PARTNERS IN DEBT: AN ENDOGENOUS NONLINEAR ANALYSIS OF INTERACTION OF PUBLIC AND PRIVATE DEBT ON GROWTH

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Abstract

This paper studies the interaction of public and private debt in determining economic growth. Both debt variables are treated as endogenous and subject to regime switch with the interaction term being the threshold variable. Then we test whether this interaction variable causes nonlinearity. We find strong evidence for a threshold effect. This threshold variable is also endogenous unlike the previous literature. Using data from 29 OECD countries from 1995-2014, the threshold effect of the interaction of public and private debt to growth is found to be negative and significant on economic growth when it reaches the level of 137%. We also decompose the private debt to household and corporate debt. It is found that the public and private debt interaction is likely to be through the channel of household debt and public debt. For a robustness check, we examine the threshold effects considering the effects of banking crises, output volatility, and institutional quality, different time periods and models.

Keywords: public and private debt, interactive effect, economic growth, endogenous threshold, dynamic panel data

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1 Introduction

It is well known that an efficiently functioning financial system provides liquidity, a risk sharing mechanism and fosters economic growth (Zingales, 2015). From the historical perspective, financial systems, especially in developed countries, are often under the threat of financial crisis. The recent Great Recession of U.S. in 2008-2012 triggered by financial crisis is a vivid example of how financial depth could be detrimental to growth. The relation between private debt and economic growth has been analyzed extensively. Early work by King and Levine (1993), Rajan and Zingales (1998) show positive effects of finance on economic development. Levine (2005) discusses theoretical considerations in which finance contributed to growth. Loayza and Ranciere (2006) find that in the short-run there can be a negative relation between financial depth and economic growth due to a financial crisis, but in the long-run the relation is positive. Recently, in a very detailed way Arcand et al. (2015) show that there is a non-linear relation between private debt and GDP growth. At low to intermediate debt levels, private debt is a positive factor towards economic growth, but at high levels of private lending, it becomes a negative factor. Specifically, they find that when the private debt/GDP ratio reaches 100% the relation becomes negative. Their view is consistent with a "vanishing effect" of financial depth proposed by Rousseau and Wachtel (2011). A linear specification can mask the non-monotonic relation, and may show a small positive effect of finance, if the truth is positive before a threshold and small negative effect after a threshold. Arcand et al. (2015) list several theoretical explanations of the possible negative effects of finance at high levels of private debt. One explanation is by Demirguc-Kunt et al. (2013), when the countries get richer, credit to the private sector by banks is not a positive factor for economic growth. Another one is by Rajan (2005), where he cautions against complicated financial structures that can contribute to financial meltdown. Another explanation is, by Beck et al. (2012), that household credit and enterprise credit are different, and there is no positive relation between household credit and growth.

A related issue is public debt. Public debt is a growing concern in rich countries. For example, US public debt is large and growing. At the end of 2017 if was 106% of GDP, the highest in peacetime history. However, the private debt of US households and businesses was approximately twice as big. It was 201% of GDP at the end of 2017. There are differences between these two types of debt, but they also interact in important ways. For example, government agencies offer loan guarantees, both explicitly and implicitly, on certain private debts that convert these nominally private debts into government debts. Government loan guarantees are prominent for

mortgage loans, which are the main source of finance for housing and the largest form of household debt. Private debt has risen substantially since the deleveraging that followed the Great Recession. Therefore, to understand the relationship between debt and economic growth, it is important to analyze private debt, public debt, and their interaction.

Recently Jorda, Schularick and Taylor (2015) show the importance of treating jointly the private and public debt. They show that public and private debt interacts. They analyze data for several advanced economies between 1870-2011. Their paper shows that recovery from a recession with large public debt is difficult if the recession is of a financial nature due to a credit boom. In Ireland and Spain, for example in 2007-2009 the public sector budget deficit ballooned when the banks were bailed out. They have a historical analysis via a long-run projection method, and find that one standard deviation above the mean in the private-public debt interaction term results in 5% less growth per capita over five years in total. Also as additional findings, the root of the financial crisis is not in fiscal issues facing governments. Private debt runs pro-cyclical, and public debt runs counter-cyclical. As iterated above, they show that private debt contributes to a financial recession, which in turn causes an increase in public debt. In their paper, Figure 1 shows that bank lending to the private sector was at 80% of GDP around 1995 and climbed to 120% around 2008 on average for the seventeen advanced countries that they analyzed.

Timing and dynamics of the debt are important because the effect on GDP over business cycles may be quite different from its effect on long-run growth. Over certain ranges for debt, it may have negligible effects on GDP, but at higher levels, the effects may be significant and even opposite to the lower levels. This suggests a non-linear relationship, such as a debt threshold. Data availability have made it expedient to use panel data, but until recently, threshold levels had to be imposed, rather than determined endogenously by the data. Our paper will apply a technique, developed recently by Seo and Shin (2016), to analyze the debt/growth nexus by estimating thresholds using panel data for a set of advanced countries.

This paper explores the interaction of public and private debt in influencing economic growth. We treat the interaction term as endogenous and subject to regime shift. The non-monotonicity of the interaction term suggests that government budgets could have been affected by increasing private debts when the debt ratios passed a certain threshold. In less extreme occasions, the relationship between debt interaction and growth could be very different from the case when the debt ratio is very high. The linear models would "iron out" the structural differences of different regimes and the average effect could be meaningless when the debt levels are far from the tipping

point, as well as in drawing corresponding policy implications. Two linear models that we use, pooled OLS, and dynamic linear panel data models, give an average positive effect of public-private debt interaction on growth. This is due to the incorrect linear nature of these models.

With a threshold model, we can test whether a model is linear or not, and then identify the threshold estimate from the data if there is non-linearity. Furthermore, unlike the previous threshold literature we allow for an endogenous threshold variable. The dynamic endogenous-panel threshold model is the main vehicle of our empirical exploration, which also addresses the potential negative bias issue of the quadratic effects as in Arcand et al. (2015). Using data from 29 OECD countries ranging from 1995-2014, the threshold effects of the interaction of public and private debt to growth are found to be significant and negative on economic growth when the interaction term reaches 137%. For example, a sudden jump by 50 percentage points of the public and private debt interaction term (e.g. from 130% to 180% increase in private debt, keeping public debt constant) has a -0.32% (e.g. decline from 3% growth to 2.68% growth) additional negative effect on average across 5 years. This is in addition to -0.30% coming from private debt. So in total, the growth will decline from 3% to 2.38% every year in the next 5 years. These can be seen from Table 5.

We also explore the channel through which private debt and public debt interact by decomposing the private debt into household and corporate debt. We find that the public and private debt interaction operates through the channel of household debt and public debt. The threshold estimate for the household debt and public debt interaction is at 35.52%. After that point, there is a negative-significant interaction on GDP growth. We do not see the same pattern for the corporate debt/public debt interaction.

For robustness checks, we examine how thresholds are affected by adding effects of output volatility, banking crises, and institutional quality, respectively. We also found that the main results are robust to taking account of outliers and short-run averages. In addition, we considered a longer time period 1975-2014, and a different panel threshold model with cross-sectionally correlated errors with similar results.

1.1 Literature Review on Non-linearities in Debt-Growth Relation

An abundant literature has studied private debt and its possible harmful effects on growth after a certain threshold is reached, such as Schularick and Taylor (2012), Cerra and Saxena (2008), Reinhart and Rogoff (2009), Jorda, Schularick and Taylor (2011, 2013), Mian and Sufi (2010). Other strands of the literature only consider a large public debt as a possible negative influence

on GDP growth. These include Reinhart and Rogoff (2010), Reinhart et al. (2012), Checherita-Westphal and Rother (2012), Caner, Grennes and Koehler-Geib (2013).

Checherita-Westphal and Rother (2012) study the impact of government debt on economic growth using 12 Euro-area countries (namely, Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain) over a period from 1970-2008. Employing the augmented conditional convergence equation which included the level of government debt as a share of GDP, it finds a non-linear impact of government debt on growth with the threshold being around 90-100%, such that government debt has a negative impact on growth beyond this turning point. The government debt's impact on growth might be through the channels of private saving, public investment and total factor productivity (TFP).

Eberhardt and Presbitero (2015) study the long-run relationship between public debt and growth using both linear and nonlinear specifications. A total of 118 countries are included in the sample for the period 1960-2012. Due to the lack of availability of data, private debt is not included in the control variables. For nonlinearity specification in country level, it uses the method by Shin et al. (2013) where upon selecting an exogenously given threshold (use 60%, the sample mean, and the popular 90% debt-to-GDP ratio) to investigate heterogeneous growth regimes (below and above the threshold) while accounting for cross-section dependence. It finds some support for a negative relationship between public debt and long-run growth across countries.

