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The Fiscal Reaction Function and Public Debt Sustainability: Evidence from G20 Economies

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Abstract

The fiscal reaction function (FRF) remains a valuable tool for gaining insights into a country's fiscal sustainability and output stability. However, there is currently no consensus on how to model it. Previous research has primarily focused on questioning the dominant cubic reaction form and enlarging the sample size. This document investigates the best functional form for the FRF by adopting a nonlinear autoregressive distributed lag approach that accounts for a potential structural break in the data across periods such as the COVID-19 crisis and the Global Financial Crisis. Contrary to what is often assumed empirically, the sample aims for generalization rather than heterogeneity reduction. Using data for G20 members' economies over the period 1998-2021, this thesis finds evidence of a fiscal reaction function with a fourth-degree polynomial (quartic) function form that shows a limited or insufficient fiscal space to overcome future crises.

Keywords: Public Debt; Fiscal Reaction Function; Debt Sustainability; G20

"The traditional attitude of economists toward the public debt is a relatively pessimistic one"

(Withers, 1945, p. 30)

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Chapter 1

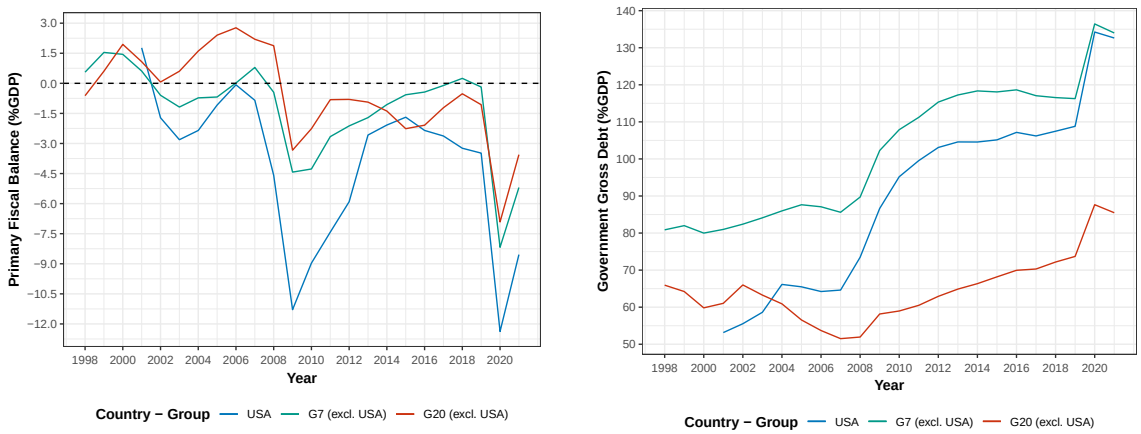
Introduction

According to the IMF (2020), in response to the COVID-19 pandemic-induced global recession, governments took significant and unparalleled fiscal measures in an environment characterized by low-interest rates. In order to overcome the crisis, many countries allocated more financial resources to the health sector by increasing spending on monitoring, containment, and mitigation. The spending eventually reached other sectors that have been experiencing downturns due to spillover effects. This is not surprising since fiscal action often appears stronger in times of crisis when financial bailouts and stimulus spending seem necessary. However, debt is not free (Moreno Badia, Medas, Gupta, & Xiang, 2022), and the new fiscal budget entailed a cost, as public debt has now risen to record highs across the globe. As Figure 1.1 indicates, record highs in debt come along with record lows in primary balance. A critical policy question is whether high and rapidly increasing debt levels could indicate worldwide fiscal space reductions, which tend to be associated with a country's fiscal maneuver constraint to face future crises or the so-called being in a fiscal fatigue position (Ghosh, Kim, Mendoza, Ostry, & Qureshi, 2013).

In this thesis, I developed a new framework perspective, following Ghosh et al. (2013) and Bohn (1998, 2008) theoretical framework, for assessing debt behavior that has been influenced by the Global Financial Crisis (GFC) and COVID-19 Crisis. In the aftermath of two major economic crises, I seek to determine a debt limit beyond which fiscal solvency is at stake for the G20's member countries. Therefore, the current fiscal space is formulated as the difference between the current debt level and its theoretical limit. My model follows Ghosh et al. (2013) structure, where sovereign borrower behavior can be represented by a Fiscal Reaction Function (FRF). The FRF outlines how the Primary Balance reacts to variations in debt levels and the actions of risk-neutral creditors who engage in arbitrage by weighing the anticipated return on Government Debt against the risk-free rate, while factoring in the likelihood of government defaults.

My analysis begins from the premise that governments in G20 members not only behave responsibly by increasing primary surpluses in response to rising debt service to stabilize the public debt-to-GDP ratio at a reasonable level as Mendoza and Ostry (2008) and Bohn (2008) suggested, but also that these governments represent in a

Figure 1.1: Primary Balance and Public Debt of G20 members, 1998–2021 (% of GDP)



(a) Primary Balance **(b)** Government Gross Debt

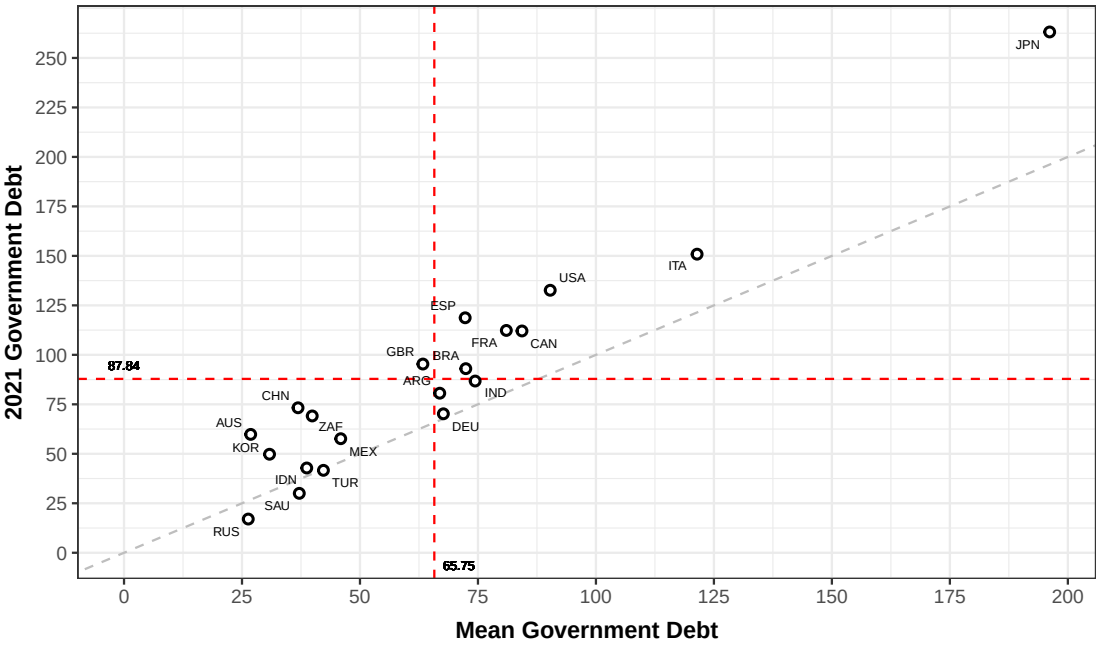
Source: World Economic Outlook Database (2021)

more accurate sample the world economy. In contrast to other studies that narrow the sample into advanced economies (Daniel & Shiamptanis, 2022; Hürtgen, 2021; Iorio & Fachin, 2021) or OECD members (Beqiraj, Fedeli, & Forte, 2018; Everaert & Jansen, 2018) following a homogeneity criterion, this study aims for a generalizable FRF assuming a higher grade of heterogeneity. Moreover, this analysis considers further studies that have shown existing inaccuracies in the theoretical framework implementation when time samples ahead of 2007 are analyzed (Everaert & Jansen, 2018; Iorio & Fachin, 2021).

