Asymmetric Public Debt Cycle and Regime-Dependent Debt Sustainability

Wen-Chieh Wu* Shu-Ling Wang† Hui-Pei Cheng‡

Steven G. Craig**

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Abstract

To analyze the behavior of public debt issue, this paper contributes to the literature by simultaneously testing cyclical asymmetry of the growth of public debt ratio and regime-dependent debt sustainability. Using a two-way fixed effect model and the panel data for 100 countries over the period of 1990-2015, we find three major results. [1] The growth rate of public debt issue appears counter-cyclical in developing economies and pro-cyclical in developed economies. [2] The growth rate of public debt issue responds asymmetrically over the business cycle: it rises significantly in contractions while insignificantly in expansions. In addition, cyclical asymmetry is more evident in developing economies than in developed economies. [3] Public debt sustainability is regime-dependent. Among three exogenous thresholds of public debt ratios (30%, 60%, and 90%), the government is more likely to conduct an unsustainable debt policy when the debt ratio is above 90% in both developing and developed economies.

Keywords: cyclical asymmetry; regime-dependent debt sustainability; behavior of public debt issue

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*Department of Public Finance, National Chengchi University, Taipei, Taiwan. E-mail: jackwu@nccu.edu.tw.

†Corresponding Author: Department of Economics and Management, Gustavus Adolphus College, Saint Peter, MN 56082, U.S. Phone: +1 (507) 933-7405. E-mail: swang3@gustavus.edu.

‡Department of Economics, Soochow University, Taipei, Taiwan. E-mail: apei919@gmail.com.

**Department of Economics, University of Houston, Houston, TX 77204-5019, scraig@uh.edu

1 Introduction

After recent global financial turmoil and European sovereign crisis, two important research questions—(i) short-run cyclicality of public debt issue and (ii) long-run public debt sustainability —have regained economists' attention. Regarding the short-run cyclicality, Barro (1979) developed the public debt theory and argues that public debt issue should act counter-cyclically to maintain tax smoothing. His perspective is supported by the Keynesian view: public debt issue for primary budget deficit should rise in downturns and fall in upturns. However, while some studies find countercyclical fiscal deficits in developed economies (e.g., Lane (2003); Talvi and Vegh (2005); Lee and Sung (2007)), others find procyclical fiscal deficits in developing countries (e.g., Gavin and Perotti (1997); Talvi and Vegh (2005); Kumar and Ter-Minassian (2007)). Subsequent research shifted the focus to cyclical asymmetry of fiscal deficits (e.g., Tornell and Lane (1999); Ostergaard et al. (2002); Hercowitz and Strawczynski (2004), Balassone et al. (2004), Lee and Sung (2007), Balassone et al. (2010), and Craig et al. (2016)) find that fiscal deficits rise in recessions but they are reduced by less in expansions.

Another line of research focuses on long-run public debt sustainability. Bohn (1998) initiated the test of public debt sustainability for the U.S.. He shows a negative response of public debt issue to an increase in the lagged debt ratio over 1916–1995, suggesting that the US' government took corrective measure to maintain debt sustainability. Since then, lagged debt ratio is regarded as a key index to determine if the government conducts sustainable debt policy in the empirical studies (e.g., Balassone et al. (2004); Fabrizio and Mody (2006); Balassone et al. (2010)). Later, Davig (2004) Arestis et al. (2004), Lima and Sampaio (2005), and Payne and Mohammadi (2006) continue testing debt sustainability through various modeling methodologies and further examine if debt sustainability is regime-dependent.

This study contributes to the literature by simultaneously examining cyclical asymmetry of the growth of public debt and regime-dependent public debt sustainability for multivariate countries. We are particularly interested in three questions. First, utilizing the panel data, does the growth rate of public debt issue display any cyclical pattern? If so, is such a pattern consistent with previous studies? Second, whether the growth of public debt issue behave asymmetrically over the business cycle? If it is, what results in such an asymmetric behavior? Third, whether long-run debt sustainability is regime (debt and income)-dependent? If so, what is the threshold beyond which the government is more likely to conduct an unsustainable debt policy? To answer these questions, we employ a two-

way fixed effect model, which controls for time and country fixed effects, and use a panel dataset of 100 countries over the period of 1990–2015 at annual frequencies. To test the behavior of public debt issue, we use the growth rate of public debt ratio as the dependent variable, rather than fiscal deficits as commonly used in the existing studies, to account for a (possible) cyclical pattern of debt interest payments. To examine (possible) short-run cyclical (a)symmetry of debt issue, we include a positive and a negative (in absolute value) real GDP growth rate as an indicator of expansions and contractions, respectively.

To examine long-run regime (debt and income)-dependent debt sustainability, we first break down all sample countries into developed and developing economies. We further distinguish the debt-regime a country falls into, considering a single and multiple exogenous debt thresholds, by comparing the lagged debt ratio to the debt thresholds.[1] We then include a dummy variable for a high-debt regime to examine if the growth rate of public debt ratio differs between a high-debt and a low-debt regime. We also consider an interactive term of lagged public debt ratio and a dummy variable of a high debt regime to investigate if the growth of public debt ratio in a high-debt regime responds to an increase in the lagged debt ratio differently from it does in a low-debt regime. While political factors are considered to alter the behavior of public debt issue as well, due to data unavailability for 100 sample countries, we include a country-specific parameter for time-invariant country-specific characteristics, such as geographic location, EU membership status, socialism, corruption, fragmentation, democracy, as well as number of political parties, and a time-specific parameter for country-invariant global factors, such as global financial crisis or global health crisis.

The growth rate of public debt ratio is hypothesized to respond asymmetrically over the business cycle, which can result from: (i) the growth of fiscal deficit (over GDP) ratio significantly rises in contractions but insignificantly falls in expansions, as found in the existing literature; (ii) the growth rate of debt interest payment (over GDP) ratio insignificantly falls in contractions, due to minimum requirement of debt payment in practice; (iii) risk premium significantly rise in recessions but could insignificantly fall in expansions if investors do not change their perception on the risk of default a country's sovereign debt bears; (iv) more strategic debt payments due to better affordability of debt payments in expansions, as argued in Lane (2003), which negatively affects the growth rate of public debt ratio. Hence, the growth rate of public debt ratio could significantly rise in contractions but

[1]Therefore, whether a country is in the high-debt or low-debt regime is time-variant: a country can sometimes be in a high-debt regime and in a low-debt regime other times.

insignificantly change in expansions, suggesting cyclical asymmetry. Such cyclical asymmetry, however, can possibly turn insignificant if the upper limit of debt ratio imposed by the institutions prevent public debt ratio from significantly rising in contractions. In addition, risk premium of interest rates can fall in accordance with lower risk of default in expansions, resulting a symmetric change in debt ratios. If these two forces dominate, it is possible to find insignificant cyclical asymmetry of the growth of public debt ratio.

