ranging from 67 percent (Baum, Checherita-Westphal, and Rother 2012) to 77 percent (Mehmet Caner, Thomas Grennes, and Fritzi Koehler-Geib 2010) to 85 percent (Cecchetti, Mohanty, and Zampolli 2011) to 90 percent (Kumar and Woo 2010), reaching as high as 100 percent of GDP (Checherita-Westphal and Rother 2012). Chang and Chiang (2009) indeed find two distinct debt-to-GDP threshold values for different regimes (32.3% and 66.25%), yet in all specifications the overall impact of debt remains positive, albeit slightly less powerful in certain specifications. Égert (2015) further argues that the threshold level of public debt to GDP is heterogeneous across countries and that when nonlinearity is observed, the turning point may be estimated to a considerably lower level of 20% to 60%, in contrast to the 90% debt-to-GDP ratio claimed by Reinhart and Rogoff (2010).

From a different perspective, Alfredo Schclarek (2014) did not find any robust evidence on the relationship between public debt and economic growth. However, Cândida Ferreira (2009) and Kumar and Woo (2010) claim that there is an inverse relationship between public debt and growth. Égert (2015), using the dataset of Reinhart and Rogoff (2010), showed that the nonlinear relationship between debt and

growth is robust. Furthermore, the paper also shows that government debt may affect growth at a lower level, beginning from 20% of GDP. However, the paper argues that the threshold level is uncertain. Ugo Panizza and Andrea F. Presbitero (2014) claim that once instrumenting public debt with foreign currency decomposition and the exchange rate, the evidence of the nonlinearity between public debt and economic growth disappears, emphasizing the role of endogeneity between public debt and growth. Nevertheless, new estimates based on the theoretical approach derived from the productivity function (Checherita-Westphal, Hughes Hallet, and Rother 2012) impose an optimal level among 22 OECD countries set considerably lower than previously believed (65.5 percent, on average), with significant variation among countries. If a common target is to be set for the euro area economies, the 50 percent threshold is estimated to be growth-maximizing.

Michael Ash, Deepankar Basu, and Arindrajit Dube (2017) study the growth-debt relationship and threshold values of public debt and argue that public debt is endogenous in the growth process and that standard growth regressions offer biased estimators. As a remedy, the authors use different specifications to reduce what they call reverse relationship and unobserved heterogeneity in the relationship using forward, rather than contemporary, growth rates, instrumenting the public debt-to-GDP ratio with its lag and controlling for lagged GDP growth. Their results confirm that the relationship between public debt and growth is virtually flat for a public debt-to-GDP ratio exceeding 30 percent when using forward growth rates and controlling for the past growth rate of GDP. The central conclusion of the authors is that the relationship runs from GDP growth to public debt, rather than *vice versa*.

Using data on a sample of 40 countriee45rs (grouped into advanced and developing) over the 1965-2010 period, Alexander Chudik et al. (2015) obtained no empirical evidence for a universally applicable threshold effect in the relationship between public debt and economic growth after accounting for the impact of global factors and their spillover effects. Regardless of the threshold, the researchers found significant negative long-run effects of public debt buildup on output growth.

Given the aforementioned discussion and subsequent considerations in light of the Great Recession experience, we selected the following set of conditioning indicators and interact them with public debt to examine whether and to what extent their cross-country variation may affect the threshold level of public debt.

a. Euro area (EA) membership

Despite being at the center of attention, there is a surprising lack of empirical estimates focusing on the optimal level of public debt among euro area countries. Baum, Checherita-Westphal, and Rother (2012) and Checherita-Westphal and Rother (2012) are two exceptions; however, none specifically discusses the differences between EA members and nonmembers despite still utilizing the EU common market. In our view, including this interaction term is important, as the policy constraints imposed on EA members far exceed those of the remaining non-EA member states.

b. Government consumption expenditures

While government consumption is perceived in the Keynesian setup as a boost to aggregate demand and growth, this notion has been disputed by various empirical studies.

In Robert J. Barro's (1991) seminal paper, using the data of 98 countries during the period of 1960-1985, he showed that, among other things, government consumption hampers economic growth. The central argument is that government consumption has no direct effect on private productivity but lowers savings and growth through the distorting effects of taxation or government expenditure programs. Analyzing data from 35 developing countries in the 1970-1990 period, Peter Evans and James E. Rauch (1999) show the negative impact of government consumption expenditure on the economic growth of developing economies. Excessive government consumption funded by external sources also has been considered one of the triggers of the recent financial crisis (Barry Eichengreen 2010). António Afonso and Davide Furceri (2008) show that once government expenditure is decomposed into various investment and consumption values, government consumption has a negative impact on the growth of real income *per capita*, both for the OECD setup and the EU scenario.

c. Domestic financial system development

In this study, we approximate domestic financial development by the value of private credit provided by the banking industry. Fiscal policy tends to be highly intertwined with the domestic financial sector, particularly in countries where the domestic financial sector represents a key source of funding for both private and public finances. It has been shown that the effect of fiscal expansion may be contractionary in countries with limited financial sector development (Ricardo J. Caballero and Arvind Krishnamurthy 2004; Jakob Christensen 2005). Conversely, a crisis occurring in the financial sector may poison healthy public finances, forcing it to take over the losses incurred in the process of saving the financial sector from itself. Athanasios Tagkalakis (2013) concludes that while a severe financial crisis increases the level of debt stock to a maximum of 4%, economies with a larger financial sector suffer from more aggravated costs than those with a relatively small financial sector. Financial development under an unstable political environment is less efficient in fostering economic growth. As indicated by Mahmoud Arayassi and Ali Fakih (2017), while domestic financial development has a positive impact in Middle East and North Africa (MENA) countries, the magnitude of the effects fades away during times of political instability.

