Financial Crises and Soreveing Debt Sustainability Risks: Exploring the Link*

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Abstract

Recent theoretical studies have highlighted that both the level of public debt and the cost of servicing debt ($r - g$) play a role in the sustainability of the public finances. This paper builds on this literature and is the first to empirically examine the link between financial crises and the total public debt burden, that is, the interaction between the level of debt and $r - g$. Our empirical analysis spans 150 years and includes 18 advanced economies. This analysis reveals three main findings. First, we document that the level of public debt and the interest-growth differential exhibited contrasting patterns over extended periods of time, strengthening the argument to use both of them in an analysis that includes public debt sustainability risks. Second, we uncover a plausible causal effect that runs from the total burden of public borrowing prior to a financial crisis to the severity of the crisis. We demonstrate that high levels of public debt burden imply that recessions experience deeper economic downturns and falls in investment, deflationary pressures and a credit crunch. Third, we show that, whilst sovereign debt sustainability risks do not systematically precede financial crises, these crises, when they occur, do systematically worsen both the level and the cost of public debt, thus increasing the likelihood of sovereign debt crises in the aftermath of financial crises.

Key Words: financial crises, sovereign debt sustainability, $r - g$, local projections.
JEL Codes: E62, G01, H63

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1 Introduction

The empirical analysis of public debt sustainability has traditionally used the *stock approach* as a proxy of public finances stability (Reinhart and Rogoff, 2009, 2010, Jordà *et al.*, 2016). However, recen theoretical research has argued that not only public debt but also the unit cost of servicing the debt, defined as the difference between the real interest rate and the output growth rate, $r-g$, is a crucial factor to determine public debt sustainability (Barrett, 2018; Blanchard, 2019; Mehrotra and Sergeyev, 2021; Mian *et al.*, 2022).[1] This stream of the literature stresses the relevance of considering $r-g$ as an additional component to determine whether the actual level of public debt can be regarded as sustainable or, on the contrary, can potentially lead to periods of public instability and ultimately to public default.

In this paper, we build on this insight to provide a historical analysis of the relationship between financial crises and sovereign debt sustainability using both the level of public debt and $r-g$. The motivation for adding $r-g$ to measure public finances vulnerabilities is further reinforced by a new historical stylized fact documented here. We show that, for a comprehensive set of advanced economies spanning the last 150 years, there has been recurring historical episodes of divergent trajectories between the debt-to-GDP ratio and $r-g$. This suggestive empirical evidence implies that advanced countries have recurrently experienced historical economic episodes when both a high debt to GDP ratio and a low or even negative unit cost of servicing the debt have simultaneously co-existed. This empirical evidence highlights the importance of considering the total cost of servicing the debt, i.e., the interaction between the level of public debt and $r-g$, and not only the level of public debt, when accounting for public debt sustainability.

Building on that novel evidence, we examine a plausible causal link between the total cost of servicing the debt and the extent of the impact of financial crises on output, investment, prices, credit and debt. Our results show that when the initial total cost of servicing the debt is historically high, the economy is characterized by larger output (and investment) losses, sluggish recoveries following financial crises, credit crunches, deflation and soaring debt levels. We do so by applying a novel approach to measure the public debt burden prior to the crisis. In particular, we argue that for our estimates to be consistently estimated the total debt burden should be computed using real-time information, incorporating a forward-looking perspective

[1] The use of the term *stock approach* is due to Mehrotra and Sergeyev (2021). They label as *stock approach* those studies that focus on the level of the public debt-to-GDP ratio or its distribution. The *flow approach*, in turn, refers to those studies that focus on the trajectory of the debt-to-GDP ratio and consider that $r-g$ plays a major role in the dynamics of public debt level.

that captures the expected future debt burden, and being non-systemically contaminated by post-crisis severity. We argue that crisis severity anticipation is very unlikely within our empirical setting because financial crises have been shown to be extremely hard to predict with historical real-time data (Gadea Rivas and Perez-Quiros, 2015; Krishnamurthy and Muir, 2017; Boyarchenko *et al.*, 2022). Furthermore, to the best of our knowledge, there is no empirical evidence regarding agents' ability to anticipate the severity of a financial crisis prior to the crisis itself. Therefore, our key empirical assumption is that the total debt burden prior to the peak is exogenous to the posterior crisis severity, that is, there is no crisis severity anticipation.

The other main empirical challenge comes down to measuring a key element of the total debt burden, namely, long-term economic growth (g). We rely on current economic growth to approximate long-term economic growth. Through an examination of our panel spanning from 1870 to 2017 across 18 advanced economies, we find a consistent positive empirical relationship between current and future economic growth across different horizons. Therefore, we use the current economic growth to proxy for future economic growth in our empirical measure of the overall debt burden. This approach allows us to capture the expected future total public debt burden based on the available information prior to the recession. We argue that our approach is consistent with recent theoretical evidence on public debt sustainability. We show that our results are robust to alternative measures of the total debt burden at the peak.

Finally, we investigate whether there is a systematic or predictable pattern between public debt instability and financial crises. We show that financial crises are not preceded by periods of high $r - g$. Furthermore, the empirical evidence points to neither public debt nor $r - g$ as predictors of financial crises. This finding does not support Alesina (2012)'s hypothesis that episodes of public finances sustainability risks systematically lead to periods of financial instability such as financial crises. Episodes of high private credit growth, therefore, remain as the main predictor of periods of high financial instability (Schularick and Taylor, 2012). We also find that financial crises are not only followed by periods of high public debt, as already well documented in the literature (e.g. Reinhart and Rogoff, 2009), but also by increases in $r - g$. This result suggests that sovereign debt sustainability is clearly threatened in the aftermath of financial crises, as simultaneous increases in public debt and $r - g$ can originate feedback loops between sovereign debt and interest rates on public debt (e.g. Engen and Hubbard, 2004; Laubach, 2009). This empirical finding points to financial stability as key to prevent future episodes of public debt instability.

Related Literature. We contribute to a range of work assessing the empirical relationship between financial crises and soreveign debt sustainability risks (Reinhart and Rogoff, 2009; Jordà *et al.*, 2016). To the best of our knowledge, there are only a few studies that empirically explore the connection between financial and public instability. Reinhart and Rogoff (2009) use a range of banking crisis episodes in both develop and emerging economies after World War I to show that financial crises have a long-lasting impact on public debt. They show that governments typically experience a substantial increase in their debt-to-GDP ratios in the aftermath of a crisis, and that the elevated debt levels persist for an extended period. We complement their work by showing that the aftermath of financial crises are not only followed by sizeable increases in public debt, but also in the unit cost of servicing the debt $r - g$. This explosive combination implies that the total debt burden dramatically increases following financial crises, making, as a result, sovereign debt crises more likely after the onset of such financial disasters. Jordà *et al.* (2016) address empirically the relationship between public debt levels at the onset of a financial crisis and the posterior crisis severity. They show that initial high levels of public debt, taken in isolation, does not necessarily translate into deeper and larger financial recessions.[2] They also find that financial crises are not predicted by public debt build-ups. We build on this work by constructing a new measure of public debt sustainability based on the total public debt burden rather in the level of public debt. We show that while episodes of high total debt burden do not predict financial crises, considering the total cost of servicing the debt to measure public debt sustainability is key to show that initial public finances conditions matters for crisis severity. This empirical evidence highlights that only considering the quantity of debt to measure sovereign debt sustainability may not be sufficient to fully account for the overall debt service burden.[3]

The remaining of the paper proceeds as follows. Section 2 describes the historical evolution of both the debt-to-GDP ratio and $r - g$ over the period 1870-2017 for a comprehensive set of advanced economies. Section 3 presents the empirical strategy and the main results of the analysis of the role of public debt burden on crisis severity. Section 4 examines whether public debt sustainability risks predict financial crises, and to what extent financial crises impact on either the level or the unit cost of public debt or on both of them. Section 5 concludes.