We find three major results. First, the growth rate of public debt ratio is significantly counter-cyclical in developing economies but insignificantly in developed economies. As most existing studies find pro-cyclical fiscal deficits in developing economies, a counter-cyclical pattern of public debt issue can be attributed to higher risk premia in recessions due to a greater chance of default and flight-to-quality that results in more debt interest payments. Second, cyclical asymmetry of the growth of public debt ratio emerges: it rises significantly in contractions but insignificantly in expansions. The result implies that public debt grows faster in recessions and slower in expansions, in line with the empirical evidence of a upward trend of public debt ratios over the past decade. We also find that such cyclical asymmetry is significant in developing economies but insignificant in developed economies, as developed economics seem to set a stringent upper limit to debt ratio that prevents debt from growing much in recessions (see Ostergaard et al. (2002) for an example). Moreover, much lower risk premia developed economies have to pay also slow down the speed of debt accumulation. Third, public debt sustainability is regime (debt and income)-dependent. Among three exogenous thresholds of the debt ratios (30%, 60%, and 90%), we find that the threshold beyond which the government is more likely to conduct unsustainable public debt policy is 90% in both developing and developed economies, due to its unwillingness or inability to pay off debt.

This study contributes to the literature along three dimensions. First, we include the growth rate of public debt ratio, rather than fiscal deficits as commonly included in prior studies, to directly infer the issue of public debt. Using the growth of public debt ratio accounts for the possibility that cyclical debt interest payments can alter or reinforce the cyclical pattern of fiscal deficits, which provides a better prediction on the debt behavior. Cyclical debt interest payments can appear owing to the following reasons: (i) governments' ability to pay off debt interest payments hinges on the business cycle, as argued in Lane (2003); (ii) risk premia that endogenously hinge on a country's external asset position can appear a counter-cyclical pattern; (iii) pro-cyclical interest rate sets by the central bank to

stabilize the business cycle; (iv) flight-to-quality effect results in less demand for unsound sovereign debt in recessions, which can push up bond returns; *vice versa*.

Second, unlike previous studies, which separately investigate cyclical asymmetry of fiscal deficits and regime-dependent debt sustainability, we simultaneously consider them as the short-run and long-run debt behavior are closely related. In the short run, as cyclical asymmetry of public debt issue attributes to debt accumulation (see Balassone et al. (2004), Lee and Sung (2007) and Balassone et al. (2010))[2], a pro-debt policy to stabilize severe contractions in a high-debt economy that has cyclical asymmetry of public debt issue should deserve policymaker's scrutiny. In the long run, if the short-run stabilization policy increases a country's debt ratio, it can switch the debt-regime this country falls into and alters the government's long-run debt policy, as our results show. Last but not least, deviating from most research concentrating on the U.S.' debt sustainability (e.g., Bohn (1998), Davig (2004) Arestis et al. (2004), Lima and Sampaio (2005), and Payne and Mohammadi (2006)), we extend the analysis to multi-variate countries. It not only allows for rich analysis of regime (debt and income)-dependent sustainability but also provides more thorough information for governments' behavior of public debt issue across time and countries, which is another contribution to the literature.

This paper is laid out as follows. Second 2 reviews related literature, and econometric strategies are developed in Section 3. Section 4 describes data and samples, Section 5 discusses empirical results, and Section 6 concludes.

2 Related Literature

Stemming from the Ricardian Equivalence proposition, Barro (1979) developed the public debt theory. Since then, one strand of the research concentrates on the cyclical behavior of fiscal deficits; the other line of the research analyzes public debt sustainability.

2.1 Symmetric cyclicality of fiscal policy

Empirical studies that analyze cyclicality of public debt issue mostly use fiscal deficits (or fiscal balance) as a proxy for public debt. Research focuses on advanced economies finds countercyclical fiscal policies. For example, Lane (2003) finds that public consumption is mild pro-cyclical while transfer

[2]In particular, Balassone et al. (2010) find that one third of the increase in average EU debt ratio is as a result of asymmetric budgetary behavior.

payments or/and debt interest payments are counter-cyclical in 22 OECD countries between 1960 to 1998; Cassou et al. (2017) find that US fiscal policy is counter-cyclical in bad times but less counter-cyclical in good times over 1955–2013. Studies that focus on developing economies alternatively find pro-cyclical fiscal policy. Gavin and Perotti (1997) find pro-cyclical fiscal policy in 13 Latin America countries between 1968 to 1995, especially in bad times. Talvi and Vegh (2005), using a panel of 56 countries over 1970-1997, conclude that fiscal policy in G7 countries appear counter-cyclical, while pro-cyclical in developing economies. Kumar and Ter-Minassian (2007) also support pro-cyclical fiscal policy in developing economies between 1970 to 2000. Lee and Sung (2007) apply a panel of 94 countries over 1972–1998 and conclude that government expenditures respond much more counter-cyclically in OECD countries than in non-OECD countries.

Explanations for procyclical fiscal policy in developing economies include: (1) international credit constraint makes developing economies hard to borrow in recessions (Gavin and Perotti (1997); Tornell and Lane (1999); Talvi and Vegh (2005)); (2) "common-pool" problems occur due to budgetary competition in good times (Tornell and Lane (1999)); (3) incomplete asset market hinders developing economies from smoothing out government consumption (Riascos and Vegh (2003)); (4) international credit constraint together with incomplete markets depress the government to run fiscal deficits in bad times, further adding spending pressure in good times (Kumar and Ter-Minassian (2007)); (5) the voracity effect forces a weak government to spend more when government revenues rise in expansions (Tornell and Lane (1999); Talvi and Vegh (2005)); Lee and Sung (2007)); (6) lack of information leads voters to demand lower taxes and more public goods in booms in a democratic economy (Alesina et al. (2008)).

In addition to cyclical behavior of primary fiscal deficit, Lane (2003) and Escolano (2010) both emphasize that public debt issue is also determined by the path of debt interest payments. Theoretically, in recessions, a decrease in funds supply through the income effect together with more funds demanded by the government to finance extra deficits jointly lead to a rise in the interest rates of government bond. However, the central bank usually cuts interest rates in downturns that would lead to a decrease in the bond interest rate through the substitution effect. In addition, "flight to quality" and "global saving glut" in a severe downturn could further push down the return on sound government bonds, as exemplified by a unprecedentedly low return on the T-bond and German Bund after the financial crisis of 2007–2009. Thus, if a decrease in bond return dominates the rise of it, a pro-cyclical

pattern of interest payments would appear, and *vice versa*.

