Assessing heterogeneous time-varying impacts in the debt-growth nexus

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Abstract

We empirically identify, measure, and describe the heterogeneity of the debt-growth nexus and the underlying factors that may explain it using panel data for 115 countries from 1995 to 2016. First, countries are endogenously grouped using the grouped fixed effects (GFE) estimator. The GFE estimator endogenously splits the sample into five groups of countries with a distinct estimated effect of public debt-to-GDP ratio on economic growth and allows us to investigate group-specific time-varying impacts. Then, we use a panel data analysis to explore the potential drivers affecting these heterogeneous links' time-varying magnitude. Our results suggest that the negative impact of public debt on economic growth is moderated by the quality of a country's institutions and the proportion of productive expenditure but intensified by indebtedness and the maturity of the debt.

Keywords: Public debt; Economic growth; Heterogeneity; Grouped fixed-effects; Panel data; Multinomial logit regression.
JEL Classification Codes: C23, F33, H63, O47, O52

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1. Introduction

Due to the sudden surge in government debt because of the Covid-19 outbreak and the concurrent hike in interest rates to battle excessive inflation[1], concerns regarding debt sustainability and the relationship between public debt and economic growth have lately returned.

Concretely, amid the fourth wave of global debt that began in 2010 (see World Bank, 2020), the Covid-19 pandemic caused a global recession forcing governments to move quickly to provide aid as economic activity collapsed. Consequently, global debt increased by 28 percentage points to 256 per cent of GDP in 2020, the highest one-year increase since World War II [see International Monetary Fund (IMF)'s Global Debt Database for more information][2] while the worldwide public debt ratio approached 100 per cent of GDP −the most outstanding level since the mid-1960s−. In the subsequent two years, government debt declined (92.1% of GDP in 2022)[3] but, despite this fact, government debt-to-GDP ratios are still above the pre-pandemic levels (84.3% in 2019 or 82.7% in 2016 –at the end of our sample period−) and debt servicing has become more difficult due to rising interest rates and slowing economies.

So, an important motivation for this paper draws on the increasing public debt levels across countries, especially after the Covid-19 pandemic and in the current context of rising prices and interest rates. Indeed, in the present environment, there has been a growing interest in determining how increasing sovereign debt may affect economic growth [see, e.g., Augustine ad Rafi (2023), Caner *et al.*, (2021), De Soyres *et al.* (2022), Kassouri *et al.* (2021) or Law *et al.* (2021), among others], and this paper aims to contribute to this empirical literature examining the

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[1] Rising prices for food and energy commodities, as well as several supply and logistical bottlenecks, were mainly caused by adjustments brought on by the pandemic but made worse by the start of the war in Ukraine.
[2] See https://blogs.imf.org/2021/12/15/global-debt-reaches-a-record-226-trillion/
[3] See IMF Fiscal Monitor, April 2023.

heterogeneity of the debt-growth nexus across a sample of 115 countries and over the period 1995-2016.

Empirical research is divided into two generations of articles in the literature already published (see Mitze and Matz, 2015). The works of Reinhart and Rogoff (2010), Pattillo *et al.* (2011), Lof and Malinen (2014), Woo and Kumar (2015), Caner *et al.* (2021), Augustine and Rafi (2023) and Law *et al.* (2021) are among those considered to be part of the "first generation". Since they mainly concentrated on the nonlinear relationship between the two variables, these papers defended the existence of an inverted U-shape relationship between public debt and economic growth (debt begins to harm growth when the debt-to-GDP ratio exceeds a given threshold - 90%, according to the seminal paper by Reinhart and Rogoff (2010)).

However, the "second generation" of publications focuses on the heterogeneity of the debt-growth relationship between nations rather than only the nonlinearities. Ghosh *et al.* (2013), Pescatori *et al.* (2014), Edberhardt and Presbitero (2015), Markus and Rainer (2016), Chudik *et al.* (2017), Chiu and Lee (2017), Gómez-Puig and Sosvilla-Rivero (2017, 2018a) or Kassouri *et al.* (2021)[4] are a few examples of studies that support this idea]. The publications in this group acknowledge that the effect of government debt on growth varies by country and is influenced by institutional, financial, and macroeconomic factors.

In this context, Bonhomme and Manresa's (2015a) pooled fixed effects estimator (GFE) was recently applied to panel data for 115 countries during the period 1995-2016 by Gómez-Puig *et al.* (2022), who also explored and measured the heterogeneity of the debt-growth nexus across nations. Using this methodology, they endogenously identified five groups of nations with a clear

[4] These authors analyse the threshold effect of debt on growth on a sample of 62 emerging and developing countries during 2000-2018 and find that its value depends mostly on the level of economic development.

correlation between public debt-to-GDP and economic growth. However, the empirical results of that research were averages for the entire sample period, not examining the impact of public debt on growth over time in the groups of countries analysed.

The objective of this paper is twofold. First, given that the GFE estimator can account for the possibility that different countries experience different dynamics in the debt-growth relationship while leaving the group-specific time patterns and individual group membership open to estimation from the data, the primary goal is to investigate whether there might be a temporal fluctuation in the parameter linking the public debt variable to the real growth rate, providing additional evidence of the heterogeneities in both the country- and time-specific effects of public debt on economic performance; whilst the second is to investigate the factors that affect how much these diverse linkages change over time. A panel data analysis is used to evaluate the impact of five different types of variables: (1) institution quality, (2) private debt, (3) public debt, (4) the makeup of debt-financed public spending, and (5) debt maturity. Since this is the first paper to analyse the heterogeneities in the debt-growth nexus across countries and over time, our analysis adds significantly to the body of existing literature and tries to shed additional light on the heterogeneous relationship between public debt and economic growth.

The structure of the paper is as follows. In Section 2, the analytical framework is covered. We describe our dataset in Section 3. While Section 4 details the econometric technique, Section 5 presents the empirical findings. Finally, Section 6 offers some final concluding remarks.

2. Analytical framework

As previously indicated, Gómez-Puig *et al.* (2022) use panel data for a large sample of nations over 22 years and apply the grouped fixed effects (GFE) estimator proposed by Bonhomme and Manresa (2015a) to study the heterogeneity of the debt-growth connection across countries. In their study, the debt-growth nexus is investigated using a public debt-added Solow model, where the real per capita GDP growth rate for a specific country *i* in time *t* (g_{ti}) is given by:

$$g_{it} = \alpha + \gamma y_{it-1} + \sum_{j=1}^{n} \delta_{ij} X_{ijt} + \beta d_{it} + \varepsilon_{it}, \text{ i=1,...,N, t=1,...,T.} \quad (1)$$

where y_{it-1} is the logarithm of initial real *per capita* GDP (to represent the "catch-up effect" or conditional convergence of the economy to its steady state), X_{ijt} (j=1, …, n) is a collection of control variables, d_{ti} is the public debt-to-GDP ratio, and ε_{it} denotes the error term.

Regarding X_{it}, a set of explanatory variables are taken into account that is consistently linked to economic growth in the literature [see, e.g., Aghion and Howitt (2009) or Sachs and Warner (1997)]: (i) population growth rate as a percentage ($POPGR_t$); (ii) the ratio of gross capital formation to GDP (GCF_t); (iii) life expectancy at birth, which serves as a proxy for the level of human capital (HK_t); (iv) openness to trade, which is determined by the sum of exports and imports over GDP ($OPEN_t$); (v) the GDP deflator inflation rate, which is taken as a gauge of macroeconomic instability and uncertainty (INF_t); and (vi) a traditional indicator of financial depth (FIN_t).

Since they have been identified as two primary determinants of economic growth in the literature (see, e.g., Solow, 1956; and Frankel, 1962), we use population growth ($POPGR_t$) and the ratio of gross fixed capital formation to real GDP (GCF_t) as proxies for the rate of labour growth and the accumulation of the physical capital stock, respectively. In order to highlight the fact that increased human capital attracts investment and encourages participation in innovative activities (Grossman and Helpman, 1991), a proxy for it (HK_t) is included in the analysis. Trade openness ($OPEN_t$) and inflation rate (INF_t) have both been incorporated in the model because the former is thought to increase productivity through efficiency gains (Seghezza and Baldwin, 2008), while some authors [see, for example, Fischer (1993) or Barro (2003)] have argued that inflation is a good indicator of how the government manages the economy and that low inflation leads to economic efficiency because economies can allocate, through the price mechanism, scarce resources to their best economic use (World Bank, 1990). According to King and Levine (1993) or Beck *et al.* (2000), the level of debt a nation can support without suffering adverse effects also depends on the development of financial markets. For this reason, we also introduce a measure of financial development. In particular, "financial depth", or the total size of the financial intermediation industry, is measured by FIN_t, which is equal to the liquid liabilities of banks and other financial intermediaries divided by GDP.

As the empirical findings of Gómez-Puig *et al.* (2022) were averages throughout the whole study period (1995-2016), they did not detail the impact of public debt on economic performance over time in the identified country groups. Therefore, since our primary objective is to investigate if there are any group-specific, time-varying effects of public debt on economic growth, our research diverges from the findings of the previous one. In order to achieve this, we employ the Bonhomme and Manresa (2015b) heterogeneous coefficients extension of the GFE model, which will be discussed in Section 4. Then, we move on to our second objective and look at the factors that affect the time-varying magnitude of these heterogeneous links using five different types of variables that measure: (1) the quality of institutions, (2) the relative public indebtedness, (3) the relative private indebtedness, (4) debt maturity, and (5) the makeup of public expenditure that is debt-financed.

