The Signaling Effects of Sovereign Borrowing*

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Abstract

We provide novel empirical evidence suggestive of signaling effects of sovereign borrowing on a country's default risk. Using the S&P sovereign rating as a proxy for default risk, we find significant state-contingent effects of sovereign debt growth on a country's rating, with the state being the country's recent fiscal performance measured by its government operating balance. Conditional on a good fiscal state, higher sovereign debt growth significantly improves the sovereign rating, indicating a positive signaling effect of sovereign borrowing that more than compensates for its direct effect of increasing a country's debt burden. Conditional on a poor fiscal state, higher debt growth significantly reduces the sovereign rating, even after the lagged rating, current government operating balance, sovereign bond yield, and other common determinants of sovereign rating are controlled for, which suggests a negative signaling effect of sovereign borrowing. We also provide a two-period model to rationalize these findings.

Keywords: sovereign borrowing, signaling, sovereign rating

JEL classifications: F34, G24, C23.

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1 Introduction

Can sovereign borrowing be informative about a country's default risk? This paper provides empirical evidence using the S&P sovereign rating as the proxy for default risk and a quarterly panel covering 21 advanced economies from 2000q2 to 2020q3. A higher sovereign debt growth rate is found to improve a country's sovereign rating if its government has good fiscal performance measured by its recent government operating balance. Conversely, if a country's government has poor fiscal performance, higher debt growth is found to decrease the sovereign rating even after relevant economic fundamentals are controlled for.

The literature has provided ample empirical evidence for the signaling effect of sovereign default on a country's default risk. A history of default (or the lack of one) has been shown to be an important determinant of a country's sovereign rating and sovereign bond spread and helps predict future sovereign default.[1]

However, very limited empirical research has been done on the signaling effect of sovereign borrowing; this effect is challenging to identify for the following reasons. First, sovereign borrowing has a direct effect on a country's default risk; namely, more borrowing today implies a higher debt burden to be serviced in the future and therefore increases default risk. Separately identifying the signaling effect and this direct effect of sovereign borrowing requires controlling for the latter.

Second, unlike sovereign default, which always acts as a negative signal and increases default risk, sovereign borrowing may be associated with either a positive or a negative signaling effect. The sign of the signaling effect could be state contingent. It is thus crucial to identify the right contingent state to avoid pooling the positive signaling effect with the negative one and arriving at a spurious insignificant result.

Third, choosing a proper proxy for a country's default risk is important for identifying the signaling effect of sovereign borrowing. An ideal proxy should be sensitive to information about default risk that may not be captured by other observable factors. It should also be relatively free from default risk–irrelevant factors that are hard to measure or control for.

We address these challenges by means of a set of innovations. First, we choose

[1] See, for example, Reinhart et al. (2003), Dell'Ariccia et al. (2006), Borensztein and Panizza (2009), D'Erasmo (2011), Qian et al. (2011), Cruces and Trebesch (2013).

the sovereign credit rating as the proxy for a country's default risk. According to the rating methodology of credit rating agencies, the sovereign rating reflects not only a sovereign government's ability but also its willingness to service its debt.[2] Relative to a country's short-term capacity for timely debt service, this willingness to repay debt affects a country's default risk in the longer term and is more sensitive to signaling effects from sovereign borrowing.

Second, we identify a key economic state – a country's lagged government operating balance – that can differentiate the positive and negative signaling effects of sovereign borrowing. Specifically, we interact a country's sovereign debt growth with its fiscal state, which can be good, normal, or poor, depending on whether the country's lagged government operating balance is above, within, or below one standard deviation around its whole-sample mean. These interaction terms allow us to identify a positive signaling effect of sovereign borrowing conditional on a good fiscal state and a negative signaling effect conditional on a poor fiscal state. Interestingly, no significant signaling effect is found if we do not condition on the fiscal state.

Third, we include the lagged sovereign rating, current government operating balance, and long-term sovereign bond yield in the set of control variables, in addition to other common determinants of sovereign rating identified by the literature and S&P's rating methodology. Having only advanced economies in our sample gives us the luxury of being able to use quarterly data on these control variables and hence better control for other economic channels through which default risk and the sovereign rating may be affected. As a result, we can more confidently interpret the estimated coefficients for debt growth as indicators of signaling effects. Most notably, the identified signaling effect of higher debt growth under a good fiscal state is to *improve* the sovereign rating, which runs counter to the direct effect of debt growth of increasing the future debt burden and thus default risk.

Our empirical analysis explicitly accounts for a possible reverse causal effect of sovereign rating on debt growth via the borrowing cost channel. We also use instrumental variable (IV) regressions to alleviate concerns over other possibly endogenous regressors. To address potential omitted variable bias, we control for two confounding

[2]Our paper uses sovereign ratings by S&P Global Ratings, whose methodology can be found at https://www.standardandpoors.com/en_US/web/guest/article/-/view/sourceId/10221157. Similar language is also used in the descriptions of Moody's and Fitch Ratings' sovereign ratings methodologies.

factors that could move the sovereign rating and sovereign debt growth at the same time and find that our empirical results remain robust. Therefore, these conditional significant effects of sovereign debt growth on sovereign rating are not a result of reverse causality or omitted variable bias. Furthermore, we show that the conditional signaling effects of debt growth are only weakly present (with the right signs but statistically insignificant) if we instead use the sovereign bond spread as the proxy for a country's default risk, which lends support for our choice to use the sovereign rating to capture the information about a country's default risk.

In the last part of the paper, we provide a stylized two-period model to rationalize the conditional signaling effects of debt growth found by our empirical analysis.

1.1 Literature Review

Our paper is related to the sovereign default literature in general and to studies on borrowing and defaulting with private information in particular. The canonical model of sovereign default à la Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), and Arellano (2008) predicts that more sovereign borrowing increases a country's default risk. Our empirical finding presents evidence that contradicts this prediction, as higher sovereign debt growth is found to improve a country's sovereign rating when its government has good recent fiscal performance. This finding, however, can be viewed as evidence for a signaling effect of sovereign borrowing, where higher debt growth serves as a positive signal to creditors that the country possesses private information indicative of a lower future default probability. Moreover, such a signaling effect is contingent on good recent fiscal performance. When the government's recent fiscal performance is poor, we instead find a negative signaling effect of sovereign borrowing.

Existing models on sovereign borrowing and default with private information focus mainly on the default decision as the informative signal. Examples include Cole et al. (1995), Cole and Kehoe (1998), Sandleris (2008), D'Erasmo (2011), Egorov and Fabinger (2016), Phan (2017a), and Amador and Phelan (2021). A few exceptions to this formulation are the works of Phan (2017b), in whose model the government can borrow to signal a favorable economic fundamental; Gibert (2016), who models fiscal austerity as signaling a country's creditworthiness in a certain information environment; Fourakis (2021), who considers three government decisions – defaulting, borrowing, and initiating restructuring – to be informative about the government's underlying preferences; and Morelli and Moretti (2022), who argue that default and inflation reports can signal whether the government is committed.

The focus of the theoretical literature on default as the primary signal is perhaps due to the ample empirical evidence of the signaling role played by a country's default history (see footnote 1). In contrast, the empirical evidence for the signaling effects of other government decisions is rather thin. Gibert (2016) finds evidence for fiscal austerity as a signal of a country's creditworthiness. Morelli and Moretti (2022) find that inflation misreports from the Argentinian government are positively correlated with sovereign debt interest rates. Fourakis (2021) constructs an aggregate measure of debt issuance history and shows that it positively correlates with emerging market sovereign bond spreads and has predictive power for future default probability. Our paper contributes to this literature by identifying state-contingent signaling effects of sovereign debt growth on a country's default risk measured by its sovereign rating.

Our paper is also related to the empirical literature on the determinants of sovereign ratings.[3] There are two main strands in this literature in terms of the econometric approach adopted. One, dating back to Cantor and Packer (1996), converts ratings linearly to a numerical scale and applies linear regression methods. The other, dating back to Hu et al. (2002), treats ratings as discrete choices and uses ordered probit/logit models for estimation. Our paper follows the first strand and uses pooled ordinary least squares (OLS) with fixed effects estimation. We choose this approach mainly to maximize the clarity of our analysis because the generalization of ordered probit to panel data is not straightforward due to the country-specific effect. Moreover, Mora (2006) and Afonso et al. (2011) use both the linear model and the ordered probit model in their estimations; the two models yield similar empirical findings in both papers. Our approach to estimation differs from those in this literature in that we incorporate sovereign debt growth in our regressions. More importantly, we interact debt growth with a fiscal dummy, which allows us to identify its state-contingent effects on the sovereign rating.

[3]Moor et al. (2018) provide a comprehensive overview of the literature on the determinants of sovereign credit ratings.

2 Empirical Specifications

In this study, we examine the signaling effects of sovereign borrowing on countries' default risk. We use the sovereign rating as a proxy for creditors' perception of a country's default risk. Relative to alternative proxies, such as sovereign bond spreads or credit default swaps (CDSs), the sovereign rating offers two major advantages.

First, S&P's rating methodology states that its "rating criteria incorporate the factors that we believe affect a sovereign government's *willingness* and ability to service its financial obligations to nonofficial (commercial) creditors."[4] This *willingness* to service debt is what S&P refers to as a "sovereign's debt payment culture" and is a longer-term determinant of a country's default risk than its capacity for timely debt service. If sovereign borrowing does contain information about default risk beyond the government's current repayment capacity, the sovereign rating should be an ideal indicator to reflect this. In S&P's methodology, the effects of such willingness are factored in mainly via human judgment. Our empirical analysis quantifies these effects.

Second, the sovereign rating mainly captures a country's default risk, and S&P is explicit about the factors that enter its rating methodology. This helps us control for other economic channels that may affect default risk to identify the signaling effects of sovereign borrowing on the sovereign rating. In contrast, asset price–based proxies vary not only with default risk but also with risk attitude, liquidity, sentiment, speculation, etc.[5] There has been no consensus in the literature on how to measure or control for these additional factors. Hence, even if we were to find effects of sovereign borrowing on these asset price–based proxies, it would be much more controversial to attribute these effects to signaling of default risk.

[4]https://www.standardandpoors.com/en_US/web/guest/article/-/view/sourceId/10221157

[5]For example, González-Rozada and Yeyati (2008) emphasize the importance of risk appetite and global liquidity in determining emerging market bond spreads. Borri and Verdelhan (2011) find that emerging sovereign excess returns increase with the correlation between past emerging bond returns and US market returns. Badaoui et al. (2013) show that liquidity shocks can explain 44.32% of the variation in sovereign CDS spreads and 26.86% of that in sovereign bond spreads. Bocola and Dovis (2019) show that 13% of the change in Italian interest rate spreads during 2008–2012 was driven by self-fulfilling nonfundamental risk.

2.1 Baseline Regression

Our baseline regression model is specified as follows:

$$\text{Rating}_{i,t} = \lambda \times \text{Rating}_{i,t-1} + \alpha \times d_{i,t} + \sum_{j=P,N,G} \beta_j \times g_{i,t} \times \mathbf{1}^j_{i,t-1} + \sum_{j=P,N,G} \theta_j \times \mathbf{1}^j_{i,t-1} + \mathbb{Z}_{i,t}\gamma' + \delta_t + \mu_i + \varepsilon_{i,t}. \tag{1}$$

$\text{Rating}_{i,t}$ is the sovereign rating of country i at the end of period t. $d_{i,t}$ is the period-t debt-to-GDP ratio, and $g_{i,t}$ is the debt growth rate since the last period. $\mathbf{1}^j_{i,t-1}$ is the fiscal state dummy, which equals 1 if the fiscal state is poor ($j = P$), normal ($j = N$), or good ($j = G$) in period $t - 1$. $\mathbb{Z}_{it}$ is a set of control variables. δ_t and μ_i are time and country fixed effects, respectively.

One natural concern with respect to our specification is that any significant effect of sovereign debt on the sovereign rating could be a result of reverse causality: what if period-t debt is affected by the period-t rating? A higher sovereign rating may reduce a country's borrowing cost and result in a higher debt growth rate.

Sovereign Rating: We address the above concern by choosing the timing of the variables so that the period-t debt level or debt growth does not respond to contemporaneous changes in the sovereign rating. Specifically, we employ higher-frequency (daily) data for the rating and use the rating score issued on the last day of the quarter as the country's period-t sovereign rating. This minimizes the chance of period-t sovereign borrowing being a result of the end-of-period-t rating and maximizes the chance that the end-of-period-t rating incorporates new debt information from the same quarter. We also control for the lagged rating to capture the past information possessed by S&P on the country's default risk.

Sovereign Debt: Our main variable of interest is sovereign debt in terms of its current level and its most recent growth rate. Compared to the debt level, debt growth is more sensitive to a country's period-by-period decisions and hence could provide additional information about its default risk. We interact sovereign debt growth with the country's fiscal state in our regression so that the impact of sovereign debt growth on the rating could vary with the country's fiscal state, which we conjecture to be a crucial factor in its debt choice. We categorize the state as good if the government operating balance in period $t-1$ is one standard deviation above its whole-sample mean, poor if it is one standard deviation below its whole-sample mean, and normal otherwise. Note that the fiscal state is determined by the lagged government operating balance, so it is determined prior to the period-t debt growth instead of being its outcome. The coefficients β_G, β_N, and β_P are thus interpreted as measuring the effect of sovereign debt growth on the rating conditional on good, normal, and poor fiscal states, respectively.

Control for Borrowing Cost: To further address the reverse causality concern, we control for the country's period-t borrowing cost, proxied by its period-t long-term sovereign bond yield, which could be affected by its period-t sovereign rating.[6] Controlling for the long-term sovereign bond yield serves two additional purposes.

First, there could be information about a country's default risk that is not captured by the observable characteristics of the country. As sovereign bond yields are often used in the literature as a proxy for default risk,[7] including the long-term bond yield as a control variable helps to mitigate concerns over omitted variable bias in our regression.

Second, one may reasonably conjecture that all information about a country's default risk is reflected in its sovereign bond yield, making its sovereign rating an inferior proxy of default risk. By controlling for the sovereign bond yield, we can interpret our estimates as evidence that additional information about default risk is captured by the sovereign rating beyond that captured by the sovereign bond yield. This echoes the previously mentioned S&P rating criteria that incorporate factors affecting a sovereign government's *willingness* to service its debt.

Other Control Variables: The rest of the control variables are chosen based on S&P's published rating methodology, which states that a country's fiscal performance, external indebtedness and liquidity, economic growth prospects, and monetary policy effectiveness are all factors contributing to the rating. We proxy these factors with the

[6]We do not use the short-term bond yield because it is the monetary policy instrument in many economies and is thus less susceptible to sovereign rating changes. In the robustness section, we show the results when we replace the long-term sovereign bond yield with the weighted average of the long-term and short-term bond yields.