2.2 Cyclical asymmetry of fiscal policy

As early in Buchanan and Wagner (1978), cyclical asymmetry of the behavior of fiscal deficits is regarded as a result of a political desire for a rise in government spending in recessions and a reluctance in a decrease in expansions (due to higher tax revenues), although most empirical literature focuses on a symmetry scenario at that time. Recent research switched the focus to cyclical asymmetry of budget deficits (or primary balance) and hypothesizes that budget deficit rises in a downturn but does not necessarily fall in an upturn due to the tendency to discretionarily cut taxes or increase public spending in expansions to offset automatic stabilizers. Political explanations for such cyclical asymmetry include: (1) the voracity effects (see Tornell and Lane (1999)) make the government unable to accumulate surpluses in expansions to finance spending for a rainy day, (2) a fiscally conservative government is incentivized to accumulate debt in expansions to hinder successor governments from raising spending in downturns, (3) incumbent politicians incline to raise spending before elections especially in expansions (i.e. political business cycle), and (4) governments tend to respond less to recessions than to expansions because deficit spending is perceived as a political embarrassment. Empirical findings that conclude cyclical asymmetry of fiscal deficits include: Hercowitz and Strawczynski (2004), who utilize a panel of 22 OECD countries over the period of 1975-1998, find that public spending ratio increased during the recessions but only partially reduced in expansions; Balassone et al. (2004) study 16 OECD countries between 1977 and 2002, confirming the asymmetric behavior of fiscal policy; Lee and Sung (2007) also find fiscal policy to be expansionary in recessions but non-contractionary during expansions; Balassone et al. (2010) use the data of 14 EU countries between 1970 and 2007, finding that transfer payments play a main role in such cyclical asymmetry. More recent research, Craig et al. (2016), use the buffer stock model to explain government consumption-saving behavior in a forward-looking framework.[3,4] They find that if current saving is above the set target (which is more likely to happen in an expansion), the government tends to spend more, and *vice versa*. The result implies cyclical asymmetry of fiscal deficits.

[3] The buffer stock model was originally used to explain households saving behavior in Angus (1991), who assume that consumers are impatient and facing borrowing constraint. They hold assets as a buffer stock to prevent consumption from sharply dropping as the bad draws of income occur.

[4] Carroll et al. (1992) and Carroll (1997) utilize the buffer stock model and find that consumers' impatience dominates prudence if their wealth stock is above the target level, which leads to dis-save; *vice versa*.

Existing studies agree that public expenditures play a main role in contributing to the asymmetric cycle of fiscal deficits, while the evidence of cyclical asymmetry of tax revenues is mixed: Ostergaard et al. (2002)and Lee and Sung (2007) find a significant asymmetric cycle of government revenues, whereas Balassone et al. (2010) find no evidence. On the other hand, the evidence of asymmetry of debt interest payments is consistent. For example, Coakley and Fuertes (2002) utilize the UK data over 1950–1999 and find cyclical asymmetry of short-run nominal interest rates: they respond more than one-for-one to an expected rise in inflation in expansions but less than one-for-one to an expected fall in recessions due to downward wage rigidity. Lane (2003) also suggests that a counter-cyclical pattern of fiscal deficits stem from the behavior of government transfers and/or debt interest payments. Fujiwara et al. (2013), who test cyclical asymmetry of bond returns for five advanced economies between 1997 and 2012, conclude that the they rise quickly while decrease slowly. However, they do not relate such asymmetry to business cycles.

2.3 Sustainability of public debt

Besides short-run cyclical behavior of public debt, another strand of the literature has empirically studied long-run sustainability of the public debt over various fiscal regimes. Arestis et al. (2004) use a threshold autoregressive model to test regime-dependent sustainability of U.S. fiscal deficits. They conclude that the U.S. budget decit is sustainable in the long run, and the government intervenes to reduce budget decit only when it reaches a certain threshold beyond which debt trajectory is considered unsustainable. Davig (2005) uses a Markov-switching time model to investigate if the sustainability of the discounted U.S. Federal debt is regime-dependent. He finds that although debt is unsustainable in an expanding regime, it does not threat long-run debt sustainability. Lima and Sampaio (2005) use a quantile autoregression model to analyze the asymmetric effect of different quantiles on the sustainability of discounted U.S. Federal debt. They use an autoregressive process with multiple lags and find band-dependent sustainability: discounted U.S. federal debt is sustainable when the debt value is around the 50th quantile, and unsustainable when the debt reaches high quantiles) or fall into low quantiles). Payne and Mohammadi (2006) use an endogenously determined structural break method and find sustainable budget deficit. They also use a threshold autoregressive model to detect the asymmetric pattern of the budget deficit in response to a deviation from the long-run trend. They find no evidence to support cyclical asymmetry.

3 Development of the Empirical Strategies

Current real public debt is the sum of previously accumulated real debt, real primary budget deficits, and real debt interest payments. Thus, real public debt of country i at time t can be expressed as:

$$D_{i,t} = \underbrace{E_{i,t} - T_{i,t-1}}_{\text{primary balance}} + \underbrace{D_{i,t-1}(1 + r_{i,t-1})}_{\text{debt principal and interest payments}} \tag{1}$$

where $D_{i,t}$ is real public debt level, $E_{i,t}$ are real fiscal expenditures, $T_{i,t}$ are real tax revenues, and $r_{i,t-1}$ is the predetermined net real interest rate of public debt. To convert all variables into the ratio of GDP, we divide both sides of Eq.(1) by real output $Y_{i,t}$. Public debt ratio can be expressed as:

$$\frac{D_{i,t}}{Y_{i,t}} = \frac{E_{i,t}}{Y_{i,t}} - \frac{T_{i,t}}{Y_{i,t}} + \frac{D_{i,t-1}}{Y_{i,t-1}}\frac{Y_{i,t-1}}{Y_{i,t}}(1 + r_{i,t-1}) \tag{2}$$

Define $\frac{Y_{i,t-1}}{Y_{i,t}}$ and $y_{i,t}$ as the gross and net real output growth rate, respectively, we rewrite Eq.(2) as:

$$d_{i,t} = e_{i,t} - \tau_{i,t} + \frac{d_{i,t-1}}{1 + y_{i,t}}(1 + r_{i,t-1}) \approx e_{i,t} - \tau_{i,t} + d_{i,t-1}(1 + r_{i,t-1} - y_{i.t}) \tag{3}$$

where $d_{i,t}$ is the public debt ratio, $e_{i,t}$ is the fiscal expenditure ratio, $\tau_{i,t}$ is the tax revenue ratio.[5] Substracting $d_{i,t-1}$ from both sides of Eq.(3) and using the change in public debt ratio to proxy for newly-issued public debt ratio, $nd_{i,t}$, we obtain:

$$nd_{i,t} \approx d_{i,t} - d_{i,t-1} \approx e_{i,t} - \tau_{i,t} + d_{i,t-1}r_{i,t-1} - d_{i,t-1}y_{i,t} = \underbrace{b_{i,t}}_{b_{i,t}} + \underbrace{i_{i,t}}_{i_{i,t}} + \underbrace{s_{i,t}}_{s_{i,t}} \tag{4}$$

Eq.(4) shows that the change in public debt ratio is affected by the primary budget deficit ratio ($e_{i,t} - \tau_{i,t}$), the amount of real interest payments associated with the debt ratio ($i_{i,t}$), and strategic adjustment of public debt ($s_{i,t}$). The higher the ratio of primary budget deficit and real interest payments, the more debt the government has to issue in the current period. The strategic adjustment of

[5] $\frac{1+r_{i,t-1}}{1+y_{i,t}} \approx 1 + r_{i,t-1} - y_{i,t}$, given $r_{i,t-1}$ (net real interest rate) and $y_{i,t}$ (net real growth rate) are both small.

public debt negatively dictates the amount of newly-issued debt: if the economy grows (i.e. positive real growth rate), the government has better ability to reduce the stock of public debt and therefore does not need to issue much debt to finance outstanding debt.