Institutional quality is a crucial contextual component; rising public debt and solid institutional integrity could have opposite effects on economic growth. Various contributions from the early 2000s established the significance of sound and effective institutions in explaining long-term growth (see Acemoglu *et al.* 2001, 2002, 2005a and 2005b). These studies showed that weaker institutions make it more difficult for nations to sustain growth and make them more susceptible to experiencing times of crisis and stagnation. In contrast, good institutions may reduce uncertainty for economic decision-makers and attract investment while providing incentives for innovative and productive activities. However, institutions' significance in illuminating the link between debt and growth has largely yet to be noticed. There are some exceptions, nevertheless, where it is shown that these factors have a significant and essential role in the linkages between debt and economic growth [see Jalles (2011), Kourtellos *et al.* (2013), Kim *et al.* (2017), Tarek and Ahmed (2017), and Sani *et al.* (2019)]. In particular, Sani *et al.* (2019) made the case that to ensure debt effectiveness, excellent institutional quality is required to minimise the negative impact of debt accumulation on the economy. Tarek and Ahmed (2017) discovered that poor institutional quality ~~costs~~ harms the macroeconomic environment. So, in keeping with previous authors, we consider institutional quality *(GQI_t)* to be a potential factor in diverse relationships. Acemoglu *et al.* (2005a) claim that the structure of property rights and access to economic resources define economic institutions (if they are good, they will provide security of property rights and relatively equal access to economic resources to a broad sector of society). However, assessing its quality is challenging, and the literature frequently measures it in terms of perceptions (which may not reflect the law's quality but the economy's actual workings). Due to its superior time-variant properties compared to other governance measures, we use the World Bank's Worldwide Governance Indicator (WGI).

As for the importance of private debt ($PRDEBT_t$), it is essential to keep in mind that, according to the IMF's Global Debt Database, of the total global debt at the end of 2020 ($226 trillion in nominal terms, or 256% of GDP), 60% was private nonfinancial debt (held by households and nonfinancial corporations), being the remaining 40% public debt. Although both types of debt are causes for legitimate concern when they are excessive and expanding, studies exploring the effect of government debt on economic growth are much more common than those analysing the dangers of private debt accumulation [Cecchetti *et al.* (2011), Lombardi *et al.* (2017) and Gómez-Puig and Sosvilla-Rivero (2018) are some of the exceptions]. Nevertheless, a "private debt overhang" has been shown to have detrimental effects on economic growth and financial stability in the literature. Borrowers' capacity to repay becomes ever more sensitive to declines in income and sales as well as to increases in interest rates as private debt levels rise. High levels of private debt can significantly affect macroeconomic stability and performance because they make it harder for households to control their consumption and impact corporate investment decisions [see, Schularick and Taylor (2012), Jordà *et al.* (2016) and International Monetary Fund (2016), among others].

Additionally, some authors (see, e.g., Fatás *et al.* (2019)) argue that the fact that not all loans are generated in the same way makes it challenging to determine the direct influence of debt on economic growth. Detragiache and Spilimbergo (2002), Rodrik and Velasco (1999), and Jeanne (2009) contend that debt maturity is a crucial factor that can influence the diverse impact of debt on growth. Consequently, we have considered short-term debt as a percentage of total external debt (STD_t) as a proxy of debt maturity.

Finally, even though there is a substantial body of literature on the subject, empirical work has yet to look at the influence of those variables in the debt-growth link. The Barro (1990 and 1991) model of endogenous growth postulates that the growth effect of government spending depends on how the government spending is allocated and carried out, predicting that unproductive governmental spending will lower the growth rate of GDP while the effect of productive governmental expenditure on the growth rate of GDP is ambiguous, depending on how the government behaves and whether the expenditure ratio is too little or too much. In a similar spirit, Devarajan *et al.* (1996), Aschauer (1989), and Kneller *et al.* (1999) note that the effect of public debt on the health of the economy may vary depending on whether the public expenditure financed by government debt is profitable or not. Productive spendings, such as that on physical infrastructure (roads and railroads), communication, information systems (phone, internet), education, or health, may have a favourable effect on the productivity of the private sector and the pace of economic growth. However, although non-productive spending typically impacts people's well-being, it has no long-term impact on the economy's performance. In some instances, it can result in unjustifiably high public debt levels.

3. Data

Over the period 1995–2016, we built a balanced panel of annual data for 115 countries, comprising developed economies, emerging market economies, and low-income developing countries (see Table 1).

[Insert Table 1 here]

In the first step, we use the World Development Indicators of the World Bank as our primary source to preserve as much homogeneity as possible for a sample of 115 countries for 22 years. We then use additional data from the International Monetary Fund (International Financial Statistics and World Economic Outlook) to strengthen our data. As previously noted, we first assess the effect of debt on economic growth using real per capita GDP, population growth rate, the ratio of gross capital formation to GDP, a human capital index, openness to trade, GDP deflator inflation, and the ratio of liquid liabilities to GDP. Table 2 provides definitions and sources for the variables, and Table 3 does the same for the variables used to explore the potential causes of the heterogeneous time-varying debt-growth relationship.

[Insert Table 2 here]

[Insert Table 3 here]

We construct our proxy for institution quality *(GQI_t)* using the WGI index. This World Bank index includes perspectives on the effectiveness of national government offered by numerous survey organizations (non-governmental or public sector among them) globally. It covers six major elements of governance for more than 200 counties since 1996. It is updated yearly using Kaufmann *et al.* (2010) methodology. The six dimensions of good governance are the following: (1) voice and accountability, (2) political stability and lack of violence, (3) government efficacy, (4) regulatory quality, (5) the rule of law, and (6) corruption control. The final four dimensions are primarily focused on the quality of the delivery of government services (see Helliwell *et al.*, 2014), so they are the ones we have chosen to build up our indicator. Then, following Chong and Gradstein (2007) and Beltratti and Stulz (2012), we have taken the simple average of them for each country and year[5]. Finally, by removing the minimum score from this raw score and dividing the result by the highest score minus the minimum score, we rescale it so that it is between zero and one. The resulting variable is the quality of government indicator (GQI_t) used in the analysis.

The IMF Global Debt Database, which provides the total gross debt of the nonfinancial sector (private and public) for an imbalanced panel of 190 countries (see Mbaye *et al.*, 2018), including the 115 countries of our sample, is where the data for private ~~and public~~ debt as a percentage of GDP *($PRDEBT_t$ ~~and $PUBDEBT_t$, respectively~~)* was taken from. Then, as shown in Table 3, we

[5] Table 3 presents the definitions of each of the four indicators included in our average measures

classified them as low-indebted, lower-middle indebted, upper-middle indebted, and high-indebted, with the first, second, and third quartiles serving as the cut-off points between each of the groups (in the same way we have also classified countries according to their public indebtedness, *PUBDEBT*$_t$). This procedure is similar to that used by the World Bank to categorise countries based on income (see Fantom and Serajuddi, 2016). In particular, we generate two dummy variables, (*DQPD*$_t$) and (*DQPRD*$_t$), which serve as our proxies for the relative public and private indebtedness. According to the public and private debt-to-GDP ratios, these dummy variables have values ranging from 1 to 4, representing the categories of low, lower-middle, middle, and high debt, respectively.

The short-term debt expressed as a percentage of total external debt (*STD*$_t$) is used as a proxy of debt maturity. Data have been obtained from the World Bank's World Development Indicators and from the Coordinated Portfolio Investment Survey (CPIS) database provided by the IMF.

The IMF Government Financial Statistics was the source utilised to compile the data for the composition of government expenditures. The categorisation of the functions of government (COFOG), which is the name of this dataset, classifies government spending into ten categories. While each of the ten kinds of spending is independently analysed for its effect on the time-varying debt-growth connection (see, Kneller *et al.,* 1999; Adam and Bevan, 2005; Christie, 2012; or Chu *et al.*, 2020, among others), following accepted practice, we distinguish between productive and ineffective spending. The first category consists of general public services *(GF01)*, defence *(GF02)*, economic affairs *(GF04)*, health *(GF07)*, housing and community amenities *(GF06)*, and education *(GF09)* –it includes transport and communication–, whereas the latter includes public order and safety *(GF03)*, environment protection *(GF05)*, recreation, culture and religion *(GF08)* and social protection *(GF10)*[6].

The technique of multiple imputations developed by King *et al*. (2001) (which enables the approximation of missing data and allows us to obtain better estimates) and the simultaneous nearest-neighbour predictors proposed by Fernandez-Rodriguez *et al*. (1999) (which infers omitted values from patterns detected in other simultaneous time series) are applied in order to produce a data matrix without missing values.

4. Econometric Methodology

We employ the heterogeneous coefficients extension of the GFE model proposed by Bonhomme and Manresa (2015b) to investigate the existence of group-specific time-varying effects of public debt on economic growth. In order to determine whether the relationship under study is heterogeneous across groups of countries, it is crucial to relax the strict assumption that the outcome variable follows the same time trend for all countries by introducing time-varying grouped patterns of heterogeneity in linear panel data models. The GFE estimator achieves this by minimising a least-squares criterion concerning all possible combinations of the cross-sectional units.