Ghosh et al. (2013) study the question of how high can public debt rise without compromising fiscal solvency. Using a theoretical model of sovereign default in which risk-neutral investors lend to a government whose ability to increase primary balances cannot keep pace with rising debt, it shows that government faces an endogenous debt limit beyond which debt cannot be rolled over. Using data for 23 advanced economies over the period 1970-2007, it finds evidence of a fiscal reaction function with these features, and use it to compute fiscal space, defined as the difference between current debt ratios and the estimated debt limits. It finds that the marginal response of the primary balance to lagged debt is non-linear, remaining positive at moderate debt levels but starting to decline when debt reaches around 90-100% of GDP.

Reinhart et al. (2012) provide the national accounting of public debt overhangs and growth rate. In the sample of advanced economies since the early 1800s, it is found that when gross public debt exceeds 90% of GDP for 5 consecutive years or more, the growth rate is lower than during other periods of no debt overhangs. Notice that in the study, several countries such as Denmark, Germany, Norway, Sweden and Switzerland have never had debt/GDP exceeding 90% in any year

in the sample, and several other countries do not meet the debt overhang criteria.

Lombardi et al. (2017) study the real effects of household debt on the growth in both short run and long run. Using data on 54 economies over 1990-2015, it shows that household debt boosts consumption and GDP growth in the short run, mostly within one year. By contrast, a 1 percentage point increase in the household debt-to-GDP ratio tends to lower growth in the long run by 0.1 percentage point. It also finds that the negative long-run effects on consumption tend to intensify as the household debt-to-GDP ratio exceeds 60%. For GDP growth, that intensification seems to occur when the ratio exceeds 80%.

Mian et al. (2017) recently show also harmful effects of household debt on growth. They have a very comprehensive paper, which covers 1960-2012 of 30 countries. They find that low mortgage spreads are associated with large levels of household debt and can hamper growth. The credit supply shocks are key to their argument. There is also evidence in their paper about non-linearity of household debt and growth relation due to wage rigidities and macro-frictions. With larger levels of debt, growth is affected negatively, but lowering debt does not increase growth due to rigidities.

Section 2 discusses theoretical developments. Section 3 provides the dynamic panel endogenous threshold model. Section 4 describes the data, and Section 5 provides the results. An appendix shows details of estimation and testing.

2 Theory

Our paper's theory analysis starts with theories linking private debt to growth rates, and then we discuss a recent paper from the literature that shows theoretical link between interaction of public and private debt with growth rate.

Demirguc-Kunt et al. (2013) show that bank-related credit is not positively correlated with growth, as countries get richer. Minsky (1974), in a very early paper, relates finance and macro-volatility. Easterly et al. (2000) show a convex, non-monotonic relation between financial depth and output growth. Excessive household lending leads to speculative bubbles in the housing market and negatively affects growth (Beck et al., 2012). Gennaioli et al. (2010) show that some neglected tail risk with complex financial derivatives increases the probability of meltdown.

Mian et al. (2017) provide theory and evidence linking household debt to the decline in growth. Mian et al. (2017) hypothesize that a positive credit supply shock is the main reason for subsequent declining growth rates. First, theories by Favilukis et al. (2015) show that a rise in foreign capital

inflows increases the credit supply, as well as positive biases of lenders, as in case of Bordalo et al. (2016). Landvoigt et al. (2016) show that lenders underestimate the true default risk facing lenders. Then Schmitt-Grohe and Uribe (2016) provide theories with relaxed lending that leads to an increase in household debt. Greenwood et al. (2016) show that high positive credit market sentiment increases lending, since low defaults today are extrapolated into future decisions. But why is there a decline in growth? Bordalo et al. (2016) provide a theoretical model such that positive sentiment is reversible, which ends up as a negative sentiment, and this will end credit boom. Then Schmitt-Grohe and Uribe (2016) provide theoretical models such that high levels of debt, wage rigidities and a deleveraging shock will result in recession and create non-linearities between private debt and growth.

All the papers above are related to either private debt–growth or household debt–growth nexus. A recent paper by Batini et al. (2016) provide the first theory linking private and public debt interaction and how it affects growth. They use the credit cycle model of Kiyotaki and Moore (1997), which shows how small negative shocks to economy may cause large output fluctuations. Public debt is also inside this model through a theory by Corsetti et al. (2013). By incorporating these elements, Batini et al. (2016) provide two links between public and private debt. When households cut spending due to large payments of debts, output is affected negatively, which also depresses government revenue. When the government intervenes to reduce the effects of large private debt, the public debt also rises. Batini et al. (2016) calibrate their model and show that the combination of high public and high private debt results in a larger contraction of GDP.

3 Dynamic Endogenous-Panel Threshold Model

Recently Seo and Shin (2016) extended the endogenous instrumental variable threshold model to one with a dynamic panel from simple cross-section. They solved the key issue of an endogenous threshold variable that cannot be addressed by Caner and Hansen (2004). We start with the following dynamic panel data model, with endogenous threshold, for $i = 1, \cdots, n$, and $t = 1, \cdots, T$, where i represents the countries, and t represents the time period.

$$\begin{aligned} y_{it} &= \alpha_i + \psi y_{i,t-1} + \Gamma' D_{it} + \phi_{11} 1_{\{q_{it} \leq \gamma\}} + \phi_{21} 1_{\{q_{it} > \gamma\}} \\ &+ \phi'_{12} r_{it} 1_{\{q_{it} \leq \gamma\}} + \phi'_{22} r_{it} 1_{\{q_{it} > \gamma\}} + v_{it}, \end{aligned} \tag{1}$$

where α_i represents unobserved heterogeneity due to country differences, and D_{it} consists of all control variables, and they are not subject to regime change, v_{it} is an error term with zero mean

finite variance. Our dependent variable, y_{it} is annual percentage growth rate of GDP, and as explanatory variable we have its lagged value. The endogenous variables r_{it} consists of private debt/GDP, public debt/GDP, and interaction of public debt/GDP with private debt/GDP ratios, and they are subject to regime shift. The threshold variable is the interaction between public debt/GDP with private debt/GDP, and it's endogenous: $E[q_{it}v_{it}] \neq 0$. Threshold value γ is in a compact with lower bound γ_l and upper bound γ_u, $\gamma \in [\gamma_l, \gamma_u]$. Vectors ϕ_{12}, ϕ_{22} are 3×1 vectors and represent coefficients on endogenous variables in regime 1 and 2 respectively. Γ is the coefficient vector on control variables D_{it}, where those are inflation, government consumption, trade openness, and education. ψ is the coefficient on lagged dependent variable.

A simple transformation (with first differencing in time and transforming variables) of (1) above as in Seo and Shin (2016) provides

$$\Delta y_{it} = \psi \Delta y_{it-1} + \Gamma' \Delta D_{it} + \beta' \Delta x_{it} + \delta' X'_{ita} 1_{\{it\}}(\gamma) + \Delta v_{it}, \tag{2}$$

where $\beta = \phi_{12}$ which is 3×1 vector, that consists of regime 1 coefficients of three endogenous variables, δ represents the difference in the coefficients between regime 2 and 1, namely $\delta = (\phi_{21} - \phi_{11}, \phi'_{22} - \phi'_{12})'$ which is 4×1 vector. Define a 2×1 vector

$$1_{it}(\gamma) = (1_{\{q_{it} > \gamma\}}, -1_{\{q_{it-1} > \gamma\}})',$$

where

$$q_{it} = (\frac{PVD}{GDP})_{it} \times (\frac{PBD}{GDP})_{it}$$

where PVD, PBD is private and public debt debt respectively. $\Delta x_{it} = x_{it} - x_{it-1}$, and we have the following 3×1 vector

$$x_{it} = \left[\left(\frac{PVD}{GDP} \right)_{it}, \left(\frac{PBD}{GDP} \right)_{it}, \left((\frac{PVD}{GDP})_{it} * (\frac{PBD}{GDP})_{it} \right) \right].$$

X_{ita} is an augmented version of X_{it}, and is defined as a 2×4 vector

$$X_{ita} = \begin{pmatrix} (1, x'_{it}) \\ (1, x'_{it-1}) \end{pmatrix}.$$

In this section we consider two important questions. First, whether there is a nonlinear threshold regression type relation between interaction of public and private debt and GDP growth. Namely, we want to test the null of $H_0 : \delta = 0$ in (2). Second question is related to estimation of different regimes, if there is a threshold, we want to learn whether first there is a positive relation between

private public debt interaction and growth and then after an estimated threshold level is passed, whether this relation turns negative. In other words, we are interested in if $\phi_{12} > 0$, and $\phi_{22} < 0$ in (1). These are the coefficient vectors on debt variables. To get estimates of ϕ_{12}, ϕ_{22} we need to get estimate for β to have estimates for ϕ_{12} in (2) and then also add that to estimate of $\phi_{22} - \phi_{12}$ in δ in (2) to get estimates for ϕ_{22}.