[2] Jordà *et al.* (2016) shows, however, that the combination of both high public-sector and private-sector debt prior to financial crises does tend to exacerbate the negative effects of post-crisis deleveraging.

[3] We show that this finding is not driven by the inclusion of the Great Financial Crisis (GFC) in our analysis.

2 The Historical Evolution of Public Debt and $r - g$

2.1 Data and Variables Definition

The main data source is the JST Macrohistory Database (Jordà *et al.*, 2017; http://www.macrohistory.net/data/). This database provides annual data on the real economy and the financial sector for 18 advanced economies over 1870-2017. The countries included in the sample are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom (UK), and the United States (US).

We now define the economic variables that will be used in this section to provide some stylize facts on the historical evolution of $r - g$ and the debt-to-GDP ratio from 1870-2017.

- **The unit cost of servicing the debt** $r - g$. The unit cost of servicing the debt is computed as the difference between the interest rate (r) and the 7-year average annual growth rate of future real GDP that we will denote by $\bar{g}$.[4] Our approach is in line with Hamilton *et al.* (2016), who used moving-averages of future realizations to capture expectations. We use a 7-year average of future economic growth to approximate the long-term economic growth g, since the average maturity of debt has been around 7 years for advanced economies (IMF, 2021). We use the nominal long-term interest rate (usually 5-10 year in maturity) to measure the interest rate (r).

- **The total cost of servicing the debt** TB**.** The total public debt burden is computed as the product of $r - g$, as defined above, and the debt-to-GDP ratio.

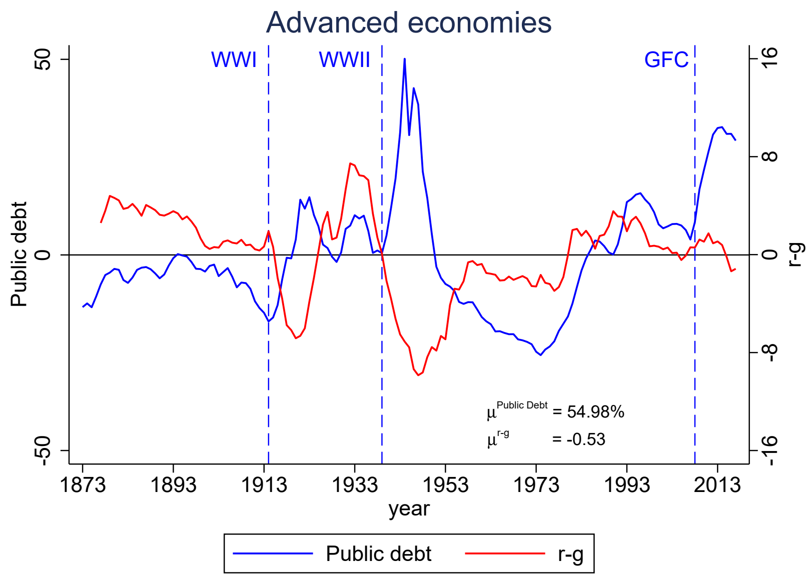
2.2 Stylised facts

This section aims to provide a historical perspective of the joint evolution of the public debt and $r - \bar{g}$. We therefore can explore to what extent the two key variables to measure public debt sustainability have been historically synchronized. A priori, since in simple terms the two variables deal respectively with the quantity and net cost of public debt in an economy, one would expect a positive and strong relationship between the two. That is, that periods of high (low) debt-to-GDP ratio were characterized as well by periods of high levels (low) of $r - \bar{g}$.

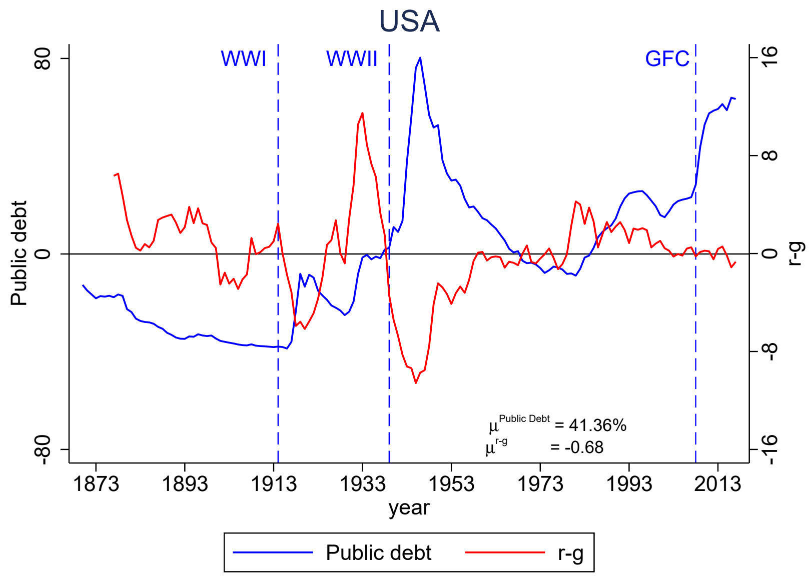
[4] Jordà *et al.* (2020) and Mehrotra and Sergeyev (2021) have recently computed similar measures of $r - g$ for empirical purposes. Jordà *et al.* (2020) construct a measure of $r - g$ to study the medium- to long-term effects of wars and pandemics on $r - g$. They define $r - g$ as the difference between the real natural rate and the growth rate of real GDP per capita, using data back from the fourteenth century. Mehrotra and Sergeyev (2021), in turn, compute $r - g$ to provide some stylized facts on such indicator for advanced economies over the last 150 years. They generate this variable as the difference between the real interest rate and the annual growth rate of GDP.

Figure 1: Historical Evolution of Public Debt and $r - g$.

Panel (a): Advanced Economies



Panel (b): United States



Notes: Sample: 1870-2017. Both the debt-to-GDP ratio and $r-g$ have been de-meaned using the country-specific historical mean. For all advances economies, we use the average historical mean across countries. $\mu^{Public\ Debt}$ and μ^{r-g} reports the debt-to-GDP ratio and $r - g$ historical mean, respectively.