From a different perspective, a highly developed financial sector is expected, in general, to stimulate economic growth through its intermediary role, channeling resources into the most productive use. In the early 1990s, economists began working toward identifying a causal link from finance to growth. Robert King and Ross Levine (1993) were the first to show that financial depth is a predictor of economic growth, and Levine and Sara Zervos (1998) showed that stock market liquidity (but not the size of the stock market) predicts GDP growth. However, recent empirical studies support the prevalence of the "too much finance" phenomenon on the basis that a point exists after which additional financial deepening could be harmful (Jean-Louis Arcand, Enrico G. Berkes, and Panizza 2011; Roland Beck, Georgios Georgiadis, and Roland Straub 2014). Reasons for such an effect include the crowding-out of more productive sectors (Era Dabla-Norris et al. 2015), as well as a lack of highly qualified human capital in nonfinancial sectors (Cecchetti and Enisse Kharroubi 2015). Financial innovations may further increase the fragility of the overall financial system as the financial

sector expands in the presence of neglected tail risk (Nicola Gennaioli, Andrei Shleifer, and Robert W. Vishny 2012).

d. Private sector indebtedness

As a final candidate for an interaction term, private sector debt as a share of GDP was considered. An influential study by Nils Holinsky, Clemens Kool, and Joan Muysken (2012) showed that the deepening of external imbalances among EA states before the Great Recession was a private rather than public debt phenomenon. Nicoletta Batini, Giovanni Melina, and Stefania Villa (2019) showed that higher levels of private debt tend to lead to greater recessions, especially if they are combined with very high levels of public debt. The authors themselves suggest that there exists a threshold in terms of public debt after exceeding which the effects of public debt on a crisis become more apparent. The question is whether the level of this threshold varies with the amount of private debt.

2. Empirical Model and Data Description

Methodologically, we follow the seminal works of Checherita-Westphal and Rother (2012) and Panizza and Presbitero (2014), who investigated the link between public debt and economic growth.

Available data on annual frequency covered most of the 1995-2014 period for all 28 EU countries. Given that the study features many "new" EU member states, not all of the indicators were available for each country over the entire period. Therefore, econometric methods were employed in the framework of unbalanced panel data with country-specific fixed effects. The list of determinants used and their descriptions are provided in Table 1. This list includes relevant determinants of standard growth regression as specified in the relevant literature discussed in Section 1.

Conceptually, we design our empirical model using the determinants of economic growth based on the augmented growth regression (N. Gregory Mankiw, David Romer, and David N. Weil 1992) and on the theoretical framework of the debt overhang models that were discussed earlier. Although there are many theoretical studies on the impact of public debt on economic growth, there are relatively few empirical studies investigating the impact of debt on growth, particularly for EU members that can be described as a blend of advanced economies with certain post-transition economies.

The departure of our approach from previous similar empirical studies is that we focus on the effects of four conditioning factors described in Section 1 (namely, EA membership, government consumption to GDP, domestic credit to GDP, and private debt to GDP) by introducing their interaction terms with debt levels.

The baseline specification takes the following form:

$$g_{it} = \alpha + \beta_1 \log\left(GDP^{pc}_{it-5}\right) + \beta_2 \left(\frac{GD_{it-6}}{GDP_{it-6}}\right) + \beta_3 \left(\frac{GD_{it-6}}{GDP_{it-6}}\right)^2 + \boldsymbol{\gamma Z_{it}} + u_i + e_t + \varepsilon_{it}. \quad (1)$$

Table 1 List of Variables

Variable	Variable definition	Source
Log(GDP p.c.)	Real gross domestic product per capita in PPS, deflated by GDP deflator for EU (2005=100), lagged by 5 periods	Penn World table/Eurostat
GDP	Gross domestic product at market prices, current prices, million euro	Eurostat
Investment	Gross fixed capital formation (% of GDP), averaged over 6 periods into the past	Eurostat
Pop. growth	Population growth rate, computed as log difference between *t* and *t*-5, divided by 5	Eurostat
REER	Real effective exchange rate (deflator: consumer price indices - 42 trading partners) index, 2005=100 (% change), computed as log difference between *t* and *t*-5, divided by 5	Eurostat
Inflation	All-items harmonized index of consumer prices (% change) computed as log difference between *t* and *t*-5, divided by 5	Eurostat
Openness	Export and import (% of GDP), averaged over 6 periods into the past	Eurostat
GD/GDP	General government consolidated gross debt (% of GDP), lagged by 6 periods	Eurostat
EA mem.	Dummy variable for euro area membership (1 if country is part of EA)	Eurostat
GC/GDP	Government consumption (% of GDP), lagged by 6 periods	Eurostat
DC/GDP	The amount of credit given to private sector by domestic banks (% of GDP), lagged by 6 periods	Eurostat
PD/GDP	Private debt (% of GDP), lagged by 6 periods	World Bank/Eurostat

Sources: Own compilation based on information from respective sources listed in the "Source" column.