4 Data Description

We explore the threshold effect of key variables of interest using the country level data of 29 OECD countries[1]. To make our results comparable with the existing literature, we mainly follow the data procedure of Arcand et al. (2015) as well as other studies of government debt (Checherita-Westphal and Rother, 2012; Reinhart and Rogoff, 2009). Our dataset sources are described in detail in Table 1, and the descriptive summary statistics is shown in Table 2. In the summary statistics, we see that private debt was at 189.76 % of GDP between 1995-2014, whereas average over 1975-1994 was 74.43%, this is a major jump on the average over time. We considered a larger set of countries starting in 1995, for which the key regression variables such as private debt are available. Another reason for 1995-2014 period is that increasing private debt starting in mid-1990s can be seen from Arcand et al. (2015). We also look at the time period, 1975-2014, for a sample of 22 OECD countries that will be listed in the subsequent sections.

We follow the earlier literature (Arcand et al. 2015; Mian et al., 2017) in using 5-year growth spells to study the interaction of debt and growth. The main exogenous control variables are openness to trade (World Bank World Development Indicators, WDI), average years of schooling of males and females above 25 years of age (Barro and Lee, 2010), inflation rate (WDI), and general government consumption (WDI). The endogenous variables which are subject to regime switch are the debt variables, where their interaction term is the threshold variable. The private sector debt is the stock of liabilities held by the sectors Non-Financial corporations and Households and Non-Profit institutions serving households (IMF STATS). We use the general gross government debt as percentage of GDP as in IMF World Economic Outlook Database. We also include the lag of

[1]Specifically, the 29 countries in 1995-2014 sample are Australia-AUS, Austria-AUT, Belgium-BEL, Canada-CAN, Switzerland-CHE, Chile-CHL, Czech Republic-CZE, Germany-DEU, Denmark-DNK, Spain-ESP, Estonia-EST, Finland-FIN, France-FRA, United Kingdom-GBR, Hungary-HUN, Ireland-IRL, Israel-ISR, Italy-ITA, Japan-JPN, Luxembourg-LUX, Latvia-LVA, Netherlands-NLD, Norway-NOR, Poland-POL, Portugal-PRT, Slovakia-SVK, Slovenia-SVN, Sweden-SWE, USA.

growth in the regression model to consider the dynamic effects of growth. For robustness checks, we consider banking crises, as well as macroeconomic volatility (Arcand et al., 2015). Rapid growth of credit to private sectors might increase the volatility or lead to financial and banking crises. We adopt the definition of volatility in Arcand et al., 2015, such that the dummy variable HVOL equals one if the country specific output growth volatility in the country-periods is higher than the whole sample average standard deviation, which is equal to 3.54% in 1995-2014 sample. For the banking crises dummy variable, we set BKCR = 1 in country-periods for which Laeven and Valencia's (2012) database has shown the country has banking crisis, and 0 otherwise. We also use data from 1975-1994 to explore the institutional quality index (ICRG), which is the index of the quality of government. The dummy variable takes value 0 when the quality is high (see more details of variable description in the data appendix Table 1).

5 Results

In this section we provide the empirical results. Our main questions are: a) whether there is a regime shift due to interaction of private-public debt? b) if there is one, what is the additional effect of this interaction below and above the threshold level. c) what is the estimated private-public debt threshold, and what percentage of the sample is above that threshold?

Before we explore the nonlinear relationship between the debt variables and growth, we first consider the linear regression models using pooled OLS and the linear dynamic panel data model, using Arellano-Bond GMM method (1991), respectively. As discussed earlier in the paper, if the true relationship of debt interaction is subject to regime shift, which we find strong evidence in later subsections, ignoring such an underlying relationship would result in the wrong empirical findings, and misguided policy implications. It is shown that linear models mask the relationship between debt interaction and growth. First, the pooled OLS shows the insignificance of the positive interaction variable as in Table 3. The private and public debt variables are negative and significant. We conjecture that when the nonlinearity is not considered, OLS estimation would cancel out the possible positive and negative effects of the interaction term in different regimes. Second, to take care of endogeneity while still using a linear model, we use a dynamic panel data model of Arellano-Bond (1991). The debt variables are shown to have stronger effects (both in magnitude and statistical significance) on growth using the linear dynamic panel data model, such that the coefficients are estimated as -0.0957 and -0.2023, compared to that of -0.0203 and -0.0865 as in the

pooled OLS model. But, without controlling for the regime shifts of the debt variables, the linear dynamic panel data model in Table 4 shows that the effect of interaction is positive, which could be misleading for the 29 OECD countries in our sample period of 1995-2014. Therefore, both linear models here may be unable to show the true effect of debt interaction on growth. The main reason is that those models do not conduct any data dependent verification whether the model is linear or not. The method that we use will first test for whether the model is linear, and then it will carry out estimation given the functional form. These issues motivate us to use a dynamic threshold panel data model, which also address the endogenous threshold variable issue.

In the following we provide answers to the questions in the beginning of this section. Our main sample is the 29 OECD countries from 1995 to 2014. We see that from Table 5 that linearity will be rejected at 10% level with a p-value of 0.056. This is due to the interaction between the public and private debt variables, since we entered this interaction variable as the threshold variable and tested whether this is tested through a Wald test for linearity, as described above in Section 3, $H_0 : \delta = 0$ versus not. We see that this threshold level, where public and private debt cause non-linearity, is 137%, which is percentage terms for public debt/GDP times private debt/GDP variable. For example, the interaction term may rise from 100% in next 5 year period, which is below the threshold, to 200%, which is above the threshold. If the country is growing at 3% on average, now it will grow at 2.35% rate on average over 5 years, which is solely due to interaction of public and private debt. This is due to the coefficient of -0.6478% in Table 5 which shows the difference between the high and low debt regimes. If we also factor in the negative effect of the private debt variable (-0.6040% difference between high and low debt) , the new growth rate will be 1.75% averaged over 5 years. It seems that the difference between high and low debt regimes is not significant for public debt variable. In other words, the public–private debt interaction variable as a threshold variable did not induce a non-linear regime in public debt, but did induce it for private debt and also public private debt interaction variable itself. Also we see that 31 % of our sample belongs to high public private debt regime between 1995-2014. In the low debt regime, we see significant positive effects of private debt alone, which could be through the channel of ideas production, among others as discussed in Madsen and Ang (2016).

5.1 Components of Private Debt

It may be informative to decompose private debt into household and corporate debt. Mian et al. (2017) provide strong empirical evidence linking household debt to growth in a negative way. Will

we see similar effects as in Table 5? Tables 6-7 answer all these questions. By analyzing Table 6, we see that there is a threshold due to household and public debt interaction, and linearity is rejected at 5% level. The differences column shows that all household, public debt and interaction variables act differently in low and high debt regimes. The threshold for household and public debt interaction is at 36%. The difference between high and low debt regimes is negative, switching from positive-insignificant interaction term (0.2691) to a negative-significant one (-0.3596). 47% of our sample belong to upper regime of high household public debt interaction term.

To give an example of the negative effects of household debt, if on average households increase their debt from 30% of GDP (below the threshold) to 80% (above the threshold), keeping the public debt constant, will have growth rates reduced by -0.31% on average over five years due to interaction being at upper debt regime at each year. Due to the increase in household debt only, there is a decline in the growth rate by -0.33%. So in total if growth rate is 3% at beginning due to increase of a 50% in household debt, average growth will decline to 2.36%. With larger jumps in household debt as described in section above, the decline in growth rates will be more dramatic.

The negative sign of the interaction term in the upper regime could be due to the interaction of household mortgages and its subsequent default risk, which aggravate the systemic risk. This result agrees with that of Bezemer et al. (2016), who found evidence that increases in household mortgage debt had a negative growth coefficient. Furthermore, our results show that both at lower and upper regimes, the individual household debt variable has a significant negative effect on growth, and this effect is large at the upper-high debt regime. We also see the same issues for the public debt variable in Table 6.

In Table 7, we see that again there is a threshold of corporate and public debt interaction terms. But this threshold of interaction only affects the corporate debt variable in a non-linear way. In other words, we see that there is a statistically significant difference between the behavior of corporate debt in a low debt regime and high debt regime. Low and high debt regimes are defined in terms of the corporate and public debt interaction terms. We see that interaction of corporate and public debt variable is not significant in either low or high debt regimes. A summary of these Tables 5-7 shows that the key is household debt in private debt–public debt interaction. In the high debt regime, joint household and public debt interaction will add to negative effects, this is a key finding, and also shows that economies should be alert to large-sudden jumps in household borrowing above 35% of GDP given the public debt is constant.