The historical evolution of public debt and $r - g$ over the last 150 years are displayed in Figure 1. The top-panel shows the evolution of the average of each of those variables for the 18 countries in the sample, while the bottom-panel shows the evolution of those variables for the US. The disconnect between the debt-to-GDP ratio and $r - g$ arises as a striking fact in the history of advanced economies.[5]

Three historical episodes exemplify the disconnect between the debt to GDP and $r - g$. First, most of the advanced economies faced a generalized build-up and subsequent stabilization in the debt-to-GDP ratio after World War I (WWI). The evolution of public debt contrasts with the one observed for $r - g$. This variable experimented a dramatic fall, a later recovery to its prewar level, and subsequent upward trend before dropping again in the last years leading up to World War II (WWII). Second, as a consequence of the war itself, most advanced countries experienced a sharp increase in the debt to GDP ratio in the post-WWII. This rise in the public debt was followed by a subsequent prolonged period of public deleveraging that took place during the reconstruction boom of the Bretton Woods era. The $r - g$ moved, at least partially, in the opposite direction. In particular, following WWII advanced economies experienced a sharp decline in $r - g$, which took negative values up to the mid-1950s. This fall in $r - g$ was followed, as in the years following WWI, by a later recovery to its pre-war levels, later stabilizing at around 3%-4% range. Third, over the last two decades of the sample, the upward trend in the debt to GDP ratio has resulted in levels not seen since the end of WWII. These high levels of public debt have simultaneously co-existed with one of the lowest historical levels in $r - g$, whose progressive fall since the 1990s can be largely explained by the drop in real interest rates that has dominated the global landscape in advanced countries over that period.

In the next two sections we address the following questions: Does the severity of financial crises depend on the pre-crisis public finances conditions? Do episodes of high $r - g$ and/or TB predict financial crises? Are the aftermath of financial crises followed by increasing risks to sovereign debt sustainability? Since we have shown that advanced economies have recurrently experienced significant economic fluctuations in periods when both a high (low) debt to GDP ratio and a low or even negative (high) total cost of servicing the debt have simultaneously co-existed over the last 150 years, both the debt to GDP ratio and $r - g$ will be considered to determine the risks to public debt sustainability.

[5] The disconnect between the debt-to-GDP ratio and $r-g$ can be exemplified by the fact that a simple pairwise correlation between the average public debt and the average $r-g$, for the set of advanced economies in the sample, yields a negative result (-0.09). This negative correlation becomes even stronger for the US (-0.25). Although this correlation is not meant to be used to draw economic conclusions on the relationship between these two variables, it may be useful to illustrate that advanced countries have faced historical periods when a high (low) debt to GDP ratio and a low or even negative (high) $r - g$ have simultaneously co-existed.

3 Crisis severity: the role of the total public debt burden

3.1 Empirical Design

We begin our empirical analysis by exploring the causal relationship between the public debt conditions at the onset of financial crises and the posterior crisis severity. In particular, we aim to answer the following question: does the pre-crisis public debt burden conditions matter for the severity of normal and financial recessions?

Our empirical approach builds on the work of Jordà *et al.* (2016). We have a panel setting, where time is denoted by $t = 1, ..., T$ and the countries are labelled with $i = 1, ..., M$. We define two indicator variables. "N" denotes a normal business cycle peak, and "F" denotes a peak associated with a systemic financial crisis, that is, when a crisis labelled as *financial* occurs within ± 2 years of the peak. Business peak dates are computed using the same method as Jordà *et al.* (2013). They use the Bry and Boschan (1971) algorithm to detect business cycle peaks for all selected advanced economies (except Ireland) over the period 1870-2008. We extend their sample by, first, identifying turning points for Ireland, and second, by expanding the time horizon up to 2017 using the Bry and Boschan (1971) algorithm. This algorithm uses real GDP per capita to identify local maximums as peaks and local minimums as troughs, exactly reproducing the NBER turning points dating for the US and being close to the turning points selected by the CEPR's dating committee for the euro area (Ferroni and Canova, 2021). In what follows, we denote by $t(p)$ the calendar peak year (the year in which the expansion ends for country i).

To examine the effect of the total cost of servicing the debt at the onset of the financial crisis, $TB_{i,t(p)}$, on the severity of the crisis, we estimate the following local projections:

$$\begin{aligned}\Delta^h y_{i,t(p)+h} =& \alpha_{i,h} + \theta_h^N N_{i,t(p)} + \theta_h^F F_{i,t(p)} + \beta_h^N N_{i,t(p)} \left(TB_{i,t(p)} - \overline{TB_i}\right) + \\ & \beta_h^F F_{i,t(p)} \left(TB_{i,t(p)} - \overline{TB_i}\right) + \sum_{l=1}^{L} \Gamma_{h,l} X_{i(p),t-l} + \varepsilon_{i,t(p)+h},\end{aligned} \tag{1}$$

where horizon $h = 1, 2, ..., H$ and $\alpha_{i,h}$ is a country fixed effect. In equation (1), $\Delta^h y_{i,t(p)+h}$ denotes the cumulative change in the outcome variable, e.g. the log of real GDP per capita from the year when the crisis starts $t(p)$ to h years later $t(p) + h$. $TB_{i,t(p)}$ denotes the pre-treatment total public debt burden for country i. That is, the total cost of debt at the peak $t(p)$. $\overline{TB_i}$ is the country-specific historical average level of TB. $N_{i,t}$ and $F_{i,t}$ are respectively dummies associated to normal and financial crises. We add a comprehensive set of macroeconomic control variables $X_{i,t}$ that include the growth rate of real GDP per capita, the consumer price index (CPI) inflation rate, the growth rate of real investment per capita, the current-account-to-GDP ratio, the growth rate of real loans per capita, the growth rate of real public debt per capita, and short-term and long-term interest rates. We include both the first and second lags of each of our controls in our baseline specification.[6] Therefore accounting for the macro-dynamics previous to recessions. To give our coefficients of interest the desire interpretation, interaction treatment terms and controls $X_{i,t}$ are computed as levels relative to their means in the financial and normal recession bins.

Our baseline sample runs from 1870 to 2017, at annual frequency for 18 advanced economies. With this specification, and armed with the discussion in Section 3.2 on how we identify plausible non-endogenous variation in $TB_{i,t(p)}$, our coefficients of interest θ_h^N and θ_h^F trace out the average cumulative outcome response in normal versus financial crisis recessions relative to peak for years 1 to 5 of the recession/recovery period when $TB_{i,t(p)}$ is at its historical country-specific mean. β_h^N and β_h^F, in turn, measure the sensitivity of the selected outcome path, e.g. log of real GDP per capita, to deviations of $TB_{i,t(p)}$ from its historical country-specific mean at the onset of normal versus financial recessions. This analysis, therefore, allows us to explore whether the total cost of servicing the debt at the peak affects crisis severity.[7]

To examine whether there is a difference in crisis severity depending on the total cost of servicing the debt, We consider two alternative scenarios: (i) the total cost of servicing the debt at the peak $TB_{i,t(p)}$ is +1sd below the country-specific historical mean (*low debt cost scenario*), (ii) the total cost of servicing the debt at the peak $TB_{it(p)}$ is +1sd above the country-specific historical mean (*high debt cost scenario*).

3.2 Measuring the total burden of public debt, TB

The study of the relationship between financial crises and sovereign debt sustainability is the primary object of interest of this paper. Therefore, a crucial issue is how to pin down non-endogenous variation in the total cost of the debt TB_{it} to identify plausible causal effects.

Overall, we face a few empirical challenges to give our aforementioned coefficients of interest

[6] The results on crisis severity depending on the initial public debt burden are robust to alternative lag specifications.

[7] We use the code for stratified Local Projections (LPs) introduced in Jordà *et al.* (2016) to estimate the model in equation (1).

a causal interpretation. First, we need $TB_{i,t(p)}$ to be computed using real-time information at the peak and incorporating the expected future total debt burden. Second, and related to the first issue, we need $TB_{i,t(p)}$ not being systematically contaminated by post-crisis severity. That is, we need no anticipation. In particular, if economic agents could predict the next crisis and its severity, the total cost of servicing the debt at the peak could be partially reflecting the pre-crisis endogenous response of agents to the forthcoming crisis. In that scenario, our estimates would be contaminated by reverse causality.