To investigate the cyclicality of fiscal policy, previous empirical studies utilize the following standard specification:

$$f_{i,t} = a_f + \beta_f Y_{i,t} + {}_{f,i,t}\ f = e_{i,t},\ \tau_{i,t},\ \text{or}\ e_{i,t} - \tau_{i.t} \tag{5}$$

where the dependent variable ($f_{i,t}$) includes fiscal variable considered to be cyclical, such as pubic spending, tax revenue, and primary deficit. The independent variable ($Y_{i,t}$), which can either be real GDP or output gap, is used as the indicator of the business cycle.

In addition to fiscal variables in the primary deficits in Eq. (5), debt interest payments are possibly cyclical due to the cyclical pattern of interest rates set by the central bank, risk premia, and strategic debt payments. Therefore, the change in the public debt ratio is possibly cyclical as it is dictated by cyclical components in Eq.(5). To test the cyclicality of the change in the public debt ratio, we specify the model as:

$$nd_{i,t} \approx e_{i,t} - \tau_{i,t} + + i_{i,t} - s_{i,t}\ \ \beta \equiv \beta_e - \beta_\tau + \beta_i - \beta_s \tag{6}$$

where β is the index of cyclicality for change in public debt ratio, which is determined by four types of cyclicality (in the underlying direction): (i) fiscal expenditure (positive), (ii) tax revenues (negative), (iii) real interest payment of public debt (positive), (iv) strategic adjustment of public debt (negative). If β is significantly positive, the change in the public debt ratio appears pro-cyclical, and *vice versa*.

Rather than use the change in the public debt ratio as the dependent variable in Eq.(6), we use the growth rate of public debt ratio to better explain the results. To ensure consistency, we changed the independent variables (business cycle indicator) to the real GDP growth rate. The growth rate of public debt ratio can be approximated by $\Delta \ln d$, and the real GDP growth rate can be approximated by $\Delta \ln Y$. The specification of the cyclical growth of public debt ratio can therefore be rewritten as:

$$\Delta \ln(d_{i,t}) = a_i + a_t + \lambda \Delta \ln(Y_{i,t}) + \varepsilon_{i,t} \quad (7)$$

where $\Delta \ln d_{i,t} = \frac{d_{i,t} - d_{i,t-1}}{d_{i,t}}$ represents the growth rate of public debt ratio, a_i and a_t capture country-specific and time-specific effects, respectively, and $\Delta \ln Y_{i,t} = \frac{Y_{i,t} - Y_{i,t-1}}{Y_{i,t}}$ stands for the growth rate of real GDP. If λ in Eq.(7) is positive, the growth rate of public debt ratio is considered pro-cyclical, and *vice versa*.

As explained in Section 1, to maintain a sustainable path of public debt, the public debt ratio should negatively (or positively) respond to the lagged public debt ratio. To simultaneously test cyclical asymmetry and debt sustainability, we added a lagged public debt ratio to Eq.(7) to proxy for a country's initial fiscal position:

$$\Delta \ln(d_{i,t}) = a_i + a_t + \lambda \Delta \ln(Y_{i,t}) + \gamma d_{i,t-1} + \varepsilon_{i,t} \quad (8)$$

To further test the asymmetric cycle of public debt growth, we replace the real growth rate with two indicators of expansions and contractions:

$$\Delta \ln(d_{i,t}) = a_i + a_t + \lambda_1 \Delta \ln(Y_{i,t})^+ + \lambda_2 \Delta \ln(Y_{i,t})^- + \gamma d_{i,t-1} + \delta X_{i,t} + \varepsilon_{i,t} \quad (9)$$

where λ_1 and λ_2 are indexes of cyclicality in expansions and contractions, respectively. Following Wu and Cheng (2010) and De Neve et al. (2018), $(Y_{i,t})^+$ is the positive real GDP growth rate, which takes a positive value in expansions and zero otherwise; $(Y_{i,t})^-$ is the absolute value of the negative real GDP growth rate, which takes a positive value in contractions and zero otherwise. We conduct the F (Wald) test to examine if λ_1 with λ_2 are significantly different. If so, it suggests that the growth rate of public debt ratio displays an asymmetric pattern over the business cycle. $X_{i,t}$ includes other variables, such as the degree of openness, that can explain the change in the growth of public debt ratio.

To test debt (regime)-dependent sustainability of public debt, we include a dummy variable for a high debt regime, which takes a value of one if the lag public debt ratio exceeds a certain threshold

(high-debt regime) and zero otherwise. We also add an interactive term of the dummy variable for a high debt regime and lagged public debt ratio to compare the change in the growth of public debt ratio in response to an increase in the lagged debt ratio over countries that fall into various debt regimes. The model used to test cyclical asymmetry and regime-dependent debt sustainability is specified as:

$$\begin{aligned}\Delta \ln(d_{i,t}) = {} & a_i + a_t + \lambda_1 \Delta \ln(Y_{i,t})^+ + \lambda_2 \Delta \ln(Y_{i,t})^- + \gamma d_{i,t-1} + \theta I(d_{i,t-1} > \bar{d}) \\ & + \varphi d_{i,t-1} I(d_{i,t-1} > \bar{d}) + \delta X_{i,t} + {}_{i,t}\end{aligned} \tag{10}$$

where θ in Eq.(10) represents the growth difference in public debt ratio between a high-debt and a low-debt regime, all else equal. A negative (positive) θ means that the public debt ratio in a high-debt economy grows faster (slower) than a low-debt economy does. φ in Eq.(10) is the coefficient of the interactive term of lagged public debt ratio and the dummy for a high debt regime. A positive (negative) φ implies that in response to an increase in the lagged debt ratio, the public debt ratio grows faster (slower) in a high-debt regime than it does in a low-debt regime.