[7]Examples include Boehmer and Megginson (1990), Baek et al. (2005), Eichler and Maltritz (2013), and Gilchrist et al. (2021).

government operating balance, current account balance and fiscal reserve, real GDP growth rate, and inflation rate. In $\mathbb{Z}_{it}$, we also include a European Union (EU) dummy, which equals 1 if country i is in the EU and 0 otherwise.

2.2 IV Regression

To further alleviate the concern that the period-t regressors may be reversely affected by the end-of-period-t sovereign rating, we perform endogeneity tests on all possibly endogenous regressors, including the lagged rating, the debt-to-GDP ratio, the interaction terms of debt growth, and the government operating balance.

It turns out that the exogeneity hypothesis is rejected for the debt-to-GDP ratio and the government operating balance. Our IV regression therefore replaces these period-t regressors with their 5 lags as instruments.

2.3 Potential Omitted Variables

Another concern in interpreting the effects of sovereign debt growth on sovereign rating as causal is the possibility that there are some time-varying omitted factors that affect both debt growth and the sovereign rating.

To address this concern, we investigate two candidates for such time-varying omitted factors: changes in government and the country's future growth prospects. Specifically, we include each candidate variable as an additional control in both the baseline OLS regression and the IV regression to check whether the effects of sovereign debt growth on the sovereign rating survive.

3 Data

We compile a quarterly unbalanced panel data set from various sources, including the International Monetary Fund (IMF), the Bank for International Settlement (BIS), S&P, and the CEIC database. Our sample includes all advanced economies for which the relevant data (on the sovereign rating, debt, fiscal performance, etc.) are available.[8] It covers 21 countries and regions from 2000q2 to 2020q3,[9] including Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Hong Kong Special Administrative Region (HKSAR), Hungary, Ireland, Israel, Italy, Luxembourg, Netherlands, New Zealand, Portugal, Spain, Sweden, the United Kingdom, and the United States. Hence, our panel features a small N (N=21) and a large T (T=80>N), which is why we adopt the fixed effects rather than the dynamic panel data (DPD) model as our specification.[10]

We choose to focus on advanced economies in this study as it provides several advantages in identifying the effects of sovereign borrowing on ratings. Firstly, the majority of sovereign debt in advanced economies is denominated in the domestic currency (Abbas et al. (2014)),[11] reducing the impact of exchange rate fluctuations on the country's debt burden, borrowing decision, and sovereign rating. Secondly, advanced economies have a more predictable and stable economic environment, making them largely immune to the risk of "sudden stops".[12] Finally, none of the advanced economies in our sample has undergone debt restructuring processes.[13] These advantages offers a clearer interpretation of the relationship between sovereign debt growth and sovereign ratings, free from the complicating effects of exchange rate fluctuations, the likelihood of a sudden stop, and debt restructuring.

The summary statistics of our data are reported in Table 1. We now describe these data in detail.

[8] Japan and South Korea are excluded from our sample due to the unavailability of quarterly data on the fiscal performance of the general government and the nominal value of consolidated general government debt, respectively. Although data was obtained for Germany, Norway, Singapore, and Switzerland, they had to be excluded as there was no variation in their rating data. Greece was also excluded due to its data inaccuracies exposed by the 2010 sovereign debt crisis and the convolutions of events following the crisis.

[9] Our sample period starts from 2000q2 due to the availability of sovereign debt data and ends at 2020q3 so as to exclude the disproportionate effect of the Covid-19 pandemic.

[10] It is well known that with a large T, DPD suffers from the problem of too many instruments (TMI) due to the need to include the time fixed effect.

[11] By contrast, a considerable portion of sovereign debt in emerging markets is denominated in foreign currencies (Arslanalp and Tsuda (2014)).

[12] It is well-known that emerging markets are prone to "sudden stops" that can simultaneously impact sovereign rating and debt, yet how to accurately measure the likelihood of a sudden stop remain controversial in the literature (Comelli (2015)).

[13] According to Asonuma and Trebesch (2016), several emerging economies, e.g., Argentina, Ecuador, Mozambique, Ukraine, have undergone debt restructuring processes between 2000 and 2020.

3.1 Rating Data

The dependent variable is the S&P Global sovereign rating. We obtain the daily rating data and use the end-of-quarter rating as the quarterly measure of a country's default risk as perceived by creditors. S&P Global's sovereign ratings are assigned to countries on a rating scale ranging from class D (default) to class AAA (prime), and the rating category is often associated with a rating outlook that takes the value of negative, stable, or positive.

Following the literature, we convert the rating categories to a linear numerical scale from 0 to 20, with 0 corresponding to class D. According to S&P, the rating outlook indicates its view regarding the potential direction of a sovereign rating change over the intermediate term (typically six months to two years).[14] As the rating outlook is changed more frequently than the rating category, we interpret the outlook as capturing positive or negative information about a country's creditworthiness that does not yet warrant a change of category. With this interpretation, we map the outlook categories {negative, stable, positive} to the numerical scale {-0.5, 0, 0.5} and add this component to the category score to obtain the total rating.

Figure 1 plots the time series of sovereign rating scores for all 21 economies in our sample. Note that most changes in scores are of a magnitude less than 1, indicating that most of the variation comes from the rating outlook. The autocorrelations of these rating series average 0.93. This high persistence motivates us to control for the lagged rating in our regression.

3.2 Debt Data

We use two sets of debt measures: the consolidated general government debt for the total amount of sovereign debt and the values of the four categories of government debt – short-term and long-term debt securities and loans – for the structure of sovereign debt.

3.2.1 Consolidated General Government Debt

We measure the total amount of sovereign debt by the quarterly series of consolidated general government debt from the BIS. Among the various debt measures, we employ

[14] www.spglobal.com/ratings/_division-assets/pdfs/guide_to_credit_rating_essentials_digital.pdf

the gross nominal value of the general government debt stock in local currency at the end of each quarter.[15]

We use the nominal value of government debt so that it is not affected by variations in the market interest rate. This allows us to disentangle the effects of debt on the sovereign rating from the effects of the interest rate. Furthermore, we focus on advanced economies, and most of their sovereign debt is denominated in local currency, according to Abbas et al. (2014). The nominal value is in local currency instead of in USD so that exchange rate fluctuations do not affect the debt measure.

We use general government debt, which consolidates the debt of central (federal), provincial (state), and local governments. According to the BIS, this consolidated debt measure better captures the actual debt burden of the sovereign government and makes it easier to compare debt sustainability across countries because, first, the outstanding debt among public subsectors can often be netted out and, second, the liabilities of state and local government sectors are often guaranteed by the central government.

Last, we use gross government debt instead of net debt, as the latter is the net outcome of debt borrowing and government liquid asset accumulation. We do so not only to focus on the sovereign borrowing decision but also to avoid any controversy in classifying assets as liquid or illiquid.

Figures 2 and 3 plot two debt measures used in our regressions: the debt-to-GDP ratio and the debt growth rate, respectively.[16]

3.2.2 Debt Structure

We combine multiple data sources – government finance statistics (GFS) from the European Central Bank and quarterly public sector debt (QPSD) from the World Bank, Hong Kong Monetary Authority, Statistics Canada, Bank of Canada, Board of Governors of the Federal Reserve System, and Reserve Bank of Australia – to construct a quarterly dataset of short-term and long-term government bonds (debt securities) and loans. Figure 4 plots the stock series of the four debt categories.[17]

[15] In the BIS data, only core debt instruments, including currency and deposits, loans, and debt securities, are considered.

[16] The debt growth rates in a few countries exhibit some degree of seasonality, but clearly, seasonality does not account for the majority of the variation in debt growth. In our regression, we also include time fixed effects to absorb the potential effects of seasonality.

[17] Data for New Zealand are not available, and some countries have missing data in certain quarters and debt categories.

We classify debt as short term if its residual maturity is shorter than or equal to 1 year. We use the net incurrence of each debt category (nominal value in local currency) as its flow measure whenever the data are available. When the net incurrence data are missing, we compute the flow measure by taking the difference in the stock of the debt category. We then measure the growth of each debt category using its current flow over the last-quarter total debt stock from the BIS.

3.3 Government Operating Balance and Fiscal State

We construct the fiscal state dummy from data on the government operating balance – specifically, the net operating balance (NOB), which is the difference between revenue and spending of the general government. The NOB includes the interest payment on sovereign debt and hence better reflects the overall fiscal performance of the government. Moreover, the NOB excludes revenue and spending of net acquisition of nonfinancial and financial assets, so it does not necessarily equal the negative of our debt growth measure. For example, a country can run a positive operating balance but increase its debt by acquiring more assets. Similarly, a country can run a negative operating balance but decrease its debt by selling assets.

Our NOB-to-GDP data are mainly from IMF International Financial Statistics (IMF.IFS). Whenever there are missing data for some countries, e.g., Israel, HKSAR, New Zealand, and Czech Republic, we use the country's overall balance (OB-to-GDP, also defined as revenue - expense) data from CEIC instead.[18] To avoid the effect of seasonality in defining our fiscal state variable, we employ the commonly used Census X-12 filter to obtain the seasonally adjusted NOB-to-GDP for our regressions.

We then categorize the fiscal state as good if the seasonally adjusted NOB-to-GDP in period $t-1$ is one standard deviation above its whole-sample mean, poor if it is one standard deviation below its whole-sample mean, and normal otherwise. In our sample, observations of good, normal, and poor fiscal states are distributed in the approximate ratio of 1 : 8 : 1.

Figure 5 plots the NOB-to-GDP (solid blue), together with the two one-standard-deviation lines (dotted blue) that we use to categorize the fiscal state. In the same

[18] We also use the overall balance data from CEIC for the U.S. because the U.S. NOB-to-GDP data from IMF.IFS are a smoothed version of the raw data, in contrast with the corresponding data for other countries in our sample.

figure, we also plot the fiscal sustainability gap (solid red) and the two associated one-standard-deviation lines (dotted red). The fiscal sustainability gap is a measure of the sustainability of government debt constructed by Kose et al. (2022) using annual data on the government fiscal balance and nominal output growth. Despite the difference in data frequency and construction, the two series exhibit strong comovement, and there is a large overlap of periods in which the series is above or below the one-standard-deviation lines. This observation lends an economic interpretation of our constructed fiscal state variable: a good fiscal state indicates that government debt is highly sustainable; a poor fiscal state indicates the opposite.

3.4 Borrowing Costs

Our long-term government bond yield measure is from IMF.IFS. For the short-term government bond yield, we use the 3-month Treasury bill (T-bill) rate from CEIC whenever it is available. When the T-bill rate is not available, we use the 3-month interbank rate from CEIC instead.

In constructing the weighted average bond yield, we use the shares of short-term bonds and long-term bonds in the total bond stock as the weights for the short-term and long-term bond yields, respectively.[19]

3.5 Other Control Variables

We obtain quarterly data on the current account balance and fiscal reserve from IMF.IFS and nominal and real GDP and inflation data from CEIC. All level variables are normalized as a percentage of nominal GDP. Real GDP growth is calculated on a year-over-year basis. The inflation rate is on a quarter-over-quarter basis.

4 Main Results

Tables 2 and 3 report the estimation results of our baseline regression and the IV regression. These results suggest that the sovereign ratings of our sample countries

[19]For Denmark, Luxembourg, Portugal, HKSAR, and New Zealand, there are missing values for the short-term and long-term bond shares. To maximize sample size, we use the sample mean of the economy's available bond shares as a proxy for the missing values.

contain information about these countries' default risk beyond what is captured by their sovereign bond yields. Moreover, the extra information about default risk is affected by sovereign debt growth, and the information content varies with the country's fiscal state. Namely, when the fiscal state is good, higher debt growth reveals positive information that reduces the perceived default risk and therefore improves the sovereign rating; when the fiscal state is poor, higher debt growth reveals negative information and therefore decreases the sovereign rating. Moreover, digging into the debt structure reveals that the positive information from high debt growth in a good fiscal state comes from a balanced debt portfolio whereas the negative information in a poor fiscal state comes mainly from high long-term loan growth.

4.1 Baseline Regression

We report the baseline estimation in Column 1 of Table 2. Consistent with the high persistence found in the sovereign rating data, the coefficient estimate for λ on the lagged rating (0.951) is positive and significant at 1%. The coefficient estimate for the debt level (debt-to-GDP) is insignificant, a result that is attributable to our control for the lagged rating and that will be discussed later. The government operating balance is estimated to have a positive effect on the rating at a significance level of 5%.[20] Not surprisingly, we find the coefficient for the long-term sovereign bond yield to be negative and significant at 1%. An increase in the long-term bond yield by 1 percentage point is associated with a decrease in the country's sovereign rating score by 0.084. This is consistent with our intuition that both the sovereign bond yield and the sovereign rating reflect creditors' perception of country default risk.

We do not find any significant effect for the remaining control variables, including real GDP growth,[21] current account balance, fiscal reserve, and inflation.[22]

[20] Many papers in the literature have derived similar findings (e.g., Mulder and Perrelli (2001), Mora (2006), and Afonso et al. (2011)).

[21] This is because we control for the long-term government bond yield. Once we remove the long-term yield, the coefficient for GDP growth becomes significantly positive at 1%.

[22] The literature on sovereign rating determinants offers mixed evidence on these variables. For example, Cantor and Packer (1996) find an insignificant coefficient for the current account but a significant coefficient for inflation, while Ferri et al. (1999) and Mora (2006) find an insignificant coefficient for inflation but a significant coefficient for the current account. Afonso et al. (2011) find that the effect of the external reserve is insignificant in the short run but significant in the long run.

4.1.1 Significant Conditional Effect of Debt Growth

The estimated coefficient β_G for sovereign debt growth conditional on a good fiscal state turns out to be *positive* and statistically significant at 10%. An increase in the debt growth rate by 1 percentage point in a quarter significantly *improves* the country's contemporaneous sovereign rating score by 0.006 (0.56% of the mean change). This effect size is three-quarters of the positive effect of the government operating balance on the sovereign rating.

Notably, this positive effect of debt growth on the sovereign rating sharply contrasts with the conventional wisdom in the literature. In a canonical model of sovereign debt and default, higher debt growth means more debt to be serviced in the next period, which could increase the default risk and in turn decrease the sovereign rating. Therefore, one would expect a nonpositive coefficient for debt growth via this canonical channel. However, our empirical result shows not only that a country's debt growth affects its sovereign rating positively when its fiscal state is good but also that the effect is statistically significant and economically sizable.

Recall that we include the long-term government bond yield as a control in the regression. This rules out the possibility that the positive effect of debt growth on the sovereign rating is due to reverse causality via the borrowing cost channel.

When a country's fiscal state is poor, the estimated coefficient β_P for sovereign debt growth turns out to be *negative* and statistically significant at 10%. An increase in the debt growth rate by 1 percentage point in a quarter significantly *decreases* the country's contemporaneous sovereign rating score by 0.011 (1% of the mean change).