We argue that crisis severity anticipation is unlikely to occur in our framework since an endogenous response to the crisis and its severity would need economic agents to predict the exact financial crises dates and its expected severity.[8] The prediction of financial crises, however, has been shown to be extremely hard with real-time data (Gadea Rivas and Perez-Quiros, 2015; Krishnamurthy and Muir, 2017; Boyarchenko *et al.*, 2022).[9] Indeed, Krishnamurthy and Muir (2017) have shown that financial crises have been historically considered a surprise from the economic agent's perspective. Furthermore, to the best of our knowledge, there is no empirical evidence regarding agents' ability to anticipate the severity of a financial crisis prior to the crisis itself. Therefore, it is not realistic to argue that, with the prediction tools available at that time, economic agents were able to predict the crisis and its expected economic cost and endogenously respond to it. Our key empirical assumption is, therefore, that the total debt burden prior to the peak is exogenous to the posterior crisis severity.

In the absence of crisis severity anticipation, our primary empirical challenge comes down to accurately measuring $TB_{i,t(p)}$. This entails computing this measure using real-time information and incorporating a forward-looking perspective that captures the future debt burden in the long run. Our proposed measure of public debt sustainability, denoted as $TB_{i,t}$ in this paper, comprises three variables: the debt-to-GDP ratio, the long-term interest rate (r), and the long-term growth of the economy (g). While the first two can be directly measured at time $t(p)$, the key empirical challenge we face lies in consistently measuring the third variable, i.e., the expected long-term economic growth g, at the onset of the crisis. Hence, measuring $TB_{i,t(p)}$ ultimately comes down to measuring $g_{i,t(p)}$. In the previous section, we approximated the long-term growth of the economy g by using a 7-year average of future GDP growth. However, in our empirical

[8]This argument is similar to the one by Jordà *et al.* (2016) using the level of public debt.

[9]Although empirical models recently developed have been able to considerably increase the predictive capacity of financial crises, these models face two caveats: (i) they are based on modern technology only recently available; and (ii) they are usually considered to be a "black box" making them unattractive for policy decisions (Boyarchenko *et al.*, 2022). This is the case of atheoretical data mining models such as random forests and other learning-based classification tree methods (Ward, 2017; Fouliard *et al.*, 2021).

framework, employing such an approach would inevitably yield spurious results since we would be utilizing post-crisis realizations of GDP growth, which, by definition, are endogenous to the severity of the crisis itself, to estimate the pre-crisis public debt service burden.

In our baseline exercise presented in equation (1), we construct $TB_{i,t(p)}$ for each country in the sample using current output growth at the peak instead of the 7-year average annual future GDP growth as we did in Section 2.[10] This way, we capture the expected total public debt burden with the available information prior to the recession. Our approach is therefore consistent with the empirical literature on public debt sustainability.[11]

To have an intuition about how the two proxies for the total cost of the debt compare over time, Figure A2 in Appendix A plot the historical evolution of the total cost of the debt $TB_{i,t}$ using information into the future, i.e., based on the 7-year average annual future GDP growth, against our proposed new measure using real-time information, i.e., based on current GDP growth. We plot these series both the average of all advanced economies in our sample. We refer to the former as our benchmark measure because, in the absence of endogeneity, we would use it to estimate the total cost of the debt at peak $t(p)$. The main takeaway from Figure A2 is that overall, and despite some differences, the proxy for $TB_{i,t}$ computed using real-time information behaves similarly to the benchmark measure. This reassures that our proposed proxy for $TB_{i,t(p)}$ does a good job capturing the total cost of the debt with the available information at the peak $t(p)$.

3.3 Empirical Results

Figure 2 displays the average outcome path in normal versus financial crises recessions depending on the size of the total cost of servicing the debt at the recession peak $t(p)$. The top panel shows that the conditional cumulative change from the start of a normal recession in most selected outcomes is sensitive to the initial public sustainability risks. In particular, when the pre-crisis service debt burden can be regarded as high, the severity of the crisis is worsened. *Ceteris paribus*, the aftermath of normal crises are followed by faster recoveries if there were good public debt conditions at the start of the crisis. The state-dependent normal recession cost is particularly reflected in the investment path following a normal crisis. While investment hardly

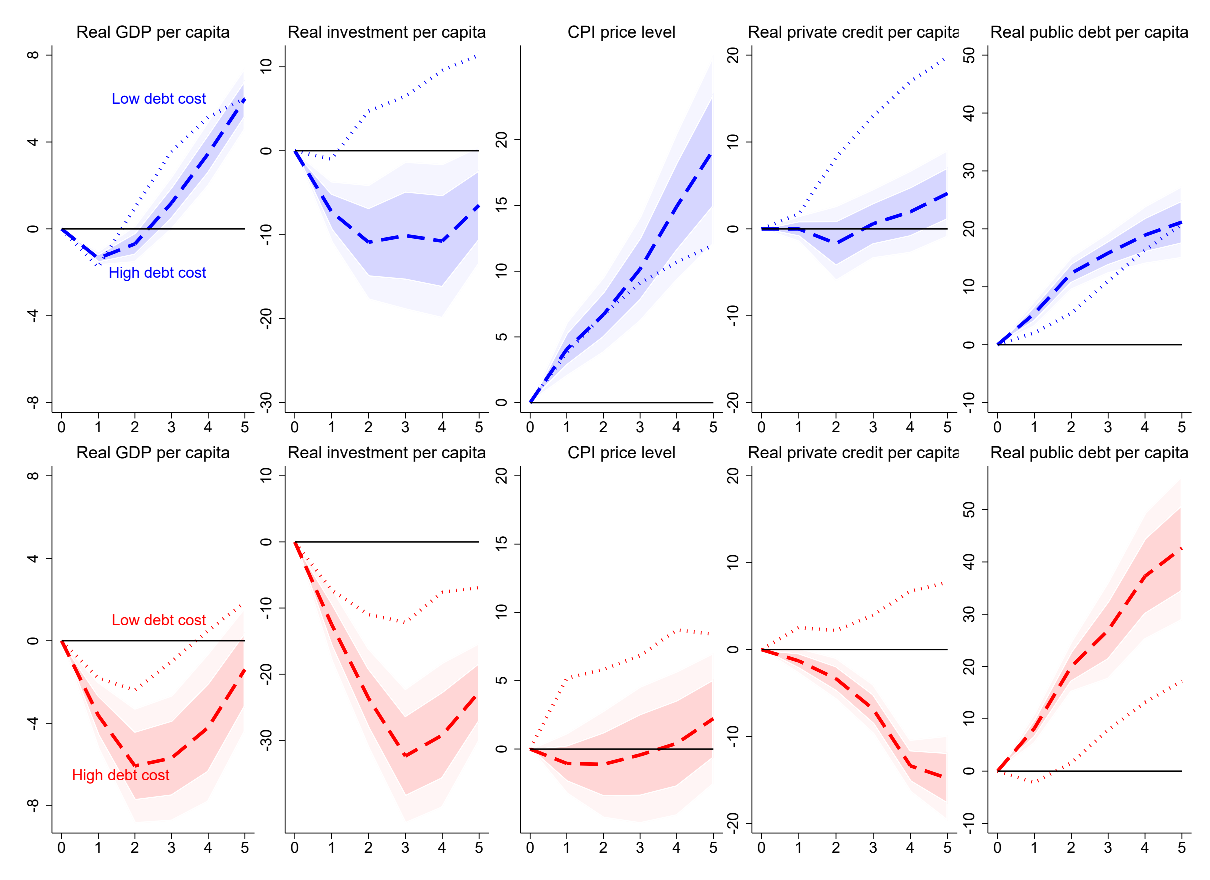
[10]We note that another alternative could be to use the forecast made at time t on future economic growth. While such data have become recently available for many economies, such an approach is not possible within our long-run historical framework because no forecasts were available in most of the periods of our sample.