Tables 8-9 also look at same issues but instead of running together public and private debt and

their interaction, they analyze the same dynamic panel threshold regression just first by having a threshold variable of private debt on the right side in Table 8, and public debt as a threshold variable in Table 9. We see that marginal effect of private debt on growth is negative on the high debt regime in Table 8 (-0.1283), but ignores the effects of public debt, and interaction term, hence a smaller negative effect compared to all negative effects of public debt and private debt-public debt interaction terms in Table 5 (-0.5498, -0.2644) respectively. The threshold of high private debt results in negative effect on average growth rate over 5 years (-0.1283), at threshold of 138.89% of GDP. In Table 9, public debt has a negative effect of -0.1028 on average growth over 5 years in high debt regime which is at 53.12% of GDP. But the difference between high and low debt regime is -0.37. To put this in perspective this means, if a country is at 50% of the public debt/GDP ratio, and if suddenly public debt increases to 150% of GDP over 5 years, then the average growth over 5 years will decline by -0.37% compared to its previous average, it has a negative cumulative effect of -1.75% over 5 years. This decline seems small, but it does not take into account the interplay between public and private debt as in Table 5.

5.2 A longer time period: 1975-2014

Another set of tables also analyze what happened between 1975-2014 for the same set of regressions, but with 22 countries instead of 29 countries[2]. For Table 10, We see that linearity is not rejected at 10% (p-value is 0.1265). However, we still estimate a non-linear model to see what the differences are in regimes, even though they are not statistically different in lower and upper debt regimes.

Table 10 shows that in the lower debt regime, the interaction term is positive and after threshold of 55% this interaction is negatively affecting average GDP growth. Here, compared to 1995-2014 Table 5 (albeit for 29 countries there), we see threshold is much lower. Also, the threshold variable is not significantly different from zero since there is a lot of variation in the interaction debt term. In Table 10, at low level of debt, private debt has a large positive effect, in Table 5, we see a moderate positive effect, but of course these are largely due to different threshold levels in two tables. It appears that effects in panel data in 1995-2014 are sharper and different from those for the period, 1975-2014. This may be due to dramatic increase in private debt starting in mid-1990s, as seen in Arcand et al. (2015).

[2]The 22 countries in 1975-1994 sample are specifically AUS, AUT, BEL, CAN, CHE, CHL, DEU, DNK, ESP, FIN, FRA, GBR, IRL, ISR, ITA, JPN, LUX, NLD, NOR, PRT, SWE, USA. Note that we also run Table 5 with only 22 countries instead of 29 countries, the results were similar and can be obtained from authors on demand.

In Table 11 we consider the effects of private debt alone as a threshold for the period 1975-2014 in 22 countries. This is very similar to Table 8. It is nonlinear, and the threshold is significant at 125% of GDP. The key difference is that private debt has no effect on growth in the lower debt regime, between 1975-2014, but both tables show negative significant effects on growth in high debt regime. Table 12 shows effects of public debt alone on GDP growth between 1975-2014. If we compare this Table 12 with 9, results are similar but threshold in Table 12 is significant and at 67% of GDP. The public debt has a positive but small effect on GDP growth in low debt regime, but its effect turns negative after the threshold, as has been observed in several studies.

5.3 Robustness result taking account of cross-sectionally dependent errors

In the previous sections, we found empirical evidence of a threshold effect of the interaction between private and government debt, using the method proposed by Seo and Shin (2016). But the inference procedure of Seo and Shin (2016) is based on the assumption that the unobserved error terms are cross-sectionally independent. In the context of our study, it is possible that the GDP growth of OECD countries in our sample could be affected by common global economic shocks or driven by the common unobserved factors other than the control variables in our model and the unobserved heterogeneity term that we used. To check the robustness of the main result, we also consider the hypothesis test of threshold effect by Chudik et al. (2017), which considers the cross-sectionally dependent errors in dynamic heterogeneous panel data models. Firstly, the threshold parameter γ is estimated using a grid search procedure which takes into account the dynamics, heterogeneity and cross-sectional dependence features. Secondly, the null hypothesis of no threshold effect in the interaction of private and government debt is tested (using the Sup$F$ and Ave$F$ in Chudik etal (2017)). We use the data of 29 OECD countries ranging from 1995-2014 for the hypothesis tests.

We borrow two setups that are used in Chudik et al. (2017). The first model that is used to test threshold in cross-sectionally dependent errors are as follows: (with $i = 1, \cdots, n$ are countries, and $t = 1, \cdots, T$ are time periods)

$$\Delta y_{it} = c_i + \phi 1_{\{d_{it} > ln(\tau)\}} + \sum_{l=1}^{p} \lambda_i \Delta y_{i,t-l} + \sum_{l=0}^{p} \beta_{il} \Delta d_{i,t-l} + \sum_{l=0}^{p} \gamma_{il} \Delta x_{i,t-l} + \sum_{l=0}^{p} w'_{il,h} \bar{h}_{t-l} + w_{ig} \bar{g}_t(\tau) + u_{it},$$

where we test $H_0 : \phi = 0$ (no threshold) against a threshold. Let c_i is the countrywide unobserved effects, d_{it} is the natural logarithm of debt/GDP ratio, τ is the threshold level to be estimated. Δy_{it} is the output growth (first difference of log of real GDP in country i, time period t), Δx_{it} is the growth in control variables (trade, inflation, education, government consumption), cross-section

averages of these variables are denoted by $\bar{h}_t = (\Delta\bar{y}_t, \Delta\bar{d}_t, \Delta\bar{x}_t)$. let $\bar{g}_t = n^{-1}\sum_{i=1}^{n} d_{it}$. We use $p = (1,1,1)$ or $(2,2,2)$.

The second setup involves a model that gives better finite sample results with moderate T (time series sample):

$$\begin{aligned}\Delta y_{it} &= c_i + \phi 1_{\{d_{it} > ln(\tau)\}} + \lambda_i \Delta d_{i,t} + \gamma_i \Delta x_{it} + \sum_{l=0}^{p} \alpha_{il} (\Delta d_{i,t-l})^2 + \sum_{l=0}^{p} \gamma_{il} (\Delta x_{i,t-l})^2 \\ &+ w_{iy}\Delta\bar{y}_t + \sum_{l=0}^{p} w_{il,d}\Delta\bar{d}_{t-l} + \sum_{l=0}^{p} w'_{il,x}\Delta\bar{x}_{t-l} + w_{ig}\bar{g}_t(\tau) + u_{it},\end{aligned}$$

where $\Delta\bar{y}_t$ is the cross section average of growth in output, $\Delta\bar{d}_{i,t-l}$ is the cross section average of debt/GDP growth at time $t-l$. $\Delta\bar{x}_{t-l}, \bar{g}_t(\tau)$ are defined similarly. We test $H_0 : \phi = 0$ (no threshold). We use $p = 0, 1, 2$ values.

From Table 13 we see that there is a significant threshold effect of the interaction between private and government debt around 130%, which is consistent with our main estimation results of Table 5[3]. E.g., the cross-sectionally augmented autoregressive distributed lag (Setup 1) with one lag has Sup$F$ and Ave$F$ tests being 22.25 and 2.83, respectively, which are both significant under 1% significance level with the critical value simulated using S=10000 as suggested by Chudik et al. (2017). We also find evidence of no strong cross-sectionally dependent errors as shown in the CD test of Chudik etal (2017) since the models have taken care of that type of heterogeneity well.

5.4 Robustness to other economic factors

In this subsection, we analyze whether our main result is robust to using 3- year averages (rather than 5 that we used), a banking crisis variable, high volatility, and institutional quality, and outlier countries, Japan, Portugal, Ireland. They are the countries with largest three debt burden points in our data set. The robustness check for using 3-year average is needed to determine whether we observe differences compared to a 5-year average. A banking crisis measure is relevant because previous studies have found that rapid credit expansion can lead to a financial-banking crisis, which can cause growth to decrease or go negative (Kaminsky and Reinhart 1999, Schularick and Taylor 2012, Rousseau and Wachtel 2011). We mainly do the robustness checks on Table 5, 1995-2014 on 29 countries. Some of the other tables are also checked as long as data is available on household debt, and longer time periods, but since they did not show qualitative changes, we will not report them. First we start with 3-year growth spells, this will show more short-run behavior of the relationship

[3]The hypothesis test results for other tables are available upon request to the authors.

compared to a 5 year spell that we did in Table 5. Table 14 provides the main results for 3-year averages. The threshold level at 137% has not changed. But at short term, we see that private debt is positive and significant in low debt regime, unlike Table 5 which showed insignificance at 5 year averages. Other debt variables behave very similarly to 5- year averages. Table 15 provides results with the banking crisis indicator. The dummy variable BCKR that takes a value of one in country-periods with banking crises using the updated database of Leaven and Valencia (2014). As expected this variable has significant and negative effect on growth. The effect of adding that variable does not change the main results much, since threshold is at 125% of GDP and private and public debt interaction is negative and significant above this threshold level. In Table 16 we have added high volatility dummy variable (HVOL) that takes a value of one for high volatility periods, specifically, when the standard deviation of annual GDP growth (measured in constant US dollars) is greater than the sample average of 3.54%. Results for debt variables are similar to our main Table 5 after controlling for the macroeconomic volatility which is negative to growth. In Table 17 we add to our main Table 5 institutional quality index (ICRG), which is the index of the quality of government. The dummy variable takes value 0 when the quality is high (see more details of this variable in the data appendix). So we expect and get ICRG variable to be negative and significant. Results on threshold do not change much since the threshold is at 126% of GDP and significant. The private and public debt interaction has a negative and significant effect on GDP growth after the threshold level, as in other Tables.