Although the negative effect of debt growth on the sovereign rating is in the same direction as the canonical channel suggests, the fact that such an effect remains significant even after controlling for borrowing costs, government operating balance, GDP growth rate, and lagged rating, highlights the informative role of debt growth. This suggests that debt growth reveals private information possessed by the government, beyond what can be explained by the country's observable economic fundamentals. This is a departure from the canonical model, where a country borrows only to smooth the effect of shocks to its economy.

4.1.2 Informative Role of Debt Growth

We interpret the significant effects of debt growth on the sovereign rating as supporting evidence of the signaling effects of sovereign borrowing. Specifically, conditional on a good fiscal state, higher debt growth reveals positive information about the country's default risk by suggesting that the government is more likely to be a type with a lower default risk. This positive information reduces the default risk perceived by creditors, resulting in a positive estimated coefficient β_G for the debt growth on the sovereign rating. On the contrary, conditional on a poor fiscal state, higher debt growth reveals negative information about the country's default risk by suggesting that the government is less likely to be a type with a lower default risk. Therefore, the estimated coefficient β_P of debt growth on the sovereign rating is significantly negative even after economic fundamentals are controlled for. We further elaborate this interpretation of our empirical results using a two-period model in Section 6.

4.1.3 Insignificant Unconditional Effect

What is the unconditional effect of debt growth on the sovereign rating? Column 2 of Table 2 reports the regression results with no interaction of debt growth with the fiscal state. Interestingly, the estimated coefficient for debt growth becomes insignificant despite the remarkable similarity of all the other estimated coefficients to those in Column 1.

To understand this sharp contrast in the estimated effect of debt growth, recall that there are approximately equal numbers of observations with good and poor fiscal states – each accounts for 10% of the total observations. The estimated coefficients for debt growth in good and poor fiscal states have opposite signs but are at the same scale. Hence, when these effects are pooled in the estimation of Column 2, they cancel each other out and cause the unconditional effect to be insignificant. This weak unconditional effect highlights the importance of identifying the relevant state to interact with debt growth to reveal its state-contingent effects.

4.1.4 Different Signaling Effects across Debt Instruments

Recall that the BIS debt data are consolidated general government debt, which includes currency and deposits, loans, and debt securities (bond). Our debt structure data cover short-term and long-term government loans and debt securities (bond) but not currency and deposits due to data availability issues.[23]

Column 3 of Table 2 reports the results of a regression in which we replace the consolidated debt growth with the growth of the sum of government bonds and loans. Columns 4–7 report the results of a regression in which we interact the fiscal state with the growth of each category of government debt.

Comparing the regression results for the consolidated debt, the sum of bonds and loans, and the four debt categories generates new empirical results. In a good fiscal state, the effect of debt growth is the strongest for consolidated debt (Column 1), becomes weaker when we strip away currency and deposits (Column 3), and becomes insignificant when we narrow our focus to a single category of debt (Columns 4–7). This suggests that the positive signaling effect of debt growth is not driven by any particular debt category but rather by all debt instruments pooled together. In other words, debt growth with a balanced structure is perceived as a positive signal by investors in a good fiscal state.

In contrast, in a poor fiscal state, the effect of debt growth is the weakest for consolidated debt (Column 1) and becomes stronger when we strip away currency and deposits (Column 3). When we narrow our focus to each category of debt, we find significantly negative coefficients for growth of both short-term and long-term government loans (Columns 6 and 7), but the effect of long-term government loans is the strongest in terms of magnitude and statistical significance (1%). This suggests that the negative signaling effect in a poor fiscal state is driven mainly by the growth of long-term government loans.[24]

4.2 IV Regression

In our baseline regression, the potentially endogenous regressors include the lagged rating, debt-to-GDP ratio, interaction terms of debt growth, and government operating balance (NOB-to-GDP). We rule out the possibility of the lagged rating being an endogenous regressor by adding country fixed effects and performing an AR(1) test on

[23]Specifically, some countries, e.g., Canada, include the central bank as part of the general government. It would be misleading to count the central bank's currency and deposits as government debt.

[24]This negative signaling is consistent with the model of Perez (2017), where long-term debt is less attractive to safe borrowers, particularly in times of financial distress.

the residuals of all our regressions to confirm the absence of serial correlation in the error term.

The remaining potentially endogenous regressors can be a result of reverse causality. Let y_{it} be the sovereign rating and x_{it} a regressor that could be reversely caused by y_{it} in our regression:

$$(2) \qquad \begin{cases} y_{i,t} = \lambda y_{i,t-1} + \alpha x_{i,t} + \delta_t + \mu_i + \epsilon_{i,t} \\ x_{i,t} = \gamma x_{i,t-1} + y_{i,t} + v_{i,t} \text{ (reverse causality)} \end{cases}$$

Replacing $y_{i,t}$ in the second equation with the first equation, we obtain $x_{i,t}$ as a function of $(x_{i,t-1}, y_{i,t-1}, \delta_t, \mu_i, \epsilon_{i,t}, v_{i,t})$, which makes it clear that $x_{i,t}$ is correlated with the error term $\epsilon_{i,t}$ and hence is an endogenous regressor.

Following the literature on the DPD model, we can use the lags of $x_{i,t}$ as its instrumental variables (IVs) because $x_{i,t-s} = f(\cdot, \epsilon_{i,t-s}, v_{i,t-s})$ is correlated with $x_{i,t}$ but not with the period-t error term $\epsilon_{i,t}$, conditional on $\epsilon_{i,t}$ not being serially correlated. We then perform Durbin–Wu–Hausman tests on all possibly endogenous regressors to compare the IV estimates, where the potentially endogenous regressors are replaced by their instruments, with the baseline OLS estimates.

The Durbin–Wu–Hausman tests are performed in two steps. In the first step, we instrument all possibly endogenous regressors with their lagged terms based on the most conservative assumption that they are all endogenous and then test the exogeneity of each one. The number of lags used as instruments for each regressor is set to 5 based on the model performance in four statistical tests: the underidentification test, overidentification test, weak IV test, and residual AR(1) test. We cannot reject the exogeneity hypothesis for any of the possibly endogenous regressors except for NOB-to-GDP. In the second step, we treat NOB-to-GDP as the only definitely endogenous regressor. We instrument NOB-to-GDP and one other possibly endogenous regressor with their lagged terms and test whether we can reject the exogeneity hypothesis for the regressor in question. The number of lags used as instruments in each test varies with the possibly endogenous regressor in question and is chosen optimally based on the aforementioned four statistical tests. The result reveals that the debt-to-GDP ratio is the only regressor of interest for which we can reject the null hypothesis of exogeneity.[25]

Based on these results, our IV regressions use 5 lags of the debt-to-GDP ratio and the NOB-to-GDP to instrument their period-t values.

4.2.1 IV Results

Table 3 reports the IV counterparts of the results in Table 2. The results are mainly in line with those of the baseline regressions, with the positive signaling effect strengthened and the negative signaling effect weakened.

Conditional on a good fiscal state, the positive coefficients of consolidated debt growth and bond-and-loan growth become larger and more significant. A one-percentage-point increase in consolidated debt growth (Column 1) improves the sovereign rating by 0.01 (0.74% of the mean change) and is statistically significant at 1%. The positive effect is weaker for the bond-and-loan growth (Column 3) but is still statistically significant at 5%. When we narrow our focus to each category of debt growth, the positive effect becomes insignificant except for growth of short-term government bonds (Column 4), which is significant only at 10%. The IV results hence confirm that the positive signaling effect of debt growth in a good fiscal state has to do with a balanced debt portfolio.

Conditional on a poor fiscal state, the negative coefficients of consolidated debt growth and bond-and-loan growth become insignificant. However, the negative coefficients of short-term and long-term government loan growth remain significant, with the former being significant at 10% and the latter at 5%. Hence, despite the weakening of the effect, the IV regression confirms that the negative signaling effect is driven mainly by long-term government loan growth in a poor fiscal state.

5 Alternative Specifications

This section addresses a few questions. First, we examine whether the conditional effects of debt growth on the sovereign rating are the result of omitted variable bias. Second, we check whether our findings are robust to using an alternative control measure for the borrowing cost, using an alternative categorization of the fiscal state or

[25] We report the detailed results of these tests in the appendix.

dropping samples with IMF loans. Third, we examine whether similar signaling effects of debt growth are found in the sovereign bond spread. Fourth, we investigate the reasons why we do not find an effect of debt-to-GDP on the sovereign rating. Fifth, we examine whether the conditional signaling effects of debt growth can be identified if it is interacted with other types of macroeconomic state defined by the debt-to-GDP ratio or the GDP growth rate.

5.1 Two Confounding Factors

There could be time-varying factors that affect both the sovereign rating and sovereign borrowing at the same time. For example, a change in government may improve the sovereign rating, and at the same time, the new government could be more tolerant of sovereign debt than the old government.[26] Another example is the country's future growth prospects. If a country is expected to experience higher growth in the future, its sovereign rating will improve, and the government of the country may borrow more even without any change in its borrowing cost. In this subsection, we show that the conditional effects of debt growth on the sovereign rating remain significant after we control for the two aforementioned confounding factors.

5.1.1 Changes in Government

We create an indicator variable to capture whether a country has experienced a change in its government. Specifically, when there was a replacement of the president or the prime minister, we set the country–quarter indicator to 1 if the replacement is from a different political party and 0.5 if the replacement is from the same party. When there was no such a replacement, the indicator is set to 0. In our sample, there are 58 observations taking the value of 1 and 30 observations taking the value of 0.5.

Table 4 reports the results of the baseline OLS regressions and the IV regressions. The estimated coefficients and their significance level are very similar to those reported in Tables 2 and 3. The indicator for government change does have a positive effect on the sovereign rating, and the effect is more significant in the IV regressions. This shows that a change in government improves the sovereign rating but does not take away the signaling effects of debt growth.

[26] We thank a referee for pointing this factor out to us.

5.1.2 GDP Growth Rate Forecast

We obtain quarterly GDP forecast data from the Economic Outlook database of the OECD. The specific variable that we use is "GDP growth forecast by volume", which is the forecast of the quarter-over-quarter real GDP percentage growth (annualized). We then replace the current GDP growth rate in our regressions with the average GDP growth rate forecast for the next 8 quarters. Table 5 reports the results.

Again, the estimated coefficients and their significance levels are similar to those reported in Tables 2 and 3. The GDP forecast has a significantly positive effect (at 10%) on the sovereign rating in the OLS regressions, and the effect remains positive but insignificant in the IV regressions.

5.2 More Robustness Checks

This subsection investigates how robust our empirical results are to variations on the key variables in the regressions.

Alternative Control for Borrowing Cost: In Table 6, we replace the government long-term bond yield with the weighed average bond yield as an alternative control for a country's borrowing cost. The results remain similar to those in Tables 2 and 3.

Alternative Categorization of Fiscal State: In our baseline OLS and IV regressions, we categorize the fiscal state on the basis of the country having an NOB-to-GDP ratio that is one standard deviation above or below the mean. In this exercise, we vary the bandwidth for categorizing good and poor fiscal states. In Table 7, we report the coefficients of key variables of interest when the bandwidth is 0.9, 0.95, or 1.05 times the standard deviation of NOB-to-GDP of a country. The larger the bandwidth, the more stringent is the qualification for a fiscal state to be good or poor. In most cases, the positive signaling effects of consolidated debt growth and bond-and-loan growth and the negative signaling effects of long-term government loan growth remain significant. Moreover, the results show that a more stringent threshold at which the fiscal state is classed as good or poor strengthens both the positive and negative signaling effects.

Dropping IMF Loans: Our empirical results above reveal that long-term government loan growth has a strong negative signaling effect on a country's default risk. It is natural to ask whether this is driven completely by countries taking on IMF loans in times of crisis. To investigate this, we drop all country–quarter observations if the country is holding IMF loans in that quarter and rerun the regressions on the four categories of government debt.[27] The results are reported in Table 8. We continue to find that the growth of long-term government loans has a negative effect on the sovereign rating at a significance level of 1% when the fiscal state is poor.

5.3 Sovereign Bond Spread as a Dependent Variable

Thus far, we have established the signaling effects of sovereign debt growth on a country's default risk in good and poor fiscal states using a regression with the sovereign rating as the dependent variable. In this subsection, we investigate whether the sovereign bond spread – another popular measure for countries' default risk – is also affected by the signaling effects of sovereign debt growth.

We answer this question by replacing the dependent variable in our baseline regression, equation (1), with the one-quarter-ahead sovereign bond spread (in percentage points), that is, the difference between the yields of a country's long-term sovereign bonds and of its US counterparts.[28] We choose to use the one-quarter-ahead sovereign bond spread to avoid contemporaneous interaction between the sovereign bond spread and sovereign borrowing, as both data are at quarterly frequency. We also control for two lags of the sovereign bond spread so that the residuals are no longer autocorrelated. With the sovereign bond spread being one period ahead of all the regressors, our endogeneity test rejects all possibly endogenous regressors. We hence report only the OLS regression results in Table 9.

The sovereign bond spread is persistent, with the estimated coefficients for the spread lagged one period being positive and those for the spread lagged two periods being negative. Higher debt-to-GDP increases the next-quarter sovereign bond spread, whereas higher NOB-to-GDP and real GDP growth reduces the next-quarter sovereign bond spread. All these effects are very intuitive.

[27] According to IMF data, these observations include those of Hungary (08Q4–10Q4), Ireland (10Q4–13Q4), and Portugal (11Q2–14Q2).

[28] We hence have to drop the US from our country sample in this regression.

Turning to the coefficients on debt growth, we find that for both consolidated debt and the sum of bonds and loans, higher debt growth in a good fiscal state reduces the next-quarter sovereign bond spread, whereas higher debt growth in a poor fiscal state increases the next-quarter sovereign bond spread. This is consistent with the signaling effects on the sovereign rating, but note that the coefficients are all insignificant. When we narrow our focus to the growth of long-term government loans, it has a significant positive effect on the next-quarter sovereign bond spread in all fiscal states. However, this significant positive effect becomes insignificant once we drop the observations for country–quarters with IMF loans, indicating that this effect is driven mainly by countries taking on IMF loans in times of crisis.

There are two reasons why the signaling effects of sovereign debt growth on the sovereign bond spread are much weaker than those on the sovereign rating. First, the sovereign bond spread can be affected by many factors other than a country's default risk (see footnote 5). Second, in contrast to the sovereign rating that is measured at daily frequency, the sovereign bond spread is measured at quarterly frequency. Both the timing and the aggregation method of reporting could differ substantially across countries, which we have no control over. This adds measurement errors in the data.

The takeaway message is that the sovereign bond spread does capture some signaling effects of sovereign debt growth but the effects are much weaker than those captured by the sovereign rating.