[11]In Appendix C1, we show that current output growth is systematically positively highly correlated with the expected future economic growth across different horizons.

suffers in recessions where initial debt conditions are favorable, it falls considerably if the onset of the crisis coincides with initial vulnerabilities in the public sector.

The severity of the crisis depending on the public debt burden at the peak is more pronounced when it comes to financial crisis recessions (bottom panel). The real GDP per capita path in the aftermath of a financial crisis is sensitive to the pre-crisis public conditions. All else being equal, the larger the initial total cost of servicing the debt, the larger and deeper the output losses associated to the financial crisis. In particular, when the total cost of servicing the debt is low, the economy recovers to its peak level four years after the crisis. When the total cost of servicing the debt is high, however, output stays severely depressed for longer and is below the previous peak even five years following the financial crisis. Moreover, in the latter case, the average fall in GDP relative to its previous peak level is almost twice as large as in the *low debt cost scenario*. The results for real GDP are unambiguous, initial vulnerabilities in the public sector make on average the financial crisis more severe.

Figure 2: State-Dependent Crises Severity: Normal vs Financial Recessions



Notes: Average cumulative path from the start of the recession of selected macroeconomic variables, depending on the total cost of servicing the debt at the peak. Sample 1870-2017. Results are displayed by type of recession: normal versus financial crises. Each graph shows local projections of the cumulative change relative to peak for years 1–5 of the recession/recovery period under different scenarios. Two scenarios: (i) the country-specific initial total cost of servicing the debt is +1sd below its mean, *low debt cost scenario* (dotted line) (ii) the country-specific initial total cost of servicing the debt +1sd above its mean, *high debt cost scenario* (dashed line). 90% (light red and blue) and 68% (dark red and blue) confidence bands for high debt cost scenarios are displayed. The top panel refers to normal recessions. The bottom panel refers to financial crisis recessions. These results are conditional on the full set of lagged macroeconomic aggregates, with paths evaluated at the means. Two world wars and 5 year windows around wars are excluded (1909-20; 1934-47).

What about the remaining selected macroeconomic outcomes? Investment suffers a considerable fall, even more than GDP, in financial crisis recessions. The investment path following a financial crisis is also influenced by the initial public debt conditions. While in the *low debt cost scenario* the peak of the fall in investment is around 15%, this shortfall in investment increases to almost 35% when the total cost of servicing the public debt at the peak is 1sd above the mean (*high debt cost scenario*). CPI prices and the real lending per capita, in turn, are also affected by the pre-crisis public debt sustainability risks. In particular, highly public leveraged financial crises are characterized by deflationary pressures and private credit crunches that last for several years, all else being equal. The picture does not change when it comes to public debt. Public debt clearly explodes in the aftermath of highly leveraged financial crises.

In sum, this section shows that initial public debt conditions notably affect crisis severity. We speculate that these results can be reasonably explained by the lack of government's fiscal space, when the initial total cost of servicing the debt can be regarded as high. In particular, deteriorated public debt conditions at the beginning of the crisis may prevent governments from using countercyclical fiscal policies to foster private and public demand. Limiting, therefore, government's ability to mitigate the downturn.

3.4 Robustness Analyses

Excluding the Great Financial Crisis (GFC). In our benchmark crisis severity exercise, we considered the whole sample period for which there is available data. One might worry, however, that the extreme episodes that took place around the GFC, particularly in the euro periphery countries, made this period potentially different in character to the rest of the sample. This sensitivity analysis, therefore, aims to check whether those findings are driven or not by this recent economic experience. In this regard, we find that the exclusion of the post-2007 period does not bear significant changes and that our baseline results hold. This robustness exercise confirms that the baseline estimates were not enterely driven by the economic episodes around the GFC.

4 Financial crises and sovereign debt sustainability risks: predictable patterns

4.1 From public sector instability to financial sector instability

Do turbulent times in the public sector precede financial crises? In the aftermath of the GFC, part of the public debate pointed to public overborrowing as one of the roots behind the triggering of such financial disaster in euro area periphery countries. The main idea behind this hypothesis was that episodes of sovereign debt sustainability risks can trigger worries about government solvency, ultimately leading to periods of financial instability through increases in the cost of servicing debt (Alesina, 2012).

While this argument is theoretically valid because periods of public debt instability can lead banks holding government bonds to face solvency threats, it does not seem to be supported by the empirical evidence. In particular, Jordà *et al.* (2016) do not find any empirical link between levels of public debt and financial crisis risk. They conclude, therefore, that historical episodes of public debt instability are not followed by periods of financial instability.

Yet, given the empirical evidence shown in section 2, one may argue that, since historical periods of high public debt have not systematically coincided with periods of high $r-g$, using public debt as a proxy for public stability may not be sufficient to capture the mechanism pointed out by Alesina (2012). It is worth exploring, therefore, the extent to what the specific link between periods of high $r-g$ and/or TB and periods of financial instability is supported or not by the data. For that purpose, we first define two indicator variables:

$$Public\ Debt^{High}_{i,t} = \begin{cases} 1 & \text{if} \quad \Delta_5 Public\ Debt_{i,t} > \Delta_5 Public\ Debt_{i,75th} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

$$(r-g)^{High}_{i,t} = \begin{cases} 1 & \text{if} \quad \Delta_5 (r-g)_{i,t} > \Delta_5 (r-g)_{i,75th} \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

where $\Delta_5 Public\ Debt$ and $\Delta_5(r-g)$ are the 5-year average annual changes in $Public\ Debt$ and $r-g$ respectively. Defining the two indicator variables at time t based on the average annual change of each variable over the previous 5 years allows us to account for medium-term fluctuations. We then estimate the following local projections (Jordà, 2005) to study whether episodes of high public debt, $r-g$, or their interaction are systematically linked to changes in the probability of financial crises:

$$\begin{aligned} Crisis^{cum}_{i,t+1 \text{ to } t+h} = \alpha_{i,h} + \beta_h\ Public\ Debt^{High}_{i,t} + \gamma_h\ (r-g)^{High}_{i,t} + \\ \theta_h\ Public\ Debt^{High}_{i,t}\ (r-g)^{High}_{i,t} + \sum_{l=0}^{L} \Gamma_{h,l}\ X_{i,t-l} + \varepsilon_{i,t+1 \text{ to } t+h}, \end{aligned} \tag{4}$$

where $\alpha_{i,h}$ is the country fixed effects, $h = 1, 2, 3$, and $Public\ Debt^{High}_{i,t}$ and $(r-g)^{High}_{i,t}$ are defined above. $X_{i,t}$ includes the five-year average annual real GDP growth, the five-year average annual real CPI inflation, and 1- and 2-year lagged values of the outcome variable ($Crisis_{i,t-1}$ and $Crisis_{i,t-2}$). In the spirit of Greenwood *et al.* (2022), the outcome variable $Crisis^{cum}_{i,t+1 \text{ to } t+h}$ is a dummy variable that takes value 1 if a crisis begins in country i in any year between $t+1$ and year $t+h$. More formally, let $Crisis_{i,t}$ be an indicator that switches on if a crisis begins in country

i in year t, then $Crisis^{cum}_{i,t+1 \text{ to } t+h} = max\{Crisis_{i,t+1}, ..., Crisis_{i,t+h}\}$.[12] This crisis specification deals with uncertainty surrounding crisis definition in at least two dimensions. First, the crisis forecasting literature has shown that the exact year of a crisis cannot be accurately predicted (Kaminsky and Reinhart, 1999; Ward, 2017). However, a small-window (e.g. 2-year and 3-year windows) within which crisis can happen can be better predicted (e.g. Ward, 2017). Second, this type of crisis-window definition addresses the uncertainty surrounding the exact dates that different crisis databases assign to common crisis events.[13]