In the last robustness check, we exclude the three most highly indebted countries in private public debt interaction in our dataset: Japan, Portugal, and Ireland. The results are in Table 18. The threshold is much lower at 109% of GDP compared with main Table 5. But still the effect of private and public debt is significant and negative in the high debt regime. Note also that the difference between low and high debt regimes, in terms of the interaction effect, is negative and significant (except banking crisis Table 15) at -0.4324 to -0.6215 in Tables 14-18. This is very similar to -0.6478 in the main Table 5, although a bit lower since we include more controls.

5.5 Dangerzone

We now give the list of the countries which are above our thresholds of 137% for public private debt interaction variables in Table 5, as well as countries which are above our threshold of 36% in Table 6 for household debt public debt interaction term.

For public private debt interaction: [4] AUT 2010 (137.84%), BEL 1995-2010 (199.43%, 199.49%, 203.18%, 252.25%), CAN 1995-2010 (176.88%, 149.03%, 148.24%, 198.74%), ESP 2010 (203.8%), FRA 2005-2010 (137.97%, 195.26%), GBR 2010 (193.85%), IRL 1995 (142.67%) and 2010 (406.7%), ITA 1995-2010 (139.23%, 143.07%, 174.43%, 226.11%), JPN 1995-2010 (306.63%, 399.22%, 447.31%, 543.07%), NLD 1995 (166.98%) and 2010 (173.85%), PRT 2005-2010 (195.92%, 364.61%), USA 2005-2010 (148.13%, 203.18%). We see that as of 2010-2014 period, the most debted three countries are: Japan at 543.07%, Ireland at 406.7%, and Portugal is at 364.61%.

In our sample used in Table 6, the country/period that crossed the public and household debt interaction threshold level of 36% are: AUT 1995-2010 (200.19%, 63.55%, 37.29%, 44.06%), BEL 1995-2010 (51.02%, 42.2%, 45.24%, 60.57%), CAN 1995-2010 (74.26%, 69.57%, 59.82%, 76.11%), CHE 1995-2010 (56.17%, 61.78%, 55.55%, 54.32%), DEU 1995-2010 (39.07%, 42.4%, 42.06%, 44.14%), DNK 1995-2010 (60.88%, 50.16%, 45.46%, 62.48%), ESP 2010 (68.39%), FIN 2010 (35.53%), FRA 2005-2010 (40.06%, 56.94%), GBR 2005-2010 (48.16%, 80.58%), IRL 1995 (133.99%) and 2005-2010 (36.71%, 111.78%), ITA 2000-2010 (39.78%, 53.05%, 70.5%), JPN 1995-2010 (88.51%, 118.47%, 114.47%, 137.94%), NLD 1995-2010 (36.96%, 46.06%, 56.13%, 81.97%), NOR 2005 (36.29%), PRT 2000-2010 (40.72%, 65.05%, 118.38%), USA 2000-2010 (35.68%, 58.74%, 73.31%). At 2010-2014, the three countries that are in debt most is: Japan at 137.94%, Portugal at 118.38%, and Ireland at 111.78%.

6 Conclusion

The relationship between debt and economic growth is complex, and full understanding of the connection requires simultaneously studying private debt, public debt, and their interaction. We have applied a technique of Seo and Shin (2016) to estimate debt thresholds from panel data from a sample of 29 advanced countries. Our results indicate a non-monotonic relationship between debt interaction and economic growth. At low levels of debt, interaction between private and public debt stimulates economic growth, but above a threshold, private/public debt interaction decreases growth. Our paper provides strong and robust evidence about the mechanism through which debt influences growth.

[4] We denote 1995 as the period average of 1995-1999, and 2000, 2005, 2010 for 2000-2004, 2005-2009, 2010-2014, respectively.

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Appendix

Here we provide details of the estimation and testing. Our instruments will be shown in detail, and will be explained. Before we introduce the moments that will lead to estimation.

For $2 < t_0, \cdots, T$, $T \geq 4$ (note we start time at $t_0 = 3$ for instruments since we lag time twice) with $l \times 1$ vector of instruments

$$E(z'_{i3}\Delta v_{i3}, \cdots, z'_{iT}\Delta v_{iT})' = 0, \tag{3}$$

where

$$z_{it} = (y_{it-2}, \Delta D'_{it}, (\frac{PVD}{GDP})_{it-2}, (\frac{PBD}{GDP})_{it-2}, (\frac{PVD}{GDP})_{it-2} * (\frac{PBD}{GDP})_{it-2})', \tag{4}$$

where $\Delta D_{it} = D_{it} - D_{it-1}$, where all the other variables are lagged twice to prevent endogeneity. Endogeneity stems from current period correlation. z_{it-1} is one period more lagged version of z_{it}. Also

$$\Delta v_{it} = \Delta y_{it} - \psi \Delta y_{it-1} - \Gamma' \Delta D_{it} - \beta' \Delta x_{it} - \delta' X_{it} 1_{\{it\}}(\gamma), \tag{5}$$

where $1_{\{it\}}(\gamma) = (1_{\{q_{it} > \gamma\}}, -1_{\{q_{it-1} > \gamma\}})'$, and $q_{it} = (\frac{PVD}{GDP})_{it} * (\frac{PBD}{GDP})_{it})$, q_{it-1} is one period lagged version of q_{it}.

Method of FD-GMM by Seo and Shin (2016) is proposed to tackle dynamic panels with endogenous thresholds for the first time. FD-GMM uses sample moments to estimate the parameters of interest. Here we provide how to implement FD-GMM of Seo and Shin (2016).

1. First for each $\gamma \in [\gamma_l, \gamma_u]$ through a simple grid search, use the linear first step GMM formula, with identity matrix as weight,

$$(\hat{\psi}_F, \hat{\Gamma}'_F, \hat{\beta}_F(\gamma)', \hat{\delta}_F(\gamma)')' = (\bar{g}_{2n}(\gamma)' \bar{g}_{2n}(\gamma))^{-1} \bar{g}_{2n}(\gamma)' \bar{g}_{1n},$$

where $\bar{g}_{1n} = n^{-1} \sum_{i=1}^{n} g_{1i}$, and $\bar{g}_{2n} = n^{-1} \sum_{i=1}^{n} g_{2i}$, and with $t = t_0, \cdots, T$

$$g_{1i} = (z'_{i3}\Delta y_{i3}, \cdots, z'_{iT}\Delta y_{iT})', \quad l \times 1$$

$$g_{2i} = \begin{pmatrix} z_{i3} & (\Delta y_{i2}, \Delta D'_{i3}, & \Delta x'_{i3}, & 1_{\{i3\}}(\gamma)' X_{i3a}) \\ \cdots & \cdots & \cdots & \cdots \\ z_{iT} & (\Delta y_{iT-1}, \Delta D'_{iT}, & \Delta x_{iT},' & 1_{\{iT\}}(\gamma)' X_{iTa}) \end{pmatrix} \quad l \times (1 + k_2 + k_1 + k_1 + 1).$$

2. Collect residuals $\Delta\hat{v}_{it}$ for each $\gamma \in [\gamma_l, \gamma_u]$

$$\Delta\hat{v}_{it} = \Delta y_{it} - \hat{\psi}_F \Delta y_{it-1} - \hat{\Gamma}'_F \Delta D_{it} - \hat{\beta}'_F(\gamma)\Delta x_{it} - \hat{\delta}_F(\gamma)' X_{ita} 1_{\{it\}}(\gamma).$$

3. For each $\gamma \in [\gamma_l, \gamma_u]$ form the optimal weight, $l \times 1$

$$W_n = (\frac{1}{n}\sum_{i=1}^{n} \hat{g}_i \hat{g}'_i - \frac{1}{n^2}\sum_{i=1}^{n} \hat{g}_i \sum_{i=1}^{n} \hat{g}'_i)^{-1},$$

with $\hat{g}_i = (\Delta\hat{v}_{i3} z'_{i3}, \cdots, \Delta\hat{v}_{iT} z'_{iT})'$ which is $l \times 1$.