5.4 Effect of the Debt Level

We now examine why our estimated coefficient for the debt-to-GDP ratio is insignificant when many studies in the literature have found that a higher debt level significantly reduces the sovereign rating.[29]

5.4.1 Omitting the Lagged Rating

We attribute the insignificant result to our inclusion of the control for the lagged rating, which absorbs the effect of the information content from the debt level on default risk.

[29] According to Table 1 in Moor et al. (2018), a negative effect of debt on ratings was reported almost unanimously in the literature before 2005, but more recent literature offers mixed evidence on whether the effect of debt is significant.

We include this control in light of the high persistence of the sovereign ratings in our sample – the autocorrelation is as high as 0.93 on average across countries.

Failure to control for a lagged dependent variable with a strong persistence effect on the current dependent variable subjects the estimation to severe omitted variable bias and could lead to spurious significant results. In fact, Columns 1 and 2 in Table 10 show that once we drop the control for the lagged rating,[30] the effect of the debt level on the rating is estimated to be negative and significant at 1%.[31]

5.4.2 Alternative Measure of Debt-to-GDP

We would also like to rule out the possibility that our debt-to-GDP measure is an excessively aggregated measure of debt since we use the consolidated debt measure from the BIS. To this end, we replace the aggregate debt-to-GDP with bonds-to-GDP and/or loans-to-GDP in our baseline OLS regression. Columns 3–5 in Table 10 report the results. After we control for the lagged rating, replacing debt-to-GDP with bonds-to-GDP and/or loans-to-GDP does not make its coefficient significant. Moreover, since bonds and loans are only part of government debt, neither bonds-to-GDP nor loans-to-GDP is a proper control for the current debt level. This introduces noise in the error term and makes the coefficients of debt growth insignificant.

5.5 Different Types of Macroeconomic States

Our empirical analysis identifies the fiscal state, defined by the lagged government operating balance (NOB-to-GDP), as the key state on which the the positive and negative signaling effects of sovereign debt growth are conditioned. This subsection explores whether other macroeconomic states, specifically, the debt-to-GDP ratio and the GDP growth rate, could serve a similar role. To this end, we replace the fiscal state that interacts with the consolidated debt growth by the alternative macroeconomic state.

[30] In the absence of the control for the lagged rating, the error in our regression is autocorrelated. To mitigate the problem of autocorrelated errors, we adopt the Newey–West estimator with the Bartlett kernel and a bandwidth equal to 8 so that the standard errors are autocorrelation robust.

[31] Mulder and Perrelli (2001) obtain similar findings with sovereign ratings for emerging economies. Using a panel vector autoregressive (PVAR) model, Boumparis et al. (2019) find a persistent negative effect of the debt-to-GDP ratio on the sovereign rating, but their panel data feature a small T (T=19).

Debt-to-GDP Ratio: We categorize the current debt state as *good* if the debt-to-GDP ratio in the previous quarter is n standard deviations below the country's mean debt-to-GDP ratio, *poor* if it is n standard deviations above the mean, and *normal* otherwise. We try different values of n to search for a "working" threshold but do not find one. Columns 1–6 of Table 11 report the results at three representative n values: $n = 0$ corresponds to an approximate distribution of 5:0:5 of {good, normal, poor} states in the sample; $n = 1.05$ to an approximate distribution of 2:6:2; and $n = 1.2$ to an approximate distribution of 1:8:1. The estimated coefficients of debt growth are insignificant in all cases and in both the OLS and IV regressions.

GDP Growth Rate: In contrast with that for the debt state, we find the "working" threshold for the GDP state without much search. However, only the good signaling effect of debt growth is present. More specifically, we categorize the current GDP state as *good* if the real GDP growth rate in the previous quarter is one standard deviation above the country's mean growth rate, *bad* if it is one standard deviation below the mean, and *normal* otherwise. This corresponds to an approximate distribution of 1:8:1 of {good, normal, poor} states in the sample. The results are shown in Columns 7–8 of Table 11. The coefficients of debt growth in the OLS regression are all insignificant. However, in the IV regression, we find the coefficient of debt growth in the good GDP state to be *positive* and statistically significant at 10%. Compared to its counterpart in the good fiscal state in Table 3, the positive signaling effect in the good GDP state is smaller in size and much less statistically significant.

6 A Simple Two-Period Model

In this section, we provide a stylized two-period model to rationalize the conditional signaling effects of debt growth identified in our empirical analysis.

There are two periods. A government receives an endowment in each period to consume with a momentary utility $\ln(\cdot)$. The government can borrow in the first period to smooth consumption. The period-1 endowment X_1 is a random draw from a log-normal distribution with parameters μ and σ and density $f(\cdot)$. The period-2 endowment is $X_2 + \varphi$, where X_2 is a random draw from a uniform distribution with support $[\underline{X}, \overline{X}]$, $\varphi \in \{\varphi_H, \varphi_L\}$ and $\varphi_H > \varphi_L$. X_1 and φ are private information of the government. A government having φ_H is of H type, and a government having φ_L is of L type.

After receiving the endowment in period 1, the government decides how much debt to borrow, B_2, based on a pricing schedule set by the creditors $q(B_2)$. The consumption level in period 1 is then $X_1 + qB_2$. In period 2, the government defaults on the debt if and only if $X_2 + \varphi - B_2 < \phi$. The uniform distribution of X_2 implies that the government defaults with probability $D(\phi + B_2 - \varphi)$, where

$$D(y) = \begin{cases} 0 & \text{if } y \leq \underline{X} \\ (y - \underline{X})/(\overline{X} - \underline{X}) & \text{if } y \in [\underline{X}, \overline{X}] \\ 1 & \text{if } y \geq \overline{X} \end{cases} \tag{3}$$

ϕ is an important parameter to be discussed later. If the government repays its debt, its period-2 consumption is $X_2 + \varphi - B_2$. If the government defaults, its period-2 consumption is $\underline{\phi}$ with $\underline{\phi} \leq \phi$ as a punishment for default.[32]

The optimization problem for a type i government is

$$\max_{B_2} \ln(X_1 + q(B_2)B_2) + D(\phi + B_2 - \varphi_i)\ln(\underline{\phi}) + (1 - D(\phi + B_2 - \varphi_i))E[\ln(X_2 + \varphi_i - B_2)|X_2 + \varphi_i - B_2 > \phi] \tag{4}$$

given the pricing function $q(B_2)$ set by creditors. This optimization yields a type-specific policy function $B_{2,i}(X_1)$.

Creditors do not observe the government's type and have a prior that the government is of H type with probability ρ_1. After observing B_2, creditors update their belief about the government's type to ρ_2 using Bayes's rule:

$$\rho_2(B_2) = \frac{\rho_1 \Pr(B_2|H)}{\rho_1 \Pr(B_2|H) + (1 - \rho_1)\Pr(B_2|L)} = \frac{\rho_1 f(X_{1,H})}{\rho_1 f(X_{1,H}) + (1 - \rho_1) f(X_{1,L})} \tag{5}$$

where $X_{1,H} = B_{2,H}^{-1}(B_2)$ and $X_{1,L} = B_{2,L}^{-1}(B_2)$.

Creditors are competitive and risk neutral so that they price the defaultable debt

[32] The punishment for default is necessary here to prevent the government from seeking to increase the default probability.

according to:

$$(6) \qquad q(B_2) = \frac{1 - [\rho_2(B_2)D(\phi + B_2 - \varphi_H) + (1 - \rho_2(B_2))D(\phi + B_2 - \varphi_L)]}{1 + r}$$

where r is the risk-free rate.

The equilibrium of the model is defined by the fixed point between the government borrowing function $B_{2,i}(X_1)$ and the creditors' pricing function $q(B_2)$.

6.1 Conditional Signaling Effects

Our focus is on how creditors' belief about the government's type ρ_2 is affected by changes in sovereign borrowing B_2. An H-type government has a lower probability of default than an L type. Therefore, if a higher B_2 increases ρ_2, this corresponds to positive signaling. If a higher B_2 decreases ρ_2, it corresponds to negative signaling.

In our simple two-period model, whether sovereign borrowing has positive or negative signaling effects depends on the parameter ϕ, as in the default probability function $D(\phi + B_2 - \varphi)$. A low value of ϕ is associated with a positive signaling effect, whereas a high value of ϕ is associated with a negative signaling effect. Note that a low (high) value of ϕ implies a low (high) default probability, regardless of the government's type. We hence interpret the value of ϕ as the fiscal state in our empirical analysis.

To see why ϕ plays a crucial role in determining the signaling effect, we first establish a result on the type-dependent borrowing functions.

Proposition 1. *Assume* $e < \overline{X} - \underline{X} + \underline{\phi}$ *and* $\phi < \frac{\overline{X} - \underline{X} + \underline{\phi}}{\ln(\overline{X} - \underline{X} + \underline{\phi})}$*:*

i) $B_{2,H}(X_1) > B_{2,L}(X_1)$ *if* $B_{2,H}(X_1) \leq \underline{X} + \varphi_L - \phi$

ii) $B_{2,H}(X_1) < B_{2,L}(X_1)$ *if* $B_{2,H}(X_1) \geq \underline{X} + \varphi_H - \phi$ *and* $B_{2,L}(X_1) < \underline{X} + \varphi_L - \underline{\phi}$

Proof. See the appendix. □

To understand this result, we write the first-order condition of the government:

(7)

$$\frac{1}{X_1 + q(B_2)B_2} \frac{\partial q(B_2)B_2}{\partial B_2} = [1 - D(\phi + B_2 - \varphi_i)]E(\frac{1}{X_2 + \varphi_i - B_2}|X_2 > \phi + B_2 - \varphi_i)$$
$$+ D'(\phi + B_2 - \varphi_i)[E(\ln(X_2 + \varphi_i - B_2)|X_2 > \phi + B_2 - \varphi_i) - \ln(\underline{\phi})]$$

The left-hand side is the marginal benefit of borrowing. It depends on X_1 but not on the government's type, so we denote it by $MB(X_1)$. The right-hand side is the marginal cost of borrowing and is type dependent. We denote it by $MC(\varphi_i)$. The marginal cost has two components. Conditional on repaying debt, more borrowing increases the utility cost of repaying debt. More borrowing also increases the probability of defaulting, in which case the government suffers a utility loss due to $\underline{\phi} \leq \phi$.

Intuition: The marginal cost of borrowing is mainly determined by the cost of repaying debt in period 2, which consists of two parts: the probability of repaying debt and the utility cost of repaying debt. Relative to the L type, the H type has a higher probability but a lower utility cost of repaying debt.[33] When the probability of repaying debt is high for both types (when $B_2 < \underline{X} + \varphi_i - \phi$, both types repay debt for certain), the difference in the repaying probability between the two types is small so that the utility cost difference dominates. As a result, the H type has a lower marginal cost of borrowing and borrows more than the L type. When the probability of repaying debt is low for both types (when $B_2 \geq \underline{X} + \varphi_i - \phi$, both types may default), the difference in the repaying probability between the two types dominates the difference in the utility cost. In this case, the H type has a higher marginal cost of borrowing and borrows less than the L type.

The Role of ϕ: The parameter ϕ determines the cutoffs in Proposition 1. With a sufficiently low ϕ, $B_{2,H}(X_1) \leq \underline{X} + \varphi_L - \phi$ for most values of X_1. As $B_{2,H}(X_1) > B_{2,L}(X_1)$, it will be the case that $B_2(X_1) < \underline{X} + \varphi_i - \phi$ for both types. In other words, a sufficiently low ϕ implies that the H type borrows more than the L type. With a sufficiently high ϕ, $B_{2,H}(X_1) \geq \underline{X} + \varphi_H - \phi$ for most values of X_1. As $B_{2,H}(X_1) < B_{2,L}(X_1)$, it will be the case that $B_2(X_1) \geq \underline{X} + \varphi_i - \phi$ for both types. In other words, a sufficiently high ϕ implies that the H type borrows less than the L type.

Belief Updating: Recall that X_1 is also private information of the government. This prevents the full revelation of its type after creditors observe B_2 and makes creditors' belief about the government's type $\rho_2(B_2)$ a smooth function of B_2.

[33] The H type also has a higher utility loss upon defaulting as long as ϕ is not too high. The upper bound of ϕ depends on B_2, which is why we impose an upper bound on $B_{2,L}$ in ii) of Proposition 1.

Conditional Signaling Effects: A bell-shaped log-normal distribution for X_1 together with the properties of the type-dependent borrowing functions in Proposition 1 yield the desirable conditional signaling effects. In particular, when ϕ is sufficiently low (high), more borrowing improves (reduces) creditors' belief that the government is the H type. A low (high) ϕ implies a low (high) default probability for both types, and is interpreted as the good (poor) fiscal state. Hence, this two-period model implies that in a good (poor) fiscal state, more borrowing improves (reduces) the sovereign rating by making creditors think that the government is more (less) likely to be the type with lower default risk (i.e., the H type).[34]

6.2 A Numerical Example

This subsection provides a numerical example of the conditional signaling effects of sovereign debt growth produced by the two-period model.

Table 12 contains the parameter values. Figure 6 reports the equilibrium functions when we set the key parameter ϕ to its lower bound $\underline{\phi} = 0.09$. The H type borrows more than the L type for all values of X_1, and ρ_2 is increasing in B_2. That is, a higher B_2 improves creditors' belief that government is of H type. As the H type has a lower probability of default, there is thus a positive signaling effect of debt growth. Additionally, note that a low value of ϕ indicates a lower default probability for both types of government. This can be interpreted as the fiscal state of the government being good. Therefore, the positive signaling of debt growth is conditional on a good fiscal state.

The equilibrium functions when we set the key parameter ϕ to a high value 2.52, which makes the default probability higher for both types of government, are reported in Figure 7. The H type borrows less than the L type for all values of X_1, and ρ_2 is decreasing in B_2. Therefore, there is a negative signaling effect of debt growth conditional on a poor fiscal state.

[34]This stylized two-period model does not explicitly consider debt with different maturities, yet the mechanism discussed can be used to interpret the empirical results on debt structure. In a good fiscal state, the likelihood of repayment is high for all debt categories, thus the positive signaling is not driven by any particular category of debt growth. On the other hand, in a poor fiscal state, the H and L types may have the greatest differences in the likelihood of repaying long-term government loans, and, as a result, their borrowing amount in these loans, among the four categories of government debt. Hence, the negative signaling in a poor fiscal state is primarily driven by an increase in long-term government loans.

7 Conclusion

In contrast to the ample empirical evidence on the signaling effects of sovereign default, there is limited evidence on whether sovereign borrowing can be informative about a country's default risk. Our paper fills the gap in the literature by providing novel findings on the empirical relationship between sovereign debt growth and sovereign ratings, suggesting conditional signaling effects of sovereign borrowing on a country's default risk.