Applying Ghosh et al. (2013) framework empirically to a sample of 20 representative economies over the period 1998-2021, I provide robust evidence of a nonlinear reduced-form correlation between Public Debt and Primary Balance. In comparison to Bohn (2008) and Ghosh et al. (2013), where the adopted functional form in the FRF is quadratic and cubic (respectively), the relationship here is well approximated by a quartic function. Considering the limitations of a higher-order polynomial function, such as having poor interpolatory properties, poor extrapolatory properties, poor asymptotic properties, and a shape/degree trade-off, I justify why a higher-order polynomial is needed in Chapter 3. Despite the new framework adjustment, the relationship works according to Ghosh et al. (2013). A slightly negative or non-existing relationship exists between the primary balance and debt in early debt levels. As debt reaches a certain point, the primary balance starts to increase, albeit the responsiveness eventually weakens until it comes to a halt and starts decreasing at very high debt levels. This relationship is robust to adding a list of control variables available for the countries' sample.

This thesis contribution is thus two-fold. First, I contrast previous findings with a new empirical implementation that strongly supports Ghosh et al. (2013) theoret-

Figure 1.2: Historical Mean & End-2021 Government Debt, 1998–2021



Source: Author's estimates and *World Economic Outlook Database* (2021).
Notes: Red dashed lines show mean values for each axis while the grey dashed line has a slope of one.

ical framework with the caveat that a significant negative shock not only narrows fiscal space but also changes the form in which the Fiscal Reaction Function is built up. Second, my model provides a new perspective explaining why governments can suddenly lose financing access and why economic crises jeopardize debt sustainability. Furthermore, this approach can quantify how policy and institutional changes could relieve the current countries' fiscal space constraints. In what follows, Chapter 2 serves as a general introduction to the domain of the Primary Balance and Public Debt relationship in the academic literature. Chapter 3 presents the theoretical framework according to Ghosh et al. (2013) and proposes a new function form in the practical implementation. Chapter 4 discusses results for the fiscal reaction function and provides fiscal space estimates for the sample of countries. Chapter 5 outlines the conclusions, limitations of the study, and recommendations for future research.

Chapter 2

Literature Review

The current literature on public debt abounds with analysis addressing its implications for economic growth. However, the central theoretical premise behind this research is that to address economic growth, the debt sustainability concept must be granted (Chudik, Mohaddes, Pesaran, & Raissi, 2017). Thus, the public debt and economic growth relationship will not be reviewed in detail and will only be referred to as appropriate. In this chapter, I first briefly provide historical motives underlying the appearance of Fiscal Reaction Function (FRF) in academic literature. Then, I review the principal theoretical and empirical transformations implemented in the FRF construction. Finally, raising criticism of literature around the current FRF is considered.

2.1 Fiscal Reaction Function Origins

Public debt has leveraged governments through crisis aftermaths since early ancient states (Dyson, 2014). However, as governments reached new record levels of public debt in recent decades, concerns among economists and policymakers have started to arise. For instance, post-war indebtedness provides an ideal scenario of coupled crisis spillovers that have triggered further discussion.

Although the notion of "debt limit" was not modeled, it was clear that "public debts must be retired before they grow so large that they are not adequately backed by the wealth of the nation that has incurred them" (Withers, 1945, p. 30). Despite being trivial, the underlying reasoning in this statement relies on the idea that continuous deficit spending consumes fiscal space and limits any further fiscal action (or debt expansion) to meet the next crisis sufficiently. According to (Withers, 1945), economists were found on one of two sharply opposed sides in the post-war aftermath. On one side were those who strongly suggested a sudden debt retirement and high war taxes. On the other were the so-called New Deal economists that reassured spending by looking for full employment and recommended financing works projects by debt expansions after the war. At a crossroads, a deterministic relationship between public debt and country credit performance becomes necessary in which debt limit and fiscal space definitions take occur.

2.2 Fiscal Reaction Function Progress

The first attempt that provides a Fiscal Reaction Function is attributed to Bohn (1998). The author developed a preliminary theoretical framework applied to U.S. public debt that strongly supports a systematic linear positive relationship between the debt-income ratio and the primary surplus. This approach goes beyond the linear model and considers nonlinearities in the surplus-debt relationship. However, empirical results (using 1983-1995 data) show that a cubic term, or higher order polynomial term, is insignificant. The quadratic term, instead, shows significant results but only under specific scenarios. Considering the empirical evidence, the debt limit concept seems vague since a critical requirement here is that the primary surplus increases at least linearly with d_t at high debt-income ratios ($-d*$). This supposes that at any given negative shock (e.g., wars, economic crises, and low growth), upward movement in the debt-GDP is expected but eventually reversed through primary surpluses.

"How do governments react to the accumulation of debt? Do they take corrective measures, or do they let the debt grow" (Bohn, 1998, p. 949) seems to be the starting point that guides further academic literature regarding the FRF, especially when results are only given by U.S. data sample. Following up on Bohn (2008), the previous analysis may consider limited model scenarios. Although Bohn (2008) continues endorsing a linear function implementation, nonlinearities and time variation are accounted as problematic since lead to weaken model assumptions, thus raising questions about the plausibility of extrapolating it into the future. This approach spread to a broader sample of countries with Iorio and Fachin (2021) reporting that if structural changes are controlled, the outcome in sustainability tests is positive. The indispensable inclusion of structural changes underlies a weak linear relationship that must change in a case-by-case scenario analysis.

Ghosh et al. (2013) identified a paradigm change in how lagged debt interacts with primary surplus among advanced economies. The emerging paradigm emphasizes the non-linear function form that explains this relationship without considering structural changes to maintain significance. To do so, the FRF must be estimated alongside a large variety of systematic determinants of the primary surplus. The catalyst for this shift towards nonlinearities was the urgency for a generalized model that allows an understanding of each country's relationship regardless of the time frame that is being analyzed. This approach argues against the idea that the primary balance would always increase with debt because, above certain high levels of debt, the primary balance might require outputs that exceed GDP. Therefore, assuming nonlinearities suggests that in early debt levels, there is a slightly negative or non-existing relationship between the primary balance and debt. As debt reaches a certain point, the primary balance starts to increase, but the responsiveness eventually weakens until it comes to a halt and starts decreasing rapidly at very high debt levels.

2.3 Fiscal Reaction Function Criticism

A closer look at the literature on FRF comes in handy for policymakers; however, it reveals several areas for improvement. Previous studies were limited to time frames under nonexistent global crises that narrowed the analysis to specific homogeneous groups of countries' affairs. According to D'Erasmo, Mendoza, and Zhang (2016), an early analysis of the public debt considering the 2008 crisis aftermath, debt sustainability in the United States and Europe raises serious questions about the prospects of fiscal adjustment and its consequences. To complete that, this paper uses three approaches in which Bohn (1998) and Ghosh et al. (2013) frameworks take part. Similarly, Romer and Romer (2019) investigate how the conduct of fiscal policy varies with the debt-to-GDP ratio, showing that countries should work hard to keep debt low as an insurance policy for future crises but, facing a scenario with high financial distress, policymakers in countries with good market access could choose not to base post-crisis fiscal policy on the debt ratio. Otherwise, weak fiscal responses could lead to much worse post-crisis output losses.