4 Data Source and Sample Statistics

The data for all variables (World Development Indicators) are from the World Bank. We utilize a panel dataset, which includes 100 countries from 1990 to 2015 at annual frequencies. We break down all sample countries into low-income, middle-low income, middle-high income, and high-income countries, and we define high-income countries as developed economies and the rest as developing economies (see Appendix A for the list of countries). To distinguish various debt regimes, we distinguish a high-debt and a low-debt regime a country's lagged debt ratio falls into by a single debt threshold (60%). We also distinguish a very low-debt, a low-debt, a high-debt, and a very high-debt regime by three exogenous debt thresholds (30%, 60%, 90%) for further analysis[6]. We choose 60% as one of the thresholds as it is the constitutional upper limit of public debt ratio in the U.S. The Stability and Growth Pact also sets 60% as the legal debt ratio that European countries should not go beyond. We choose 90% as another threshold as Reinhart and Rogoff (2010) and subsequent studies find that countries significantly grow more slowly when the debt ratio exceeds 90%.

[6]Reinhart and Rogoff (2010) also choose these three thresholds in their analysis.

Regarding the definition of variables, the growth rate of public debt ratio is the percentage change in the ratio of sovereign debt (external and internal debt are both included) to GDP; the growth rate of GDP is the percentage change in real GDP per capita; the lagged debt ratio is the ratio of lagged debt level to GDP; the growth rate of openness degree is the percentage change in the sum of a country's exports and imports to GDP ratio. Table 1 reports descriptive statistics for all sample countries over 25 countries, which shows that the average public debt ratio is 59.15%, the average growth rate of public debt ratio is −0.14%, the average growth rate of real GDP is −1.9%, and the average growth rate of openness degree is 75.06%. Given two debt regimes, using 60% as the threshold, 62.3% of 2500 samples (100 countries over 25 years) fall into the high-debt regime and 37.7% of them are in the low-debt regime; given four debt regimes, sample countries that fall in the very low debt regime, low debt regime, high debt regime, and very high debt regime take up 24.4%, 37.8%, 20.7%, and 16.9%, respectively.

Table 1: Descriptive Statistics. Data source: World Bank, World Development Indicators. Sample size: 2500.

	Mean	Standard Deviation
Public Debt ratio	0.5905	0.4340
Growth Rate of Real GDP Per Capita	-0.0201	0.1416
Openness	0.7540	0.4737
Growth Rate of Public Debt Ratio	-0.0014	0.1090
Low debt regime	0.6232	-
High debt regime	0.3768	-
Very low debt regime	0.2448	-
Low debt regime	0.3784	-
High debt regime	0.2076	-
Very high regime	0.1692	-

Our sample countries include 37 developed countries and 63 developing countries. Table 2 summarizes sample statistics for both groups. The mean public debt ratios is 65.5% in developing countries and 48% in developed countries. The mean growth rate of real GDP is −3.63% in developing countries and 0.76% in developed countries. The growth rate of the openness degree is 0.71 in developing countries and 0.82 in developed countries. The average growth rate of public debt ratio is −1.2% in developing countries and 1.7% in developed countries. Given two debt regimes, using 60% as the threshold, 43.8% of developing countries fall into a high debt regime, while only 27% of developed countries fall into that regime. Given four debt regimes, using 30%, 60%,and 90% as

three thresholds, 19% of developing countries are in a very low-debt regime, while there is as much as 33.6% of developed countries are in that regime. Moreover, 20.5% of developing countries fall into a very high-debt regime, while merely 11.2% of developed countries fall into a very high-debt regime.

Table 2: Descriptive statistics by income. Data source: World Bank, World Development Indicators. Sample size: 925 (developed economies), 1525 (developing economies).

	Mean	Standard Deviation
Panel A Developing Group (sample size: 925)		
Public Debt Ratio	0.6552	0.4828
Growth Rate of Real GDP Per Capita	-0.0363	0.1543
Openness	0.7123	0.3999
Growth Rate of Public Debt Ratio	-0.0122	0.1031
Debt Regimes with Single Threshold		
Low debt regime	0.5613	-
High debt regime	0.4387	-
Debt Regimes with Multiple Thresholds		
Very low debt regime	0.1911	-
Low debt regime	0.3702	-
High debt regime	0.2362	-
Very high debt regime	0.2025	-
Panel B Developed Group (sample size: 1525)		
Public Debt Ratio	0.4803	0.3054
Growth Rate of Real GDP Per Capita	0.0076	0.1117
Openness	0.8250	0.5714
Growth Rate of Public Debt Ratio	0.0170	0.1161
Debt Regimes with Single Threshold		
Low debt regime	0.7286	-
High debt regime	0.2714	-
Debt Regimes with Multiple Thresholds		
Very low debt regime	0.3362	-
Low debt regime	0.3924	-
High debt regime	0.1589	-
Very high debt regime	0.1124	-

5 Estimation Results

5.1 Symmetric Cyclicality and Debt Sustainability

We begin our analysis by assuming cyclical symmetry in the growth of public debt ratio. Table 3 reports the estimation results of cyclical symmetry and public debt sustainability within all sample economies, given three different model specifications: no fixed effects, country-fixed effect only, and two-way fixed effects.[7] Model specification (1) in Table 3, in which no time and country-fixed effects are considered, is similar to that in Bohn (1998). Results delivered by Model (1) are close to those in Bohn (1998) as well: counter-cyclical public debt issue, due to a significant negative estimate of GDP growth rate, and sustainable debt, due to a significant negative estimate of lagged debt ratio. However, different from Bohn (1998), who use time-series data for the U.S., we use the panel data and thus we should control time and country fixed effects. Under the two-way effects model, we find that the growth rate of public debt ratio is still counter-cyclical as the estimated coefficient associated with real GDP growth rate is -0.086. However, pubic debt ratio turns insignificantly sustainable, which implies that part of the negative impact of lagged public debt ratio on debt sustainability is explained by the country fixed effects (such as corruption, number of political parties, or fragmentation) and time fixed effects (such as global financial crisis or world health issues). Finally, the growth rate of public debt ratio responds positively to the degree of openness at a significance level of 10%, as an open economy has greater access to borrowing from foreign countries, compared to a close economy, resulting in a higher growth rate public debt. However, the impact is not statistically significant at a significance level of 5%.

5.2 Asymmetric Cyclicality and Debt Regime-dependent Sustainability

To examine the asymmetric issue of public debt over the business cycle, we distinguish between recessions and expansions in this section. Moreover, to test regime-dependent debt sustainability, we consider a high-debt and a low-debt regime for countries whose lagged debt ratios are greater and smaller than an exogenous single threshold of 60%, respectively. Table 4 shows the estimation results. Within all sample countries, two results stand out. First, the growth rate of public debt

[7]We report the results under three specifications to compare them with previous studies, specifically Bohn (1998). In the subsequent sections, we will focus on the results delivered by the two-way effects model. The results generated by one-way effect model are available upon request.