In Equation (1), g_{it} represents the annualized 5-year growth rate of GDP *per capita* (computed as a logarithm difference between t and t-5 divided by 5), $\log\left(GDP_{it-5}^{pc}\right)$ represents the natural logarithm of the initial level of GDP *per capita*, $\left(\frac{GD_{it-6}}{GDP_{it-6}}\right)$ represents the 6-year lag of the gross government debt-to-GDP ratio, $\boldsymbol{Z_{it}}$ represents the vector of other explanatory variables, u_i represents the country fixed effect, e_t represents the period fixed effect (captured *via* time dummies), and ε_{it} represents the idiosyncratic error term.

To address the endogeneity problem, we use the lagged values of government debt as well as of key macroeconomic variables of interest (government consumption, domestic credit, and private debt). As our dependent variable is calculated as the 5-year average growth rate, we use a lag of t-6.

Our study, as opposed to previous studies, is based on the assumption that the identical effect of debt-to-GDP level on economic growth across EU countries is unlikely to be achieved. Therefore, we further investigated possible heterogeneity using interaction terms as indicated in Equation (2) below. These terms allow us to distinguish the heterogeneity caused by different debt-growth determinants in each of the countries analyzed conditional on their performance in a selected interacted variable (namely, EA membership, government consumption to GDP, domestic credit to GDP, and private debt to GDP). From a theoretical perspective, this approach was equivalent to assuming that parameter β_2 is a function of other factors, which is denoted as $\beta_2^*(\cdot)$.

$$g_{it} = \alpha + \beta_1 \log\left(GDP_{it-5}^{pc}\right) + \beta_2^*(\cdot)\left(\frac{GD_{it-6}}{GDP_{it-6}}\right) + \beta_3\left(\frac{GD_{it-6}}{GDP_{it-6}}\right)^2 + \boldsymbol{\gamma Z_{it}} + u_i + e_t + \varepsilon_{it}. \quad (2)$$

In Equation (2) g_{it} represents the annualized 5-year growth rate of GDP *per capita* (computed as a logarithm difference between t and t-5 divided by 5), $\log\left(GDP_{it-5}^{pc}\right)$ represents the natural logarithm of the initial level of GDP *per capita*,

$\left(\frac{GD_{it-6}}{GDP_{it-6}}\right)$ represents the 6-year lag of the gross government debt-to-GDP ratio, $\boldsymbol{Z_{it}}$ represents the vector of other explanatory variables, parameter $\beta_2^*(\cdot)$ is a function of specific factors, u_i represents the country fixed effect, e_t represents the period fixed effect (captured *via* time dummies), and ε_{it} represents the idiosyncratic error term.

Introducing an arbitrary factor x_{it} to the parameter function $\beta_2^*(\cdot)$ in Equation (2), the overall effect denoted by parameter β_2 can be computed as:

$$\beta_2^*(\boldsymbol{\theta}, x_{it}) = \theta_0 + \theta_1 x_{it}. \tag{3}$$

In Equation (3), $\boldsymbol{\theta}$ is the vector of unknown parameters for which θ_0 quantifies the unconditional part of the overall effect and θ_1 the conditional part dependent on factor x_{it}. By substituting different factors for x_{it} in Equation (3) (particularly EA membership, government consumption to GDP, domestic credit to GDP, and private debt to GDP), various specifications with different heterogeneity assumptions may be investigated. As an example, in the case of the factor of public consumption to GDP, the parameter function $\beta_2^*(\cdot)$ takes the following linear form:

$$\beta_2^*\left(\boldsymbol{\theta}, \frac{GC_{it}}{GDP_{it}}\right) = \theta_0 + \theta_1 \frac{GC_{it}}{GDP_{it}}. \tag{4}$$

In Equation (4), $\left(\frac{GC_{it}}{GDP_{it}}\right)$ represents the public consumption, and vector $\boldsymbol{\theta}$ is a vector of the estimated parameters for the unconditional term and the debt-to-GDP ratio terms.

Estimated parameters $\boldsymbol{\theta}$ were subsequently used for the quantification of the country-specific slope coefficients (results of the $\beta_2^*(\cdot)$ function) of public debt on economic growth, conditional on the selected variables. The average value of the aforementioned determinants over the 1995-2014 period was imputed.