The data are used to estimate both the group membership and the group-specific time patterns. The relationship between observed variables and the unobserved group heterogeneity is unrestricted, allowing for the existence of correlations that would create omitted variable bias in standard fixed-effects estimates.

[6] A more detailed overview of the items included in each category is presented in Table 3. In each country, expenditure in the different groups is expressed as a percentage of GDP.

We take into account the following linear model, which has the following shape and explains economic growth with grouped patterns of heterogeneity:

$$g_{it} = z_{it}^{'}\theta_{g_{r_1}t} + \alpha_{g_{r_j}t} + \vartheta_{it} \tag{2}$$

where $g_{r_j} \in [1,...,G]$ denotes group membership, z_{it} are the covariates that are assumed to be contemporaneously uncorrelated with the error term ϑ_{it}, but are allowed to be arbitrarily correlated with group-specific unobserved heterogeneity $\alpha_{g_{r_j}}$. The group membership is constant across time, and the countries included in a group share the same temporal profile. The number of groups is determined or estimated by the researcher.

Essentially, countries that share analogous time profiles of growth – net of the explanatory variables– are grouped together, being the fundamental presumption that group composition does not change over time.

Additive time-invariant fixed effects, which is our preferred specification, can be simply added to the model[7].

The GFE model (equation 2) is the outcome of the minimisation of the following expression:

$$(\hat{\beta},\hat{\alpha},\hat{\gamma}) = \underset{(\beta,\alpha,\gamma)\in\Theta^{G}x\mathrm{A}^{TG}x\Gamma_{G}}{\arg\min} \sum\nolimits_{i=1}^{N}\sum\nolimits_{t=1}^{T}(g_{it} - z_{it}^{'}\beta_{g_{r_j}t} - \alpha_{g_{r_j}t})^{2}, \tag{3}$$

where the minimum is taken over all possible groupings $\gamma = (g_{r_1},...,g_{rN})$ of the N units into G groups, common parameters θ and group-specific time effects α. We denote as γ the set of all

[7] The objective is to account for time-invariant country-specific unobserved and time-variant group-specific heterogeneity. For a detailed description, see the Supplementary Appendix to "Grouped Patterns of Heterogeneity in Panel Data", available at https://manresaelena.wixsite.com/home.

$\ddot{\alpha}_{g_{r_{ij}}t}$'s, and as α the set of all g_{r_j}'s. Thus, $\alpha \in \Gamma_G$ denotes a particular grouping of the N units, where Γ_G is the set of all groupings of $\{1,\ldots, N\}$ into at most G groups.

For computational purposes, an alternative characterization, based on concentrated group membership variables, is introduced. Then, the optimal group assignment for each country is given by:

$$\hat{g}_{r_i}(\hat{\theta},\hat{\alpha}) = \underset{g_r \in [1,\ldots,G]}{\arg\min} \sum_{t=1}^{T} (g_{it} - z_{it}^{'}\theta_{g_{r_j}t} - \alpha_{g_{r_j}t})^2, \tag{4}$$

where the minimum g_{r_i} is chosen in case of a non-unique solution. The GFE estimator of $(\hat{\theta},\hat{\alpha})$ could be expressed as:

$$(\hat{\theta},\hat{\alpha}) = \underset{(\beta,\alpha)\in \Theta x \mathrm{A}^{TG}}{\arg\min} \sum_{i=1}^{N}\sum_{t=1}^{T} (g_{it} - z_{it}^{'}\theta_{g_{r_j}t} - \alpha_{\hat{g}_{r_j}(\beta,\alpha)t})^2, \tag{5}$$

where $\hat{g}_{r_j}(\hat{\theta},\hat{\alpha})$ is given by (equation 3) and the group probabilities are unrestricted and individual-specific.

We employ a simple iterative strategy to minimise expression (5), which is especially suitable for small-scale data sets[8].

To determine the optimal number of groups (separately for each outcome variable), we run GFE estimations with a number of groups G varying between 1 and 8 and calculate the Bayesian information criterion (BIC) to assess the statistical benefit of having more groups[9].

[8] Highly similar results were produced using an alternative strategy exploiting recent advances in data clustering.
[9] In the first version of the paper, we considered six as the maximum number of groups, and the BIC indicated the existence of five groups of countries in our sample. Although, at the suggestion of an anonymous referee, we expanded the maximum number of groups to eight, the BIC still indicated the existence of five differentiated groups of countries in our sample, rejecting the benefit of considering six, seven or eight groups.

As explained, an important feature of the GFE estimator is that group membership of the countries in our sample is not pre-determined but is estimated according to a least-squares criterion. Countries whose time profiles of the outcome variable (growth rate of real *per capita* GDP) – net of the effect of covariates – are most similar are grouped together. Assume that the countries in our sample are categorised in a number of groups *J* indexed by $j = 1, \ldots, J$. The number of groups *J* must be small in comparison with the number of countries. The time-varying GFE is better suited to deal with endogeneity in the presence of time-varying unobserved heterogeneity, which is another benefit of the GFE estimator. In this case, our regression equation takes the following specification:

$$g_{it} = \phi y_{it-1} + \delta_1 INF_{it} + \delta_2 HK_{it} + \delta_3 OPEN_{it} + \delta_4 POPGR_{it} + \delta_5 GCF_{it} + \delta_6 FIN_{it} + \beta_{gr_{jt}} d_{it} + \alpha_{j_i t} + \varepsilon_{it} \qquad (6)$$

where $\beta_{gr_{jt}}$ denotes the heterogeneous, time-varying coefficients capturing the impact of public debt on economic growth and $\alpha_{j_i t}$ denotes the group-specific time fixed effect which includes group fixed effects as well as time fixed effects.

Once the groups of countries are determined, to control for the possible endogeneity of the public debt-to-GDP ratio, model (6) is estimated using a two-stage least squares methodology with panel corrected standard errors clustered by countries, using the exogenous variables and their lags as instruments. We will refer to this procedure as the GFE-2SLS estimator.

Finally, we conduct regressions of the time-varying coefficients of the impact of public debt-to-GDP ratio on economic growth by country groups ($\beta_{gr_{it}}$) on their potential drivers to investigate the potential determinants of the discovered heterogeneous dynamic group impacts of public debt on growth:

$$\beta_{gr_{jt}} = \lambda_1 \mathrm{GQI}_{gr_{jt}} + \lambda_2 \mathrm{DQPD}_{gr_{jt}} + \lambda_3 \mathrm{DQPRD}_{gr_{jt}} + \lambda_4 \mathrm{GF01}_{gr_{jt}} + \lambda_5 \mathrm{GF02}_{gr_{jt}} + \ldots + \lambda_{13} \mathrm{GF10}_{gr_{jt}} + \lambda_{14} \mathrm{STD}_{gr_{jt}} + \alpha_{j_i t} + \varsigma_{it} \qquad (7)$$

where the subscript gr_{jt} denotes the group category.

5. Empirical Results

5.1. Identifying heterogeneous dynamic group effects of public debt on growth

First, we begin with the study described in Gómez-Puig *et al.* (2022), where five groups are identified after applying the GFE-2SLS approach, which accounts for individual effects, correlated unobserved heterogeneity, and correlated unobserved heterogeneity (the number being selected using the information on the change in the criterion function). Table 4 lists the estimated classification of the countries included in each group. Note that, for expository convenience, the endogenously identified groups have been named according to their estimated impact, being Group 1, the one with the highest estimated impact and Group 5, the one with the lowest estimated impact. As is shown, Group 1 consists of 18 developing or low-income nations. Group 2 consists of 28 nations, most emerging market economies. Group 3 comprises 40 nations, including developed and developing market economies. Finally, low-income developing nations in Sub-Saharan Africa make up two-thirds of the economies in Groups 4 and 5.

[Insert Table 4 here]

Table 5 reports the results obtained by Gómez-Puig *et al.* (2022) when estimating the growth model by GFE-2SLS, allowing for specific slopes by including interactions of the debt variable (d_{it}) with the group indicator variables[10.] It should be noted that the variables HK and FIN

[10] The regression includes country fixed effects and year fixed effects. Using this specification, we rule out that the inference regarding the parameters of interest is contaminated by unobserved determinants that are constant over time (country fixed effects) or affect all countries at a given point in time in the same way (year fixed effects).

were found to be non-significant, and as such, they were eliminated from the final estimation in accordance with the general idea of parsimonious data modelling.

[Insert Table 5 here]

It can be seen that the estimated impact varies from -0.027 in Group 1 to -0.006 in Group 5 and that the coefficient of the interaction term is negative and significant for all groups. These results imply that a one standard deviation increase in the public debt-to-GDP ratio reduces the growth rate by about 1.83 on average for Group 1, 0.84 for Group 2, 0.33 for Group 3, 0.30 for Group 4 and 0.16 for Group 5.

We proceed further by estimating the time varying GFE model (equation 6). To this end, we interacted the variable d_{ti} with the group indicator variables and year dummies. Figure 1 shows the evolution of the estimated coefficient of public debt-to-GDP ratio on economic growth by country groups over time. As can be seen, there is time-varying heterogeneity within and between identified country groups.