Given our crisis definition, the residuals in equation (4) will be serially correlated within the same unit when $h > 1$. Moreover, units in our panel are likely not independent, therefore the residuals in equation 4 are likely contemporaneously correlated across countries in a given point in time. To account for both time-series and cross-section correlation, we compute Driscoll and Kraay (1998) standard errors. In particular, for $h = 1$ we use Driscoll and Kraay (1998) errors with no lags, while for $h > 1$ we do allow arbitrary residual correlation within our panel up to horizon ($1.5 \times h$).

Table 1: Financial crisis prediction.

	Crisis within 1 year				Crisis within 2 years				Crisis within 3 years			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Public Debt^{High}	-1.62	-1.50	-2.46**	-3.75***	-2.94	-2.90	-4.22**	-3.57**	-5.02	-4.96	-5.32	-3.19
	(1.01)	(0.99)	(1.16)	(1.40)	(1.95)	(1.94)	(1.82)	(1.52)	(2.77)	(2.81)	(2.73)	(1.75)
$(r-g)^{High}$		-0.79	-1.69	-1.89		-0.32	-1.54	0.91		-0.89	-1.21	-0.58
		(1.03)	(1.21)	(1.29)		(2.33)	(2.83)	(2.38)		(2.76)	(3.49)	(1.93)
Public Debt^{High} *x* (r-g)$^{\text{High}}$			3.08	3.14			4.19	3.03			1.11	-1.43
			(1.83)	(1.84)			(2.93)	(2.33)			(3.61)	(1.91)
Unconditional crisis probability, p	3.5 %				7.02 %				10.58 %			
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Controls	✗	✗	✗	✓	✗	✗	✗	✓	✗	✗	✗	✓
R^2	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.31	0.03	0.03	0.03	0.43
Observations	1912	1847	1847	1847	1894	1829	1829	1829	1876	1811	1811	1811

Notes: Sample 1870-2017. Driscoll and Kraay (1998) standard errors in parentheses. Two world wars and 3 year windows around wars are excluded (1911-20; 1936-47). ** $p < 0.05$, *** $p < 0.01$

Table 1 presents the main results from our prediction exercise. For each horizon h, we report four alternative specifications. The first specification only includes the indicator variable for high public debt to predict financial crises. In the second specification, we add to the previous regression the indicator variable which, as defined above, takes value 1 when $r - g$ is in the top quartile of the distribution. The third specification includes a dummy variable that switches on when both public debt and $r - g$ can be regarded as high at a given point in time, according to

[12]Similarly, Schularick *et al.* (2021) define a crisis dummy that takes value 1 if a systemic financial crisis occurs in country i at year t or in the following two years.

[13]For instance, a recent survey on financial crises by Sufi and Taylor (2021) has shown that the three most commonly used crisis databases in the literature (BEKM, RR, and JST) often differ in the date assigned to the crisis.

rules defined in equations (2) and (3). The latter specification allows us to directly test whether episodes of high total cost of the debt are systematically linked to future financial crises. Finally, in the fourth and last specification, we include to the previous regression the set of controls listed above. All specifications include country-fixed effects.

We note that overall, and regardless of the horizon h, our regressors do not have predictive ability over financial crises. That is, the unconditional and conditional probability of a financial crisis is statistically the same across horizons. This result holds across the four alternative specifications. The first column shows that episodes of high public debt are negatively related to the probability of future financial crises. In the second and third columns, we directly test Alesina (2012)'s hypothesis by exploring to what extent episodes of high $r-g$ or TB are successful to predict future financial crises. The results are unambiguous, regardless of the specification and horizon h, neither economic variable has predictive ability over such periods of financial and economic distress.

This exercise shows that neither episodes of high $r - g$ nor episodes of high total cost of the debt TB are associated with the future probability of a financial crisis. Therefore, the data does not support the theoretical hypothesis that periods of vulnerabilities in the public sector could translate into future periods of financial instability.

4.2 From financial sector instability to public sector instability

The empirical literature has shown that the aftermath of financial crises are followed by large increases in the public debt (Reinhart and Rogoff, 2009; Jordà *et al.*, 2016). But, what happen with $r - \bar{g}$ in the aftermath of financial crises? This section aims to complement the existing empirical evidence by examining whether the aftermath of financial crises are not only characterized by large increases in public debt, but also in its unit cost $r - \bar{g}$. The latter scenario would imply that financial crises are often followed by turbulent times in the public sector, as simultaneous increases in public debt and $r - \bar{g}$ would significantly worsen public finance conditions, increasing the likelihood of sovereign debt crises.

To shed light on this issue we estimate through local projections the unconditional path of public debt and $r - g$ in the aftermath of normal versus financial recessions:

$$\Delta^h y_{i,t+h} = \theta_h^N N_{i,t} + \theta_h^F F_{i,t} + \varepsilon_{i,t+h}, \tag{5}$$

where $h = 1, 2, ..., 5$. The outcome variables, y_i, are the public debt-to-GDP ratio and $r - \bar{g}$. $N_{i,t}$ and $F_{i,t}$ are defined as before. Under this specification, θ_h^N and θ_h^F trace out the h-horizon average cumulative change (relative to peak) in y_i following normal versus financial crisis. Moreover, we formally test whether there are significant differences between such changes, that is we test $\theta_h^N = \theta_h^F$.

Table 2 presents the evolution of public debt and $r - \bar{g}$ in the aftermath of normal versus financial recessions relative to peak. The results point to a strong link between crises and periods of public debt sustainability risks. In particular, the aftermath of economic recessions, either normal or financial, are followed by significant increases in both public debt and $r - \bar{g}$. Nonetheless, the build-up in public debt following a recession is even larger when the downturn has a financial character. This result is already well documented in the literature (Reinhart and Rogoff, 2009). The picture is alike when we explore the evolution of $r - \bar{g}$ following normal and financial crises. In particular, while there is a significant increase in $r - g$ following normal recessions, it rises more sharply in the aftermath of financial crises. Broadly, $r - \bar{g}$ increases by around 150-200 basis points between two and five years following a financial crisis.[14]

Table 2: Public Debt and $r - \bar{g}$ in the aftermath of normal versus financial crises.