Although results appear consistent with prior theoretical frame research, they appear inconsistent with recent empirical implementation findings. Iorio and Fachin (2021) re-visit the relationship between the primary balance and public debt, showing that positive evidence in favor of the existence of long-run FRFs is available only for 6 out of 22 countries. These results recommend reconsidering the widespread practice of estimating homogeneous polynomial panel FRFs either using cubic, quadratic, or linear specifications.

Previous research can only be considered the first step toward a more profound understanding of fiscal space estimation. In recent years, there has been an increasing interest in studying public debt's role from a policymaker's standpoint. These studies have narrowed the sample by relying on homogeneity criteria, albeit the studied countries have shown non-significant behavior toward cubic, quadratic, or linear specifications in the Fiscal Reaction Function. Even though new studies span different (recent) time frames, empirical approaches have remained still. In other words, global economic crises have not been considered since the consensus empirical approach does not account for global crises reaction; thus, an essential issue in the literature is the need to address criticism under the leading theoretical framework. This thesis addresses the need for an up-to-date generalizable empirical implementation, so far lacking in the scientific literature.

Chapter 3

Methodology

Notwithstanding the limitations of the methodology work undertaken, the available evidence suggests that a non-linear Fiscal Reaction Function is achievable under robustness improvements in the empirical implementation. The underlying argument favoring its use relies upon the theoretical framework consensus that accounts for fiscal fatigue analysis.

3.1 Theoretical Framework

The government budget constraint can be written as

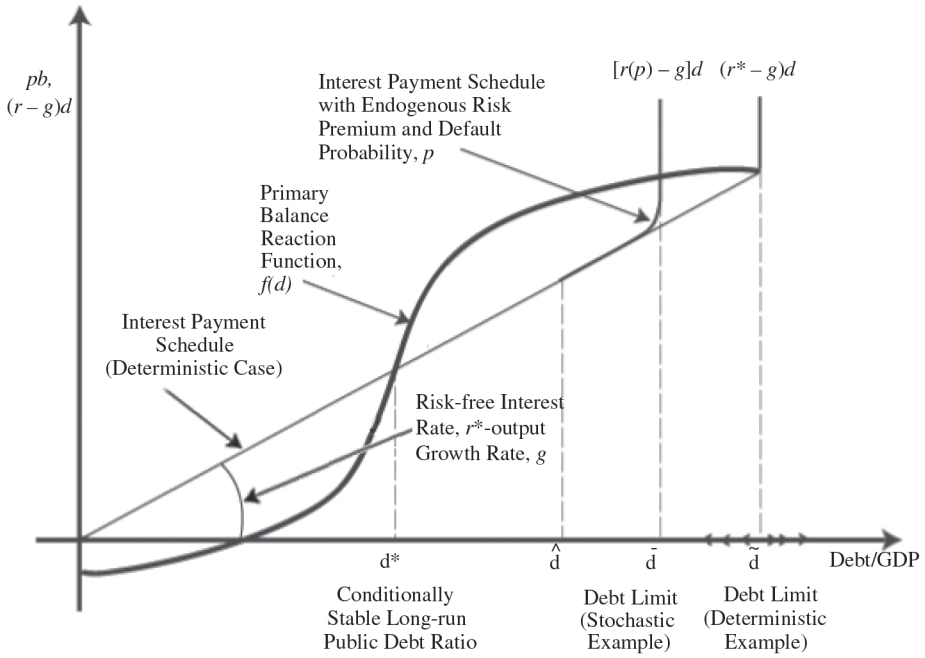
$$d_{t+1} - d_t = (r_t - g)d_t - s_{t+1} \tag{1}$$

Where d is a measure of government debt, s is the seignorage inclusive primary surplus, g is the real GDP growth rate and r is the real interest rate on the debt contracted in period t and due in period t + 1. According to the literature, I consider debt and primary balance normalized by GDP. Following Ghosh et al. (2013) framework, the government budget constraint must satisfy three assumptions to provide a nonlinear relation between lagged debt and primary balance as shown below.

$$s_{t+1} = \mu + f(d_t) + \varepsilon_{t+1} \tag{2}$$

The fundamental assumptions of the models are: (I) Fiscal reaction function under fiscal fatigue assumption supposes that finite support in debt is plausible since the primary deficit or surplus cannot exceed 100% of GDP. (II) The default rule assumption supposes that the government would default if and only if debt exceeds the debt limit (d^*). The default rule here stated thus takes the form shown in Eq. 3. (III) Risk-neutral creditors supposed that a finite interest rate compensates risk-neutral lenders for the risk of default. It should be noted that assumptions I-III are sufficient to guarantee the existence of $\bar{d}$ (finite debt limit). Any government debt to ever exceed that limit would tend to rise without bounds; hence, cutting off market access, the interest rate would become infinite, and the default becomes imminent.

Figure 3.1: Determination of Debt Limit in Deterministic Example



Source: (Ghosh et al., 2013, p. 11)

$$D_{t+1} = \begin{cases} 1 & \text{if } d_{t+1} > \bar{d} \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

Based on these assumptions, the deterministic case is easy to solve. In the deterministic case, the market will lend at the risk-free rate until the debt limit is reached, and for any level of debt above this point, the market will charge an infinite interest rate. As previously noted, the debt limit refers to the maximum amount of debt that a government can sustainably service. As such, determining the debt limit involves identifying the largest root in the following equation:

$$\mu + f(\bar{d}) = (r^* - g)\bar{d} \tag{4}$$

As shown in Figure 3.3, the equilibrium level of debt, the debt limit, and the interest payment schedule can all be illustrated for this deterministic case. As a rule, there will be two stationary equilibria. The last is the second stationary equilibrium that corresponds to the debt limit implied by the model, but the lower intersection denoted as d^*, or the first stationary equilibrium, corresponds to the long-run public-debt ratio to which the economy converges conditionally. More simply, if the government maintains $d < \bar{d}$ condition, the first stationary equilibrium is achievable, however, the $d > \bar{d}$ condition left no space for any stationary equilibrium ergo meaning imminent default.

3.2 Empirical Implementation

This section applies the theoretical framework developed previously based on the IMF's "World Economic Outlook Database" (WEO) to a sample of 20 economies that constitute the G20[1]. The G20 selection relies upon the same principles on which it was established. The G20 was founded in response to several world economic crises and became relevant after the Global Financial Crisis; moreover, it accounts on average for 80% of the global GDP, 60% of the world population, and 75% of global exports.

Table 3.1: Descriptive Statistics Main Variables, 1998-2021.