[Insert Figure 1 here]

It can be observed that, in general, the more volatile the estimated effect over time (measured by the standard deviation), the higher the impact. It is noticeable that estimated parameters are quite stable in Groups 2, 3 and 4, Group 5 being the exception as it records the highest volatility. This last feature could be related to the fact that Group 5 is mainly composed of low-income developing countries. These economies are traditionally characterized by relatively recurrent growth accelerations but nearly as frequent growth collapses, coupled with a heightened balance of payments vulnerability and debt overhang (UNCTAD, 2012). It is also noticeable that, in four out of the five groups (1, 2, 4 and 5), the negative estimated effect of debt on economic growth reaches its maximum value (in absolute terms) during the period 2007-2011, coinciding with the

Great Recession (2007-2013)[11]. The exception is Group 3, where the highest estimated effect takes place in 2001, being connected with the early 2000s recession mainly registered in developed countries. Finally, it is remarkable the occurrence of positive effects in Group 5, being especially high in 2009 and 2012.

We perform some robustness checks to evaluate the sensitivity of our results. We first test whether the results are robust to using alternative groupings of countries[12]. Although the estimation results suggest that the optimal number of groups according to BIC is G=5, we evaluate the effect of imposing G=3 and G=4 on the GFE-2SLS estimator[13]. Figures 2 and 3 show the results of the estimated heterogeneous time-varying impacts in the debt-growth nexus obtained in these cases. As in the case G=5, and to facilitate comparison, we have again ordered the groupings from highest to lowest estimated impact. As can be seen, compared with Figure 1, the optimal selection of five groups provides a much more differentiated impact by groups of the relationship between public debt and economic growth than that offered by the suboptimal country grouping (G=3 and G=4), suggesting that the selection of G=5 is capturing fundamental characteristics of the countries that influence this relationship and that are not present in the other cases. This, in turn, provides further support to the use of the BIC criterion as a model selection guide among a finite set of models, adequately identifying the relative amount of information lost by a given model in comparison to others since the less information a model loses, the higher the quality of that model.

[Insert Figures 2 and 3 here]

[11] According to Eichengreen *et al.* (2019), about two-thirds of the increase in the advanced-country debt ratio during the Great Recession was accounted for by the cumulative increase in the primary deficit, reflecting revenue losses and expansionary fiscal policies.

[12] We are grateful to an anonymous referee for suggesting this exploratory analysis.

[13] The detailed list of countries included in each group under these alternative groupings is not shown here to save space, but they are available from the authors upon request.

Next, we evaluate the potential effect of the global financial crisis (GFC) through the inclusion of a dummy taking value 1 in 2007 and 2008 in equation (6)[14]. The GFC dummy is found to be positive and statistically significant, but, as can be seen in Figure 4, it only marginally affects the estimation of the time-varying effects of public debt on economic growth during the last years of the analysed period.

[Insert Figure 4 here]

All in all, our sensitivity analysis supports the existence of heterogeneous time-varying impacts in the debt-growth nexus within the group of countries under study detected in Figure 1, further supporting the validity of those results.

5.2. Analysing the determinants of the identified heterogeneous dynamic group effects of public debt on growth

Once we have endogenously grouped the countries that share similar temporal profiles of effects of public debt on growth, to analyse the potential determinants of the identified heterogeneous dynamic group effects, ~~of public debt on growth~~, we run regressions of the time-varying coefficients of the impact of public debt-to-GDP ratio on economic growth by country groups (depicted in Figure 1) on their potential drivers using equation (7). To overcome the problem of coefficient comparison when the variables are measured in different units, we use standardised coefficients to evaluate the relative importance of the different explanatory variables. To this end, following the proposal of Bring (1994), we use the variance inflation factor to calculate partial standard deviations that provide standardized coefficients directly related to the reduction in R^2 obtained by excluding the variable from the model. Table 6 displays the results.

[14] We express our gratitude to an anonymous referee for proposing this further robustness analysis.

[Insert Table 6 here]

As can be seen, the variable (GQI_t) that measures the quality of the institutions has a significant positive effect on the relationship between public debt and growth across all groups, indicating that the stronger the institutions, the less adverse or more advantageous the impact of an increase in public debt on economic growth will be. This suggests that GQI_t has a beneficial moderating effect on the link between public debt and economic growth, in line with Jalles (2011), Kourtellos *et al.* (2013), and Kim *et al.* (2017), who offer empirical support for the notion that the degree of democracy, the effectiveness of anti-corruption measures, and the standard of governance are significant determinants of the link between debt and economic growth.

The variable measuring relative public indebtedness ($DQPD_t$) has a negative, statistically significant effect on the relationship between debt and growth in all groups of countries, except for Group 3, for which this effect is negative, although not statistically significant. It is interesting to notice that Groups 1 and 2 have low relative public debt levels, whereas Groups 4 and 5 have high relative public debt levels. These findings imply that country-specific thresholds exist at which a rise in public debt negatively affects economic growth. (see, e.g., Edberhardt and Presbitero (2015) or Chudik *et al.* (2017)). In particular, this threshold is substantially lower in Groups 1 and 2 (i.e., there exists little room for manoeuvre for growing public debt in these nations even when it is low) than in Groups 4 and 5 (where the estimated effect of debt on economic growth is much lower, although their level of public indebtedness is considerably higher).

Except for Group 5, the relative level of private debt ($DQPRD_t$) has a strong negative impact on the link between debt and growth in all groups of countries in accordance with Schularick and

Taylor (2012) and Jordà *et al.* (2016), who highlighted the harmful effects of excessive private debt on economic growth and financial stability.

As for the relationship between expenditure composition and the debt-growth relationship, our findings support the notion that the effect of a rise in public debt on the performance of the economy may depend on whether the public expenditure financed by government debt is productive or unproductive [as pointed out by Aschauer (1989) and Devarajan *et al.* (1996), among others]. It can be seen that when public debt is used to finance unproductive spending [$GF01_t$ (general public services), $GF02_t$ (defence), and $GF08_t$ (recreation, culture and religion)], it has a negative effect on the economic growth (being statistically significant in four, three and five out of five groups in the case of $GF01_t$, $GF02_t$ and $GF08_t$ respectively). However, when sovereign debt is used to finance productive expenses, it favours economic growth in some groups of countries. In particular, our results indicate that the following categories of public expenditure have a positive and statistically significant impact on the debt-growth nexus in all country groups: $GF04_t$ (economic affairs, which includes roads, railways, communication, and information systems), $GF09_t$ (education), and $GF10_t$ (social protection,). For the other four public spending categories, we only find a statistically significant, positive effect on the debt-growth nexus in several groups of countries. Specifically, a rise in $GF03_t$ (public order and security, including law courts) implies a positive, significant impact in the debt-growth relationship in countries in Groups 2, 3, and 5. In contrast, an increase in $GF05_t$ (environmental protection, including sewage system operation) only implies a significant, positive impact in the debt-growth relationship in countries in Groups 1, 2 and 3 (we should recall that Groups 4 and 5 include some of the lowest-income developing countries in our sample), and a rise in $GF07_t$ (health) is associated with a significant, positive impact in the debt-growth nexus in all detected groups of countries, except for Group 3. For $GF06_t$ (housing and community amenities), our results suggest the existence of a positive effect and statistically significant for Groups 3, 4 ad 5.

Finally, we find that in all groups of countries, an increase in debt has a more detrimental effect on economic growth if most of the debt is issued in the short term, as indicated by Fatás *et al.* (2019) (being the effect exceptionally high in Groups 1 and 4).

6. Concluding remarks

In this paper, we have examined the dynamic heterogeneous link between public debt and economic growth, using a global sample comprising 115 advanced, emerging and developing economies from 1995 to 2016. To that end, we have applied an extension of the GFE method that allows for group-specific coefficients (Bonhomme and Manresa, 2015b) to explore how the relationship behaviour differs over time between groups of countries. In particular, the GFE accounts for unobserved time-varying heterogeneity across groups of countries in panel data models, with group membership being estimated along with the other parameters in the model by minimising the sum of squares of residuals. A two-stage least squares method is combined with the GFE estimator to address the potential endogeneity of the public debt-to-GDP ratio. In addition, we have also analysed the drivers of the detected heterogeneous dynamic impact of the public debt-to-GDP ratio on economic growth by running regressions to assess the relative role played by the quality of institutions, the composition of public expenditure funded with debt, the relative public indebtedness, the relative private indebtedness, and the maturity of the debt.

Because the results were produced using a specific group of countries over a specific period and using a specific econometric methodology, they should be interpreted cautiously, as with any empirical analysis. In this regard, our findings indicate country-group differences in the relationship between the public debt-to-GDP ratio and growth. Specifically, the GFE estimator divides the sample endogenously into five groups, each with a distinct estimated influence of the public debt on economic growth and various time patterns (varying from -0.027 in Group 1 to -0.006 in Group 5). Our analysis of the underlying factors that determine the differentiated impact by country groups reveals that the quality of a country's institutions partially mitigates the occurrence of a strong impact, while the level of both public and private debt and the maturity of the debt crucially intensify it. The heterogeneous relationship between public debt and economic growth is significantly influenced by the type of spending financed with debt (negatively in the case of unproductive spending and positively in the case of productive spending) These findings offer some insights into the empirical quantification and characterisation of the heterogeneity of the debt-growth nexus among groups of countries and identify relevant factors that contribute to it.

