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Does High Public Debt Consistently Stifle Economic Growth? A Critique of Reinhart and Rogoff

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Abstract

We replicate Reinhart and Rogoff (2010a and 2010b) and find that coding errors, selective exclusion of available data, and unconventional weighting of summary statistics lead to serious errors that inaccurately represent the relationship between public debt and GDP growth among 20 advanced economies in the post-war period. Our finding is that when properly calculated, the average real GDP growth rate for countries carrying a public-debt-to-GDP ratio of over 90 percent is actually 2.2 percent, not −0.1 percent as published in Reinhart and Rogoff. That is, contrary to RR, average GDP growth at public debt/GDP ratios over 90 percent is not dramatically different than when debt/GDP ratios are lower.

We also show how the relationship between public debt and GDP growth varies significantly by time period and country. Overall, the evidence we review contradicts Reinhart and Rogoff's claim to have identified an important stylized fact, that public debt loads greater than 90 percent of GDP consistently reduce GDP growth.

1 Introduction

In "Growth in Time of Debt," Reinhart and Rogoff (hereafter RR 2010a and 2010b) propose a set of "stylized facts" concerning the relationship between public debt and GDP growth. RR's "main result is that whereas the link between growth and debt seems relatively weak

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at 'normal' debt levels, median growth rates for countries with public debt over roughly 90 percent of GDP are about one percent lower than otherwise; (mean) growth rates are several percent lower" (RR 2010a p. 573).

To build the case for a stylized fact, RR stresses the relevance of the relationship to a range of times and places and the robustness of the finding to modest adjustments of the econometric methods and categorizations. The RR methods are non-parametric and appealingly straightforward. RR organizes country-years in four groups by public debt/GDP ratios, 0–30 percent, 30–60 percent, 60–90 percent, and greater than 90 percent. They then compare average real GDP growth rates across the debt/GDP groupings. The straightforward non-parametric method highlights a nonlinear relationship, with effects appearing at levels of public debt around 90 percent of GDP. We present RR's key results on mean real GDP growth from Figure 2 of RR 2010a and Appendix Table 1 of RR 2010b in Table 1.

Table 1: Real GDP Growth as the Level of Public Debt Varies
20 advanced economies, 1946–2009

	Ratio of Public Debt to GDP			
	Below 30 percent	30 to 60 percent	60 to 90 percent	90 percent and above
Average real GDP growth	4.1	2.8	2.8	−0.1

Sources: RR 2010b Appendix Table 1, line 1, and similar to average GDP growth bars in Figure 2 of RR 2010a.

Figure 2 in RR 2010a and the first line of Appendix Table 1 in RR 2010b in fact do not match perfectly, but they do deliver a consistent message about growth in time of debt: real GDP growth is relatively stable around 3 to 4 percent until the ratio of public debt to GDP reaches 90 percent. At that point and beyond, average GDP growth drops sharply to zero or slightly negative.

A necessary condition for a stylized fact is accuracy. We replicate RR and find that coding errors, selective exclusion of available data, and unconventional weighting of summary

statistics lead to serious errors that inaccurately represent the relationship between public debt and growth among these 20 advanced economies in the post-war period. Our most basic finding is that when properly calculated, the average real GDP growth rate for countries carrying a public debt-to-GDP ratio of over 90 percent is actually 2.2 percent, not −0.1 percent as RR claims. That is, contrary to RR, average GDP growth at public debt/GDP ratios over 90 percent is not dramatically different than when public debt/GDP ratios are lower.

We additionally refute the RR evidence for an "historical boundary" around public debt/GDP of 90 percent, above which growth is substantively and non-linearly reduced. In fact, there is a major non-linearity in the relationship between public debt and GDP growth, but that non-linearity is between the lowest two public debt/GDP categories, 0–30 percent and 30–60 percent, a range that is not relevant to current policy debate.