4. Run linear second step GMM with optimal weight in step 3 above, and for each $\gamma \in [\gamma_l, \gamma_u]$

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

5. Find the threshold estimator, $\hat{\gamma} = argmin_{\gamma \in [\gamma_l, \gamma_u]} J_n(\hat{\psi}, \hat{\Gamma}, \hat{\beta}(\gamma), \hat{\delta}(\gamma))$ where

$$J_n(\hat{\psi}, \hat{\Gamma}, \hat{\beta}(\gamma), \hat{\delta}(\gamma)) = [\hat{g}_n(\hat{\psi}, \hat{\Gamma}, \hat{\beta}(\gamma), \hat{\delta}(\gamma))]' W_n [\hat{g}_n(\hat{\psi}, \hat{\Gamma}, \hat{\beta}(\gamma), \hat{\delta}(\gamma))].$$

and

$$\hat{g}_n(\hat{\psi}, \hat{\Gamma}, \hat{\beta}(\gamma), \hat{\delta}(\gamma)) = n^{-1} \sum_{i=1}^{n} g_i(\hat{\psi}, \hat{\Gamma}, \hat{\beta}(\gamma), \hat{\delta}(\gamma)),$$

and

$$g_i(\hat{\psi}, \hat{\Gamma}, \hat{\beta}(\gamma), \hat{\delta}(\gamma)) = \begin{pmatrix} z_{i3}(\Delta y_{i3} - \hat{\psi}\Delta y_{i2} - \hat{\Gamma}'\Delta D_{i3} - \hat{\beta}(\gamma)'\Delta x_{i3} - \hat{\delta}(\gamma)' X_{i3} 1_{\{i3\}}(\gamma)) \\ \cdots \\ z_{iT}(\Delta y_{iT} - \hat{\psi}\Delta y_{iT-1} - \hat{\Gamma}'\Delta D_{iT} - \hat{\beta}(\gamma)'\Delta x_{iT} - \hat{\delta}(\gamma)' X_{iT} 1_{\{iT\}}(\gamma)) \end{pmatrix}.$$

6. To get slopes impose $\hat{\gamma}$ in slopes to have $\hat{\beta} = \hat{\beta}(\hat{\gamma}), \hat{\delta} = \hat{\delta}(\hat{\gamma})$.

Estimation of standard errors

The limits of FD-GMM estimators of Seo and Shin (2016) are shown in their Theorem 1. They are nothing more than standard GMM limits. The variance matrix of all estimators $(\hat{\psi}, \hat{\Gamma}, \hat{\beta}, \hat{\delta}, \hat{\gamma})$ is estimated by $(k_1 = 3, k_2 = 4, l = 16)$

$$(\hat{G}' \hat{\Omega}^{-1} \hat{G})^{-1},$$

and

$$\hat{G} = [\hat{G}_\psi, \hat{G}_\Gamma, \hat{G}_\beta, \hat{G}_\delta, \hat{G}_\gamma], \quad l \times [1 + k_2 + k_1 + (k_1 + 1) + 1]$$

with

$$\hat{G}_\psi = \begin{bmatrix} -n^{-1}\sum_{i=1}^n z_{i3}\Delta y_{i1} \\ \cdots \\ -n^{-1}\sum_{i=1}^n z_{iT}\Delta y_{iT-2} \end{bmatrix} \quad l \times 1.$$

$$\hat{G}_\Gamma = \begin{bmatrix} -n^{-1}\sum_{i=1}^n z_{i3}\Delta D'_{i3} \\ \cdots \\ -n^{-1}\sum_{i=1}^n z_{iT}\Delta D'_{iT} \end{bmatrix} \quad l \times k_2.$$

$$\hat{G}_\beta = \begin{bmatrix} -n^{-1}\sum_{i=1}^n z_{i3}\Delta x'_{i3} \\ \cdots \\ -n^{-1}\sum_{i=1}^n z_{iT}\Delta x'_{iT} \end{bmatrix}. \quad l \times k_1$$

$$\hat{G}_\delta = \begin{bmatrix} -n^{-1}\sum_{i=1}^n z_{i3}1_{\{i3\}}(\hat{\gamma})'X_{\{i3a\}} \\ \cdots \\ -n^{-1}\sum_{i=1}^n z_{iT}1_{\{iT\}}(\hat{\gamma})'X_{\{iTa\}} \end{bmatrix} \quad l \times (k_1+1).$$

$$\hat{G}_\gamma = \begin{bmatrix} -(nh)^{-1}\sum_{i=1}^n z_{i3}[(1,x'_{i2})K\left(\frac{\hat{\gamma}-q_{i2}}{h}\right) - (1,x'_{i3})K\left(\frac{\hat{\gamma}-q_{i3}}{h}\right)]\hat{\delta} \\ \cdots \\ -(nh)^{-1}\sum_{i=1}^n z_{iT}[(1,x'_{iT-1})K\left(\frac{\hat{\gamma}-q_{iT-1}}{h}\right) - (1,x'_{iT})K\left(\frac{\hat{\gamma}-q_{iT}}{h}\right)]\hat{\delta} \end{bmatrix} \quad l \times 1.$$

We also have $l \times l$ matrix

$$\hat{\Omega} = \frac{1}{n}\sum_{i=1}^n \hat{g}_i\hat{g}'_i - (n^{-1}\sum_{i=1}^n \hat{g}_i)(n^{-1}\sum_{i=1}^n \hat{g}_i)',$$

where $\hat{g}_i$ is defined in step 2-3 of algorithm at $\gamma = \hat{\gamma}$ here.

Testing via Wald

This is done via a Wald test as described in Seo and Shin (2016). They use $H_0 : \delta = 0$ against $H_1 : \delta \neq 0$. Since test statistics will depend on γ there will be a grid search over scalar threshold variable values, and we use a sup Wald test specifically for test.

$$\sup W = \sup_{\gamma \in [\gamma_l, \gamma_u]} W_n(\gamma),$$

where

$$W_n(\gamma) = n\hat{\delta}(\gamma)'[R(\hat{G}(\gamma)'\hat{\Omega}^{-1}(\gamma)\hat{G}(\gamma))^{-1}R']^{-1}\hat{\delta}(\gamma),$$

and $\hat{G}(\gamma), \hat{\Omega}(\gamma)$ is exactly as in $\hat{G}, \hat{\Omega}$ but these quantities are evaluated in testing at each $\gamma \in [\gamma_l, \gamma_u]$ rather than $\hat{\gamma}$ in estimation.

Since we have 4 restrictions to test, intercept as well as 3 slope changes corresponding to 3 debt variables, $k_1 = 3, k_2 = 4$, so we have the following 4×13 vector

$$R = [0_{(k_1+1)\times 1}, 0_{(k_1+1)\times k_2}, 0_{(k_1+1)\times k_1}, I_{k_1+1}, 0_{(k_1+1)\times 1}].$$

The limit is established in Theorem 2 of Seo and Shin (2016). It is non standard but can be bootstrapped, as in p.173-174 of Seo and Shin (2016). The bootstrap algorithm is as follows.

1. Compute FD-GMM residuals

$$\Delta\hat{v}_{it} = \Delta y_{it} - \hat{\psi}\Delta y_{it-1} - \Delta D_{it}'\hat{\Gamma} - \Delta x_{it}'\hat{\beta} - \hat{\delta}' X_{ita}' 1_{\{it\}}(\hat{\gamma}).$$

2. For $i = 1, \cdots, n$, and for any time period t, select a random draw i^* from $\{1, \cdots, i, \cdots, n\}$ and set $x_{it}^* = x_{i^*t}$, $q_{it}^* = q_{i^*t}$, $z_{it}^* = z_{i^*t}$, $\Delta v_{it}^* = \Delta\hat{v}_{i^*t}$, $D_{it}^* = D_{i^*t}$, and for the lagged dependent variable, select $y_{i1}^* = y_{i^*1}$, and $y_{i2}^* = y_{i^*,2}$.

3. Generate the data under the null, recursive for lagged dependent variable,

$$\Delta y_{it}^* = \hat{\psi}\Delta y_{it-1}^* + \Delta D_{it}^{*'}\hat{\Gamma} + \Delta x_{it}^{*'}\hat{\beta} + \Delta v_{it}^*.$$

   Step 3 here provides time series data for a given cross section i^*.

4. Repeat previous step 3 n times, which amounts to collecting data for all cross sections. Steps 3 and 4 provide us bootstrapped panel data.

5. Construct $supW^*$ test which is the $supW$ calculated from bootstrap sample in step 4 above.

6. Repeat steps 2-5, $B = 1000$ times and evaluate the bootstrap p-value by the frequency of $supW^*$ that exceeds the sample statistic $supW$.