Using an unbalanced quarterly panel of 21 advanced economies from 2000q2 to 2020q3, we show that a higher sovereign debt growth rate significantly improves a country's sovereign rating if its government has good fiscal performance, as measured by its recent government operating balance. This positive effect stands in sharp contrast to the conventional wisdom from the sovereign debt and default literature, according to which more sovereign borrowing increases a country's debt burden and thus should decrease its sovereign rating. We therefore interpret this finding as evidence of a positive signaling effect of sovereign borrowing. Moreover, this positive signaling effect is conditional on the country's recent fiscal performance being good. If the country's recent fiscal performance is poor, we instead find a negative signaling effect of sovereign borrowing: a higher sovereign debt growth rate significantly decreases a country's sovereign rating, even after the lagged rating, sovereign bond yield, and other relevant economic fundamentals are controlled for.

Although the hypothesis explored in this paper emphasizes the role of private information held by the government, it is important to acknowledge that there could be other factors at play. This study serves as a starting point for further investigation and refinement of our understanding of these empirical findings, including exploring other potential hypotheses and determining whether they extend to emerging or developing economies.

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Table 1: Summary Statistics

Variable	(1) Obs	(2) Mean	(3) SD	(4) Min	(5) Max	(6) Auto Corr
Rating	1,535	17.978	1.156	8.500	20.000	0.930
Debt	1,535	61.356	13.461	6.800	149.300	0.976
Debt Growth (quarterly p.p.)	1,535	1.711	3.910	−15.334	76.995	0.116
Bond+Loan Growth (to Gross Debt)	1,400	1.526	3.575	−15.757	77.025	0.049
Bond Growth (to Gross Debt)	1,400	1.260	3.291	−15.542	60.732	0.053
Loan Growth (to Gross Debt)	1,400	0.265	1.187	−15.492	16.294	−0.048
ST Bond Growth (to Gross Debt)	1,400	0.140	1.599	−12.051	18.467	−0.065
LT Bond Growth (to Gross Debt)	1,400	1.120	2.782	−15.542	60.732	0.038
ST Loan Growth (to Gross Debt)	1,400	0.047	0.641	−6.642	8.828	−0.217
LT Loan Growth (to Gross Debt)	1,400	0.219	0.856	−15.456	15.525	0.138
Good Fiscal State Dummy	1,535	0.107	0.289	0.000	1.000	0.402
Normal Fiscal State Dummy	1,535	0.794	0.388	0.000	1.000	0.362
Poor Fiscal State Dummy	1,535	0.099	0.286	0.000	1.000	0.330
Gov. Operating Balance	1,535	−1.498	3.203	−43.495	21.053	0.599
Real GDP Growth (annualized p.p.)	1,535	2.014	2.734	−21.568	29.093	0.778
∼ Forecast (quarterly annualized p.p.)	1,470	2.105	1.908	−7.993	21.105	0.591
Current Account Balance	1,535	−0.566	2.696	−31.859	32.499	0.759
Fiscal Reserve	1,535	12.665	3.947	0.317	134.362	0.934
Inflation (quarterly p.p.)	1,535	0.476	0.644	−3.025	3.803	0.069
LT Yield (annualized p.p.)	1,535	3.618	1.656	−0.480	13.223	0.974
Weighted Yield (annualized p.p.)	1,504	3.438	1.615	−0.475	10.988	0.975

* Debt, Government Operating Balance, Current Account Balance, and Fiscal Reserve are all normalized by the nominal GDP level of the same period and presented in percentage points.

Table 2: Main Regression Results: OLS

OLS	(1) BIS	(2) BIS	(3) Bond+Loan	(4) ST Bond	(5) LT Bond	(6) ST Loan	(7) LT Loan
L(rating)	0.951***	0.951***	0.949***	0.950***			
	(0.008)	(0.008)	(0.008)	(0.008)			
Debt	−0.000	0.000	0.000	-0.0003			
	(0.001)	(0.001)	(0.001)	(0.0009)			
Debt Growth		−0.001					
		(0.001)					
$\mathbf{1}^G \times$Debt Growth	0.006*		0.005*	0.005	0.003	0.023	0.006
	(0.003)		(0.003)	(0.004)	(0.003)	(0.015)	(0.008)
$\mathbf{1}^N \times$Debt Growth	−0.001		−0.001	(0.001)	0.000	−0.005	−0.004
	(0.001)		(0.001)	(0.003)	(0.002)	(0.007)	(0.008)
$\mathbf{1}^P \times$Debt Growth	−0.011*		−0.026*	0.006	−0.008	−0.067*	−0.103***
	(0.007)		(0.015)	(0.032)	(0.014)	(0.040)	(0.038)
Operating Balance	0.008**	0.008**	0.013***	0.0094***			
	(0.004)	(0.004)	(0.004)	(0.003)			
Real GDP Growth	0.004	0.004	0.004	0.004			
	(0.004)	(0.004)	(0.004)	(0.004)			
CA Balance	−0.000	−0.000	0.000	0.001			
	(0.002)	(0.002)	(0.002)	(0.002)			
Fiscal Reserve	−0.000	−0.000	−0.001	-0.001			
	(0.001)	(0.001)	(0.002)	(0.002)			
Inflation	0.005	0.005	0.012	0.012			
	(0.017)	(0.017)	(0.017)	(0.017)			
LT Rate	−0.084***	−0.084***	−0.086***	-0.074***			
	(0.019)	(0.019)	(0.020)	(0.0198)			
Time Fixed Effects	YES	YES	YES	YES			
Country Fixed Effects	YES	YES	YES	YES			
Constant	1.055***	1.025***	1.248***	1.128***			
	(0.184)	(0.183)	(0.208)	(0.204)			
N	1535	1535	1400	1400			
R^2	0.994	0.993	0.994	0.994			
Robust std err in ()	*:p<0.100	**:p<0.050	***: p <0.01				

Notes: Regressions include two fiscal state dummies and an EU dummy that are not shown in the table.

Table 3: Main Regression Results: IV

IV	(1) BIS	(2) BIS	(3) Bond+Loan	(4) ST Bond	(5) LT Bond	(6) ST Loan	(7) LT Loan
L(rating)	0.953***	0.953***	0.950***	0.949***			
	(0.008)	(0.008)	(0.008)	(0.008)			
Debt	0.001	0.001	0.001	0.000			
	(0.001)	(0.001)	(0.001)	(0.001)			
Debt Growth		−0.000					
		(0.001)					
$\mathbf{1}^G \times$Debt Growth	0.010***		0.007**	0.010*	0.004	0.033	0.001
	(0.004)		(0.003)	(0.005)	(0.003)	(0.021)	(0.010)
$\mathbf{1}^N \times$Debt Growth	−0.000		0.000	0.002	0.000	−0.004	−0.004
	(0.001)		(0.001)	(0.003)	(0.002)	(0.007)	(0.007)
$\mathbf{1}^P \times$Debt Growth	−0.008		−0.021	0.011	−0.006	−0.072*	−0.148**
	(0.008)		(0.015)	(0.032)	(0.013)	(0.040)	(0.066)
Operating Balance	0.022***	0.022***	0.014**	0.014**			
	(0.006)	(0.006)	(0.007)	(0.006)			
Real GDP Growth	0.002	0.002	0.004	0.003			
	(0.004)	(0.004)	(0.004)	(0.004)			
CA Balance	0.000	0.000	0.001	0.001			
	(0.002)	(0.002)	(0.003)	(0.003)			
Fiscal Reserve	−0.001	−0.001	−0.002	-0.002			
	(0.001)	(0.001)	(0.002)	(0.002)			
Inflation	−0.005	−0.005	0.006	0.007			
	(0.017)	(0.017)	(0.017)	(0.017)			
LT Rate	−0.084***	−0.084***	−0.085***	-0.071***			
	(0.019)	(0.019)	(0.021)	(0.02)			
Time Fixed Effects	YES	YES	YES	YES			
Country Fixed Effects	YES	YES	YES	YES			
Constant	1.347***	1.329***	1.388***	1.388***			
	(0.197)	(0.198)	(0.215)	(0.211)			
N	1457	1457	1299	1299			
R^2	0.993	0.993	0.994	0.994			
Robust std err in ()	*:p<0.100	**:p<0.050	***: p <0.01				

Notes: Regressions include two fiscal state dummies and an EU dummy that are not shown in the table.

Table 4: Controlling for Changes in Government

OLS	(1) BIS	(2) Bond+Loan	(3) ST Bond	(4) LT Bond	(5) ST Loan	(6) LT Loan
L(rating)	0.951***	0.949***	0.9497***			
	(0.008)	(0.008)	(0.0083)			
Debt	−0.000	0.001	-0.0003			
	(0.001)	(0.001)	(0.0009)			
$\mathbf{1}^G \times$Debt Growth	0.006*	0.005*	0.004	0.002	0.022	0.006
	(0.003)	(0.003)	(0.005)	(0.003)	(0.015)	(0.008)
$\mathbf{1}^N \times$Debt Growth	−0.001	−0.001	0.000	0.000	−0.005	−0.004
	(0.002)	(0.001)	(0.003)	(0.002)	(0.007)	(0.008)
$\mathbf{1}^P \times$Debt Growth	−0.012*	−0.026*	0.006	−0.009	−0.069*	−0.104***
	(0.007)	(0.014)	(0.032)	(0.014)	(0.040)	(0.037)
LT Rate	−0.085***	−0.093***	-0.0738***			
	(0.019)	(0.021)	(0.0198)			
Gov Change	0.034	0.046	0.0588*			
	(0.027)	(0.030)	(0.0305)			
IV	**BIS**	**Bond+Loan**	**ST Bond**	**LT Bond**	**ST Loan**	**LT Loan**
L(rating)	0.953***	0.949***	0.9485***			
	(0.008)	(0.009)	(0.0082)			
Debt	0.001	0.001	0.0001			
	(0.001)	(0.001)	(0.0009)			
$\mathbf{1}^G \times$Debt Growth	0.010***	0.007**	0.009*	0.004	0.032	0.001
	(0.004)	(0.003)	(0.005)	(0.003)	(0.021)	(0.010)
$\mathbf{1}^N \times$Debt Growth	−0.000	0.000	0.002	0.001	−0.004	−0.004
	(0.001)	(0.001)	(0.003)	(0.002)	(0.007)	(0.007)
$\mathbf{1}^P \times$Debt Growth	−0.008	−0.022	0.011	−0.007	−0.074*	−0.148**
	(0.008)	(0.015)	(0.032)	(0.013)	(0.039)	(0.066)
LT Rate	−0.084***	−0.092***	-0.0713***			
	(0.020)	(0.022)	(0.0197)			
Gov Change	0.039	0.059**	0.0498*			
	(0.027)	(0.029)	(0.0274)			
Robust std err in ()	*:p<0.100	**: p <0.05	***:p<0.010			

Notes: Regressions include other control variables as in the benchmark regressions.

Table 5: Controlling for GDP Forecasts

	(1)	(2)	(3)	(4)	(5)	(6)
OLS	BIS	Bond+Loan	ST Bond	LT Bond	ST Loan	LT Loan
L(rating)	0.948***	0.951***		0.9527***		
	(0.009)	(0.008)		(0.0082)		
Debt	−0.000	−0.000		-0.0004		
	(0.001)	(0.001)		(0.0009)		
$\mathbf{1}^G \times$Debt Growth	0.005*	0.005	0.005	0.002	0.023	0.005
	(0.003)	(0.003)	(0.005)	(0.003)	(0.015)	(0.008)
$\mathbf{1}^N \times$Debt Growth	−0.002	−0.000	0.001	0.001	−0.006	−0.005
	(0.002)	(0.001)	(0.003)	(0.002)	(0.007)	(0.008)
$\mathbf{1}^P \times$Debt Growth	−0.019*	−0.026*	0.005	−0.008	−0.069*	−0.102***
	(0.010)	(0.015)	(0.032)	(0.014)	(0.040)	(0.038)
LT Rate	−0.089***	−0.084***		-0.0703***		
	(0.023)	(0.021)		(0.0207)		
GDP forecast	0.010*	0.011*		0.0109*		
	(0.006)	(0.006)		(0.0061)		
IV	BIS	Bond+Loan	ST Bond	LT Bond	ST Loan	LT Loan
L(rating)	0.951***	0.951***		0.9499***		
	(0.008)	(0.008)		(0.0082)		
Debt	0.001	0.000		-0.0000		
	(0.001)	(0.001)		(0.0010)		
$\mathbf{1}^G \times$Debt Growth	0.009***	0.007**	0.010*	0.004	0.033	0.001
	(0.003)	(0.003)	(0.005)	(0.003)	(0.021)	(0.009)
$\mathbf{1}^N \times$Debt Growth	−0.000	0.000	0.003	0.001	−0.004	−0.004
	(0.001)	(0.001)	(0.003)	(0.002)	(0.007)	(0.007)
$\mathbf{1}^P \times$Debt Growth	−0.013	−0.021	0.011	−0.007	−0.073*	−0.148**
	(0.011)	(0.015)	(0.032)	(0.013)	(0.040)	(0.066)
LT Rate	−0.088***	−0.085***		-0.0704***		
	(0.021)	(0.023)		(0.0208)		
GDP forecast	0.005	0.006		0.0065		
	(0.006)	(0.006)		(0.0058)		
Robust std err in ()	*:p<0.100	**: p <0.05	***:p<0.010			

Notes: Regressions include other control variables as in the benchmark regressions.

Table 6: Robustness: Controlling for Weighted Average Sovereign Bond Yield

OLS	(1) BIS	(2) BIS	(3) Bond+Loan	(4) ST Bond	(5) LT Bond	(6) ST Loan	(7) LT Loan
L(rating)	0.956***	0.956***	0.954***	0.955***			
	(0.008)	(0.008)	(0.008)	(0.008)			
Debt	0.000	0.000	0.000	-0.000			
	(0.001)	(0.001)	(0.001)	(0.001)			
Debt Growth		−0.002					
		(0.001)					
$\mathbf{1}^G \times$Debt Growth	0.006*		0.005	0.005	0.003	0.022	0.005
	(0.003)		(0.003)	(0.005)	(0.003)	(0.016)	(0.008)
$\mathbf{1}^N \times$Debt Growth	−0.001		−0.001	0.000	0.000	−0.004	−0.006
	(0.001)		(0.001)	(0.003)	(0.002)	(0.006)	(0.007)
$\mathbf{1}^P \times$Debt Growth	−0.012*		−0.027*	0.006	−0.008	−0.068*	−0.105***
	(0.007)		(0.015)	(0.032)	(0.014)	(0.041)	(0.038)
Wavg Rate	−0.078***	−0.078***	−0.082***	-0.069***			
	(0.018)	(0.018)	(0.019)	(0.018)			
IV	**BIS**	**BIS**	**Bond+Loan**	**ST Bond**	**LT Bond**	**ST Loan**	**LT Loan**
L(rating)	0.959***	0.959***	0.956***	0.954***			
	(0.008)	(0.008)	(0.008)	(0.008)			
Debt	0.002*	0.002*	0.001	0.000			
	(0.001)	(0.001)	(0.001)	(0.001)			
Debt Growth		−0.000					
		(0.001)					
$\mathbf{1}^G \times$Debt Growth	0.010**		0.006*	0.009*	0.004	0.033	0.000
	(0.004)		(0.003)	(0.006)	(0.003)	(0.022)	(0.010)
$\mathbf{1}^N \times$Debt Growth	−0.000		−0.000	0.002	0.000	−0.002	−0.005
	(0.001)		(0.001)	(0.003)	(0.002)	(0.006)	(0.007)
$\mathbf{1}^P \times$Debt Growth	−0.008		−0.022	0.013	−0.006	−0.074*	−0.155**
	(0.008)		(0.015)	(0.032)	(0.013)	(0.041)	(0.064)
Wavg Rate	−0.076***	−0.076***	−0.078***	-0.065***			
	(0.018)	(0.018)	(0.020)	(0.018)			
Robust std err in ()	*:p<0.100	**:p<0.050	***: p <0.01				

Notes: Regressions include other control variables as in the benchmark regressions.