From the methodological perspective, a fixed effects estimator based on the ordinary least squares method was initially utilized. The economic and social time-invariant characteristics are captured by fixed effects. Cluster-robust standard errors (Colin A. Cameron and Pravin K. Trivedi 2010) were preferred to ordinary standard errors, given the very likely serial correlation within clusters. For the validation of the estimated models, the normal distribution of residuals was tested using Patrick Royston's (1991) adjusted version of the normality test of Ralph B. D'Agostino, Albert Belanger, and Ralph B. D'Agostino Jr. (1990). Furthermore, the assumption of the independence of cross-sectional units was verified using a M. Hashem Pesaran (2021) test. To account for the dependence of cross-sectional units, John C. Driscoll and Aart C. Kraay's (1998) estimator implemented in Stata by Daniel Hoechle (2007), which took into account cross-sectional fixed effects, heteroskedasticity, serial correlation and cross-sectional correlation in the panel data, was used.

Finally, the statistical significance of the computed public debt threshold values was assessed using 95% confidence intervals computed *via* the delta method. The empirical turning point denotes a threshold after which the effect of public debt on GDP growth decreases with an increasing level of debt. It can be derived from Equation (2) by finding the level of government debt-to-GDP ratio $\left(\frac{GD_{it-6}}{GDP_{it-6}}\right)$ at which the first derivative of economic growth with respect to government debt is set to zero:

$$Threshold = \beta_2^*(\cdot)/(-2\beta_3). \quad (5)$$

Since the parameter function $\beta_2^*(\cdot)$ is dependent on the value of the conditioning variable (namely, EA membership, government consumption to GDP, domestic credit to GDP, and private debt to GDP), the turning point also varies accordingly. We evaluate the threshold in Equation (5), based on the sample average for interacted variables across countries and time.

To support the baseline results and further explore heterogeneity among cross-sectional units (countries), we employ a quantile regression approach. The use of such an approach in output growth estimations has been endorsed by several publications (e.g., Marcello Mello and Roberto Perrelli 2003; Raul A. Barreto and Anthony W. Hughes 2004). According to Mello and Perrelli (2003), quantile regression is a suitable estimation methodology in a growth context, as it captures countries' heterogeneity and assesses how policy variables affect countries according to their position on the conditional growth distribution. In this context, quantile regression has been used to investigate the conditional effects of health investments (Silva F. Rosendo Silva, Marta Simões, and João Sousa Andrade 2018), trade openness (Gilles Dufrenot, Valerie Mignon, and Charalambos Tsangarides 2010), tourism (Sarantis Lolos, Panagiotis Palaios, and Evangelia Papapetrou forthcoming), and a wide set of explanatory variables (Jesus Crespo-Cuaresma, Neil Foster, and Robert Stehrer 2011) on the growth rate of *per capita* income.

The quantile regression with nonadditive fixed effects (David Powell 2020), which was implemented in Stata by Matthew Baker, Powell, and Travis Smith (2016), was utilized. The estimation for each percentile was carried out by the Markov chain Monte Carlo (MCMC) method, using 1000 draws (100 of which were dropped as a burn-in period) and an acceptance rate of 0.5. The conditioning variables were expressed as sample means over all available data for a particular variable. The standard errors for the turning point were obtained using bootstrapping of the described MCMC estimation procedure, with 1000 replications.

Descriptive statistics for all variables are provided in Table 2.

Table 2 Descriptive Statistics

	Obs.	Mean	Std. dev.	Min	Max
GDP p.c. growth	367	0.01	0.02	-0.08	0.09
Log(GDP p.c.)	367	9.85	0.45	8.82	11.03
Pop. growth	367	0.00	0.01	-0.02	0.03
REER	367	0.01	0.02	-0.05	0.09
Inflation	367	0.03	0.04	0.00	0.49
Investment	367	-1.48	0.14	-1.92	-1.09
Openness	367	1.06	0.56	0.46	3.42
GD/GDP	367	0.49	0.28	0.04	1.31
$(GD/GDP)^2$	367	0.35	0.37	0.00	2.56
EA mem.	367	0.53	0.50	0.00	1.00
GC/GDP	366	0.19	0.03	0.12	0.26
DC/GDP	361	0.81	0.51	0.07	2.52
PD/GDP	326	0.67	0.45	0.20	3.47

Sources: Own compilation based on sources listed in the "Source" column of Table 1.

3. Results and Discussion

3.1 Sensitivity to Country Selection, Period of Crisis and Use of Time Dummy Variables

As our analyzed period features the Great Recession as well as the subsequent debt crisis that ensued, the results of the benchmark specification as in Equation (1) vary substantially with the inclusion of the full set of time dummies for capturing period-specific fixed effects (Table 3).

It also can be observed that the effect of the inclusion of time dummies is not dependent on the choice of analyzed countries, as shifts of the estimated parameters are fairly noticeable for the EU28[1], EU15[2], and EU12[3] country groups. In other words, changes in estimated coefficients are mostly attributed to the presence of time dummies rather than the inclusion/exclusion of new EU member states.