Table 1: Data Description and Sources

Variable	**Description and sources**
Growth	Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2010 U.S. dollars. Source: The World Bank, World Development Indicators (WDI), 2017. https://data.worldbank.org/data-catalog/world-development-indicators
Trade	Trade openness (calculated as exports plus imports divided by GDP). Source: WDI (2017)
Edu	Average years of schooling of males and females above 25 years of age. Year 2014 data is interpolated using spline functions (in Matlab R2017b using the method of de Boor, 1978) and time series data from 1950-2010. Source: Barro and Lee (2010): A new data set of educational attainment in the world, 1950-2010. NBER WP15902. Cambridge, MA: National Bureau of Economic Research. http://www.barrolee.com/data/yrsch2.htm)
Inflation	Inflation as measured by the consumer price index (annual %). Source: WDI (2017)
Gov consumption	General government final consumption expenditure as a percentage of GDP. Source: WDI (2017)
Private debt	Private sector debt, as a percentage of GDP. The private sector debt is the stock of liabilities held by the sectors Non -Financial corporations and Households and Non-Profit institutions serving households. Source: OECD STATS http://stats.oecd.org/index.aspx?queryid=34814
Public debt	Government debt. Source: IMF World Economic Outlook Database, 2017.
House debt	Household debt (all liabilities that require payment or payments of interest or principal by household to the creditor at a date or dates in the future) as a percentage of GDP. Source: OECD. https://data.oecd.org/hha/household-debt.htm
Corp debt	Corporate debt as a percentage of GDP. Source: CEIC global dataset https://www.ceicdata.com/ (where if not available, use domestic credit to private sector per World Bank subtract household debt)
HVOL	Dummy variable that takes a value of one in country-periods for which the standard deviation of annual GDP growth (measured in constant US dollars) is greater than 3.5%. Source: own calculations based on WDI (2017)
BKCR	Banking crisis dummy. BKCR = 1 in country-periods for which the Laeven and Valencia (2012) database signals the presence of a banking crisis and BKCR = 0 in tranquil periods.
ICRG	International Country Risk Guide (ICRG), index of the quality of government. We first create ICRG index variable which is the mean value of the ICRG variables "Corruption", "Law and Order" and "Bureaucracy Quality", scaled 0-1. We then create dummy variable that takes a value of one if the continuous quality of government index is smaller than 0.25, the lower quartile of the index. Source: http://epub.prsgroup.com/products/icrg-historical-data

Table 2: Summary Statistics

	Obs	Mean	s.d.	Min	Max
5-year panel 1995-2014					
Growth	116	2.62	1.76	-0.84	9.71
Trade	116	92.37	53.72	18.56	342.36
Edu	116	10.72	1.49	5.92	13.42
Inflation	116	2.99	2.98	-0.51	18.85
Gov consumption	116	19.39	3.47	10.69	26.45
Private debt	116	189.76	65.26	88.13	457.21
Public debt	116	56.64	36.90	4.82	233.14
House debt	116	63.66	42.72	6.58	303.86
Corp debt	116	95.06	54.79	5.07	367.90
5-year panel 1975-1994					
Growth	88	8.73	7.24	-12.18	19.85
Trade	88	64.25	35.63	16.63	187.41
Edu	88	8.41	1.88	2.98	12.32
Inflation	88	12.20	25.54	0.70	177.53
Gov consumption	88	19.17	5.53	2.68	38.67
Private debt	88	74.43	70.69	21.01	659.63
Public debt	88	69.07	39.79	13.36	222.29

Table 3: Pooled OLS results. Time Frame: 1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.1856*	0.1058
Controls	Tra de	-0.0023	0.0101
	Edu	0.2363*	0.1307
	Inflation	-0.2884	0.2803
	Gov consumption	-0.0025	0.0137
Controls (debt)	Private debt	-0.0203*	0.0121
	Public debt	-0.0865**	0.0415
	Pri*Public debt	0.0114	0.0175
	F-test p value	0.0000	
	Adjusted R-squared	0.4366	

Note: ***, **, * represents significance at 1, 5, 10% respectively.

Table 4: Arellano-Bond linear dynamic panel data results. Time frame: 1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	0.3092	0.2192
Controls	Trade	-0.0048	0.0480
	Edu	1.1497***	0.2476
	Inflation	-1.2469	0.8698
	Gov consumption	-0.0317	0.0553
Controls (debt)	Private debt	-0.0957***	0.0235
	Public debt	-0.2023***	0.0753
	Pri*Public debt	0.0754**	0.0298
	Wald test p value	0.0000	

Note: ***, **, * represents significance at 1, 5, 10% respectively, standard errors are computed using robust VCE estimator.

Table 5: Threshold panel data model results. Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2765***	0.0825
Controls	Trade	-0.3069	0.2482
	Education	1.0231***	0.1574
	Inflation	0.6312***	0.1768
	Govnmt Consumption	1.5767**	0.1768
Lower Regime	Private Debt	0.2752***	0.0968
	Public Debt	-0.3915	0.6396
	Pri*Public Debt	0.3834	0.3445
Upper Regime	Private Debt	-0.3288***	0.0313
	Public Debt	-0.5498***	0.0663
	Pri*Public Debt	-0.2644***	0.1122
Difference	Private Debt	-0.6040***	0.1017
	Public Debt	-0.1583	0.6430
	Pri*Public Debt	-0.6478*	0.3718
Threshold	Pri*Public Debt	137.27***	44.58
	Upper Regime %	31.03	
	Linearity:p-value	0.0560	
	J-Test:p-value	0.7869	

Note: ***, **, * represents significance at 1, 5, 10% respectively.

Table 6: Decomposition of private debt (household debt). Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	0.0770***	0.0920
Controls	Trade	0.1829***	0.0181
	Education	3.9822	3.0087
	Inflation	2.5431***	0.4104
	Govnmt Consumption	0.0171	0.0185
Lower Regime	Household Debt	-0.8801***	0.1229
	Public Debt	-0.4224***	0.0622
	HH*Public Debt	0.2691	0.3058
Upper Regime	Household Debt	-1.5456***	0.1683
	Public Debt	-1.8926***	0.1460
	HH*Public Debt	-0.3596***	0.0638
Difference	Household Debt	-0.6655***	0.2083
	Public Debt	-1.4702***	0.1586
	HH*Public Debt	-0.6287**	0.3123
Threshold	HH*Public Debt	35.52***	8.5113
	Upper Regime %	47.13	
	Linearity:p-value	0.0340	
	J-Test:p-value	0.3324	

Note: HH represents household debt. ***, **, * represents significance at 1, 5, 10% respectively.

Table 7: Decomposition of private debt (corporate debt). Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2446***	0.0825
Controls	Trade	-0.1755	0.2482
	Education	3.8014	0.1574
	Inflation	0.9403***	0.1768
	Govnmt Consumption	0.0276	0.6387
Lower Regime	Corporate Debt	0.3655***	0.0968
	Public Debt	-0.5242	0.6396
	Corp*Public Debt	0.3620	0.3545
Upper Regime	Corporate Debt	-0.1956***	0.0313
	Public Debt	-0.1478**	0.0663
	Corp*Public Debt	-0.1319	0.1112
Difference	Corporate Debt	-0.5611***	0.1017
	Public Debt	0.3764	0.6430
	Corp*Public Debt	-0.4939	0.3715
Threshold	Corp*Public Debt	49.68**	22.26
	Upper Regime %	56.27	
	Linearity:p-value	0.0090	
	J-Test:p-value	0.5377	

Note: Corp represents corporate debt. ***, **, * represents significance at 1, 5, 10% respectively.

Table 8: Threshold panel data model results (private debt only). Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2398***	0.0682
Controls	Trade	0.2910***	0.0557
	Education	3.8372**	1.8429
	Inflation	0.2383*	0.1216
	Govnmt Consumption	-0.2334	0.2831
Lower Regime	Private Debt	0.4121**	0.2023
Upper Regime	Private Debt	-0.1283***	0.0392
Difference	Private Debt	-0.5404***	0.2060
Threshold	Private Debt	138.89**	69.29
	Upper Regime %	78.39	
	Linearity:p-value	0.0521	
	J-Test:p-value	0.7951	

Note: ***, **, * represents significance at 1, 5, 10% respectively.

Table 9: Threshold panel data model results (public debt only). Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.3132***	0.0613
Controls	Trade	0.0221	0.0242
	Education	3.1289***	1.1243
	Inflation	0.4320	0.2983
	Govnmt Consumption	0.1892	0.1812
Lower Regime	Public Debt	0.2673**	0.1182
Upper Regime	Public Debt	-0.1028***	0.0348
Difference	Public Debt	-0.3701***	0.1232
Threshold	Public Debt	53.1290**	34.93
	Upper Regime %	50.12	
	Linearity:p-value	0.0023	
	J-Test:p-value	0.9593	

Note: ***, **, * represents significance at 1, 5, 10% respectively.