Our research has significant policy ramifications because they show that the relationship between the public debt-to-GDP ratio and economic growth varies among nations and is closely linked to the variety and quality of the institutions and public policies that make up the socioeconomic environment. The results presented in this paper suggest that reducing corruption and fostering effective governance and the rule of law could help limit the harmful effects of public debt on economic growth. Our findings also show that short-term debt may be a primary source of financial fragility, further influencing the debt-growth relationship, justifying issuing long-term debt and raising the fraction of outstanding long-term debt. Finally, we also provide evidence supporting the need to thoroughly examine the expenditure composition to enhance economic performance and achieve a higher steady-state growth rate. Our results have practical implications for national policymakers and international organizations charged with monitoring the state of the world economy and could shed some light on the possible effects of the successive expansive measures implemented in recent years may have on the growth rates of different countries (first to control the economic and health crisis caused by the coronavirus pandemic in 2020 and, subsequently, to mitigate the effects of the war in Ukraine).

Declaration of interest

The authors have no declaration of interest to make.

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Figure 1: Time-varying coefficients of public debt-to-GDP ratio on economic growth: GFE-2SLS classification (*G*=5)

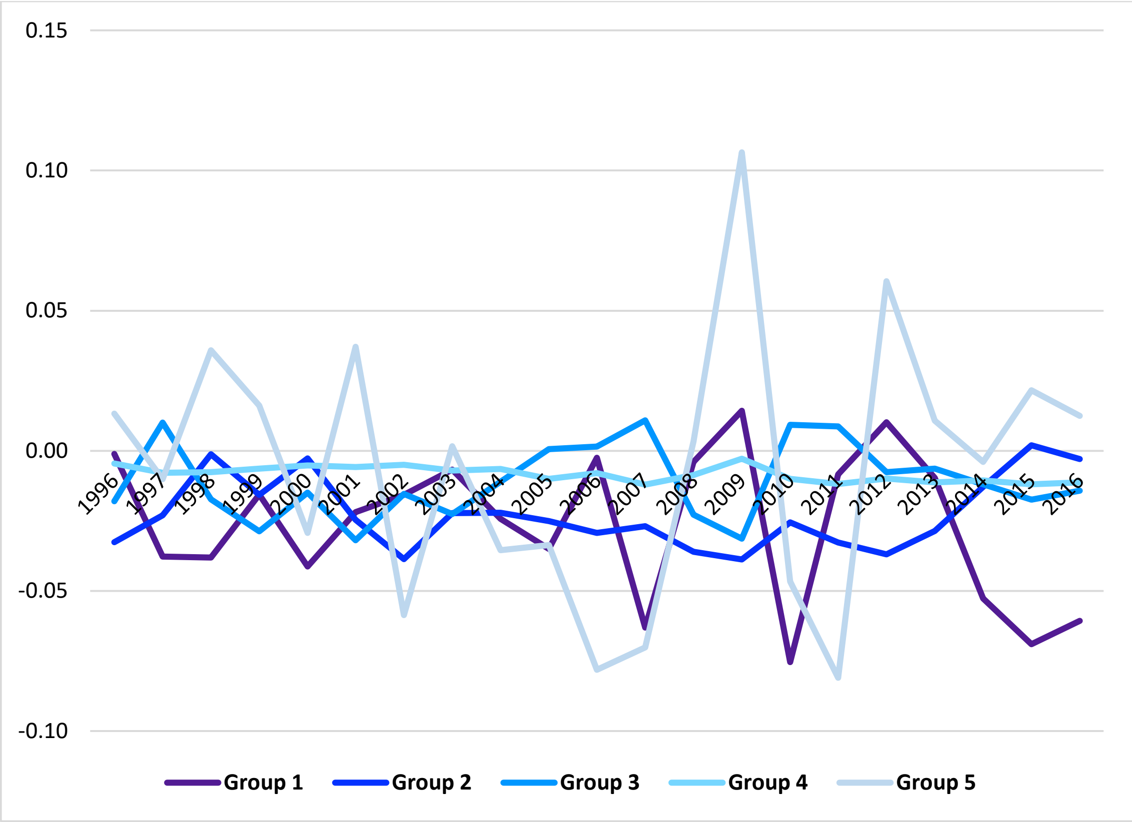

Figure 2: Time-varying coefficients of public debt-to-GDP ratio on economic growth: GFE-2SLS classification (*G*=3)

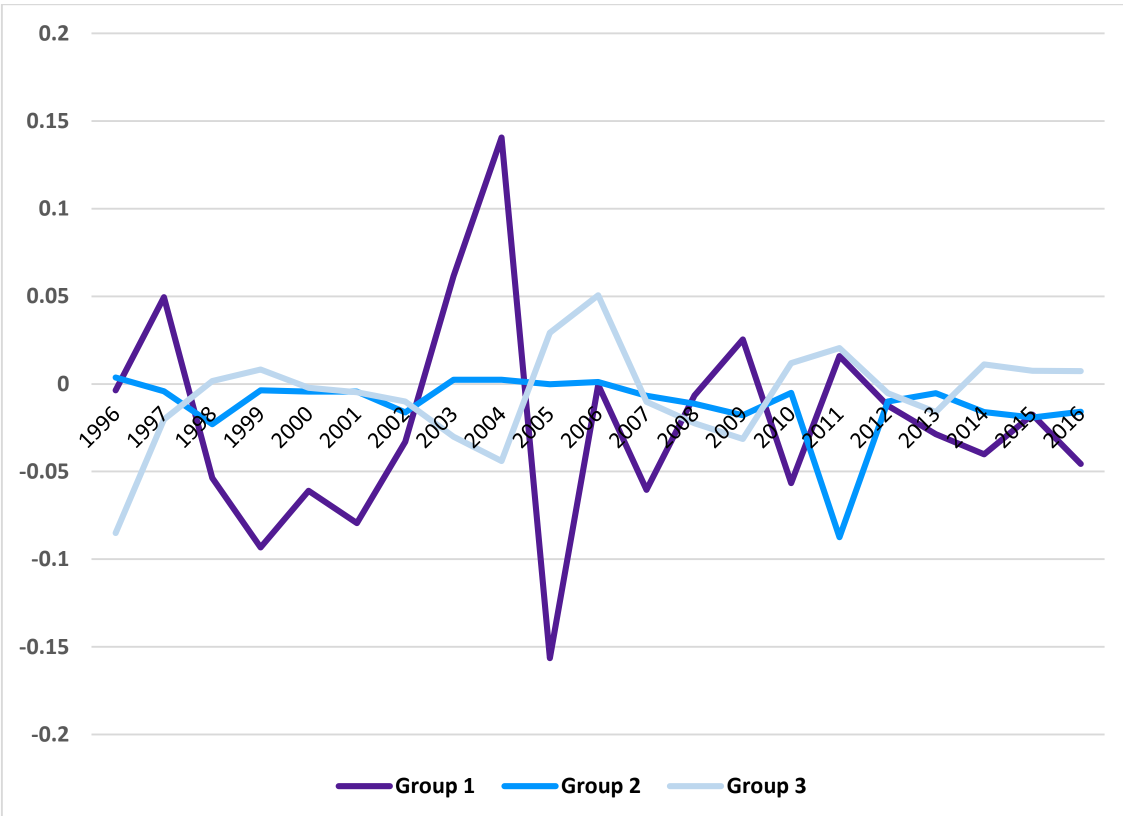

Figure 3: Time-varying coefficients of public debt-to-GDP ratio on economic growth: GFE-2SLS classification (*G*=4)