	Public Debt					$r - \bar{g}$				
	(1) Year 1	(2) Year 2	(3) Year 3	(4) Year 4	(5) Year 5	(1) Year 1	(2) Year 2	(3) Year 3	(4) Year 4	(5) Year 5
Normal recession	1.553***	2.657***	2.913***	3.702***	4.164***	0.430**	0.563***	0.619***	0.646**	0.621**
	(0.380)	(0.612)	(0.806)	(0.966)	(1.111)	(0.109)	(0.175)	(0.225)	(0.267)	(0.304)
Financial recession	2.244***	5.487***	6.238***	8.812***	10.56***	0.900***	1.597***	1.795***	1.932**	1.798***
	(0.649)	(1.045)	(1.377)	(1.646)	(1.892)	(0.190)	(0.306)	(0.394)	(0.467)	(0.529)
Normal, Obs	207	207	207	207	207	190	190	190	190	190
Financial, Obs	71	71	71	71	71	62	62	62	62	62
Norm=Fin, p-value	0.36	0.02	0.04	0.01	0.00	0.03	0.00	0.01	0.02	0.05

Notes: Sample 1870-2017. Clustered standard errors in parentheses. Two world wars and 5 year windows around wars are excluded (1909-20; 1934-47). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Why $r - \bar{g}$ goes up, particularly in the aftermath of financial crises? The risk premium channel coupled with years of economic stagnation following financial crises seem to be a reasonable candidate to explain that finding. In particular, financial crises may increase doubts about the solvency of the sovereign, leading the government's lenders to demand a higher compensation in the aftermath of such financial disasters.

The results presented in this section extend the empirical evidence on the economic costs of financial crises by showing that the aftermath of these financial disasters are characterized

[14] Jordà *et al.* (2020) study the long-run evolution of $r - \bar{g}$ in the aftermath of wars and pandemics. They show that while $r - \bar{g}$ it is not very sensitive to pandemics, the aftermath of wars is followed by an increase in $r - \bar{g}$ of around 100 basis points.

by meaningful jumps in both public debt and $r - \bar{g}$. This explosive cocktail following financial recessions dramatically heightens public debt sustainability risks, increasing, consequently, the likelihood of sovereign debt crises after the onset of a financial crisis.

5 Conclusions

This paper uses the quasi-universe of advanced countries' economic experiences over the past 150 years to uncover new insights about the relationship between financial crises and sovereign debt sustainability risks. Our empirical analysis includes several contributions. The first one is that we consider both the level and the cost $(r - g)$ of public debt to compute public debt sustainability risks. This is supported by arguments put forward by recent theoretical literature suggesting that both of those factors should be taken into consideration when examining the burden of public debt. In this regard, we document a historical disconnect between the level of debt and $r - g$. This empirical evidence reinforces the argument that our analysis of debt sustainability risks and financial crises should take both of those factors into consideration. Hence, as our second contribution, we examine the impact of the total costs of servicing the debt, that is, debt level multiplied by unit cost $r - g$, on macroeconomic outcomes following a financial crises. Our empirical design introduces a novel approach to proxy for $r - g$ in the econometric model to account for endogeneity issues. The empirical findings suggest that low or high overall public debt burden prior to the financial crisis will have different implications in terms of its severity. In particular, the aftermath of a financial crises preceded by a high debt burden will be characterised by deeper and longer economic declines, deflationary pressures and credit slumps. This result highlights the importance of having enough fiscal space, in case a financial crisis materialises, so that the government can mitigate the downturn through countercyclical fiscal policies.

In our third and final contribution we show that whilst public debt sustainability risks do not predict upcoming financial crises, the latter, when they occur, make sovereign debt crises more likely. In particular, the aftermath of financial crises are usually characterized not only by build-ups in levels of public debt, but also by increases in $r - g$. This empirical finding points to financial stability as an additional element to enhance public debt stability.

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Appendix

A Crisis dates and Summary Statistics

Table A1: Systemic Financial Crises, 1870-2017

Australia	1893, 1989
Belgium	1870, 1876, 1885, 1925, 1931, 1934, 1939, 2008
Canada	1907
Denmark	1877, 1885, 1908, 1921, 1987, 2008
Finland	1877, 1900, 1921, 1931, 1991
France	1882, 1889, 1930, 2008
Germany	1873, 1891, 1901, 1931, 2008
Ireland	2008
Italy	1873, 1887, 1893, 1907, 1921, 1930, 1935, 1990, 2008
Japan	1871, 1890, 1901, 1907, 1920, 1927, 1997
Netherlands	1921, 2008
Norway	1899, 1922, 1931, 1988
Portugal	1890, 1920, 1923, 1931
Spain	1883, 1890, 1913, 1920, 1924, 1931, 1977, 2008
Sweden	1878, 1907, 1922, 1931, 1991, 2008
Switzerland	1870, 1910, 1931, 1991, 2008
United Kingdom	1890, 1974, 1991, 2007
United States	1873, 1893, 1907, 1930, 1984, 2007

Notes: Systemic crisis dates used in the local projection models estimated in subsection 4.1. Source: JST Macrohistory Database (Jordà *et al.*, 2017; http://www.macrohistory.net/data/)

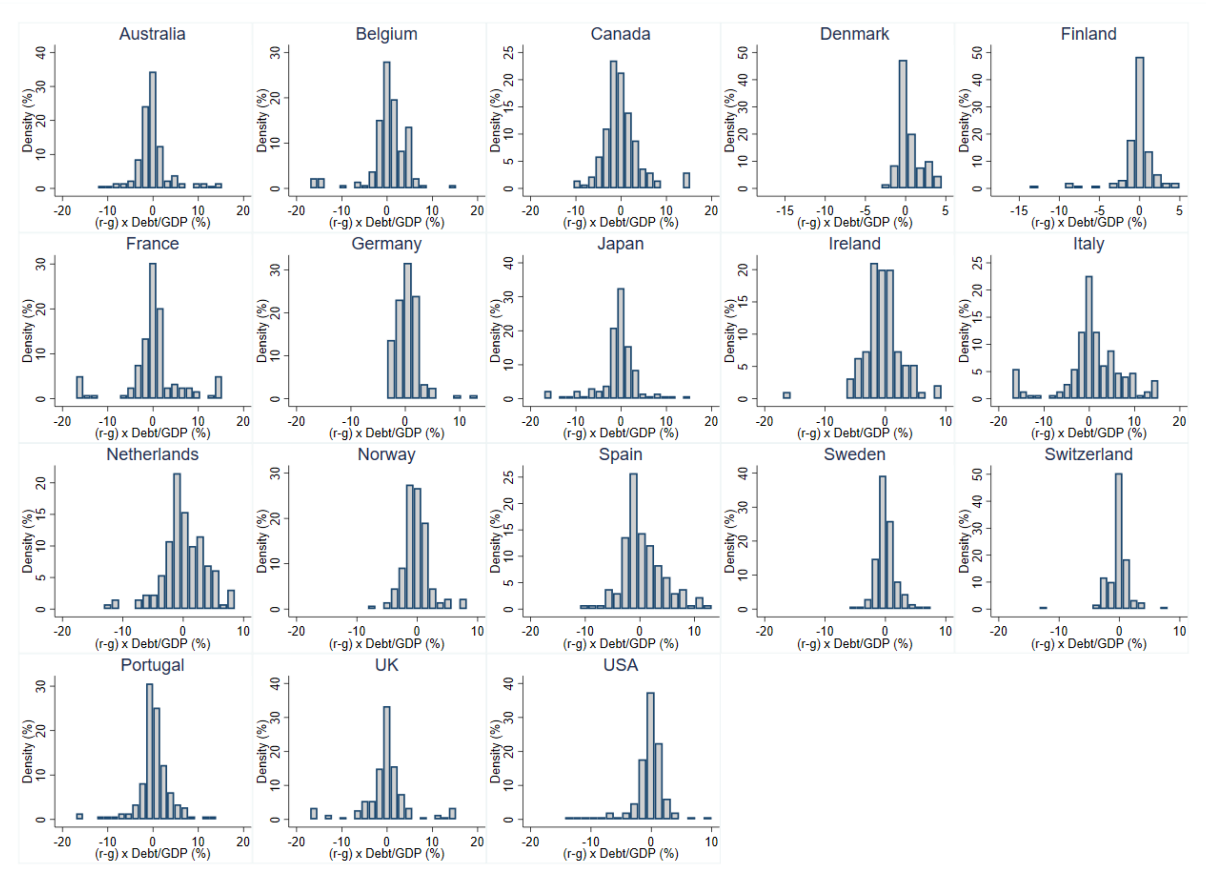
Table A2: Normal and Financial Crisis Recession Peaks, 1870-2017