For the purposes of this discussion, we follow RR in assuming that causation runs from public debt to GDP growth. RR concludes, "At the very minimum, this would suggest that traditional debt management issues should be at the forefront of public policy concerns" (RR 2010a p. 578). In other work (see, for example, Reinhart and Rogoff (2011)), Reinhart and Rogoff acknowledge the potential for reverse causality, i.e., that weak economic growth may increase debt by reducing tax revenue and increasing public expenditures. RR 2010a and 2010b, however, make clear that the implied direction of causation runs from public debt to GDP growth.

Publication, Citations, Public Impact, and Policy Relevance

According to Reinhart's and Rogoff's website,[1] the findings reported in the two 2010 papers formed the basis for testimony before the Senate Budget Committee (Reinhart, February 9, 2010) and a *Financial Times* opinion piece "Why We Should Expect Low Growth amid Debt"

[1] `http://www.reinhartandrogoff.com/related-research/growth-in-a-time-of-debt-featured-in` (visited 7 April 2013.

(Reinhart and Rogoff, January 28, 2010). The key tables and figures have been reprinted in additional Reinhart and Rogoff publications and presentations of Centre for Economic Policy Research and the Peter G. Peterson Institute for International Economics. A Google Scholar search for the publication excluding pieces by the authors themselves finds more than 500 results.[2]

The key findings have also been widely cited in popular media. Reinhart's and Rogoff's website lists 76 high-profile features, including *The Economist*, *Wall Street Journal*, *New York Times*, *Washington Post*, Fox News, National Public Radio, and MSNBC, as well as many international publications and broadcasts.

Furthermore, RR 2010a is the only evidence cited in the "Paul Ryan Budget" on the consequences of high public debt for economic growth. Representative Ryan's "Path to Prosperity" reports

> A well-known study completed by economists Ken Rogoff and Carmen Reinhart confirms this common-sense conclusion. The study found conclusive empirical evidence that gross debt (meaning all debt that a government owes, including debt held in government trust funds) exceeding 90 percent of the economy has a significant negative eect on economic growth. (Ryan 2013 p. 78)

RR have clearly exerted a major influence in recent years on public policy debates over the management of government debt and fiscal policy more broadly. Their findings have provided significant support for the austerity agenda that has been ascendant in Europe and the United States since 2010.

2 Replication

RR examines three data samples: 20 advanced economies over 1946–2009; the same 20 economies over roughly 200 years; and 20 emerging market economies 1970–2009. We

[2] A search on `[Reinhart Rogoff "Growth in a Time of Debt" -author:rogoff -author:reinhart]` yielded 538 Google Scholar results on 7 April 2013).

replicate the results only from the first sample as these are the most relevant to current U.S. and European policy debates, and they require the least splicing of data from multiple sources. We focus exclusively on their results regarding means because these have generated the most widespread attention. On their website, Reinhart and Rogoff provide public access to country historical data for public debt and GDP growth in spreadsheets with complete source documentation.[3] However, the spreadsheets do not include guidance on the exact data series, years, and methods used in RR.

We were unable to replicate the RR results from the publicly available country spreadsheet data although our initial results from the publicly available data closely resemble the results we ultimately present as correct. Reinhart and Rogoff kindly provided us with the working spreadsheet from the RR analysis. With the working spreadsheet, we were able to approximate closely the published RR results. While using RR's working spreadsheet, we identified coding errors, selective exclusion of available data, and unconventional weighting of summary statistics.

Selective exclusion of available data and data gaps

RR designates 1946–2009 as the period of analysis of the post-war advanced economies with table notes indicating gaps or other unavailability of the data. In general, RR used data if they were available in the working spreadsheet. Most differences in period of coverage concern the starting year of the data. For example, the US series extends back to 1946. Outside the US, the series for some countries do not begin until the 1950's and that for Greece is unavailable before 1970. Nine countries are available from 1946, seventeen from 1951, and all countries but Greece enter the dataset by 1957. There are some gaps and oddities in the data. For example, public debt/GDP is unavailable for France for 1973–1978, real GDP growth is unavailable for Spain for 1959–1980, Austria experienced 27.3 and 18.9 percent real

[3]See `http://www.reinhartandrogoff.com/data/browse-by-topic/topics/9/` and `http://www.reinhartandrogoff.com/data/browse-by-topic/topics/16/`

GDP growth in 1948 and 1949 (with both years in lower public-debt groups), and Portugal's debt/GDP jumps by 25 percentage points from 1999 to 2000 when the country's currency and the denomination of the series changed from the escudo to the euro. We largely accept the RR data on debt/GDP and real GDP growth as given and do not pursue the implications of data gaps.