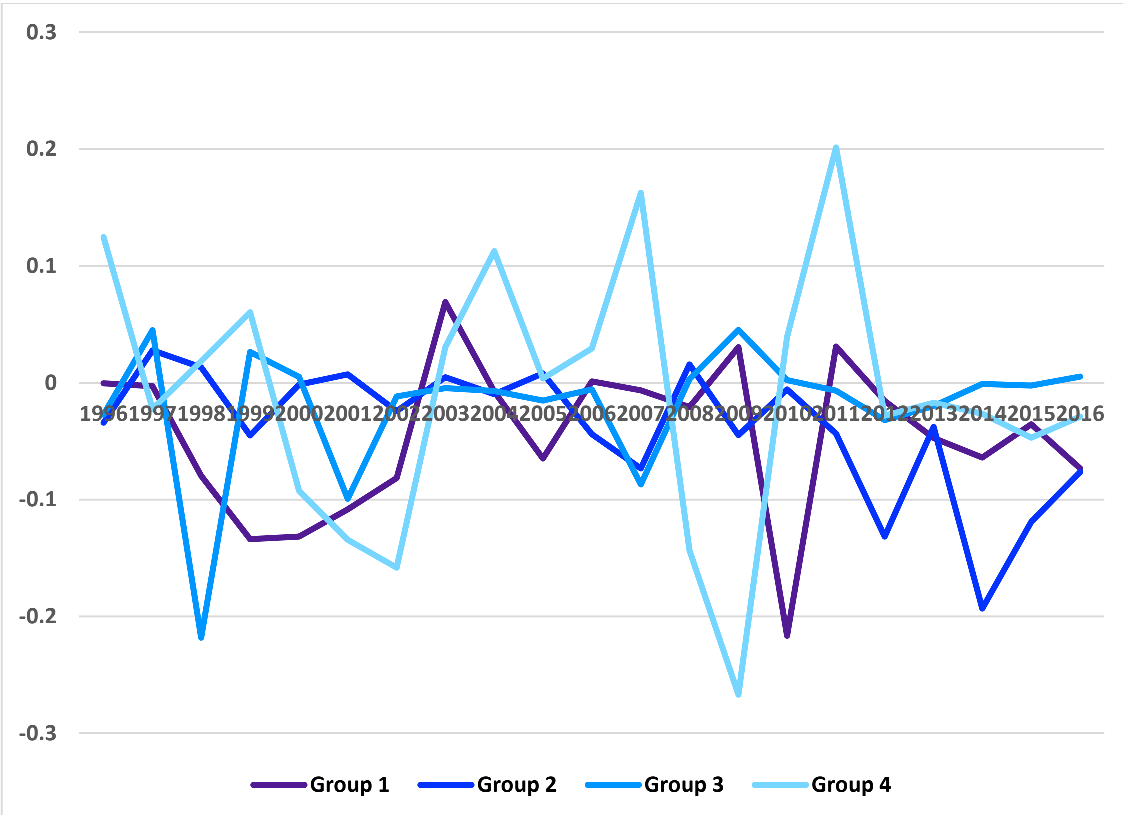

Figure 4: Time-varying coefficients of public debt-to-GDP ratio on economic growth: GFE-2SLS classification (*G*=5) with GFC dummy

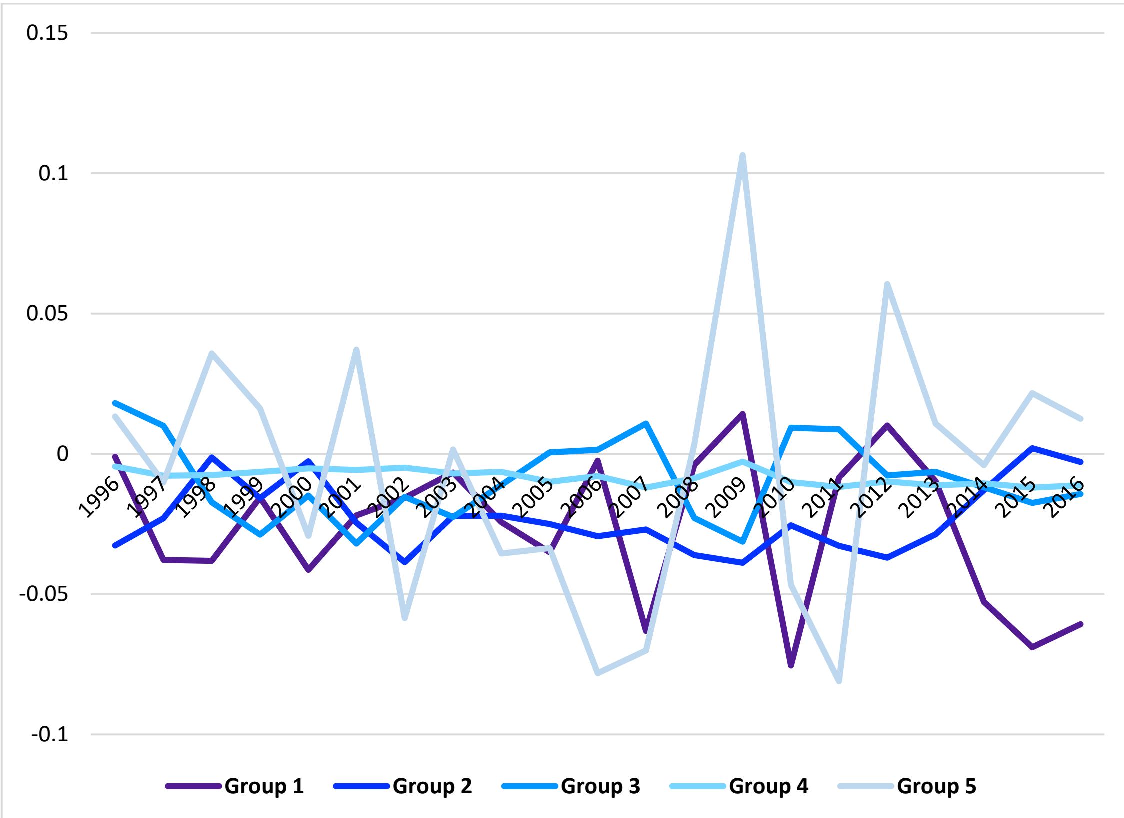

Table 1: List of 115 countries included in the sample by income group

Income group	Countries
29 Low-income developing countries (LIDC)	Burkina Faso, Cameroon, Cape Verde, Comoros, Congo Republic, Congo Democratic Republic, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guyana, Haiti, Honduras, Kenya, Kyrgyz Republic, Madagascar, Malawi, Mali, Mauritania, Moldova, Nepal, Nicaragua, Niger, Nigeria, Rwanda, Senegal, Sudan, Tanzania, Uganda.
54 Emerging market economies (EM)	Algeria, Argentina, The Bahamas, Bahrain, Barbados, Belarus, Belize, Bolivia, Botswana, Brazil, Bulgaria, Chile, China, Colombia, Costa Rica, Croatia, Dominican Republic, Ecuador, Egypt, El Salvador, Eswatini, Fiji, Gabon, Guatemala, Hungary, India, Indonesia, Iran, Jamaica, Jordan, Kazakhstan, Malaysia, Mauritius, Mexico, Morocco, Namibia, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Romania, Russia, Saudi Arabia, Seychelles, South Africa, Sri Lanka, Thailand, Tunisia, Turkey, Ukraine, Uruguay.
32 Advanced economies (AE)	Austria, Belgium, Canada, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea Republic, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, New Zealand, Norway, Portugal, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States.

Note: The main criteria used by the International Monetary Fund to classify the world into advanced economies, emerging markets and developing economies are (1) per capita income level, (2) export diversification — thus, oil exporters that have high real *per capita* GDP would not make the advanced classification because around 70% of its exports are oil; and (3) degree of integration in the global financial system.

Table 2: Explanatory variables and data sources used in the GFE estimation.

Variable	Description	Source
Real growth rate (*g*)	The growth rate of real *per capita* GDP (annual %)	World Development Indicators (World Bank)
Level of Output (*y*)	*Per capita* Gross domestic product at 2010 market prices	World Development Indicators (World Bank)
Public debt-to-GDP ratio (*d*)	The ratio of public debt to GDP	World Economic Outlook (International Monetary Fund)
Population growth (*POPGR*)	Population growth (annual %)	World Development Indicators (World Bank)
GCF-to-GDP ratio (*GCF*)	The ratio of gross capital formation to GDP (%)	World Development Indicators (World Bank)
Human capital (*HK*)	Life expectancy at birth, total (years)	World Development Indicators (World Bank)
Openness (*OPEN*)	The absolute sum of exports and imports over GDP	World Development Indicators (World Bank)
Inflation (*INF*)	Inflation as measured by the consumer price index (annual %)	World Development Indicators (World Bank)
Financial development (*FIN*)	Liquid Liabilities to GDP (%)	Financial Development and Structure Dataset (World Bank)

Table 3: Explanatory variables and data sources used in panel regression analysis.

Variable		Description	Source
(*GQI*) This is an average of the value of the following four indicators, rescaled so that it lies between zero and one.	Government effectiveness (*GE*)	Perceptions of the quality of: public services, civil service and the degree of its independence from political pressures, policy formulation and implementation, and of the credibility of the government's commitment to such policies.	The Worldwide Governance Indicators (World Bank)
	Regulatory Quality (*RQ*)	Perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	The Worldwide Governance Indicators (World Bank)
	Rule of law (*RL*)	Perceptions of the extent to which agents have confidence in and abide by the rules of society (the quality of contract enforcement, property rights, the police, the courts), as well as the likelihood of crime and violence.	The Worldwide Governance Indicators (World Bank)
	Control of corruption (*CC*)	Perceptions of the extent to which public power is exercised for private gain, including corruption, as well as "capture" of the state by elites and private interests.	The Worldwide Governance Indicators (World Bank)
(*DQPD*) Dummy variable that takes values 1 to 4 corresponding to low, low-middle, upper-middle, and high-indebted countries	Public Debt-to-GDP (*PUBDEBT or d*)	The ratio of public debt over GDP	World Development Indicators (World Bank)
(*DQPRD*) Dummy variable that takes values 1 to 4 corresponding to low, low-middle, upper-middle, and high-indebted countries	Private Debt-to-GDP (*PRDEBT)*	This variable is calculated as the sum of two components: (1) bank loans to domestic households and nonfinancial corporations, drawn from the IMF's Standardised Reporting Forms (SRFs) and International Financial Statistics (IFS) and (2) the outstanding stock of debt securities issued (on the domestic and international markets) by non-financial corporations, calculated based on securities issuance data from Dealogic database. Data are in percentage of GDP.	Global Debt Database (International Monetary Fund)
(*STD)* Debt maturity		Short-term debt expressed as a percentage of total external debt.	World Development Indicators (World Bank) and Coordinated Portfolio Investment Survey, CPIS (IMF)