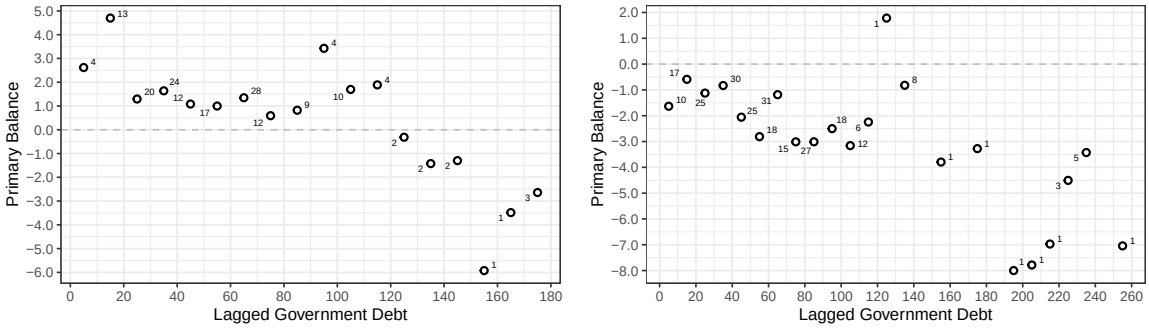
Variables	Primary Balance (% GDP)				Gross Debt (% GDP)			
	Mean	Max	Min	SD	Mean	Max	Min	SD
Argentina	-0.62	5.21	-6.21	3.05	66.90	147.20	34.14	30.72
Australia	-1.28	1.92	-7.61	2.79	26.84	59.80	9.67	15.01
Brazil	0.80	3.78	-9.14	3.08	72.42	98.68	60.19	11.20
Canada	0.28	5.76	-10.93	3.68	84.33	117.75	66.86	12.21
China	-1.82	0.44	-9.73	2.30	36.87	73.25	20.66	14.69
France	-1.68	1.24	-7.87	2.23	81.01	115.15	58.34	18.19
Germany	0.46	2.66	-3.89	1.87	67.66	81.99	58.19	7.36
India	-3.81	0.26	-7.59	1.91	74.40	90.05	66.40	6.99
Indonesia	0.46	3.84	-4.10	1.89	38.72	87.43	22.95	17.48
Italy	1.14	4.49	-6.31	2.32	121.43	155.31	103.89	15.33
Japan	-5.03	-1.67	-8.73	2.33	196.14	263.14	116.02	42.56
Korea	1.36	5.10	-2.72	1.65	30.83	49.77	14.32	10.73
Mexico	0.18	2.61	-2.06	1.36	45.92	60.29	37.20	6.89
Russia	1.51	8.34	-6.19	4.07	26.32	135.19	7.44	30.11
Saudi Arabia	1.57	28.56	-17.85	11.96	37.13	102.99	1.56	36.11
South Africa	0.01	3.41	-5.62	2.41	39.88	69.42	24.04	12.98
Spain	-1.82	3.37	-9.95	4.23	72.29	119.95	35.76	26.92
Turkey	1.04	4.61	-3.20	2.53	42.25	75.51	27.36	14.18
United Kingdom	-2.50	3.00	-11.72	3.49	63.33	102.60	33.89	24.04
United States	-4.01	1.76	-12.37	3.72	90.31	134.23	53.14	24.72

Source: Author's estimates and *World Economic Outlook Database* (2021).

[1]All members of the European Union (EU) constitute the G20, however, this study only considers Spain as a representative of the EU since it is the only invited each year as a permanent guest.

The data set starts in 1998, a year before the G20 was founded, while the final year is 2021. Table 6.1 provides a technical overview of each variable retrieved, allowing for a better understanding. The descriptive statistics obtained from the preliminary analysis are summarised in Table 3.1 and Table 6.2, accounting for Primary Balance and Gross Debt (Main Variables), and GDP, Inflation, and Government Expenditure (Control Variables) respectively. Following Table 3.1 results, it is vital to highlight that some countries display high standard deviation (SD). For instance, Saudi Arabia shows a high SD for the Primary Balance, while Japan reports a high SD for the Gross Debt. It is possible to hypothesize that these outliers are due to specific country-related conditions, whereas Saudi Arabia's reliance on oil (Osintseva, 2022) or Japan's debt issue (Akram, 2019). It is also essential to consider that countries may change a regime change within the time frame analyzed. A closer inspection of Figure 3.2 shows a clear trend of a significant decrease in Primary Balance levels after 2008.

Figure 3.2: Primary Balance and Public Debt, 1998-2021 (% of GDP)



(a) Before 2008 **(b)** After 2008

Source: Author's estimates and *World Economic Outlook Database* (2021).
Notes: Mean Primary Balance for G20 economies. Calculated for a given range of debt as every 10% (i.e. 0-10%, 11-20%, 21-30%, etc.).

Having said that, the first question regarding the G20 data is whether the "fiscal fatigue" behavior consensus postulated by Ghosh et al. (2013) remains reliable. According to Iorio and Fachin (2021), this consensus just applies to a few countries and even less after 2008. Given the plausible regime change, I expect a primary deficit trend regardless of the debt level assumed since economies have faced two global crises with fiscal expansion. This expectation is mainly confirmed by the visual analysis of the summary plots in Figure 3.2 that follows Ghosh et al. (2013) idea of a non-linear justification scatter plot process. In other words, previous findings failed when the analysis included cross-country crises. Therefore, I suggest the following fixed effects panel regression as the Fiscal Reaction Function:

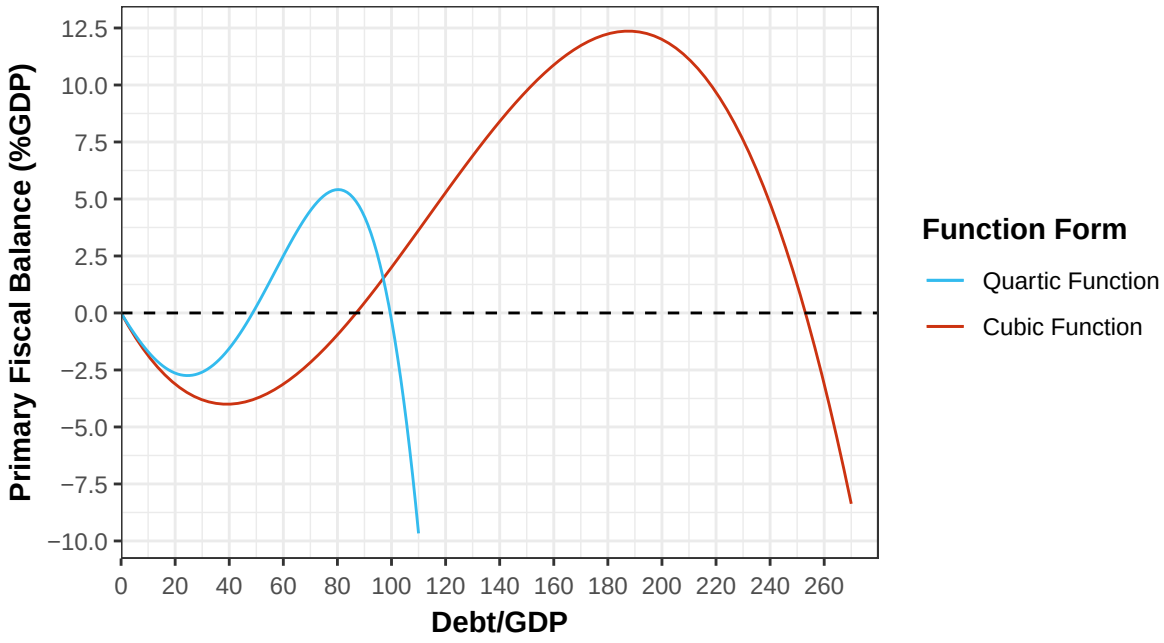
$$Y_{it} = \alpha_i + \beta_{21} X_{2it-1} + \beta_{22} X^2_{2it-1} + \beta_{23} X^3_{2it-1} + \beta_{23} X^4_{2it-1} +$$

$$\beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + \beta_6 GFC_t + \beta_7 COVID_t + \varepsilon_{it} \quad (5)$$