More significant are RR's data exclusions with three other countries: Australia (1946–1950), New Zealand (1946–1949), and Canada (1946–1950).[4] The exclusions for New Zealand are of particular significance. This is because all four of the excluded years were in the highest, 90 percent and above, public debt/GDP category. Real GDP growth rates in those years were 7.7, 11.9, −9.9, and 10.8 percent. After the exclusion of these years, New Zealand contributes only one year to the highest public debt/GDP category, 1951, with a real GDP growth rate of −7.6 percent. The exclusion of the missing years is alone responsible for a reduction of −0.3 percentage points of estimated real GDP growth in the highest public debt/GDP category. Further, RR's unconventional weighting method that we describe below amplifies the effect of the exclusion of years for New Zealand so that it has a very large effect on the RR results.

RR reports 96 country-years in the highest public debt/GDP category. Our corrected analysis finds 110 country-years in the highest, above-90-percent public debt/GDP, category. The difference is accounted for by the years that RR excluded: 5 years for Australia; 5 years for Canada; and 4 years of New Zealand. With the spreadsheet error discussed below, RR in fact estimated GDP growth in the highest public debt/GDP category with only 71

[4]All of these cases would contribute observations to the highest public debt/GDP category. In contrast to these exclusions, all of the data for the US, which contributes all of its four observations in the highest public debt/GDP category in these early years, are included. The US series includes the very large GDP decline associated with post-World War II demobilization discussed in detail in Irons and Bivens (2010). In 1946, the US public debt/GDP ratio was 121.3 percent, and the economy contracted by 10.9 percent. In the 1946–2009 study period, the U.S. had exactly four years, 1946–1949, with a public debt/GDP ratio above 90 percent. Growth in these years was −10.9, −0.9, 4.4, and −0.5. See Irons and Bivens (2010) for more detailed discussion.

country-years of data: 25 years of Belgium were dropped in addition to the 14 already accounted for by the years that RR excluded.

Spreadsheet coding error

A coding error in the RR working spreadsheet entirely excludes five countries, Australia, Austria, Belgium, Canada, and Denmark, from the analysis.[5] The omitted countries are selected alphabetically and, hence, likely randomly with respect to economic relationships. This spreadsheet error, compounded with other errors, is responsible for a −0.3 percentage-point error in RR's published average real GDP growth in the highest public debt/GDP category. It also overstates growth in the lowest public debt/GDP category (0 to 30 percent) by +0.1 percentage point and understates growth in the second public debt/GDP category (30 to 60 percent) by −0.2 percentage point.

Unconventional weighting of summary statistics

RR adopts a non-standard weighting methodology for measuring average real GDP growth within their four public debt/GDP categories. After assigning each country-year to one of four public debt/GDP groups, RR calculates the average real GDP growth for each country within the group, that is, a single average value for the country for all the years it appeared in the category. For example, real GDP growth in the UK averaged 2.4 percent per year during the 19 years that the UK appeared in the highest public debt/GDP category while real GDP growth for the US averaged −2.0 percent per year during the 4 years that the US appeared in the highest category. The country averages within each group were then averaged, equally weighted by country, to calculate the average real GDP growth rate within each public debt/GDP grouping.