Table 3 (continued)

	Variable	Description	Source
Productive Expenditure	General Public Services (*GF01*)	Executive and legislative organs, financial and fiscal affairs, external affairs; foreign economic aid; general services; basic research; R&D related to general public services; general public services not else classified (n.e.c.); public debt transactions, transfers of a general character between different levels of government.	Government Financial Statistics (International Monetary Fund)
	Defence (*GF02*)	Military defence; civil defence; foreign military aid, R&D related to defence; defence n.e.c.	Government Financial Statistics (International Monetary Fund)
	Economic affairs (*GF04*)	General economic, commercial and labour affairs; agriculture, forestry; fishing and hunting; fuel and energy; mining, manufacturing and construction; transport; communication; other industries, R&D related to economic affairs; economic affairs n.e.c.	Government Financial Statistics (International Monetary Fund)
	Housing and community amenities (*GF06*)	Housing development; community development; water supply; street lighting; R&D related to housing and community amenities; housing and community amenities n.e.c.	Government Financial Statistics (International Monetary Fund)
	Health (*GF07*)	Medical products, appliances and equipment; outpatient services; hospital services; public health services; R&D related to health; health n.e.c.	Government Financial Statistics (International Monetary Fund)
	Education (*GF09*)	Pre-primary, primary, secondary and tertiary education, post-secondary non-tertiary education, education non definable by level, subsidiary services to education, R&D; n.e.c.	Government Financial Statistics (International Monetary Fund)
Unproductive Expenditure	Public order and safety (*GF03*)	Police services; fire-protection services; law courts; prisons; R&D related to public order and safety; public order and safety n.e.c.	Government Financial Statistics (International Monetary Fund)
	Environment protection (*GF05*)	Waste management; water waste management; pollution abatement; protection of biodiversity and landscape; R&D related to environmental protection.	Government Financial Statistics (International Monetary Fund)
	Recreation, culture and religion (*GF08*)	Recreational and sporting services; cultural services; broadcasting and publishing services; religious and other community services, R&D related to recreation, culture and religion; recreation; culture and religion n.e.c.	Government Financial Statistics (International Monetary Fund)
	Social protection (*GF10*)	Sickness and disability; old age; survivors; family and children; unemployment; housing; R&D; social protection and social exclusion n.e.c.	Government Financial Statistics (International Monetary Fund)

Table 4: Composition of detected groups ordered according to the debt coefficient.

GROUP 1:	*Region*	*Income group*	*Other classifications*	*Public indebtedness*	*Private indebtedness*
Belize	Latin America & Caribbean	EM		HI	
Cape Verde	Sub-Saharan Africa	LIDC		HI	LMI
China	East Asia & Pacific	EM	G20	LI	UMI
Congo Rep.	Sub-Saharan Africa	LIDC	OPEC	HI	LI
Egypt, Arab Rep.	Middle East & North Africa	EM	Oil Exporter	HI	LMI
El Salvador	Latin America & Caribbean	EM		LMI	LMI
Eswatini	Sub-Saharan Africa	EM		LI	
Fiji	East Asia & Pacific	EM		LMI	
Guatemala	Latin America & Caribbean	EM		LI	LMI
Guyana	Latin America & Caribbean	LIDC		HI	LMI
Indonesia	East Asia & Pacific	EM	G20; Oil Exporter	LI	LMI
Jordan	Middle East & North Africa	EM		HI	UMI
Morocco	Middle East & North Africa	EM		UMI	UMI
Nigeria	Sub-Saharan Africa	LIDC	OPEC	LI	LI
Paraguay	Latin America & Caribbean	EM		LI	LMI
Sri Lanka	South Asia	EM		HI	LMI
Tunisia	Middle East & North Africa	EM		UMI	
Ukraine	Europe & Central Asia	EM		LMI	UMI

GROUP 2:	*Region*	*Income group*	*Other classifications*	*Public indebtedness*	*Private indebtedness*
Algeria	Middle East & North Africa	EM	OPEC	LI	LI
Belarus	Europe & Central Asia	EM		LI	
Botswana	Sub-Saharan Africa	EM		LI	LI
Bulgaria	Europe & Central Asia	EM	EU	LI	UMI
Chile	Latin America & Caribbean	EM	OECD	LI	UMI
Colombia	Latin America & Caribbean	EM		LMI	LMI
Costa Rica	Latin America & Caribbean	EM		LMI	LMI
Dominican Rep.	Latin America & Caribbean	EM		LI	LMI
Ecuador	Latin America & Caribbean	EM	OPEC	UMI	LMI
Estonia	Europe & Central Asia	AE	OECD; EMU	LI	HI
Kazakhstan	Europe & Central Asia	EM	Oil Exporter	LI	LMI
Korea, Rep.	East Asia & Pacific	AE	G20; OECD	LI	HI
Latvia	Europe & Central Asia	AE	OECD; EMU	LI	LMI
Lithuania	Europe & Central Asia	AE	EMU	LI	UMI
Malaysia	East Asia & Pacific	EM		UMI	HI
Mauritius	Sub-Saharan Africa	EM		UMI	UMI
Namibia	Sub-Saharan Africa	EM		LI	
Panama	Latin America & Caribbean	EM		UMI	
Peru	Latin America & Caribbean	EM		LMI	LMI
Poland	Europe & Central Asia	EM	OECD; EU	LMI	LMI
Romania	Europe & Central Asia	EM	EU	LI	LMI
Russia	Europe & Central Asia	EM	G20; Oil Exporter	LI	UMI
Seychelles	Sub-Saharan Africa	EM		HI	
Singapore	East Asia & Pacific	AE		HI	HI
Slovak Republic	Europe & Central Asia	AE	OECD; EMU	LMI	UMI
Thailand	East Asia & Pacific	EM		LMI	HI

Turkey	Europe & Central Asia	EM	G20; OECD	LMI	LMI
Uruguay	Latin America & Caribbean	EM		UMI	LMI

Table 4 (continued)

GROUP 3:	***Region***	***Income group***	***Other classifications***	***Public indebtedness***	***Private indebtedness***
Argentina	Latin America & Caribbean	EM	G20	LMI	LMI
Austria	Europe & Central Asia	AE	OECD; EMU	UMI	HI
Bahamas, The	Latin America & Caribbean	EM		LI	HI
Bahrain	Middle East & North Africa	EM		LI	UMI
Barbados	Latin America & Caribbean	EM		HI	
Belgium	Europe & Central Asia	AE	OECD; EMU	HI	HI
Brazil	Latin America & Caribbean	EM	G20	HI	HI
Canada	North America	AE	G20; OECD	HI	HI
Croatia	Europe & Central Asia	EM	EU	LMI	UMI
Cyprus	Europe & Central Asia	AE	EMU	UMI	HI
Czech Republic	Europe & Central Asia	AE	OECD; EU	LI	UMI
Denmark	Europe & Central Asia	AE	OECD; EU	LMI	HI
France	Europe & Central Asia	AE	G20; OECD; EMU	LMI	HI
Gabon	Sub-Saharan Africa	EM	OPEC	UMI	
Germany	Europe & Central Asia	AE	G20; OECD; EMU	UMI	UMI
Greece	Europe & Central Asia	AE	OECD; EMU	HI	UMI
Hungary	Europe & Central Asia	EM	OECD; EU	UMI	UMI
Iceland	Europe & Central Asia	AE	OECD	LMI	HI
Iran, Islamic Rep.	Middle East & North Africa	EM	OPEC	LI	LMI
Ireland	Europe & Central Asia	AE	OECD; EMU	HI	HI
Israel	Middle East & North Africa	AE	OECD	UMI	UMI
Italy	Europe & Central Asia	AE	G20; OECD; EMU	HI	UMI
Jamaica	Latin America & Caribbean	EM		HI	UMI
Japan	East Asia & Pacific	AE	G20; OECD	HI	HI
Luxembourg	Europe & Central Asia	AE	OECD; EMU	LI	HI
Malta	Middle East & North Africa	AE	EMU	UMI	HI
Mexico	Latin America & Caribbean	EM	G20; OECD; Oil Exporter	LMI	LMI
Netherlands	Europe & Central Asia	AE	OECD; EMU	UMI	HI
New Zealand	East Asia & Pacific	AE	OECD	LMI	HI
Norway	Europe & Central Asia	AE	OECD; Oil Exporter	LMI	HI
Oman	Middle East & North Africa	EM	Oil Exporter	LI	UMI
Portugal	Europe & Central Asia	AE	OECD; EMU	UMI	HI
Saudi Arabia	Middle East & North Africa	EM	G20; OPEC	LI	LMI
Slovenia	Europe & Central Asia	AE	EMU	LI	UMI
South Africa	Sub-Saharan Africa	EM	G20	LMI	UMI
Spain	Europe & Central Asia	AE	OECD; EMU	UMI	HI
Sweden	Europe & Central Asia	AE	OECD; EU	LMI	HI
Switzerland	Europe & Central Asia	AE	OECD	UMI	HI
United Kingdom	Europe & Central Asia	AE	G20; OECD	LMI	HI
United States	North America	AE	G20; OECD	UMI	HI