Where Y_{it} is the primary balance (as a percentage of GDP), α_i represents each country's fixed effect, and X_{2it-1} is the government-lagged debt (allowing for a quartic function or fourth-degree polynomial function to capture the two inflection points in the steeper curvature of the response). Moreover, I include a range of control variables such as the government expenditure gap to measure the effect of temporary fluctuations in the government budget (e.g., increases or decreases in the military budget), the lagged inflation rate to examine the possible effects of inflation, and the output gap to control for the effect of business cycles. Additionally, the FRF considers the two dummy variables that separate the effect of the major crises, the Global Financial Crisis (2008) and the Covid-19 crisis (2020-2021). Under these parameters, the estimation of the FRF raises econometric issues related to the dependence of lagged debt on past values of the primary balance that should be addressed accurately. First, lagged debt is necessarily correlated with the unobserved country-specific determinants of the primary balance as described in Ghosh et al. (2013). Therefore, countries that can generate higher primary balances on average due to favorable fixed effects, would tend to have lower levels of public debt. The control for this source of endogeneity bias is considered in Eq. 5 through the inclusion of country fixed effects as α_i. Second, the error term must consider that, even when country fixed effects are included, the debt dynamics would render lagged debt in (2) endogenous; thus, inducing a downward bias in its estimated coefficient. In the estimation below, this possible bias is addressed by allowing for serial correlation in the error term as modeling (ε_{t+1}) as ($\rho\varepsilon_t + \upsilon_t$) or AR (1) process.

Moreover, as a previously established rule, the FRF must follow assumptions I-III to guarantee fiscal fatigue behavior. Although the function form has changed, the analysis remains still. In Figure 3.3, the scatter plot illustrates a comparison between the debt coefficients found in this research (quartic function) and the coefficients provided by Ghosh et al. (2013). Thus, the polynomial function form used in Eq. 5 satisfies assumptions and provides a curvature that highlights the new reduced and risky fiscal space.

Figure 3.3: Fiscal Reaction Function Form



Source: Author's estimates and Ghosh et al. (2013). *Notes:* The Quartic Function Form (Blue Line) illustrates lagged debt coefficients in Model 3 (Table 4.1) while the Cubic Function Form (Red Line) illustrates lagged debt coefficients retrieved from Ghosh et al. (2013) in 1970-2007 case scenario.

Chapter 4

Empirical Results

In this chapter, I present the primary balance reaction function estimates. In the same stage, I show how my proposal FRF form is a better fit than the mainstream cubic function. After that, I determine the appropriate interest rate-growth rate differential. Finally, I calculate each country's debt limit and associated fiscal space (defined as the difference or space between current debt and estimated debt limit).

The Fiscal Reaction Function estimation results are retrieved from Eq. 5 and presented in Table 4.1. Estimates for three different models are considered, where (1) accounts for the consensus cubic form specification and (2) - (3) implements the fourth-degree polynomial. Model (3) takes into account a panel regression with AR (1) Prais-Winsten correction and panel-corrected standard errors. Overall, the presented results indicate that the coefficients of the quartic functional form capture the increasing but slowing response of the primary and ensure that quartic coefficients are statistically more significant than cubic ones. Furthermore, the estimated coefficients indicate that the marginal reaction of the primary balance to lagged debt begins to diminish when debt levels reach approximately 80% of GDP, eventually turning negative as the debt ratio approaches 100% of GDP. These results support the theoretical framework but contrast with the empirical implementation of Ghosh et al. (2013), which shows the expected primary balance to lagged debt relationship behavior but starts to decline around 90-100% and becomes negative when debt approaches about 150% of GDP. Figure 3.3 compares both function forms, showing that economies face tighter fiscal spaces for recent reference periods.

The estimated coefficients included in the FRF as control variables are also statistically significant and broadly in line with previous studies. For instance, the government expenditure gap variable captured temporary increases in government outlays and negatively affected the primary balance in models (1), (2), and (3). The primary balance in the model (3) responds positively to the inflation and output gap. Additionally, the estimated coefficients for the Global Financial Crisis (GFC) and COVID-19 highlight remarkable differences in the response of the primary balance; for instance, the estimated coefficients seem favorable for the GFC and harmful for the COVID-19 crisis across the sample. Although the GFC certainly affected multiple countries besides the USA, the spillover seems not to have reached most of the G20

Table 4.1
Estimation Results for the Fiscal Reaction Function, 1998-2021.

	Cubic Form	Quartic Form	
	(1)	(2)	(3)
Lagged Debt	-0.27265^{***}	-0.39217^{***}	-0.1955^{***}
	(0.026)	(0.033)	(0.050)
Lagged Debt^2	0.00033	0.00707^{***}	0.00173
	(0.009)	(0.001)	(0.001)
Lagged Debt^3	0.00002^{*}	0.00026^{***}	0.00008^{**}
	(0.001)	(0.001)	(0.001)
Lagged Debt^4		-0.000002^{***}	-0.0000008^{*}
		(0.001)	(0.001)
Output gap	0.13825^{*}	0.09778	0.1304^{**}
	(0.061)	(0.060)	(0.063)
Government Expenditure	-0.81307^{***}	-0.81624^{***}	-0.9846^{***}
	(0.095)	(0.091)	(0.132)
Inflation	0.00907^{*}	-0.00197	0.05792^{**}
	(0.023)	(0.022)	(0.028)
COVID-19	-2.4946^{***}	-2.5235^{***}	-0.5697
	(0.724)	(0.698)	(0.801)
GFC	1.4159^{**}	1.1618^{*}	1.043^{*}
	(0.614)	(0.594)	(0.560)
Observations	424	424	424
No. Countries	20	20	20
R^2	0.52	0.56	0.54
AR (1) coef.	$-$	$-$	-0.96

Source: Author's estimates.
Notes: Robust standard errors reported in parentheses; ***, ** and * denote significance at 1%, 5% and 10% levels respectively.

members' sample economies. By contrast, the COVID-19 crisis suggests a significant negative response across the sample for either considering a cubic form (1) or quartic form (2) in the regression, while non-significance in (3) is considered as a result of AR (1) incorporation.

Along with FRF estimates, estimates of the applicable interest rates on public debt are required to retrieve the fiscal space from Eq. 4. From the historical average approach, the interest rate–growth rate differentials are reported, as shown in Table 4.2. The differential results indicate that most economies have grown more than the paid interests. It is noteworthy that G20 economies have considerably increased debt levels up to the point that current levels are significantly high by historical standards. In addition to these findings, the historically high debt levels coupled with the interest rate–growth rate differentials highlight G20 economies that hold

Table 4.2
Public Debt and Interest Rate–Growth Rate Differential (%)

	Debt/GDP			Interest rate - growth rate differencial
Country	2000	2008	2020	Historical*
Argentina	40.8	53.8	102.7	−0.288
Australia	19.5	11.7	57.8	−0.017
Brazil	65.5	62.3	98.6	0.032
Canada	80.4	67.8	117.7	−0.017
China	22.9	27.1	68.0	−0.094
France	58.8	68.7	115.1	0.004
Germany	59.3	65.6	68.7	−0.018
India	73.6	72.8	90.0	−0.063
Indonesia	87.4	30.2	39.7	−0.038
Italy	109.0	106.1	155.3	0.025
Japan	135.6	180.7	258.9	−0.0009
Korea	16.6	26.9	48.8	−0.013
Mexico	40.3	42.4	60.2	−0.012
Russia	55.8	7.4	19.2	−0.043
Saudi Arabia	86.7	12.0	32.3	−0.008
South Africa	37.9	24.0	69.4	0.004
Spain	57.8	39.7	119.9	0.015
Turkey	51.3	37.7	39.5	−0.080
United Kingdom	36.6	49.0	102.6	0.0008
United States	33.3	73.4	134.2	−0.010

Source: IMF's WEO database.
* Average of 2010–2020 based on the implied interest rate on public debt.

a high degree of indebtedness (>100% debt ratio) and show a positive differential. This implies that some economies, such as France, Italy, and Spain, started to get highly indebted without even growing as much as the effective paid interest. On the other hand, the limitations of the historical approach for the interest rate–growth rate differentials naturally presume that countries have paid off debt interests on a year-by-year basis, and Argentina is the exception to the rule. Argentina is the only country in the sample that delivery defaulted on its debt, which allows for 0% interest payments and positive growth, thus, spoiling the historical approach measure.