Table 10: Threshold panel data model results. Time Frame:1975-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2294***	0.0692
Controls	Trade	0.1193	0.1782
	Education	1.7835***	0.2682
	Inflation	0.1475**	0.0773
	Govnmt Consumption	0.0154***	0.0057
Lower Regime	Private Debt	1.2648*	0.6731
	Public Debt	-1.3527***	0.9605
	Pri*Public Debt	0.2530	0.2257
Upper Regime	Private Debt	-0.5942***	0.0611
	Public Debt	-1.2847***	0.1946
	Pri*Public Debt	-0.5134*	0.2972
Difference	Private Debt	1.8590***	0.6758
	Public Debt	-0.0680	0.9800
	Pri*Public Debt	-0.7664**	0.3731
Threshold	Pri*Public Debt	54.7425	40.1760
	Upper Regime %	59.09	
	Linearity:p-value	0.1285	
	J-Test:p-value	0.9249	

Note: ***, **, * represents significance at 1, 5, 10% respectively.

Table 11: Threshold panel data model results (private debt only). Time Frame:1975-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.6893***	0.0892
Controls	Trade	0.2985***	0.0239
	Education	1.7782***	0.5582
	Inflation	-0.0397***	0.0057
	Govnmt Consumption	-0.0192***	0.0124
Lower Regime	Private Debt	0.0356	0.0298
Upper Regime	Private Debt	-0.1803***	0.0262
Difference	Private Debt	-0.2159***	0.0396
Threshold	Private Debt	124.2516***	46.5251
	Upper Regime %	52.27	
	Linearity:p-value	0.0001	
	J-Test:p-value	0.7235	

Note: ***, **, * represents significance at 1, 5, 10% respectively.

Table 12: Threshold panel data model results (public debt only). Time Frame:1975-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.3146***	0.1304
Controls	Trade	0.2602 ***	0.0473
	Education	1.8451***	0.4972
	Inflation	0.0225***	0.0091
	Govnmt Consumption	0.0126***	0.0039
Lower Regime	Public Debt	0.1693*	0.0875
Upper Regime	Public Debt	-0.4724***	0.1482
Difference	Public Debt	-0.6417***	0.1721
Threshold	Public Debt	67.5101***	22.3445
	Upper Regime %	67.4829	
	Linearity:p-value	0.0025	
	J-Test:p-value	0.8405	

Note: ***, **, * represents significance at 1, 5, 10% respectively.

Table 13: Tests of private and public debt interaction-threshold effects, 1995-2014

	Setup 1		Setup 2			
	(1,1,1)	(2,2,2)	P = 0	P = 1	P = 2	P = 3
$\hat{\tau}$	1.3	1.2	1.4	1.3	1.2	1.2
Sup$\mathcal{F}$	22.45***	8.57***	10.38***	18.29***	10.27***	8.58***
Ave$\mathcal{F}$	2.83***	2.33	1.86***	2.40***	2.86***	3.13***
CD	-0.94	0.76	1.79	-0.90	-0.82	-1.47

The Setups 1 and 2 are given by equations (24) and (25) in Chudik et al. (2017). We report the Sup$\mathcal{F}$ and Ave$\mathcal{F}$ test statistics for the statistical significance of the threshold variable. Statistical significance of the Sup$\mathcal{F}$ and Ave$\mathcal{F}$ test statistics denoted by *10%, **5%, and ***1%. CD is the cross-section dependence test statistic of Pesaran (2004)where the null is weak cross section dependence in errors.

Table 14: Threshold panel data model results (3-year averages). Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2340***	0.0480
Controls	Trade	0.0154	0.0972
	Education	2.6176***	0.2371
	Inflation	0.3819**	0.1654
	Govnmt Consumption	0.1327***	0.0093
Lower Regime	Private Debt	0.2903***	0.0510
	Public Debt	-0.2830	0.2336
	Pri*Public Debt	0.3832***	0.0624
Upper Regime	Private Debt	-0.7397***	0.2650
	Public Debt	-0.9753***	0.1835
	Pri*Public Debt	-0.2239***	0.1030
Difference	Private Debt	-1.0300***	0.2698
	Public Debt	-0.6923**	0.2970
	Pri*Public Debt	-0.6071***	0.1204
Threshold	Pri*Public Debt	137.48***	29.32
	Upper Regime %	25.12	
	Linearity:p-value	0.0030	
	J-Test:p-value	0.4774	

Note: ***, **, * represents significance at 1, 5, 10% respectively.

Table 15: Banking crisis Included. Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2963***	0.0743
Controls	Trade	-0.2157	0.2268
	Education	1.4790***	0.2872
	Inflation	0.4056***	0.1833
	Govnmt Consumption	1.8225**	0.7846
	BKCR	-1.4767***	0.4399
Lower Regime	Private Debt	0.2364***	0.0783
	Public Debt	-0.3823	0.5562
	Pri*Public Debt	0.2947	0.3006
Upper Regime	Private Debt	-0.3563***	0.0313
	Public Debt	-0.4825***	0.0663
	Pri*Public Debt	-0.2274*	0.1285
Difference	Private Debt	-0.5927***	0.0843
	Public Debt	-0.1002	0.5601
	Pri*Public Debt	-0.5221	0.3269
Threshold	Pri*Public Debt	124.84***	48.68
	Upper Regime %	29.31	
	Linearity:p-value	0.0040	
	J-Test:p-value	0.8854	

Note: ***, **, * represents significance at 1, 5, 10% respectively. BKCR represents the banking crisis dummy variable.

Table 16: Macroeconomic volatility included. Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2928***	0.0745
Controls	Trade	-0.2445	0.2142
	Education	1.4729***	0.2451
	Inflation	0.5831**	0.2839
	Govnmt Consumption	1.0328**	0.4956
	HVOL	-0.3864***	0.1253
Lower Regime	Private Debt	0.2644***	0.0863
	Public Debt	-0.3385	0.5735
	Pri*Public Debt	0.3717	0.3279
Upper Regime	Private Debt	-0.3842***	0.0490
	Public Debt	-0.5109***	0.0725
	Pri*Public Debt	-0.2498**	0.1204
Difference	Private Debt	-0.6126***	0.0992
	Public Debt	-0.1724	0.5780
	Pri*Public Debt	-0.6215*	0.3493
Threshold	Pri*Public Debt	130.83***	48.74
	Upper Regime %	26.72	
	Linearity:p-value	0.0438	
	J-Test:p-value	0.8129	

Note: ***, **, * represents significance at 1, 5, 10% respectively. HVOL represents the high volatility dummy variable.

Table 17: Institutional quality included. Time Frame:1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2483***	0.0815
Controls	Trade	-0.2872	0.2404
	Education	1.2849***	0.3158
	Inflation	0.3069*	0.1837
	Govnmt Consumption	0.9573*	0.5528
	ICRG	-0.0835*	0.0472
Lower Regime	Private Debt	0.2394***	0.0926
	Public Debt	-0.3852	0.4937
	Pri*Public Debt	0.3347	0.3053
Upper Regime	Private Debt	-0.3075***	0.0525
	Public Debt	-0.5270***	0.0792
	Pri*Public Debt	-0.2306*	0.1346
Difference	Private Debt	-0.5469***	0.1064
	Public Debt	-0.1418	0.5001
	Pri*Public Debt	-0.5653*	0.3336
Threshold	Pri*Public Debt	126.26***	50.26
	Upper Regime %	31.03	
	Linearity:p-value	0.0037	
	J-Test:p-value	0.7842	

Note: ***, **, * represents significance at 1, 5, 10% respectively. ICRG represents the quality of institutions in a country where high quality is denoted by 0, anything else is 1.

Table 18: Japan, Portugal, Ireland excluded. Time Frame: 1995-2014

	Variables	Estimates	Standard Errors
	Lagged Growth	-0.2483**	0.1037
Controls	Trade	0.0926	0.1794
	Education	1.9842***	0.4825
	Inflation	0.2931*	0.1672
	Govnmt Consumption	1.3820**	0.6851
Lower Regime	Private Debt	0.1403*	0.0782
	Public Debt	-0.1875	0.4928
	Pri*Public Debt	0.2585	0.2147
Upper Regime	Private Debt	-0.1874**	0.0783
	Public Debt	-0.4982***	0.1732
	Pri*Public Debt	-0.1739**	0.0837
Difference	Private Debt	-0.3277***	0.1107
	Public Debt	-0.3107	0.5223
	Pri*Public Debt	-0.4324*	0.2304
Threshold	Pri*Public Debt	108.73**	53.39
	Upper Regime %	36.54	
	Linearity:p-value	0.0358	
	J-Test:p-value	0.8927	

Note: ***, **, * represents significance at 1, 5, 10% respectively.