GROUP 4:	*Region*	*Income group*	*Other classifications*	*Public indebtedness*	*Private indebtedness*
Congo, Dem. Rep.	Sub-Saharan Africa	LIDC		HI	LI
Ghana	Sub-Saharan Africa	LIDC		UMI	LI
India	South Asia	EM	G20	UMI	LMI
Kyrgyz Republic	Europe & Central Asia	LIDC		HI	LI
Malawi	Sub-Saharan Africa	LIDC		UMI	LI
Mauritania	Sub-Saharan Africa	LIDC		HI	LMI
Moldova	Europe & Central Asia	LIDC		LMI	LI
Philippines	East Asia & Pacific	EM		UMI	LMI
Rwanda	Sub-Saharan Africa	LIDC		HI	LI
Sudan	Sub-Saharan Africa	LIDC	Oil Exporter	HI	LI

Table 4 (continued)

GROUP 5:	*Region*	*Income group*	*Other classifications*	*Public indebtednes s*	*Private indebtedness*
Bolivia	Latin America & Caribbean	EM	Oil Exporter	LMI	
Burkina Faso	Sub-Saharan Africa	LIDC		LMI	LI
Cameroon	Sub-Saharan Africa	LIDC	Oil Exporter	HI	LI
Comoros	Sub-Saharan Africa	LIDC		HI	LI
Cote d'Ivoire	Sub-Saharan Africa	LIDC		HI	LI
Gambia, The	Sub-Saharan Africa	LIDC		UMI	LI
Guinea	Sub-Saharan Africa	LIDC		UMI	LI
Haiti	Latin America & Caribbean	LIDC		LMI	LI
Honduras	Latin America & Caribbean	LIDC		UMI	LMI
Kenya	Sub-Saharan Africa	LIDC		UMI	LMI
Madagascar	Sub-Saharan Africa	LIDC		UMI	LI
Mali	Sub-Saharan Africa	LIDC		LMI	LI
Nepal	South Asia	LIDC		UMI	LMI
Nicaragua	Latin America & Caribbean	LIDC		HI	LMI
Niger	Sub-Saharan Africa	LIDC		HI	LI
Pakistan	South Asia	EM		UMI	LMI
Senegal	Sub-Saharan Africa	EM		LI	LI
Tanzania	Sub-Saharan Africa	LIDC		LMI	LI
Uganda	Sub-Saharan Africa	LIDC		UMI	LI

Note:
Regarding income groups, for operational and analytical purposes, economies are divided among three groups according to the International Monetary Fund (IMF) classification. Therefore, AE, EM and LIDC stand for Advanced Economies, Emerging Market Economies and Low-Income Developing countries. The main criteria used by the IMF to classify the world into advanced economies, emerging market and developing economies are (1) per capita income level, (2) export diversification— so oil exporters that have high real *per capita* GDP would not make the advanced classification because around 70% of its exports are oil; and (3) degree of integration into the global financial system. As for other classifications: OECD: Organisation for Economic Cooperation and Development; EU: European Union; EMU: European Economic and Monetary Union; OPEC: Organization of the Petroleum Exporting Countries; G20: Group of twenty economies that account for around 90% of the gross world product. In relation to relative public and private indebtedness, based on public and private debt-to-GDP ratios, we have classified them as low indebted (LI), lower middle indebted (LMI), upper middle indebted (UMI), and high indebted (HI), the cut-off points between each of the groups being the first, the second and the third quartile.

Table 5: Heterogeneous effects by groups, GFE-2SLS

lagged y	-0.0002*** (0.0000)
Group 1**d***	-0.0266*** (0.0031)
Group 2**d***	-0.0227*** (0.0025)
Group 3**d***	-0.0110*** (0.0018)
Group 4**d***	-0.0083*** (0.0024)
Group 5**d***	-0.0061*** (0.0016)
OPEN	0.0229*** (0.0017)
INF	-0.0129*** (0.0020)
POPGR	-0.7225*** (0.1911)
GCF	0.1075*** (0.0212)
N	2435

Notes:
The table reports estimated coefficients from the extended model to explore the possibility of heterogeneous effects, given by equation (6), including interactions of the variable d_t with the group indicator variables.
The dependent variable is *g*, the growth rate of real *per capita* GDP. Lagged *y* is lagged real *per capita* GDP, *d* is the public debt-to-GDP ratio, *OPEN* is openness to trade, *INF* is the GDP deflator inflation rate, *POPGR* is the population growth rate and *GCF* is the ratio of gross capital formation to GDP.
Group 1, Group 2, …, Group 5 are dummy variables that take the value 1 if the country belongs to the corresponding group or zero otherwise. See Table 4 for the list of countries belonging to each group. Robust standard errors in round brackets. Regression includes group FE, year FE and group year FE.
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Exploring drivers of time-varying coefficients by groups.

	Group 1	Group 2	Group 3	Group 4	Group 5
GQI	0.0357**	**0.1473****	**0.1427****	**0.1047****	**0.0358****
	(0.0137)	**(0.0537)**	**(0.0519)**	**(0.0383)**	**(0.0132)**
DQPD	**-0.0388*****	**-0.0351****	-0.2164	**-0.3289****	**-0.3513****
	(0.0113)	**(0.0127)**	(0.1738)	**(0.1213)**	**(0.1283)**
DQPRD	**-0.4302****	**-1.5438****	**-1.6129*****	**-0.3268****	-0.7373
	(0.1639)	**(0.5476)**	**(0.5146)**	**(0.1250)**	(0.4248)
GF01	**-0.8376****	**-1.6037****	-6.3998	**-3.1010*****	**-6.7587*****
	(0.3204)	**(0.5732)**	(5.3327)	**(0.9936)**	**(2.1226)**
GF02	**-0.4250*****	**-1.2957*****	**-0.6889*****	-0.6551	-0.2499
	(0.1316)	**(0.4343)**	**(0.2222)**	(0.6222)	(0.3874)
GF03	0.3073	**1.7905****	**0.1071*****	-0.4762	**0.6613*****
	(0.2366)	**(0.6441)**	**(0.0342)**	(0.6696)	**(0.2101)**
GF04	**0.1472****	**0.5406*****	**0.8374*****	**0.4575****	**0.9743*****
	(0.0556)	**(0.1703)**	**(0.2608)**	**(0.1717)**	**(0.3033)**
GF05	**0.1317*****	**0.1899*****	**0.0731****	0.0245	0.5038
	(0.0430)	**(0.0617)**	**(0.0262)**	(0.0211)	(0.5450)
GF06	0.2225	1.7939	**0.1634*****	**0.6396*****	**0.7227*****
	(0.2203)	(1.5405)	**(0.0525)**	**(0.2138)**	**(0.2315)**
GF07	**1.6693****	**2.9609****	1.1865	**0.9771****	**0.7310****
	(0.5077	**(0.9357)**	(0.9875)	**(0.3702)**	**(0.2680)**
GF08	**-0.4060*****	**-0.2321*****	**-0.2883****	**-0.1682*****	**-0.0865****
	(0.1298	**(0.0072)**	**(0.1030)**	**(0.0507)**	**(0.0317)**
GF09	**1.2073*****	**2.0412****	**1.0801****	**2.4472*****	**2.0118****
	(0.3842)	**(0.6552)**	**(0.3588)**	**(0.7821)**	**(0.7484)**
GF010	**1.8344****	**0.4091*****	**1.5783*****	**1.0145****	**1.7216****
	(0.6754)	**(0.1370)**	**(0.5023)**	**(0.3779)**	**(0.6438)**
STD	**-3.4046*****	**-0.8631****	**-2.8737****	**-3.5639*****	**-2.0258*****
	(1.0372)	**(0.2318)**	**(1.9596)**	**(1.1488)**	**(0.6726)**
Constant	**-0.0625****	**-0.0007*****	**-0.0170*****	**-0.0152****	**-0.2487*****
	(0.0233)	**(0.0002)**	**(0.0052)**	**(0.0056)**	**(0.0822)**
Adjusted R^2	0.6759	0.6712	0.6864	0.6124	0.6388
RMSE	2.1888	2.6551	1.8534	3.1812	2.9593

Notes: The table reports estimated coefficients from a regression of the time-varying slopes by groups depicted in Figure 1 on its postulated determinants. *GQI* is a government quality indicator; *DQPD* and *DQPRD* are relative public and private indebtedness, respectively; *GF01* denotes expenditure on general public services; *GF02* denotes expenditure on defence; *GF03* denotes expenditure on public order and safety; *GF04* denotes expenditure on economic affairs; *GF05* denotes expenditure on environment protection; *GF06* denotes expenditure on housing and community amenities; *GF07* denotes expenditure on health; *GF08* denotes expenditure on recreation, culture and religion; *GF09* denotes expenditure on education; *GF10* denotes expenditure on social protection; and *STD* is a proxy the short-term debt.
See Table 4 for the list of countries belonging to each group. Robust standard errors in round brackets. *** p<0.01, ** p<0.05, * p<0.1. The bold letters show the statistically significant coefficients.