RR does not indicate or discuss the decision to weight equally by country rather than by country-year. In fact, possible within-country serially correlated relationships could support

[5]RR averaged cells in lines 30 to 44 instead of lines 30 to 49.

an argument that not every additional country-year contributes proportionally additional information. Yet equal weighting of country averages entirely ignores the number of years that a country experienced a high level of public debt relative to GDP. Thus, the existence of serial correlation could mean that, with Greece and the UK, 19 years carrying a public debt/GDP load over 90 percent and averaging 2.9 percent and 2.4 percent GDP growth respectively do not each warrant 19 times the weight as New Zealand's single year at −7.6 percent GDP growth or five times the weight as the US's four years with an average of −2.0 percent GDP growth. But equal weighting by country gives a one-year episode as much weight as nearly two decades in the above 90 percent public debt/GDP range. RR needs to justify this methodology in detail. It otherwise appears arbitrary and unsupportable.

Table 2 presents average results by country for the above-90-percent public debt/GDP category for the alternative methods. (Table A-1 presents the full results for all debt/GDP categories.) The first three columns show the number of years that each country spent in the highest debt/GDP category. The Correct column reports the most available data for 1946–2009. The RR Exclusion column excludes available early years of data for Australia (1946–1950), Canada (1946–1950), and New Zealand (1946–1949). The RR Spreadsheet Error column reflects the spreadsheet error that omits all years for Australia, Austria, Belgium, Canada, and Denmark from the analysis. The Weights columns show the alternative weightings to compute average real GDP growth. The Country-Years weights column shows weights proportional to the number of country-years in the highest public debt/GDP category. The RR weights column shows the equal weighting by country used in RR. The GDP Growth columns show average real GDP growth for each country in the years in which it appeared in the highest debt/GDP category. The Correct GDP Growth column shows the average real GDP growth for all available country-years. The RR GDP Growth column shows the average real GDP growth used in RR with excluded years, spreadsheet errors, and a transcription error.

For example, Canada spent 5 years in the highest public debt/GDP category (4.5 percent of the 110 country-years in this category) and Canada's average real GDP growth during these 5 years was 3.0 percent per year. However the RR spreadsheet error and the RR years exclusion result in Canada not providing any data for the computation of the average for the highest debt/GDP category.

In the case of New Zealand, instead of constituting 5 of 110 country-years at 2.6 percent growth, the country contributes -7.9 percent growth for a full 14.3 percent (one-seventh) of the RR's GDP growth estimate for the above 90 percent public debt/GDP grouping.[6]

110 country-years appear in the highest public debt/GDP category with only 10 countries ever appearing in the category. Three of these, Australia, Belgium, and Canada, were excluded from the analysis by spreadsheet error, leaving seven countries in the highest category in RR. The included countries are Greece (19 years in the highest category with average real GDP growth of 2.9 percent per year); Ireland (7 years with average growth of 2.4 percent); Italy (10 years with average growth of 1.0 percent); Japan (11 years with average growth of 0.7 percent); New Zealand (1 year with average growth of −7.6 percent), the UK (19 years with average growth of 2.4 percent), and the US (4 years with average growth of −2.0 percent).

As we noted above, the exclusion of four years for New Zealand (only a 4.5 percent loss of country-years in the highest public debt/GDP category) has a major effect on the computed average in the highest public debt/GDP category. It reduces the average growth for New Zealand in the highest public debt/GDP category from 2.6 to −7.6 percent per year. The combined effect of excluding the years for New Zealand and equally weighting the countries (rather than weighting by country-years) reduces the measured average real GDP growth in the highest public debt category by a very substantial 1.9 percentage points.

[6] An apparent transcription error in transferring the country average from the country-specific sheets to the summary sheet reduced New Zealand's average growth in the highest public debt category from −7.6 to −7.9 percent per year. With only seven countries appearing in the highest public debt/GDP group, this transcription error reduces the estimate of average real GDP growth by another −0.1 percentage point.

Summary: years, spreadsheet, weighting, and transcription

Table 3 summarizes the errors in RR and their effect on the estimates of average real GDP growth in each public debt/GDP category. Some of the errors have strong interactive effects. Table 3 shows the effect of each possible interaction of the spreadsheet error, selective year exclusion, and country weighting.

The errors have relatively small effects on measured average real GDP growth in the lower three public debt/GDP categories. GDP growth in the lowest public debt/GDP category is roughly 4 percent per year and in the next two categories is around 3 percent per year with or without correcting the errors.