In regard to prior assumptions about the parameters of standard growth regression determinants (i.e., control variables), the initial level of GDP p.c. has a negative effect on economic growth, thus confirming the expected conditional convergence. A higher population growth rate apparently decreases the GDP p.c. growth, a result also obtained by Checherita-Westphal and Rother (2012). A negative effect is consistently observed for real effective exchange rate (REER) growth, as REER appreciation hinders economic growth. Overall, inflation does not have a statistically significant impact on economic growth or yield the wrong sign, although this finding is partially refuted in smaller samples and specifications that control for common time trends. Investment has a positive, although mostly statistically insignificant, effect, with the exception of the benchmark regression, which is in line with the conditional convergence setup and was previously observed in Checherita-Westphal and Rother (2012). We attribute the statistically significant positive impact in Specification (1) in Table 3 to the inclusion of "newer" member states, which could be characterized by a major increase in their investment rates due to the catch-up process observed during the initial years of their transformation. Openness has a positive effect, a finding again empirically confirmed by Checherita-Westphal and Rother (2012), but only in specifications including "older" member states (Specifications 3 and 5). This may point to the fact that the highest benefits from trade openness come at the later stage of participation in international trade. Alternatively, the specificities of trade openness may matter due to the position in the global value chains. As the "newer members" are in general positioned in the downstream part of the production (Ewa Cieślik, Jadwiga Biegańska, and Stefania Środa-Murawska 2016), their benefits from international trade may not have been that substantial.

[1] EU28 group contains Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.
[2] EU15 group contains Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.
[3] EU12 group contains Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and the United Kingdom.

Table 3 Comparison of Benchmark Results for Different Country Groups and Inclusion of Time Dummies

	(1)	(2)	(3)	(4)	(5)	(6)
GDP p.c. growth	EU28	EU28	EU15	EU15	EU12	EU12
Log(GDP p.c.)	-0.122***	-0.144***	-0.119***	-0.141***	-0.119***	-0.142***
	(0.012)	(0.025)	(0.017)	(0.023)	(0.017)	(0.021)
Pop. growth	-1.032***	-1.370***	-1.121***	-1.148***	-1.072***	-1.210***
	(0.176)	(0.137)	(0.127)	(0.321)	(0.067)	(0.251)
REER	-0.641***	-0.490***	-0.629***	-0.232**	-0.666***	-0.300**
	(0.015)	(0.052)	(0.049)	(0.095)	(0.054)	(0.101)
Inflation	0.021	-0.013	0.114*	0.026	0.155*	0.174
	(0.013)	(0.010)	(0.058)	(0.165)	(0.081)	(0.153)
Investment	0.031**	0.018	0.029	-0.000	0.023	0.002
	(0.014)	(0.012)	(0.019)	(0.027)	(0.017)	(0.024)
Openness	0.006	-0.004	0.022***	0.006	0.015***	0.003
	(0.005)	(0.010)	(0.003)	(0.019)	(0.003)	(0.018)
GD/GDP	0.037***	0.034***	0.041***	0.029**	0.045***	0.029**
	(0.009)	(0.008)	(0.011)	(0.011)	(0.011)	(0.011)
$(GD/GDP)^2$	-0.027***	-0.036***	-0.029***	-0.034***	-0.033***	-0.033***
	(0.003)	(0.007)	(0.008)	(0.010)	(0.008)	(0.010)
Constant	1.256***	1.464***	1.242***	1.438***	1.240***	1.453***
	(0.127)	(0.250)	(0.203)	(0.254)	(0.197)	(0.227)
CS FE	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	No	Yes	No	Yes	No
R^2	0.865	0.751	0.882	0.744	0.866	0.720
No. of obs.	367	367	199	199	157	157
Norm. test	1.312	0.723	14.867	40.674	20.416	28.846
Norm. test (p)	0.519	0.697	0.001	0.000	0.000	0.000
Pesaran	-2.157	31.967	-2.184	15.911	-1.796	12.974
Pesaran (p)	0.031	0.000	0.029	0.000	0.072	0.000
Turning point (%)	**68.871**	**48.230**	**70.265**	**41.965**	**68.480**	**44.362**

Notes: The dependent variable is the 5-year overlapping growth rate computed as the difference in logarithms across five years divided by five. Driscoll-Kraay standard errors are presented in parentheses. The number of asterisks * indicates significance of the parameter at the 0.1 (*), 0.05 (**), and 0.01 (***) levels.

Source: Own calculations based on data listed in Table 1.

The statistical significance of public debt on economic growth remains unaffected by the inclusion of time dummies or a reduction in the sample size. However, the parameter for the linear term of public debt increased with the inclusion of time dummies, and the parameter for the quadratic term of public debt decreased, with the exception of EU12, for which it remained unchanged. This tendency was consequently reflected in computed turning points, as they are higher when time dummies are included for each examined country group.

Apart from changes in the parameters for debt and debt squared, other notable shifts are observed in parameters for other control variables, including the initial level of GDP, REER growth, investment, and openness. With the exception of the real effective exchange rate, the parameters always increase when the time dummies are included.

Given the previous discussion, we use specifications with time dummies in the next steps of our empirical analysis. The lower levels of optimal thresholds observed in specifications without time dummies are likely to reflect the underlying tendency of increases in debt levels during times of economic stress and downturns. The global slowdown of the economy in the late nineties as well as financial and economic crises are exactly those kinds of adverse shocks that, without being controlled for by the time dummies, would affect estimates of the optimal threshold levels.

Last, given the results of the Pesaran test, the cross-sectional dependence is rather high. Due to this fact, Driscoll-Kraay standard errors were reported.