Table 3: Estimation results of symmetric debt cycle and debt sustainability within all countries

	Model (1)	Model (2)	Model (3)
	Growth of Public Debt Ratio (dependent var.)		
GDP growth rate	-0.067**	-0.094***	-0.086**
	(0.028)	(0.031)	(0.034)
Lagged debt ratio	-0.024***	-0.011	-0.015
	(0.005)	(0.011)	(0.010)
Openness growth	0.112	0.125	0.201*
	(0.087)	(0.095)	(0.103)
Constant	0.010*	0.002	0.015
	(0.005)	(0.006)	(0.011)
R-squared	0.016	0.101	0.192
Country FE	NO	YES	YES
Year FE	NO	NO	YES
Observation	2500	2500	2500

Note: Number in the parentheses is the standard error clustered at the country level. *, ** and *** denote 10 % significance level, 5 % significance level and 1 % significance level respectively.

ratio rises significantly in contractions but insignificantly in expansions. The F (Wald) test shows that the two coefficients associated with the recessions and expansions are significantly different at a significance level of 5%, confirming cyclical asymmetry of public debt growth. Second, we find a negative relationship between the growth rate of public debt ratio and the lagged public debt ratio, suggesting sustainable public debt.

Considering a high-debt and a low-debt regime, we find that the growth rate of public debt ratio in a high-debt regime is lower than that in a low-debt regime, as the estimated coefficient of θ in Eq.(10) takes a negative value of -0.053, all else equal. More importantly, a positive coefficient of the interactive term of lagged public debt ratio and the dummy variable for a high debt regime, at 0.137, implying that an 1% rise in the lagged public debt ratio results in the growth rate of public debt ratio in a high-debt regime to raise 0.137% more than it does in a low-debt regime. In other words, public debt grows faster when a country is in a high-debt regime as the lagged public debt ratio rises, which increases the chance of entering into an unsustainable territory.

Table 5 summarizes the estimation results, given four debt regimes (very low, low, high, very high), using 30%, 60% and 90% as three thresholds. Again, within all sample countries, the asymmetric cycle of public debt growth still exists, and public debt is still considered sustainable. To compare the growth rate of public debt across four debt regimes, using a very low-debt regime as

Table 4: Estimation results of asymmetric debt cycle and regime-dependent debt sustainability with a single debt threshold (60%).

	Growth of Public Debt Ratio (dependent var.)
Positive GDP growth	0.007
	(0.034)
Negative GDP growth	0.145***
	(0.039)
High debt	-0.053**
	(0.025)
Lagged debt ratio	-0.144***
	(0.047)
Lagged debt ratio * High debt	0.137***
	(0.049)
Openness growth	0.219**
	(0.101)
Constant	0.049**
	(0.020)
F (Wald) test	6.10**
	[0.015]
R-squared	0.205
Country FE	YES
Year FE	YES
Observation	2500

the reference, we find that a country in a higher public regime has a relatively lower growth rate of public debt ratio that it does in a very low-debt regime, as the coefficient of the dummy variables for a low-debt, a high-debt, and a very high-debt regimes all take negative values, at -0.055, -0.146, and -0.079, respectively. In particular, the coefficient for a high-debt regime (whose lagged debt ratios fall into 60%–90%) is the most negative, suggesting that countries fall into a 60%–90% debt regime have the lowest growth rate of public debt ratio, followed by those fall into a very high-debt regime (90% –120%) and then a low-debt regime (30% –60%).

Regarding regime-dependent debt sustainability, we find that the coefficient of the interactive term of lagged public debt ratio and dummy variable for a high-debt and a very high-debt regime are both significantly positive, at 0.378 and 0.290, respectively, implying that an increase in the lagged public debt ratio significantly raises the growth of public debt ratio when countries fall into those regimes. Therefore, compared to a very low-debt regime, public debt is more likely to enter into a unsustainable territory if a country's public debt ratio exceeds 60%, as the governments do not take corrective measures to slow down the speed of debt accumulation.

5.3 Developed and Developing Economies

To conduct more detailed analysis countries, we break down all countries into high-debt, low-debt, developing, and developed economies. Again, we begin by analyzing the symmetric cycle of public debt ratio, as Table (6) shows, before shifting our focus to the asymmetric scenario. According to Table 6, we find that the growth rate of public debt ratio is significantly counter-cyclical in developing economies, but insignificantly counter-cyclical in developed economies. As Eq.(4) shows, the change in public debt ratio is composed of primary deficits, $e_{i,t} - \tau_{i,t}$, and debt interests payments, $d_{i,t-1}(r_{i,t-1} - y_{i,t})$. As existing studies, as introduced in Section 2, find pro-cyclical primary deficits in developing economies, a counter-cyclical pattern of public debt issue implies that a rise in debt interest payments dominates a decrease in fiscal deficits during a recession, which could be a result of (i) risk premium, as investors demand a higher premium to compensate for default risk, (ii) the flight-to-quality effect, as investors switch their asset portfolio from riskier bonds to safer bonds, resulting in a higher interest rate developing economies have to pay to obtain required funds, and (iii) negative economic growth rate, which reduces government's ability to pay off interest payments and leads to more newly-debt issue. On the contrary, such a counter-cyclical pattern of the growth rate of public debt ratio is insignificant in developed economies. Along with the findings of counter-cyclical primary deficits in prior empirical studies, debt interest payments are pro-cyclical in developed economies because in a recession, the central bank lowers interest rates to stabilize the economy, investors request for lower (or no) risk premia, and the flight-to-quality effect depresses the interest rate paid by developed economies.

In comparison wth debt sustainability across two income groups, we find that the growth rate of public debt respond significantly negatively to the lagged public debt ratio in both developing and

Table 5: Estimation results of asymmetric debt cycle and regime-dependent sustainability with multiple debt thresholds (30%, 60%, and 90%)

	Growth of Public Debt Ratio (dependent var.)
Positive GDP growth	0.006
	(0.035)
Negative GDP growth	0.147***
	(0.038)
Low debt	-0.055
	(0.039)
High debt	-0.146***
	(0.044)
Very high debt	-0.079*
	(0.042)
Lagged debt ratio	-0.300**
	(0.134)
Lagged debt ratio*Low debt	0.208
	(0.140)
Lagged debt ratio*High debt	0.378***
	(0.137)
Lagged debt ratio*Very high debt	0.290**
	(0.134)
Openness growth	0.217**
	(0.103)
Constant	0.081**
	(0.034)
F (Wald) test	6.14**
	[0.015]
R-squared	0.208
Country FE	YES
Year FE	YES
Observation	2500

developed economies, implying that debt is sustainable within each group. Moreover, the coefficient of lagged debt ratio is more negative in developed economies, suggesting that the government in developed economies take a more conservative stance on public debt issue. If we further compare the estimated coefficients of the dummy variable for a high-debt economy, we find that within developing

economies, a country that falls into a high-debt regime has a significantly lower growth rate of public debt ratio than it does in a low-debt regime, while such a difference is insignificant within developed economies. Accordingly, within developing economies, while we find that countries in a high-debt regime are more likely to conduct relatively unsustainable debt policy compared to they do in a low-debt regime, such a difference does not exist within developed economies.