Table 4.3
Long-run d^* and $\bar{d}$ under Projected Market Interest Rate-Growth Rate (% of GDP), 1998-2021

Country	Debt (end-2021)	d^*	$\bar{d}$
Argentina	80.61	8.12	124.35
Australia	59.80	47.06	101.33
Brazil	93.01	49.03	96.77
Canada	112.05	41.41	102.80
China	73.25	32.76	109.99
France	112.33	53.00	97.68
Germany	70.20	36.68	103.79
India	86.75	47.80	104.40
Indonesia	42.82	38.75	104.95
Italy	150.85	44.55	98.63
Japan	263.14	62.38	93.59
Korea	49.77	20.35	104.40
Mexico	57.62	39.83	102.74
Russia	17.02	30.62	106.57
Saudi Arabia	30.02	20.30	103.92
South Africa	69.12	46.89	99.74
Spain	118.71	57.93	94.71
Turkey	41.64	27.50	109.67
United Kingdom	95.34	56.62	96.44
United States	132.62	65.29	91.18
Mean	87.83	41.34	102.38

Source: Author's estimates and IMF's WEO database.

Tables 4.1 and 4.2 provide the coefficients that allow for Eq. 4 solving [1]. From Table 4.1, Model (3) results are chosen, and Figure 6.2 illustrates its performance summary. Extracting the roots from Eq. 4, the debt limits, $\bar{d}$, as well as the long-run debt ratio to which each country's public debt conditionally converges, d^*, are presented in Table 4.3. This table is quite revealing in several ways. First, the Asian region displays the highest debt limits in the sample as China (109.99), Turkey (109.67), Russia (106.57), Indonesia (104.95), and Korea (104.40)[2], which denote better sustainability debt levels. Second, the last debt level mean (end-2021 in our study)

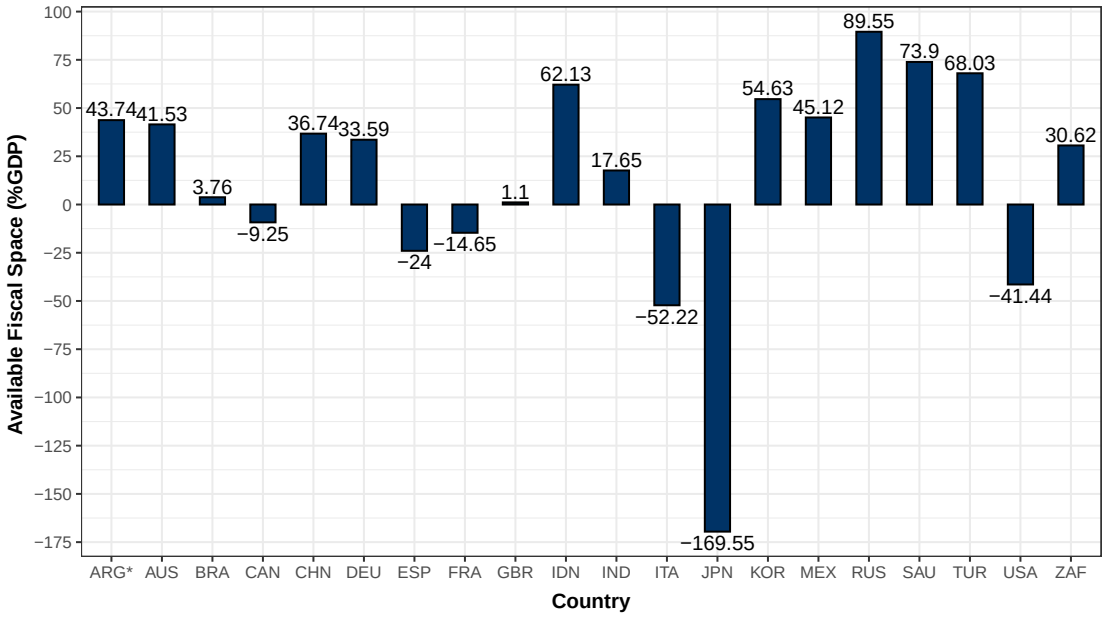
[1]Fixed effects are not shown in Table 4.1 but illustrated in Figure 6.3 instead.

[2]Argentina is no longer considered since its highest debt limit value came from the issue discussed above.

and the long-run debt ratio mean (d^*) are comparable to Ghosh et al. (2013) results. Nonetheless, there is a major difference between debt limits ($\bar{d}$). The current study found a debt limit of around 102%, while Ghosh et al. (2013) suggested around 195% (under the same historical approach methodology for the interest rate–growth rate differentials). Interestingly, these results suggest that economies in a high-indebted world have far less maneuvering space than expected.

Turning now to the fiscal space analysis, some countries stand out for surpassing their associated debt limit while others experience great fiscal solvency. As shown in Figure 4.1, Japan, Italy, the United States, Spain, France, and Canada present a negative fiscal space that denotes a higher default risk and future struggles in fiscal expansion. Some of the issues emerging from this finding relate specifically to the question, "how high can the debt limit be surpassed without compromising the national economy?". Theoretically speaking, there is no equilibrium point once the debt limit is surpassed, thus, ensuring an imminent default scenario in the foreseeable future. Correspondingly, in a follow-up study, Moreno Badia et al. (2022) also reported record public debt levels and found that beyond certain debt levels, the likelihood of crises increases regardless of the interest-growth differential. Nevertheless, these findings could have described transitional fiscal spaces; therefore, imminent default is granted only under *ceteris paribus* conditions.

Figure 4.1: Fiscal Space by Country



Source: Author's estimates

The present study raises the possibility that non-available fiscal space countries may not face a rollover crisis, but instead, the crisis momentum can play out for some time before default actually occurs. In an analysis of sovereign debt markets, Lorenzoni and Werning (2019) describe this phenomenon as a "slow-moving crisis". This

slow-moving crisis mechanism differs from the rollover crisis as it considers investors forming expectations as the future default probabilities. In other words, investors' confidence allows higher debt levels even when debt limits are surpassed. Still, if expectations suddenly plunge, so economies will. Policymakers, thereby, should do one's utmost to increase government income rapidly in the short term and stimulate economic growth without increasing government expenditure in the long term. Increasing government income cannot rely only on taxes increases and should be studied carefully since high debt levels along taxes increases have proven self-defeating (Fotiou, 2022). Countries with barely positive available fiscal space, such as the United Kingdom and Brazil, might follow similar fiscal policies to distance themselves from their debt limits.