Table 7: Robustness: Using an Alternative Categorization of Fiscal State

BIS	(1) OLS: 0.9	(2) OLS: 0.95	(3) OLS: 1.05	(4) IV: 0.9	(5) IV: 0.95	(6) IV: 1.05
L(rating)	0.950***	0.950***	0.951***	0.953***	0.953***	0.953***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Debt	−0.000	−0.000	−0.000	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\mathbf{1}^G$×Debt Growth	0.002*	0.002**	0.005*	0.002	0.003	0.009**
	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)	(0.004)
$\mathbf{1}^N$×Debt Growth	−0.001	−0.001	−0.001	0.000	−0.000	0.000
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
$\mathbf{1}^P$×Debt Growth	−0.013**	−0.013*	−0.012*	−0.010	−0.009	−0.009
	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)
LT Rate	−0.084***	−0.084***	−0.084***	−0.084***	−0.084***	−0.083***
	(0.019)	(0.019)	(0.019)	(0.020)	(0.020)	(0.019)
Bond+Loan	OLS: 0.9	OLS: 0.95	OLS: 1.05	IV: 0.9	IV: 0.95	IV: 1.05
L(rating)	0.949***	0.949***	0.949***	0.950***	0.950***	0.950***
	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)
Debt	0.000	0.000	0.000	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\mathbf{1}^G$×Debt Growth	0.002*	0.002*	0.003	0.002*	0.002*	0.005*
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
$\mathbf{1}^N$×Debt Growth	−0.001	−0.001	−0.000	−0.000	−0.000	0.000
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)
$\mathbf{1}^P$×Debt Growth	−0.024**	−0.026*	−0.035**	−0.020*	−0.021	−0.030*
	(0.012)	(0.013)	(0.015)	(0.012)	(0.014)	(0.017)
LT Rate	−0.086***	−0.087***	−0.086***	−0.085***	−0.085***	−0.084***
	(0.020)	(0.020)	(0.020)	(0.021)	(0.021)	(0.021)
LT Loan	OLS: 0.9	OLS: 0.95	OLS: 1.05	IV: 0.9	IV: 0.95	IV: 1.05
L(rating)	0.950***	0.950***	0.950***	0.949***	0.949***	0.949***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Debt	−0.000	−0.000	−0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\mathbf{1}^G$×Debt Growth	0.004	0.004	0.001	0.003	0.003	−0.002
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.008)
$\mathbf{1}^N$×Debt Growth	−0.011	−0.006	−0.004	−0.009	−0.005	−0.004
	(0.009)	(0.010)	(0.008)	(0.009)	(0.009)	(0.007)
$\mathbf{1}^P$×Debt Growth	−0.081**	−0.098***	−0.107***	−0.093*	−0.133**	−0.160**
	(0.033)	(0.035)	(0.039)	(0.055)	(0.060)	(0.068)
LT Rate	−0.073***	−0.073***	−0.073***	−0.072***	−0.071***	−0.070***
	(0.021)	(0.020)	(0.020)	(0.021)	(0.020)	(0.020)
Robust std err in ()	*:p<0.100	**:p<0.050	***:p<0.01			

Notes: The benchmark regressions categorize the fiscal state on the basis of a one-standard-deviation bandwidth around the sample mean of NOB-to-GDP. This robustness exercise varies the bandwidth from 0.9 to 1.05 times the standard deviation. Regressions include other control variables as in the benchmark regressions.

Table 8: Robustness: Dropping Observations with IMF Loans

OLS	(1) ST Bond	(2) LT Bond	(3) ST Loan	(4) LT Loan
L(rating)	0.954***			
	(0.008)			
Debt	-0.000			
	(0.001)			
$\mathbf{1}^G \times$Debt Growth	0.004	0.002	0.022	0.006
	(0.004)	(0.003)	(0.015)	(0.008)
$\mathbf{1}^N \times$Debt Growth	0.000	−0.000	−0.000	−0.002
	(0.003)	(0.002)	(0.005)	(0.005)
$\mathbf{1}^P \times$Debt Growth	0.020	−0.003	−0.057	−0.171***
	(0.032)	(0.013)	(0.037)	(0.048)
LT Rate	-0.093***			
	(0.024)			
IV	**ST Bond**	**LT Bond**	**ST Loan**	**LT Loan**
L(rating)	0.951***			
	(0.008)			
Debt	0.000			
	(0.001)			
$\mathbf{1}^G \times$Debt Growth	0.010*	0.004	0.034*	0.005
	(0.005)	(0.003)	(0.020)	(0.010)
$\mathbf{1}^N \times$Debt Growth	0.003	0.001	0.001	−0.002
	(0.003)	(0.002)	(0.005)	(0.005)
$\mathbf{1}^P \times$Debt Growth	0.022	−0.001	−0.065*	−0.212***
	(0.030)	(0.012)	(0.037)	(0.051)
LT Rate	-0.098***			
	(0.024)			
Robust std err in ()	*:p<0.100	**:p<0.050	***: p <0.01	

Notes: We drop the country–quarter observation if the country holds an IMF loan in that quarter. Regressions include other control variables as in the benchmark regressions.

Table 9: Next-Quarter Sovereign Bond Spread as Dependent Variable

OLS	(1) BIS	(2) BIS	(3) Bond+Loan	(4) LT Loan	(5) LT Loan (no IMF loan)
Spread	1.282***	1.283***	1.295***	1.262***	1.204***
	(0.056)	(0.056)	(0.062)	(0.059)	(0.061)
L(Spread)	−0.395***	−0.395***	−0.410***	−0.390***	−0.313***
	(0.048)	(0.048)	(0.052)	(0.050)	(0.052)
Debt	0.002**	0.002**	0.002**	0.003**	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Debt Growth		0.000			
		(0.002)			
$\mathbf{1}^G$×Debt Growth	−0.012		−0.004	0.021**	0.016
	(0.007)		(0.005)	(0.010)	(0.010)
$\mathbf{1}^N$×Debt Growth	0.000		0.000	0.027*	0.001
	(0.002)		(0.002)	(0.014)	(0.007)
$\mathbf{1}^P$×Debt Growth	0.006		0.013	0.088***	0.064
	(0.008)		(0.013)	(0.033)	(0.055)
Operating Balance	−0.008*	−0.008*	−0.009*	−0.004	−0.005
	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Real GDP Growth	−0.008*	−0.008*	−0.010*	−0.009*	−0.010**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
CA Balance	0.001	0.001	0.003	0.001	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Fiscal Reserve	0.002	0.002	0.001	0.001	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Inflation	0.012	0.011	0.007	0.007	0.018
	(0.020)	(0.020)	(0.021)	(0.021)	(0.021)
Time Fixed Effects	YES	YES	YES	YES	YES
Country Fixed Effects	YES	YES	YES	YES	YES
Constant	−0.807***	−0.782***	0.324**	0.278*	0.274
	(0.188)	(0.184)	(0.164)	(0.166)	(0.168)
N	1453	1453	1306	1308	1273
R^2	0.968	0.968	0.971	0.970	0.966
Robust std err in ()	*:p<0.100	**:p<0.050	***:p<0.01		

Notes: Regressions include two fiscal state dummies and an EU dummy that are not shown in the table.

Table 10: Alternative Specifications for Debt-to-GDP

	(1)	(2)	(3)	(4)	(5)
BIS	OLS	IV		OLS	
L(rating)			0.946***	0.955***	0.952***
			(0.008)	(0.009)	(0.010)
Debt	−0.057***	−0.058***			
	(0.005)	(0.005)			
Bond			−0.001		−0.001
			(0.001)		(0.001)
Loan				0.003	0.002
				(0.003)	(0.003)
$\mathbf{1}^G \times$Debt Growth	0.010	0.010	0.005	0.005	0.005
	(0.014)	(0.016)	(0.003)	(0.003)	(0.003)
$\mathbf{1}^N \times$Debt Growth	0.003	0.007	−0.002	−0.001	−0.001
	(0.005)	(0.005)	(0.002)	(0.002)	(0.002)
$\mathbf{1}^P \times$Debt Growth	−0.014	−0.002	−0.015	−0.014	−0.014
	(0.018)	(0.021)	(0.011)	(0.011)	(0.011)
Operating Balance	−0.009	0.018	0.010**	0.011**	0.010**
	(0.015)	(0.044)	(0.005)	(0.004)	(0.005)
Real GDP Growth	−0.029	−0.042**	0.004	0.004	0.004
	(0.019)	(0.021)	(0.004)	(0.004)	(0.004)
Current Account Balance	−0.102***	−0.106***	0.000	−0.000	0.000
	(0.020)	(0.021)	(0.003)	(0.002)	(0.003)
Fiscal Reserve	0.064***	0.058***	−0.001	−0.001	−0.001
	(0.010)	(0.010)	(0.002)	(0.002)	(0.002)
Inflation	0.232***	0.197***	0.008	0.007	0.007
	(0.060)	(0.063)	(0.017)	(0.017)	(0.017)
LT Rate	−0.496***	−0.470***	−0.085***	−0.088***	−0.087***
	(0.064)	(0.062)	(0.019)	(0.020)	(0.020)
Time Fixed Effects	YES	YES	YES	YES	YES
Country Fixed Effects	YES	YES	YES	YES	YES
Constant	21.260***	21.639***	1.290***	1.031***	1.162***
	(0.533)	(0.750)	(0.203)	(0.212)	(0.235)
N	1535	1457	1369	1368	1368
R^2	0.897	0.901	0.994	0.994	0.994
Robust std err in ()	*:p<0.100	**:p<0.050	***:p<0.010		

Notes: Regressions include two fiscal state dummies and an EU dummy that are not shown in the table.

Table 11: Different Types of Macroeconomic States

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BIS	Debt State						GDP State	
	0*std (5:0:5)		1.05*std (2:6:2)		1.2*std (1:8:1)		1.0*std (1:8:1)	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
L(rating)	0.951***	0.954***	0.952***	0.954***	0.952***	0.954***	0.950***	0.953***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Debt	0.000	0.002	−0.000	0.001	−0.000	0.001	0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\mathbf{1}^G \times$Debt Growth	0.000	0.000	0.003	0.001	0.004	0.002	0.001	0.007*
	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
$\mathbf{1}^N \times$Debt Growth			−0.003	−0.001	−0.002	−0.001	−0.000	0.000
			(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$\mathbf{1}^P \times$Debt Growth	−0.004	−0.002	−0.001	0.002	−0.002	0.001	−0.003	−0.002
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)	(0.003)	(0.003)
Operating Balance	0.008**	0.023***	0.008**	0.023***	0.008**	0.023***	0.008**	0.023***
	(0.004)	(0.006)	(0.004)	(0.006)	(0.004)	(0.006)	(0.004)	(0.006)
Real GDP Growth	0.004	0.002	0.004	0.002	0.004	0.002	0.006	0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
CA Balance	−0.000	0.001	−0.001	0.000	−0.000	0.000	−0.000	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Fiscal Reserve	0.000	−0.001	0.001	−0.001	0.001	−0.001	0.000	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Inflation	0.005	−0.005	0.005	−0.004	0.005	−0.005	0.004	−0.005
	(0.017)	(0.017)	(0.016)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
LT Rate	−0.084***	−0.084***	−0.083***	−0.083***	−0.084***	−0.083***	−0.085***	−0.084***
	(0.019)	(0.020)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)
Time Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
Country Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
Constant	1.022***	1.315***	1.044***	1.318***	1.022***	1.328***	1.069***	1.375***
	(0.199)	(0.204)	(0.196)	(0.201)	(0.191)	(0.199)	(0.191)	(0.205)
N	1535	1457	1535	1457	1535	1457	1534	1456
R^2	0.993	0.993	0.993	0.993	0.993	0.993	0.993	0.993
Robust std err in ()	*: p <0.10 **: p <0.05 ***:p<0.01							

Notes: Regressions include two fiscal state dummies and an EU dummy that are not shown in the table.