3.2 Interacted Panel Model

The estimated results based on the 5-year overlapping growth model in Equation (2) are presented in Table 4 below. The estimated results for the set of standard growth-regression determinants, as discussed in the previous section, remain to a high degree unchanged for the results presented in Table 4. One notable exception is the parameter for inflation, which turns negative for the estimated specification that includes private debt.

Regarding the validity of the models, only one specification shows a distribution of residuals that, according to the normality test, is significantly different from the normal distribution. As the test for the statistical significance of individual parameters relies on the assumption of normality, one should be cautious when making judgments about statistical significance for results for private debt.

Among the set of four new conditioning variables introduced in this study, EA membership is shown to unlikely have any effect on economic growth. Unconditional government consumption appears to have a positive effect on economic growth. In contrast, the financial development variable is associated with an unconditional, negative, highly statistically significant effect on economic growth, corroborating the hypothesis of the potentially harmful effects of the domestic financial system due to the unwinding of the financial crisis. A similar finding is reported for private debt, potentially reflecting the role of overindebtedness in countries affected by the financial crisis.

Taking into account the results in Section 3.1 (Table 3), our estimates indicate that, on average, there exist both positive and negative impacts of public debt on the economic growth of EU28 countries, depending on the amount of acquired public debt. Hence, there is ample evidence of the existence of an unconditional turning point within the EU countries, as the quadratic debt term appears to have a negative and highly statistically significant effect in every estimated model, particularly in those that exhibit residuals with apparent normal distribution.

The growth-maximizing level of debt is difficult to narrow down to a single number for the entire EU28, as multiple estimates are obtained based on the models used. All the models provide a turning point at a debt level higher than 60% of GDP, which was initially set by the Maastricht criteria. Our results are reminiscent of the results in Égert (2015), who argues for a heterogeneous distribution of optimal debt levels, or Chang and Chiang (2009), who propose that there might exist two optimal turning points for different regimes (lower and higher sustainable levels).

However, this statutory-set debt level is within the boundaries of confidence intervals for the turning point for all of our specifications. Since the confidence intervals do not cover value "0", all of the turning point estimates are statistically significant. On the other hand, there also is evidence that the debt level of the turning point may change conditional on the level of government consumption and private debt, as the respective parameters of the interaction terms are statistically significant at the 1% significance level. Furthermore, the turning point may potentially be dependent on domestic credit as analogous parameter is statistically significant at the 10% level but not at the 5% level.

Based on the obtained results, it appears that additional government consumption results in a lower turning point and, thus, a lower sustainable level of public debt. Interestingly, while the common narrative of unsound government expenditures posing a threat to economic growth (Afonso and Furceri 2008) was not confirmed in our sample, we show that the effect of government expenditures has burdened the government finances in EU28 by lowering the optimal growth-maximizing public debt.

Table 4 Relationship between Debt and per-capital GDP Growth, 5-Year Overlapping Growth Rate

GDP p.c. growth	(1)	(2)	(3)	(4)	(5)
Log(GDP p.c.)	-0.122***	-0.116***	-0.120***	-0.117***	-0.125***
	(0.012)	(0.015)	(0.010)	(0.013)	(0.012)
Pop. growth	-1.032***	-0.879***	-1.132***	-1.110***	-1.219***
	(0.176)	(0.158)	(0.152)	(0.166)	(0.094)
REER	-0.641***	-0.660***	-0.670***	-0.651***	-0.568***
	(0.015)	(0.012)	(0.014)	(0.018)	(0.027)
Inflation	0.021	0.009	0.045***	0.013	-0.020
	(0.013)	(0.017)	(0.014)	(0.013)	(0.031)
Investment	0.031**	0.023	0.034***	0.029*	0.033***
	(0.014)	(0.017)	(0.012)	(0.014)	(0.012)
Openness	0.006	0.007	0.006	0.000	0.017*
	(0.005)	(0.006)	(0.006)	(0.007)	(0.009)
GD/GDP	0.037***	0.043***	0.104***	0.037***	0.031***
	(0.009)	(0.013)	(0.027)	(0.010)	(0.008)
$(GD/GDP)^2$	-0.027***	-0.031***	-0.025***	-0.024***	-0.032***
	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
EA mem.		-0.007			
		(0.005)			
EA mem. * (GD/GDP)		-0.002			
		(0.011)			
GC/GDP			0.156***		
			(0.047)		
(GC/GDP) * (GD/GDP)			-0.354***		
			(0.102)		
DC/GDP				-0.008***	
				(0.002)	
(DC/GDP) * (GD/GDP)				-0.006*	
				(0.004)	
PD/GDP					-0.005*
					(0.002)