In contrast to countries with tight fiscal maneuvering, Figure 4.1 also displays economies with healthier indebtedness levels. For instance, India, South Africa, Germany, China, Australia, and Mexico account for enduring debt sustainability even throughout global and extended crises. Furthermore, the healthiest indebtedness levels are described here as economies with an available fiscal space above 50%, which denotes substantial fiscal maneuvering for Russia, Saudi Arabia, Turkey, Indonesia, and South Korea. Nonetheless, these findings may be limited by considering market access.

Chapter 5

Conclusion

This thesis aimed to develop a simple technique for understanding public debt sustainability throughout two global crises and comparing the resultant properties and estimates with previous findings. As a result of this research, the consensus framework remains empirically accountable by introducing a quartic form in the Fiscal Reaction Function. This empirical approach found that economies face tighter fiscal spaces and higher debt levels above their debt limits. Therefore, displaying a world economy where countries coexist from ample or limited maneuvering space conditions to ones theoretically incapable of overcoming a new crisis. These results contribute to the vast literature on public debt sustainability by enhancing the empirical implementation of the Fiscal Reaction Function and providing a fresh perspective on countries' indebtedness.

This thesis applies the framework empirically to a sample of G20 members' economies from 1998-2021 and finds that the marginal response of the primary balance to lagged debt is non-linear, which empirically supports the fiscal fatigue characteristics described in Ghosh et al. (2013). Altogether, the FRF estimates, considering each country's fixed effect and the historical interest rate–growth rate differential, illustrate that the debt limits and fiscal space vary remarkably across countries. Interestingly, the marginal response of the primary balance to lagged debt remains positive for debt levels above 41% but starts to decline when debt reaches 80% until it becomes negative around 102%. For the countries accounted, fiscal space estimates imply little or no available room for fiscal maneuver for Canada, France, Italy, Japan, Spain, and the USA. By contrast, China, Turkey, Russia, Indonesia, and South Korea demonstrate ample fiscal spaces.

This project challenged conventional ideas about the generalized relationship between Primary Balance and Public Debt by reading the unfolding of the Fiscal Reaction Function as a quartic form response. In doing so, this thesis revises the ways in which debt limit has been theorized by insisting on the inherent non-linear relationship that characterizes fiscal fatigue behaviors. Speaking from a policymaker's point of view, debt limit estimates enable to point out economies where fiscal consolidation may be urgently needed to ensure that debt remains on a sustainable path and that shocks, such as COVID-19 and the Global Financial Crisis considered, do not

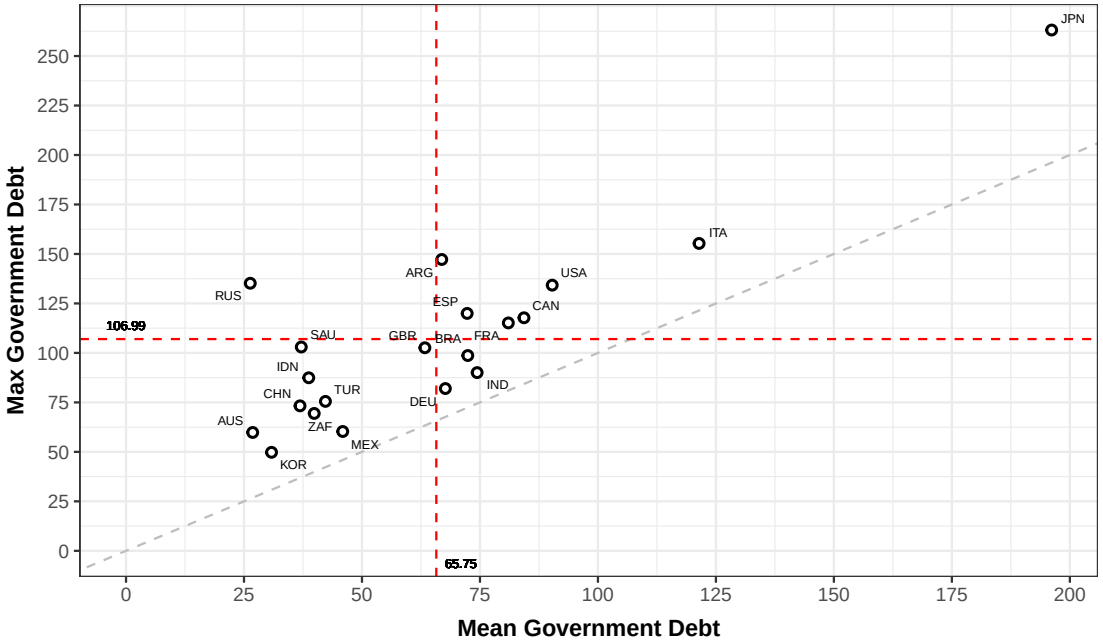
derail sustainability. However, future research should consider the potential effects of unobserved control variables more carefully; for instance, Saudi Arabia's surplus might be highly influenced by oil prices which might not be as significant in the general case scenario.