Figure 1: Rating plus Outlook Score

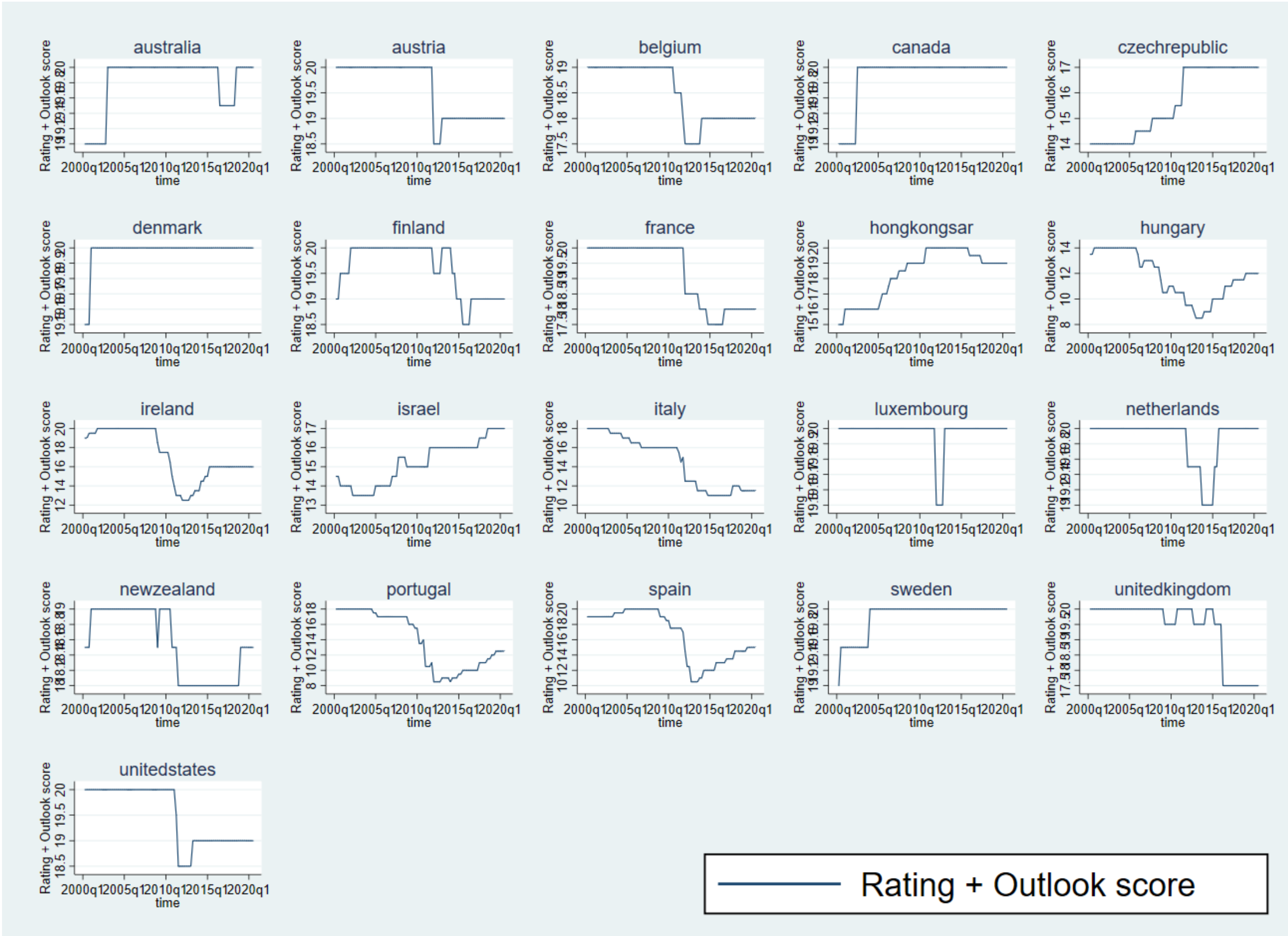


Figure 2: Debt-to-GDP Ratio

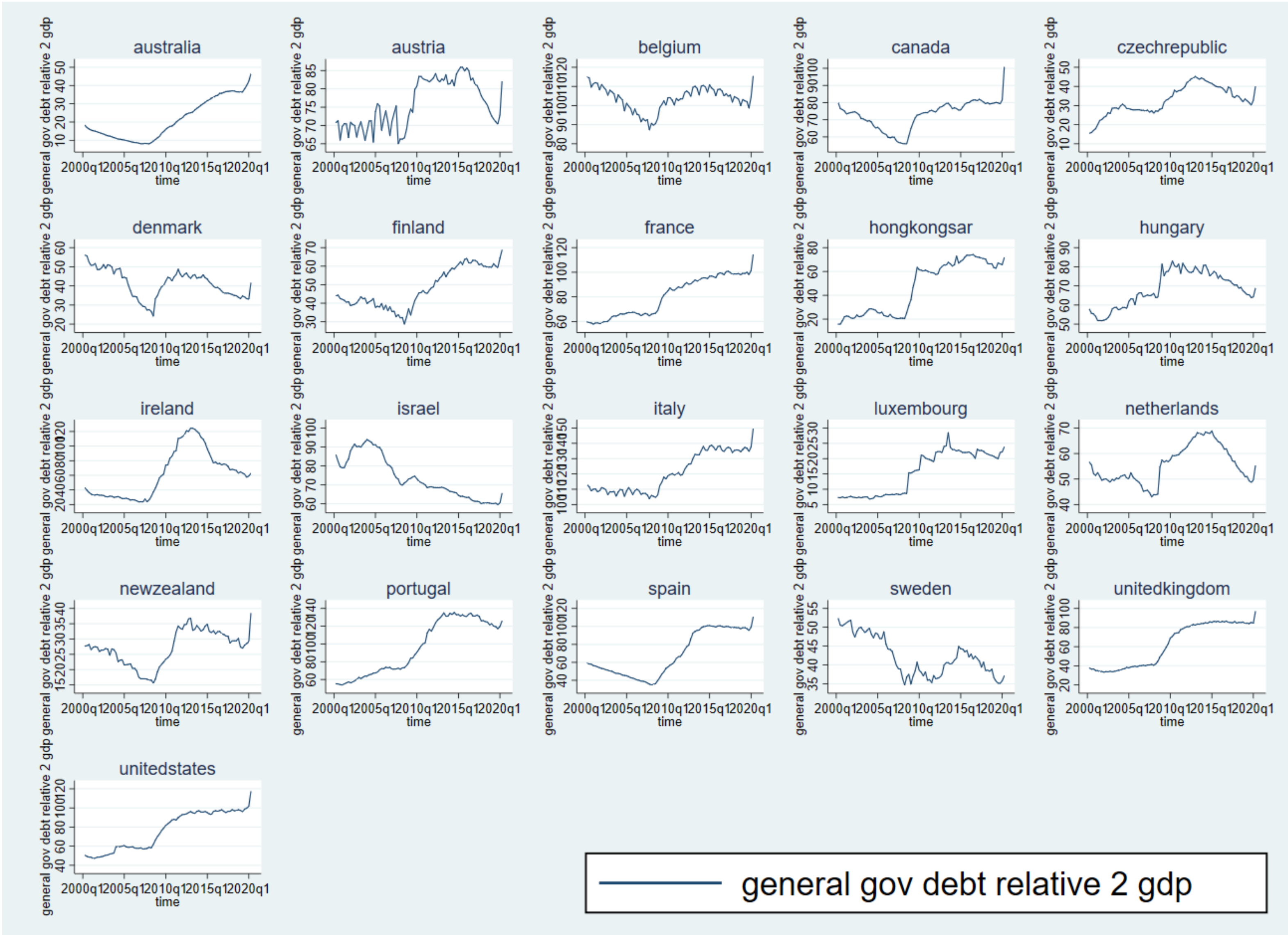


Figure 3: Debt Growth

Figure 4: Debt Structure: Stock of Debt in Four Categories

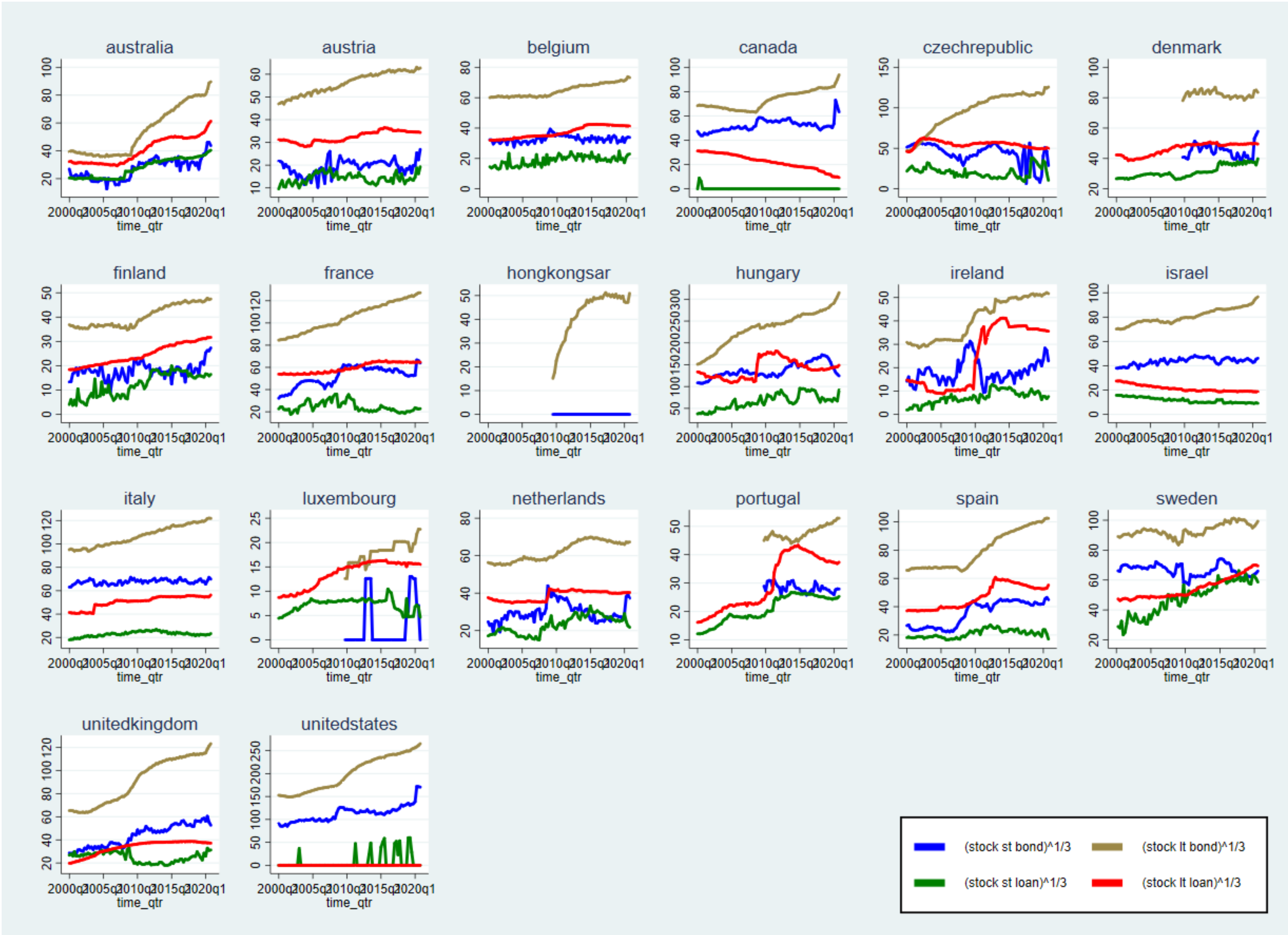


Figure 5: Net Operating Balance and Fiscal Sustainability Gap

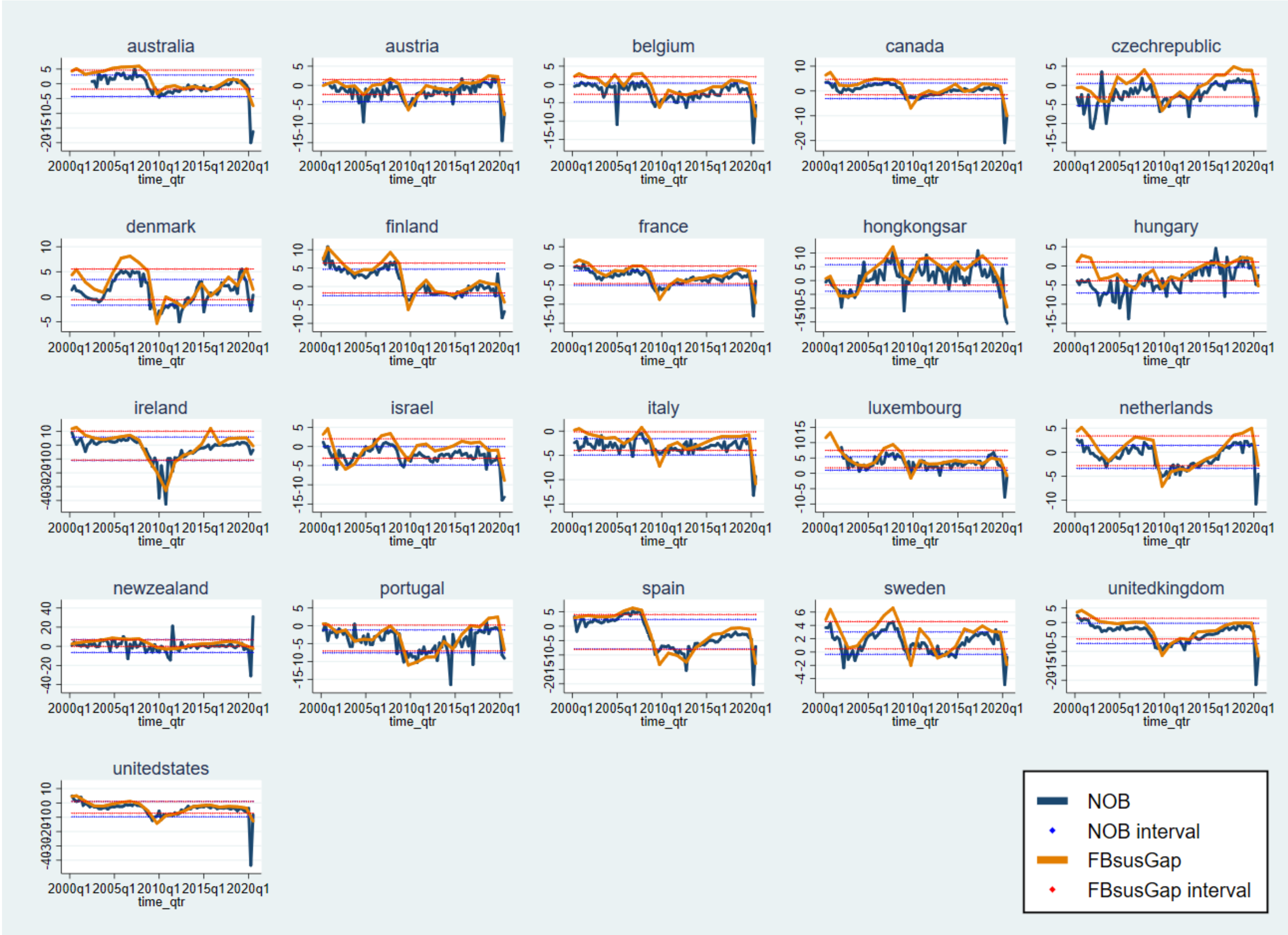


Table 12: Parameter Values

Parameter	μ	σ	$\underline{X}$	$\overline{X}$	$\underline{\phi}$	φ_H	φ_L	r	ρ_1
Value	1	0.8	1.08	7.2	0.09	1.44	0	0.02	0.5