PD/GDP * (GD/GDP)					0.022***
					(0.007)
Constant	1.256***	1.189***	1.204***	1.222***	1.276***
	(0.127)	(0.159)	(0.101)	(0.134)	(0.128)
CS FE	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes
R^2	0.865	0.869	0.869	0.863	0.874
No. of obs.	367	367	366	361	326
Norm. test	1.312	1.654	1.020	0.340	10.281
Norm. test (p)	0.519	0.437	0.601	0.843	0.006
Turning point (%)	**68.87**	**68.27**	**70.50**	**67.41**	**72.29**
CI (95%) lower	30.39	33.70	25.50	23.06	38.95
CI (95%) upper	107.36	102.84	115.51	111.76	105.64
Turning point (%) - p10	.	**69.78**	**92.07**	**75.53**	**59.90**
CI (95%) lower - p10	.	17.05	34.80	28.43	33.62
CI (95%) upper - p10	.	122.51	149.34	122.64	86.19
Turning point (%) - p90	.	**66.94**	**45.58**	**58.27**	**84.41**
CI (95%) lower - p90	.	46.75	13.45	14.55	43.32
CI (95%) upper - p90	.	87.13	77.70	101.99	125.50

Notes: The dependent variable is the 5-year overlapping growth rate computed as the difference in logarithms across five years divided by five. Driscoll-Kraay standard errors are presented in parentheses. The number of asterisks * indicates significance of the parameter at the 0.1 (*), 0.05 (**), and 0.01 (***) levels. p10 indicates that the turning point is evaluated using the 10th percentile derived from the overall empirical distribution of the conditioning variable, according to Specifications (4) and (5). p90 indicates that the turning point is evaluated using the 90th percentile derived from the overall empirical distribution of the conditioning variable, according to Specifications (4) and (5).

Source: Own calculations based on data listed in Table 1.

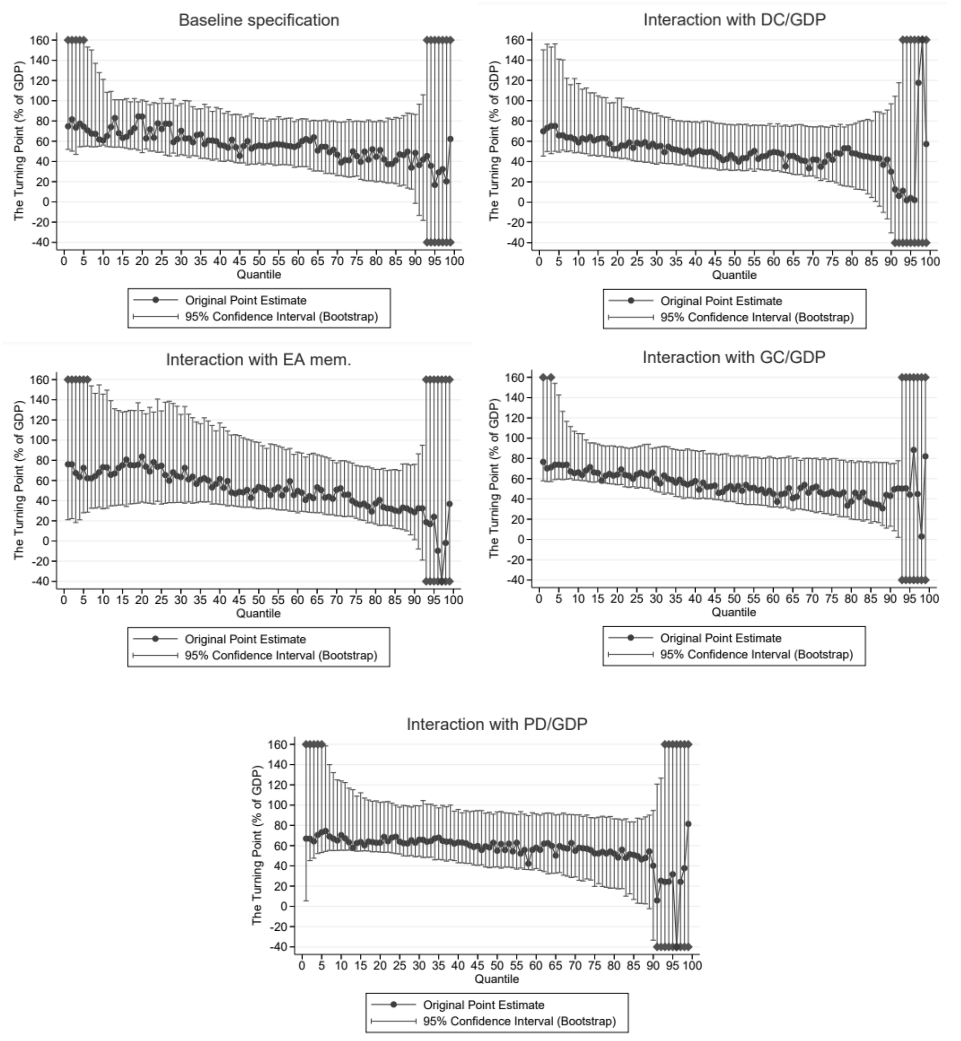
Similarly, increasing domestic credit provisioning potentially leads to a lower turning point, which can be interpreted as the probable effect of the too-much-finance hypothesis linking the slowdown in economic growth to the overfinancialization of developed economies (Arcand, Berkes, and Panizza 2011). On the other hand, the results indicate that the proportion of the level of private debt increases the level of country-specific turning points.