Chapter 6

Appendix

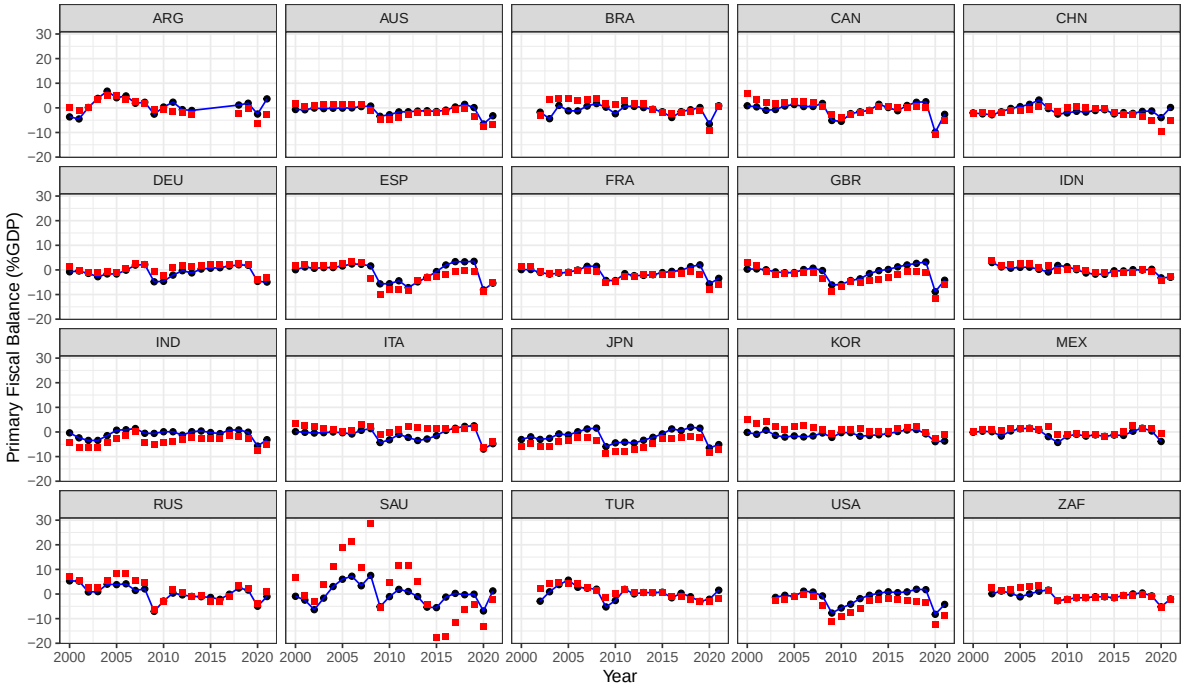
6.1 Figures

Figure 6.1: Historical Mean & Max Government Debt, 1998–2021



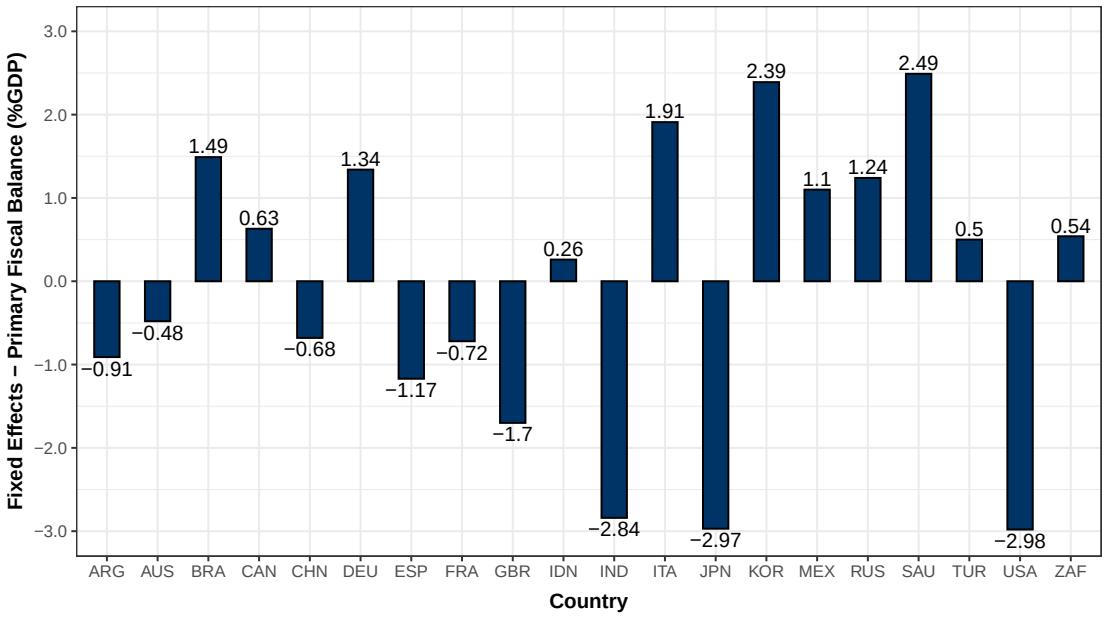
Source: Author's estimates and *World Economic Outlook Database* (2021).
Notes: Red dashed lines show mean values for each axis while the grey dashed line has a slope of one.

Figure 6.2: Model (3) Performance Summary



Source: Author's estimates. *Notes:* Blue dots/lines report model output while red squares display actual values.

Figure 6.3: Fixed Effects by Country



Source: Author's estimates

6.2 Tables

Table 6.1: Explanatory variables and data sources

Subject Code	Subject Descriptor	Subject Notes
GGXONLB_NGDP	General government primary net lending/borrowing	Primary net lending/borrowing is net lending (+)/borrowing (-) plus net interest payable/paid (interest expense minus interest revenue).
GGXWDG_NGDP	General government gross debt	Gross debt consists of all liabilities that require payment or payments of interest and/or principal by the debtor to the creditor at a date or dates in the future. This includes debt liabilities in the form of SDRs, currency and deposits, debt securities, loans, insurance, pensions and standardized guarantee schemes, and other accounts payable.
GGX_NGDP	General government total expenditure	Total expenditure consists of total expense and the net acquisition of nonfinancial assets. Note: Apart from being on an accrual basis, total expenditure differs from the GFSM 1986 definition of total expenditure in the sense that it also takes the disposals of nonfinancial assets into account.

Continued on next page

Table 6.1: Explanatory variables and data sources (Continued)

NGDP_RPCH	Gross domestic product, constant prices	Annual percentages of constant price GDP are year-on-year changes; the base year is country-specific. Expenditure-based GDP is total final expenditures at purchasers' prices, less the f.o.b. value of imports of goods and services.
PCPIPCH	Inflation, average consumer prices	Annual percentages of average consumer prices are year-on-year changes.
GC.XPN.INTP.CN	Interest payments (current LCU)	Interest payments include interest payments on government debt–including long-term bonds, long-term loans, and other debt instruments–to domestic and foreign residents.

Source: *World Economic Outlook Database* (2021) and *Government Finance Statistics* (2021)

Table 6.2: Descriptive statistics control variables, 1998-2021.

Variables	GDP (Δ %)				Inflation (Δ %)				Government Expenditure (% GDP)			
	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Argentina	1.68	10.20	-10.89	6.31	15.73	53.54	-1.16	16.28	32.31	42.09	21.85	7.13
Australia	2.87	4.69	-2.17	1.37	2.44	4.45	0.85	1.04	36.72	44.67	34.34	2.49
Brazil	2.07	7.52	-3.87	2.96	6.11	14.71	3.19	2.57	38.38	42.86	34.48	1.80
Canada	2.15	5.17	-5.23	2.27	1.89	3.39	0.29	0.73	41.23	53.00	38.37	3.08
China	8.58	14.24	2.24	2.39	1.90	5.90	-1.40	1.89	24.58	36.37	12.73	7.23
France	1.45	6.97	-7.98	2.66	1.47	3.16	0.08	0.82	55.18	61.71	51.65	2.64
Germany	1.22	4.18	-5.69	2.33	1.47	3.21	0.24	0.79	46.42	51.48	43.39	2.21
India	6.48	10.26	-6.59	3.40	6.47	13.12	3.42	2.92	27.39	31.05	25.40	1.41
Indonesia	4.00	7.44	-13.12	4.11	8.91	58.44	1.56	11.38	17.53	19.50	15.07	1.29
Italy	0.38	6.63	-9.02	2.98	1.72	3.49	-0.14	1.05	49.15	56.99	46.53	2.63
Japan	0.51	4.09	-5.69	2.12	0.09	2.75	-1.33	0.84	36.95	44.52	33.05	2.84
Korea	3.83	11.46	-5.12	3.22	2.48	7.51	0.38	1.59	19.59	26.30	16.46	2.37
Mexico	1.91	5.16	-8.16	3.14	5.55	16.56	2.71	3.57	24.93	28.65	20.32	3.06
Russia	3.29	10.04	-7.82	4.40	13.82	85.74	2.87	16.53	33.92	39.68	29.04	2.90
Saudi Arabia	2.83	11.21	-4.13	4.03	1.64	6.12	-2.12	2.26	33.85	40.81	26.68	3.85
South Africa	2.27	5.60	-6.43	2.59	5.51	11.02	1.38	1.93	27.47	34.86	22.21	3.67
Spain	1.68	5.12	-10.82	3.60	2.03	4.07	-0.50	1.45	42.75	52.43	38.37	4.03
Turkey	4.64	11.20	-5.75	4.60	21.30	84.72	6.25	22.06	35.29	44.03	31.54	3.07
United Kingdom	1.70	7.44	-9.27	3.00	1.96	4.46	0.04	1.02	39.59	48.92	33.93	3.88
United States	2.21	5.67	-3.40	2.03	2.21	4.68	-0.32	1.12	36.49	45.29	32.8	3.17

Source: Author's estimates and *World Economic Outlook Database* (2021).

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