In the over-90-percent public debt/GDP category, however, the effects of the errors are substantial. For example, the impact of the excluded years for New Zealand is greatly amplified when equal country weighting assigns 14.3 percent (1/7) of the weight for the average to the single year in which New Zealand is included in the above-90-percent public debt/GDP group. This one year is when GDP growth in New Zealand was −7.6 percent. The exclusion of years coupled with the country—as opposed to country-year—weighting alone accounts for almost −2 percentage points of under-measured GDP growth. The spreadsheet and transcription errors account for an additional −0.4 percentage point. In total, as we show in Table 3, actual average real growth in the high public debt category is +2.2 percent per year compared to the −0.1 percent per year published in RR. The actual gap between the highest and next highest debt/GDP categories is 1.0 percentage point (i.e., 3.2 percent less 2.2 percent). In other words, with their estimate that average GDP growth in the above-90-percent public debt/GDP group is −0.1 percent, RR overstates the gap by 2.3 percentage points or a factor of nearly two and a half.

Figure 1 presents all of the country-year data, as continuous real GDP growth rates plotted against public debt/GDP categories. RR mean growth estimates are indicated by diamonds with the corrected growth estimates indicated by filled circles. The substantial

error in the RR estimates of mean real GDP growth in the 90 percent public debt/GDP category is evident in the plot as is the relatively inconsequential errors in the lower three categories. The plot also shows large variation in real GDP growth in each public debt/GDP category. Finally, the plot includes an empty square as the data point for New Zealand in 1951, which alone accounts for one-seventh of RR's result for the highest public debt/GDP category.

3 Non-linearity at the "historical boundary"?

Our revised results also provide an opportunity to re-examine non-linearity in the relationship between public debt and growth. RR asserts, "The nonlinear response of growth to debt as debt grows towards historical boundaries is reminiscent of the 'debt intolerance' phenomenon developed in Reinhart, Rogoff, and Savastano (2003)" (RR 2010a p. 577).

The corrected means within each public debt/GDP category cast doubt on the identification of a nonlinear response that was an important component of RR's findings. We explore the question in several ways. First, we add an additional public debt/GDP category, extending by an additional 30 percentage points of public debt/GDP ratio—that is, we add 90–120 percent and greater-than-120 percent categories. Figure 2 shows the results of the extension. Far from appearing to be a break, average real GDP growth in the category of public debt/GDP between 90 and 120 percent is 2.4 percent, reasonably close to the 3.2 percent GDP growth in the 60–90 percent category. GDP growth in the new category between 120 and 150 percent is lower at 1.6 percent but does not fall off a nonlinear cliff. Equally significant, as Figure 2 shows, variation in real GDP growth within each public debt/GDP category is large.

In Figure 3, we present a scatterplot of all of the country-years with continuous real GDP growth plotted against public debt/GDP ratio and include a locally fitted regression

function.[7] No particular boundary or non-linearity is evident in either dimension around public debt/GDP of 90 percent. The data thin out gradually between 70 and 120 percent as is visible from the points in the scatterplot and the widening 95 percent confidence interval for mean growth. More generally, the wide range of GDP growth at various public debt levels is evident.

Finally, the scatterplot does suggest a non-linearity in the relationship, but that occurs in the change in the public debt/GDP ratio from 0 to 30 percent. This contradicts RR's claim that "it is evident that there is no obvious link between debt and growth until public debt reaches a threshold of 90 percent" (RR 2010a p. 575). Figure 4, which is a close-up of Figure 3 shows more clearly that average growth declines sharply with public debt/GDP between 0 and 30 percent; at 0 percent debt/GDP, average growth is almost 5 percent and by 30 percent it has declined to slightly more than 3 percent. The relationship between average GDP growth and public debt/GDP is relatively flat over a wide domain of debt/GDP values. Between public debt/GDP ratios of 38 percent and 117 percent, we cannot reject a null hypothesis that average real GDP growth is 3 percent.