Australia	N	1875	1878	1881	1883	1885	1887	1889	1896	1898	1900	1904
		1910	1913	1926	1938	1943	1951	1956	1961	1973	1976	1981
		2008										
	F	1891	1894	1989								
Canada	N	1891	1871	1877	1882	1884	1888	1894	1903	1913	1917	1928
		1944	1947	1953	1956	1981	1989	2007				
	F	1874	1907									
Switzerland	N	1875	1880	1886	1890	1893	1899	1902	1906	1912	1916	1920
		1933	1939	1947	1951	1957	1974	1981	1994	2001		
	F	1871	1929	1990	2008							
Germany	N	1879	1898	1905	1913	1922	1943	1966	1974	1980	1992	2001
	F	1875	1890	1908	1928	2008						
Denmark	N	1870	1880	1887	1911	1914	1916	1923	1939	1944	1950	1962
		1973	1979	1992								
	F	1872	1876	1883	1920	1931	1987	2007				
Spain	N	1873	1877	1892	1894	1901	1909	1911	1916	1927	1932	1935
		1940	1944	1947	1952	1958	1974	1980	1992			
	F	1883	1889	1913	1925	1929	1978	2007				
France	N	1872	1874	1892	1894	1896	1900	1905	1907	1909	1912	1916
		1920	1926	1933	1937	1939	1942	1974	1992			
	F	1882	1929	2007								
United Kingdom	N	1871	1875	1877	1883	1896	1899	1902	1907	1918	1925	1929
		1938	1943	1951	1957	1979						
	F	1873	1889	1973	1990	2007						
Italy	N	1870	1883	1897	1918	1923	1925	1932	1939	1974	2002	2004
	F	1874	1887	1891	1929	2007	1992					
Japan	N	1875	1877	1880	1887	1890	1892	1895	1898	1903	1919	1921
		1929	1933	1940	1973	2001	2007					
	F	1882	1901	1907	1913	1925	1997					
Netherlands	N	1870	1873	1877	1889	1894	1899	1902	1913	1929	1957	1974
		1980	2001									
	F	1892	1906	1937	1939	2008						
Norway	N	1876	1881	1885	1893	1902	1916	1923	1939	1941	1957	1981
		2007										
	F	1897	1920	1930	1987							
Sweden	N	1873	1876	1881	1883	1885	1888	1890	1899	1901	1904	1913
		1916	1924	1939	1976	1980						
	F	1879	1907	1920	1930	1990	2007					
United States	N	1875	1887	1889	1895	1901	1909	1913	1916	1918	1926	1937
		1944	1948	1953	1957	1969	1973	1979	1981	1990	2000	
	F	1873	1882	1892	1906	1929	2007					
Belgium	N	1872	1874	1887	1890	1900	1913	1916	1942	1951	1957	1974
		1980	1992									
	F	1870	1883	1926	1930	1937	2008					
Finland	N	1870	1883	1890	1898	1907	1913	1916	1938	1941	1943	1952
		1957	1975	2008								
	F	1876	1900	1929	1989							

Portugal	N	1870	1973	1877	1888	1893	1900	1904	1907	1912	1914	1916
		1925	1927	1934	1937	1939	1941	1944	1947	1951	1973	1982
		1992	2002	2004	2010							
	F	1890	1923	1929	2007							
Ireland	N	1922	1931	1936	1939	1946	1955	1974	1982	2010		
	F	2007										

Notes: Normal and financial crisis recession peaks used in the models estimated in section 3 and subsection 4.2.
Source: Jordà *et al.* (2013) + Authors' estimation.

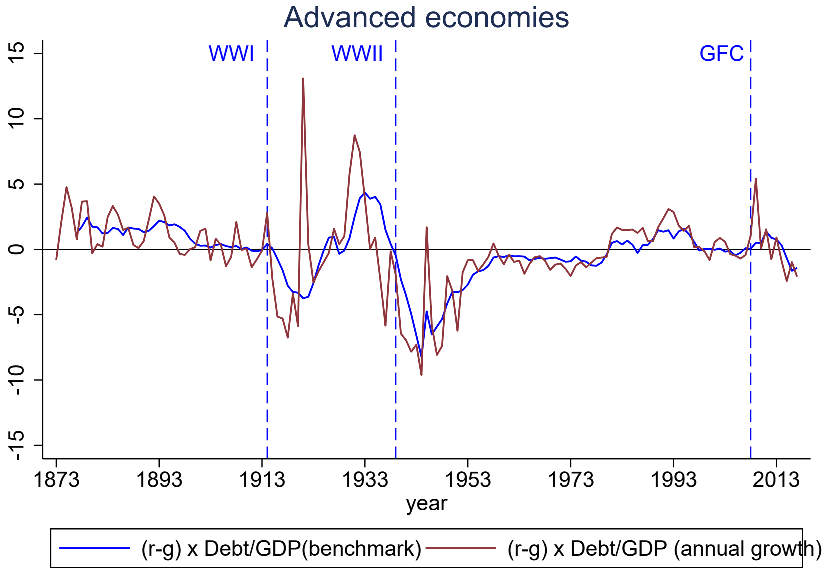
Figure A1: Distribution of the total cost of the debt $TB_{i,t}$



Notes: Distribution of $TB_{i,t}$ for each of the 18 advanced-economy in our sample.

Figure A2: Historical Evolution of the total cost of the debt TB.

Panel (a): Advanced Economies



Notes: $TB = (r - g)\ x\ Debt/GDP$. We plot two measures: the benchmark measure, which has been constructed using the $(r - g)$ as defined in section 2 and our proposed measured for the empirical analysis, where $(r - g)$ has been constructing using the slope of the yield curve spread instead of g. For all advances economies, we use the average historical mean across countries.

B Other analyses

B.1 Current economic growth predicting future economic growth

Table C1.1: Predicting future economic growth with current economic growth

	g_{t+4}	g_{t+5}	g_{t+6}	g_{t+7}
g_t	0.26***	0.20***	0.16***	0.16***
	(0.04)	(0.04)	(0.02)	(0.02)
Country FE	✓	✓	✓	✓
Observations	2335	2305	2275	2245

Notes: Sample period is 1870-2017, for 18 advanced economies. Robust standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.