Figure 6: Equilibrium Functions with Low $\phi = \underline{\phi}$

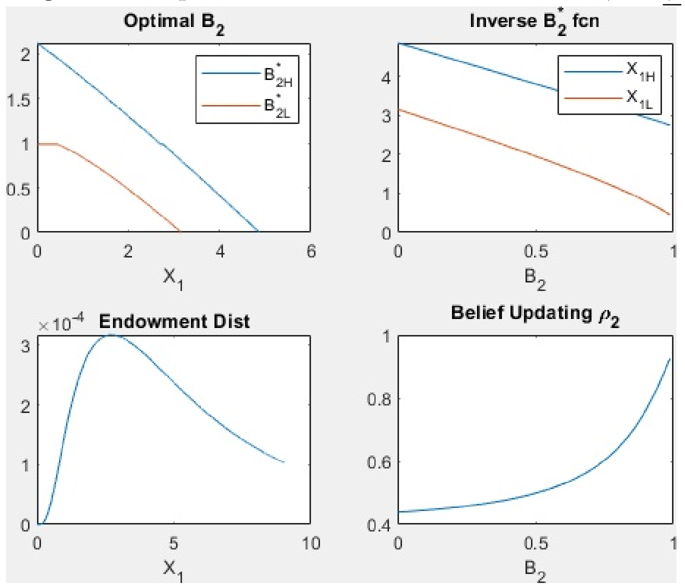
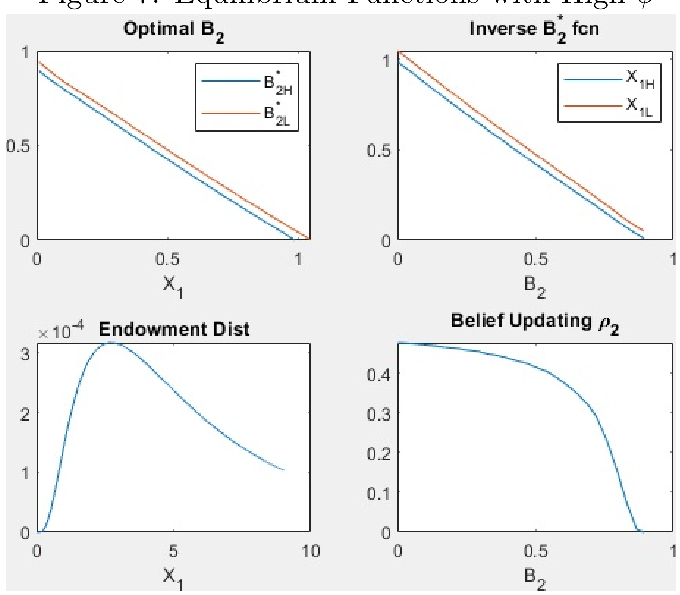


Figure 7: Equilibrium Functions with High ϕ



A Results of the Endogeneity Test

In Tables 13 and 14, we report the results of the endogeneity tests, which determine that NOB-to-GDP and debt-to-GDP are the only two variables that could be endogenous. In each setting with potentially endogenous variables, we choose the lag order for the IVs by evaluating the model performance based on the results of four tests: the underidentification test (UnderID), weak instrument test (WeakIV), overidentification test (OverID), and autocorrelation test (AR(1)). On the basis of the chosen good-performing lag specifications, we then determine the exogeneity or endogeneity of potentially endogenous variables based on the result of the endogeneity test (EndogTest). The details of the five tests are as follows:

- UnderID. The null hypothesis is that the model is not identified. Rejecting the null (p value less than 0.1) means that the instruments are "relevant", i.e., correlated with the endogenous regressors.

- WeakIV. The null hypothesis is that the instruments are weak, i.e., correlated with the endogenous regressors but only weakly. One can reject the null hypothesis when the Cragg–Donald Wald F statistic is greater than the critical values. Rejecting the null means that the correlations between the IVs and endogenous variables are not weak.

- OverID. The null hypothesis is that the instruments are valid, i.e., uncorrelated with the error terms. Rejecting the null means that the IVs are correlated with the error terms and thus invalid.

- AR(1). The null hypothesis is that the series has no autocorrelation. Rejecting the null means that the series has first-order autocorrelation.

- EndogTest. The null hypothesis is that the specified endogenous regressors can actually be treated as exogenous. Rejecting the null means that the series should be taken as endogenous.

A good-performing model should reject UnderID and WeakIV and not reject OverID or AR(1). We use a $\surd$ symbol to indicate the good-performing results in the summary tables, Tables 13 and 14 below. For EndogTest, on the other hand, we use a $\surd$

symbol to indicate that the test reveals the potentially endogenous variable to indeed be endogenous. There are two things to note here. First, for the specification with more than three potentially endogenous variables, the critical value for the WeakIV test is not available. We skip the result of WeakIV in these cases when evaluating the model performance. Second, for the IV with lagged order 1, the OverID test is not feasible in that the IV with only one lag is the case of just identification, which is beyond the scope of the overidentification test. We skip the result of OverID in this case when evaluating the model performance.

Next, we report the two-step results of the endogeneity test.

Recall that in the first step, we instrument all six potentially endogenous regressors with their lagged terms, conservatively assuming that they are all endogenous, and then test the exogeneity of each one. For the main regression, we have six potentially endogenous variables: debt-to-GDP (debt2gdp), NOB-to-GDP (nob2gdp), three state-interacted (good/normal/poor) debt growth terms, and the long-term interest rate. Since they share the same structure, we do not differentiate the three interaction terms when testing endogeneity and thus test their joint endogeneity.

In the first step, we find that the only variable with a high possibility of endogeneity among the six tested variables is NOB-to-GDP. The four rows of Table 13 report the results for the endogeneity tests on debt-to-GDP (debt2gdp), NOB-to-GDP (nob2gdp), the three interacted debt growth terms (interacted growths), and the long-term rate. Among the four statistical tests, the model performs well in the OverID test and AR(1) test, with the order of IV lags varying from 5 to 20. NOB-to-GDP is determined to be endogenous under all good-performing model specifications, while the other suspects are determined to be uniformly exogenous. Because of the flaws of the model performance in the UnderID test and WeakIV test, we conclude step one conservatively by taking NOB-to-GDP as the only confirmed endogenous regressor and continuing to consider all the other suspects potentially endogenous.

We treat NOB-to-GDP as the only definitely endogenous regressor and move to the second step. In the second step, we instrument NOB-to-GDP and one other potentially endogenous regressor with their own lagged terms and test whether we can reject the exogeneity hypothesis for each.

We cannot reject the exogeneity hypothesis for either of the remaining variables except debt-to-GDP. In the first row of Table 14, we find a rejection of the exogeneity hypothesis for debt-to-GDP when it is tested together with NOB-to-GDP. In the second row, we confirm the joint endogeneity of NOB-to-GDP and debt-to-GDP for good-performing specifications with IV lagged orders from 5 to 20. From the third row to the fifth row, we confirm the exogeneity of the three interacted debt growths. First, the joint endogeneity test returns a result of exogeneity for specifications with lagged IV orders from 5 to 20. We skip the evaluation of the result of the WeakIV test because the critical value is missing. According to Stock and Yogo (2002), the critical value for the WeakIV test is available for specifications with at most 3 endogenous variables. To make the WeakIV critical value available, we repeat the three-term joint endogeneity test by removing NOB-to-GDP. Unfortunately, as shown in the fourth row, in the most favorable specifications with lagged IV orders determined at 9 to 10, the WeakIV test returns the result that the IVs are too weakly related. Despite the poor performance in WeakIV, the three interacted debt growth terms are determined to be exogenous. We further confirm their joint exogeneity by testing their endogeneity solely on unconditional debt growth. Because the states of the economies used for the interactions are essentially predetermined, it is then sufficient to determine the exogeneity of the interacted debt growth terms by confirming that the unconditional debt growth is exogenous. The fifth row of Table 14 shows that unconditional debt growth can be taken as exogenous under the IV specification with a lagged order from 5 to 20. The model performs well in all four tests except for the WeakIV test. Finally, we confirm that the long-term bond yield can be taken as exogenous under specifications with IV lagged orders from 5 to 11.

Table 13: Step 1 of Endogeneity Test

EndogTest On	(1) Lag	(2) UnderID	(3) WeakIV	(4) OverID	(5) AR(1)	(6) EndogTest	(7) Holds For
debt2gdp	5	Not Reject × p=0.6866	NA* Cragg–Donald=2.9097	Not Reject √ p=0.5295	Not Reject √ p=0.3773	Not Reject × p=0.7199	lag 5-20
interacted growths	5	Not Reject × p=0.6866	NA Cragg–Donald=2.9097	Not Reject √ p=0.5295	Not Reject √ p=0.3773	Not Reject × p=0.9897	lag 5-20
nob2gdp	5	Not Reject × p=0.6866	NA Cragg–Donald=2.9097	Not Reject √ p=0.5295	Not Reject √ p=0.3773	Reject √ p=0.0096	lag 5-20
LT rate	5	Not Reject × p=0.6866	NA Cragg–Donald=2.9097	Not Reject √ p=0.5295	Not Reject √ p=0.3773	Not Reject × p=0.1580	lag 5-20

Table 14: Step 2 of Endogeneity Test

EndogTest On	Lag	UnderID	WeakIV	OverID	AR(1)	EndogTest	Hold For
debt2gdp	5	Reject √ p=0.0000	Reject √ Cragg–Donald=44.0638	Not Reject √ p=0.6651	Not Reject √ p=0.4617	Reject √ p=0.0318	lag 5-20
nob2gdp + debt2gdp	5	Reject √ p=0.0000	Reject √ Cragg–Donald=44.0638	Not Reject √ p=0.6651	Not Reject √ p=0.4617	Reject √ p=0.0021	lag 5-20
interacted growths	7	Reject √ p=0.0806	NA* Cragg–Donald=3.4684	Not Reject √ p=0.3317	Not Reject √ p=0.3236	Not Reject × p=0.8143	lag 7**
interacted growths***	9	Reject √ p=0.0895	Not Reject × Cragg–Donald=3.6270	Not Reject √ p=0.5815	Not Reject √ p=0.3967	Not Reject × p=0.7082	lag 9-10
debtGrowth	5	Reject √ p=0.0000	Not Reject × Cragg–Donald=6.7279****	Not Reject √ p=0.3991	Not Reject √ p=0.4963	Not Reject × p=0.5828	lag 5-20
LT rate	5	Reject √ p=0.0000	Reject √ Cragg–Donald=41.7749	Not Reject √ p=0.3717	Not Reject √ p=0.4593	Not Reject × p=0.1411	lag 5-11

√: Food-performing result, meaning that the IV is relevant (UnderID), is not weak (WeakIV) or is valid (OverID) or that the model residual is not autocorrelated (AR(1)) or that the potentially endogenous variable being tested is endogenous (EndogTest);
×: Poor-performing result, meaning that the IV is not relevant (UnderID), is too weak (WeakIV) or is not valid (OverID) or that the model residual follows a first-order autocorrelation process (AR(1)) or that the potentially endogenous variable being tested can be taken as exogenous (EndogTest).
*WeakIV is NA because Stock and Yogo (2002) list the critical value only for cases with at most 3 endogenous variables and 100 IVs; here, the number of our potentially endogenous variables is greater than 3.
**UnderID holds only for lag 7, while other results hold for lags 5–20.
****Conducted removing debt2gdp from the regression.
****According to the Stock–Yogo weak ID test critical values table, this F statistic lies between 10% and 20% of the maximal relative IV bias.

B Proof for Proposition 1

The first-order condition of the government is $MB(X_1) = MC(\varphi_i)$, where

$$MB(X_1) = \frac{1}{X_1 + q(B_2)B_2} \frac{\partial q(B_2)B_2}{\partial B_2}$$
$$MC(\varphi_i) = [1 - D(\phi + B_2 - \varphi_i)]E(\frac{1}{X_2 + \varphi_i - B_2}|X_2 > \phi + B_2 - \varphi_i)$$
$$+ D'(\phi + B_2 - \varphi_i)[E(\ln(X_2 + \varphi_i - B_2)|X_2 > \phi + B_2 - \varphi_i) - \ln(\underline{\phi})]$$

If $\phi + B_{2,i} - \varphi_i < \underline{X}$ for both types, $D(\phi + B_2 - \varphi_i) = D'(\phi + B_2 - \varphi_i) = 0$ and $MC(\varphi_i) = E(\frac{1}{X_2+\varphi_i-B_2}) = \frac{1}{\overline{X}-\underline{X}}[\ln(\overline{X} + \varphi_i - B_2) - \ln(\underline{X} + \varphi_i - B_2)]$. In this case, $MC(\varphi_H) < MC(\varphi_L)$, and in turn, $B_{2,H}(X_1) > B_{2,L}(X_1)$. $B_{2,H}(X_1) \leq \underline{X} + \varphi_L - \phi$ is therefore a sufficient condition for $\phi + B_{2,i} - \varphi_i < \underline{X}$ for both types.

If $\phi + B_{2,i} - \varphi_i > \underline{X}$ for both types, $D(\phi + B_2 - \varphi_i) > 0$ and $D'(\cdot) = (\overline{X} - \underline{X})^{-1}$. The first term in $MC(\varphi_i)$ equals:

$$\frac{\ln(\overline{X} + \varphi_i - B_2) - \ln(\phi)}{\overline{X} - \underline{X}}$$

which is increasing in φ_i. The second term in $MC(\varphi_i)$ is increasing in φ_i if and only if $E(\ln(X_2 + \varphi_i - B_2)|X_2 > \phi + B_2 - \varphi_i)$ is

$$E(\ln(X_2+\varphi_i - B_2)|X_2 > \phi + B_2 - \varphi_i)$$
$$= \frac{\overline{X} + \varphi_i - B_2}{\overline{X} + \varphi_i - B_2 - \phi}[\ln(\overline{X} + \varphi_i - B_2) - 1] - \frac{\phi \ln(\phi) - \phi}{\overline{X} + \varphi_i - B_2 - \phi}$$

The second part on the right-hand side is increasing in φ_i. Taking the derivative of the first part w.r.t. φ_i yields

$$\frac{\overline{X} + \varphi_i - B_2 - \phi \ln(\overline{X} + \varphi_i - B_2)}{(\overline{X} + \varphi_i - B_2)^2}$$

It is positive if and only if

$$\phi < \frac{\overline{X} + \varphi_i - B_2}{\ln(\overline{X} + \varphi_i - B_2)} \tag{8}$$

$\frac{\overline{X}+\varphi_i-B_2}{\ln(\overline{X}+\varphi_i-B_2)}$ is decreasing and then increasing in $(\overline{X} + \varphi_i - B2)$ and reaches a minimum at $\overline{X} + \varphi_i - B_2 = e$. Hence, if at $B_2 = \underline{X} + \varphi_L - \underline{\phi}$, $\overline{X} + \varphi_L - B_2 > e$, $\frac{\overline{X}+\varphi_L-B_2}{\ln(\overline{X}+\varphi_L-B_2)}$

is increasing in φ_L and decreasing in B_2. Therefore, $\phi < \frac{\overline{X}+\varphi_L-B_2}{\ln(\overline{X}+\varphi_L-B_2)}|_{B_2=\underline{X}+\varphi_L-\underline{\phi}} = \frac{\overline{X}-\underline{X}+\underline{\phi}}{\ln(\overline{X}-\underline{X}+\underline{\phi})}$ is sufficient for inequality (8) to hold at any $B_2 < \underline{X}+\varphi_L-\underline{\phi}$, in which case $MC(\varphi_H) > MC(\varphi_L)$ and, in turn, $B_{2,H}(X_1) < B_{2,L}(X_1)$. $B_{2,H}(X_1) \geq \underline{X}+\varphi_H-\phi$ is thus sufficient for $\phi + B_{2,i} - \varphi_i > \underline{X}$ for both types.