For each conditioning variable, we also evaluate the growth-maximizing turning point at two locations of the underlying distribution, the 10th and 90th percentiles. The cross-country heterogeneity in optimal thresholds further manifested in the sizeable differences between estimated values for these two distinct points. Countries with a large government sector, high levels of financial sector development and smaller levels of domestic private indebtedness are characterized by comparably lower levels of growth-maximizing debt than member states on the opposite side of that distribution.

As part of the robustness check, we look at the behavior of the optimal turning point when public debt is interacted with one direct (output gap) and one indirect measure (cyclical deficit) of the business cycle. In both cases, the results (available upon request) do not deliver statistically significant results.

3.3 Quantile Regression Estimates

To investigate the issue further, a quantile regression in a panel data framework was employed. Figure 1 presents the level of the turning point computed for the quantile regression results for each percentile based on the specifications presented in Table 4. The turning points are evaluated at the average of the underlying distribution of conditioning variables, based on all data available.



Notes: The values of the elements in every chart were truncated at -40 and 160, marking them with a red diamond symbol if the coefficient estimate (blue) or boundary of confidence interval (maroon) exceeded these values.

Source: Own calculations based on data listed in Table 1.

Figure 1 Turning Point Estimates Based on Quantile Regressions

In all specifications, the level of the turning point is not stable across all percentiles but shows a declining trend. While more imprecise at both edges of the distribution (wider confidence intervals), relatively stable results are achieved for the center of the growth distribution (between the 15th and 85th percentiles), i.e., the medium-growth economies.

The quantile regression for specifications with public debt interacted with government consumption, domestic credit or private debt has confirmed that high-growing countries do have turning points set lower than countries experiencing smaller than median growth. However, while in the case of low-growth countries we do not find observations with an optimal turning point lower than 40 percent of GDP, in the high-growth countries we still report a substantial number of observations that are attainable even at the optimal debt level as high as 80 percent of GDP. The results also indicate that relatively higher levels of economic growth are still attainable at levels of government debt substantially higher than the Maastricht criterion. On the other hand, in the presence of levels close and highly above the Maastricht criterion, the chance of being located in the low-economic growth environment steadily increases.

3.4 Model Discussion and Policy Implications

Following the controversial 90% optimal public debt-to-GDP ratio that was suggested by Reinhart and Rogoff (2010), which was based on stylized facts, heated policy debates in terms of targeting the optimal size of public debt as well as the necessary austerity policy measure to reduce the size of public debt to the suggested threshold level were nonetheless triggered. Such bias in determining the optimal debt threshold level has been disputed on the grounds that it does not reflect country-specific and time-specific conditioning factors that can potentially lead to cross-country variation in the optimal level of the public debt-to-GDP ratio.

Turning to the EU, which is the target group in our study, the violation of the 60% optimal debt-to-GDP ratio during the period of the Great Recession caused fierce disputes among EU member states that partially brought the future of the euro as a common currency into a spotlight. Our results offer a considerable innovation in this important policy debate, as they provide a set of conditioning factors that allow policy-makers to differentiate the optimal level of public debt for countries in the EU depending on their magnitude.

Based on our findings, we can conclude that the preventive arm of the Stability and Growth Pact, with its expenditure binding rule, may not only primarily affect EU member states *via* its direct impact on economic growth but also indirectly by creating additional space for expansion of growth-maximizing public debt levels. From different perspectives, as countries with an oversized financial sector were, in general, marked by lower economic growth and suffered from comparably lower levels of growth-maximizing public debt, unconstrained deepening of the financial sector coupled with unlimited growth of indebtedness may bring about negative consequences for the potential of future economic growth.

Last, although there is evidence that supports the notion of a sufficiently homogenous reaction of economic growth toward mounting public debt across the EU, there also are hints that the country-specific differences in optimal threshold values are

noticeable; thus, the adoption of a "one-size-fits-all" public debt threshold level may lead to potentially suboptimal outcomes.

4. Conclusion

This paper elaborates on the relationship between public debt and economic growth in the EU context and expands the standard debt-growth nexus framework by introducing new conditioning factors that may affect this relationship. The results are estimated on an unbalanced panel for the EU28 countries and from 1995 to 2014 with an interacted panel fixed effect model and quantile regression approach. Our paper contributes to the current discussion along three dimensions.

First, our findings confirm that there exists a debt overhang in the EU region, as the effect of debt on economic growth changes from positive to negative as the debt surpasses a certain threshold value. Additionally, the estimated values of the optimal turning point for different models are located on average 10 percent above the policy-set 60% debt-to-GDP ratio, although the difference between the estimated and statutory-set threshold values is statistically insignificant due to relatively wide confidence intervals.

Consequently, the results indeed indicate that there is a significant cross-country variation in public debt threshold values. This finding also may open room for further refinement of the aforementioned control variables to accurately estimate the growth-enhancing level of public debt as well as challenge the "one-size-fits-all" approach.

Last, among all the debt-turning point conditioning variables considered (EA membership, government consumption, domestic credit and private debt), government consumption stands at the forefront in adversely affecting the optimal turning point and, with it, the amount of sustainable debt that a country can accumulate. It appears that European countries with higher government consumption in relation to their GDP may experience more negative effects of public debt on economic growth earlier and with a higher magnitude.

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