Table 6: Estimation results of symmetric debt cycle and regime-dependent debt sustainability by income groups and by single debt threshold (60%)

	Growth of Public Debt/GDP (dependent var.)	
	Developing	Developed
GDP growth	-0.083**	-0.040
	(0.040)	(0.046)
High debt	-0.073***	-0.059
	(0.023)	(0.058)
Lagged debt ratio	-0.155***	-0.226*
	(0.040)	(0.121)
Lagged debt ratio*High debt	0.145***	0.178
	(0.044)	(0.108)
Openness growth	0.098	0.753**
	(0.090)	(0.335)
Constant	0.095***	0.059
	(0.020)	(0.049)
R-squared	0.263	0.211
Country FE	YES	YES
Year FE	YES	YES
Observation	1575	925

We then switch our focus to an asymmetric scenario of public debt issue. According to the F (Wald) test in Table 7, we find that the cyclical asymmetry of the growth rate of public debt ratio significantly exists in developing countries: public debt ratio significantly grows in recessions but insignificantly grows in expansions. However, such a cyclical asymmetry is not statistically significant

in developed countries, which could be attributed to stricter upper limit of public debt ratio imposed by the law and lower risk premium due to better debt management in developed economies. The results of regime-dependent sustainability of public debt are similar to those in Table 6: countries that fall into the high-debt regime (> 60%) has a tendency to employ more unsustainable debt policy within developing economies, while such an implication does not exist within developed economies.

Table 7: Estimation results of asymmetric debt cycle and regime-dependent debt sustainability by income groups and a single debt threshold (60%)

	Growth of Public Debt/GDP (dependent var.)	
	Developing	Developed
Positive GDP Growth	0.021	-0.011
	(0.040)	(0.056)
Negative GDP Growth	0.145***	0.068
	(0.043)	(0.064)
High debt	-0.074***	-0.058
	(0.022)	(0.058)
Lagged debt ratio	-0.159***	-0.224*
	(0.039)	(0.122)
Lagged debt ratio* High debt	0.148***	0.177
	(0.043)	(0.108)
Openness growth	0.098	0.755**
	(0.088)	(0.336)
Constant	0.087***	0.055
	(0.020)	(0.050)
F (Wald) test	3.62*	0.50
	[0.0618]	[0.4832]
R-squared	0.270	0.211
Country FE	YES	YES
Year FE	YES	YES
Observation	1575	925

Finally, we consider four debt regimes and two income groups in the analysis. As shown in Table 8, four results stand out. First, we still find that cyclical asymmetry of the growth rate of public debt ratio is statistically significant in developing economies but not in developed economies. Second, a representative country within each group is considered sustainable, as the coefficient of the lagged debt ratio is -0.103 and -0.141 in developing and developed economies, respectively. Third, we find that countries fall into a 60% –90% debt regime has the lowest growth rate of public debt ratio in both developing and developed economics. Finally, as the coefficient of the interactive term of lagged public debt ratio and the dummy variable for a very high-debt regime (> 90%) are both statistically significant within developing and developed economies, which suggests that the government is more likely to conduct relatively unsustainable debt policy when the lagged debt ratio exceeds a debt ratio of 90%. Although we previously find such a unsustainable debt policy is more likely to occur when the debt ratio exceeds 60% when a single debt threshold is considered (see Tables 6 and 7), through the analysis in this three-threshold scenario, we conclude that countries conduct unsustainable public debt policy are those whose lagged debt ratios exceed > 90%, not between 60% and 90%.

5.4 Country and Time Fixed Effects

As shown in 9, Poland has the highest country fixed effect. The estimated parameter is 0.067, suggesting that time-invariant Poland-specific characteristics attributs 6.7% of the growth rate of public debt ratio. Top ten countries that have the highest estimated country fixed effects are mostly developed economies. Besides Japan and the U.S., developed economies on the top-ten list are in the euro area, and more than half of top-twenty countries are in the euro area as well. We also find that almost no European and Asian countries have very low country fixed effects. The bottom-twenty countries are mostly in Africa, Middle East, and Latin America. Chile and Iran are countries that have the lowest country fixed effects.

Eurozone membership —a time-invariant country-specific characteristic—may explain why European countries have relatively high country fixed effects. As a member of EU, the government has independent fiscal policy but no independent monetary policy. Therefore, debt financing is a popular policy tool for a member country of EU. The ownership status of oil—a time-invariant country-specific characteristic—may explain why Middle-east countries, such as Iran and Saudi Arabia, constantly have relatively lower growth rates of public debt ratios. Furthermore, Chile is considered as

Table 8: Estimation results of asymmetric debt cycle and regime-dependnet sustainability by income and multiple debt thresholds (30%, 60%, 90%)

	Growth rate of Public Debt/GDP (dependent var.)	
	Developing	Developed
Positive GDP growth	0.021	-0.016
	(0.040)	(0.055)
Negative GDP growth	0.145***	0.071
	(0.043)	(0.063)
Low debt	-0.063	-0.047
	(0.040)	(0.046)
High debt	-0.140***	-0.141**
	(0.047)	(0.065)
Very High debt	-0.103**	-0.046
	(0.039)	(0.080)
Lagged debt ratio	-0.247**	-0.332*
	(0.115)	(0.172)
Lagged debt ratio*Low debt	0.000	0.000
	(0.000)	(0.000)
Lagged debt ratio*High debt	0.168	0.170
	(0.135)	(0.152)
Lagged debt ratio*Very High debt	0.294**	0.374**
	(0.128)	(0.172)
Openness Growth	0.237**	0.261
	(0.117)	(0.168)
Constant	0.092	0.752**
	(0.090)	(0.341)
F (Wald) test	3.62*	0.44
	[0.0616]	[0.5093]
R-squared	0.273	0.214
Country FE	YES	YES
Year FE	YES	YES
Observation	1575	925

the model economy in Latin America, which successfully reformed its pension system. Therefore, its public debt ratio stays very low (i.e. 4.08% in 2007, 12% in 2013, and 23.5% in 2018).

Table 9: Country-fixed effects

Top 1 to 30	F.E.	Top 31 to 60	F.E.	Top 61 to 90	F.E.	Top 91 to 108	F.E.
Poland	0.067967	South Africa	0.017261	Morocco	-0.00985	Guyana	-0.04364
Malta	0.067668	Canada	0.016401	Cameroon	-0.01113	Comoros	-0.05373
Bhutan	0.067574	Ghana	0.015787	Papua New Guinea	-0.01197	Haiti	-0.05509
Japan	0.062999	Hungary	0.013925	Switzerland	-0.01204	Madagascar	-0.05601
Finland	0.061654	Nepal	0.013578	Burundi	-0.01209	Saudi Arabia	-0.06486
France	0.061646	India	0.010689	Moldova	-0.01217	Nigeria	-0.06588
Iceland	0.056294	Burkina Faso	0.010104	New Zealand	-0.01307	Paraguay	-0.0714
Greece	0.054504	Bangladesh	0.009161	Thailand	-0.01386	Algeria	-0.08387
Portugal	0.054041	Central African	0.007676	Malawi	-0.0139	Iran	-0.08737
United States	0.046152	Gambia	0.007423	Honduras	-0.01554	Chile	-0.08831
United Kingdom	0.045971	Uruguay	0.005789	Guinea	-0.01564		
Spain	0.044814	Sweden	0.005708	Togo	-0.01571		
Lebanon	0.043107	Colombia	0.004751	Mauritania	-0.016		
Bahrain	0.038968	Sri Lanka	0.004582	Cote d'Ivoire	-0.01626		
Bahamas	0.038343	Latvia	0.004053	Senegal	-0.0163		
Germany	0.038225	Jordan	0.002196	Venezuela	-0.01847		
Croatia	0.037186	Lithuania	0.001628	Norway	-0.01907		
Austria	0.036561	Belgium	0.001306	Niger	-0.02106		
Zimbabwe	0.032232	Czech Republic	0.001165	Sudan	-0.02195		
Oman	0.029495	Vietnam	0.001081	Kyrgyz	-0.02199		
Pakistan	0.024651	Rwanda	-0.00225	Benin	-0.02292		
Chad	0.023936	Indonesia	-0.0027	Israel	-0.02412		
Italy	0.022139	Jamaica	-0.00393	Sierra Leone	-0.02428		
Eritrea	0.022073	Denmark	-0.0045	Mexico	-0.02708		
Ireland	0.022059	Malaysia	-0.00615	Solomon Islands	-0.03075		
Singapore	0.021414	Bulgaria	-0.00686	Australia	-0.03381		
Costa Rica	0.020557	Ecuador	-0.00708	Guinea-Bissau	-0.03468		
Kenya	0.020221	El Salvador	-0.00738	Guatemala	-0.0357		
Vanuatu	0.018773	Argentina	-0.00774	Botswana	-0.04133		
Slovenia	0.017948	Uganda	-0.00874	Mali	-0.04322		

Results in 10 indicate that the estimated sizes of the time fixed effects turn from positive to negative during the period of 1997-2000. One possible explanation is that the worldwide growth rate of public debt ratio was negatively impacted by the 1997 Asian financial crisis—tight supply of funds in the global capital market made public debt financing difficult. We then find that the time fixed effects had gradually increased due to decaying impact of the Asian financial crisis and reached a peak of 0.03 in 2003 due to the outbreak of global health crisis (SARs) as the government raised funds to deal with SARs through debt financing. Since 2005, the estimated size of the time fixed effects turned negative again due to economic expansions (especially in the housing market) and reached a peak (in a negative value) of -0.08 and -0.09 in 2008 and 2009, respectively, suggesting that the US subprime mortgage crisis of 2008–2009 had a significantly negative impact on the worldwide growth rate of public debt ratio due to a credit freeze in the global capital market. Later, the European sovereign debt crisis of 2010 –2013 greatly increased the worldwide growth rate of public debt ratio. As a re-

sult, the size of negative time fixed effects have gradually shrunk and even turned positive in 2013.

Table 10: Time-fixed effects

year	fe	event
1992	0.0226525	
1993	0.005245	
1994	0.0143385	
1995	0.0284953	
1996	0.0130835	
1997	-0.0104606	
1998	-0.0273252	
1999	-0.0233489	
2000	-0.0153245	
2001	0.0029135	
2002	0.0054868	
2003	**0.0304073**	SARs
2004	0.0160998	
2005	-0.0102341	
2006	-0.0255497	
2007	-0.0508883	
2008	**-0.0806862**	financial crisis
2009	**-0.0933534**	financial crisis
2010	-0.0452492	debt crisis
2011	-0.0313897	debt crisis
2012	-0.0013872	debt crisis
2013	0.0234046	debt crisis
2014	**0.0328216**	
2015	0.0067498	

6 Concluding Remarks

This study contributes to the literature by simultaneously testing asymmetric public debt growth over the business cycle and regime (debt and income)-dependent debt sustainability. Using annual panel data including 37 developed countries and 63 developing countries over the period of 1990–2015,

we find three major results from the two-way fixed effect model. First, the growth rate of public debt issue displays a significantly counter-cyclical pattern in developing economies, which could be attributed to higher risk premia and flight-to-quality effects. However, such a pattern is insignificant in developed economies. Second, the growth rate of public debt ratio displays a pattern of cyclical asymmetry: it insignificantly rises in expansions but significantly rises in contractions. Moreover, cyclical asymmetry is significant in developing economies but insignificant in developed economies. Upper limit of public debt ratio imposed by constitution and better debt management in developed economies can possibly explain the insignificant asymmetry. Last but not least, countries which fall into a high-debt regime ($60\% - 90\%$) have the lowest growth rate of public debt ratio in both income groups. Moreover, countries which has a lagged debt ratio above 90% are more likely to conduct an unsustainable behavior of public debt in response to an increase in the lagged debt ratio.

Our empirical findings deliver two policy implications. First, a strict upper limit of public debt ratio imposed by constitution and a better management of public debt can possibly reduce the cyclical asymmetry of the growth rate of public debt ratio, which can reduce debt accumulation, as implied in Balassone et al. (2004), Lee and Sung (2007) and Balassone et al. (2010). Second, once a country's public debt ratio exceeds 90%, policymakers are more likely to conduct an unsustainable public debt behavior either because they not willing or not capable of paying off debt.

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Appendix A List of Countries

Developed Country	Developing Country	Developing Country
Argentina	Algeria	Solomon Islands
Australia	Botswana	Sri Lanka
Austria	Bulgaria	Sudan
Bahamas, The	Colombia	Vanuatu
Bahrain	Costa Rica	Vietnam
Belgium	Ecuador	Benin
Canada	Guatemala	Burkina Faso
Chile	Guyana	Burundi
Croatia	Iran, Islamic Rep.	Central African Repub
Czech Republic	Jamaica	Chad
Denmark	Jordan	Comoros
Finland	Lebanon	Eritrea
France	Madagascar	Gambia, The
Germany	Mali	Guinea
Greece	Mauritania	Guinea-Bissau
Hungary	Mexico	Haiti
Iceland	Morocco	Malawi
Ireland	Nepal	Malaysia
Israel	Paraguay	Malta
Italy	South Africa	Nigeria
Japan	Thailand	Rwanda
Latvia	Venezuela, RB	Senegal
Lithuania	Bangladesh	Sierra Leone
New Zealand	Bhutan	Togo
Norway	Cameroon	Uganda
Oman	Cote d'Ivoire	Zimbabwe
Poland	El Salvador	
Portugal	Ghana	
Saudi Arabia	Honduras	
Singapore	India	
Slovenia	Indonesia	
Spain	Kenya	
Sweden	Kyrgyz Republic	
Switzerland	Moldova	
United Kingdom	Niger	
United States	Pakistan	
Uruguay	Papua New Guinea	

Figure A.1: List of countries: developing and developed economies.