In Table 4, we present regression analysis of real GDP growth by public debt/GDP category. The first row in both columns confirms significantly and substantively higher growth rates in the lowest 0–30 percent public debt/GDP category relative to other public debt/GDP categories.[8] The results show modest differences among the other categories.

In the first column, average GDP growth in the category of public debt/GDP above 90 percent is lower by about 1 percentage point than GDP growth in the 30–60 percent and

[7]The locally smoothed regression function is estimated with the general additive model with integrated smoothness estimation using the `mgcv` package in R. The smoothing parameter is selected with the default cross-validation method. Alternative methods, e.g., loess, and smoothing parameters produced substantively similar results.

[8]Neither the US nor the UK ever appeared in the 0 to 30 percent debt/GDP range between 1946 and 2009. 121 of the 426 country years in the lowest debt/GDP category consist of Germany (48), Japan (22), and Norway (51). These are special cases (two historically specific "growth miracles" and a petroleum producer), and the lessons for public debt management and growth for Europe and the U.S. today are limited.

60–90 percent public debt/GDP categories. In the second column, average GDP growth in the category of public debt/GDP above 120 percent is substantially lower than GDP growth in the 30–60 percent and 60–90 percent debt/GDP categories. However, in the second column, which includes the new above-120-percent public debt/GDP category, differences in average GDP growth in the categories 30–60 percent, 60–90 percent, and 90–120 percent cannot be statistically distinguished. An F-test on the hypothesis that, relative to the 30–60 category, the 60–90 difference and the 90–120 differences are both zero cannot be rejected (p-value = 0.11). To summarize, the regression results show that there is a non-linearity in the relationship between GDP growth and public debt between public debt levels of 0 to 30 percent of GDP. The results also indicate that average GDP growth tails off somewhat when the public debt/GDP ratio increases towards 120 percent, but there is no sharp turning point.

Thus, the non-linearity in the relationship between public debt levels and GDP growth is not around a public debt/GDP ratio of 90 percent where RR have identified it. That is, the non-linearity is not in the domain of public debt/GDP values that is currently the focus of policy debate in the US and Europe.

Different results by period

We further explore the historical specificity of the result by examining average real GDP growth by public debt category for subsampled periods of the data. Table 5 presents results for 1950–2009, 1960–2009, 1970–2009, 1980–2009, 1990–2009, and 2000–2009. We see that the high GDP growth in the lowest public debt/GDP category erodes substantially in the shorter more recent periods. Thus, in the lowest, 0–30-percent public debt/GDP, GDP growth of 4.1 percent per year in the 1950–2009 sample declines to only 2.5 percent per year in the 1980–2009 sample. Growth in the middle two public debt/GDP categories also decelerates noticeably, with the average dropping by more than a percentage point in the

samples limited to later years. In contrast, average growth in the highest debt/GDP category is quite stable across all samples of years, remaining within 0.3 percentage points of 2 percent per year throughout. In recent years, real GDP growth in the highest, above-90-percent public debt/GDP category has outperformed that in the next highest category.

These patterns suggest two important conclusions: (1) even the apparent non-linearity between the lowest-debt country-years and higher-debt country-years is an historically specific pattern, not a robust result across the full time period; and (2) the relationship between public debt and GDP growth is weaker in more recent years relative to the earlier years of the sample.

4 Conclusion

The influence of RR's findings comes from its straightforward, intuitive use of data to construct a stylized fact characterizing the relationship between public debt and GDP growth for a range of national economies. However, this laudable effort at clarity notwithstanding, RR has made significant errors in reaching the conclusion that countries facing public debt to GDP ratios above 90 percent will experience a major decline in GDP growth.[9] The key identified errors in RR, including spreadsheet errors, omission of available data, weighting, and transcription, reduced the measured average GDP growth of countries in the high public debt category. The full extent of those errors transforms the reality of modestly diminished average GDP growth rates for countries carrying high levels of public debt into a false image that high public debt ratios inevitably entail sharp declines in GDP growth. Moreover, as we show, there is a wide range of GDP growth performances at every level of public debt among the 20 advanced economies that RR survey.

[9]For econometricians a lesson from the problems in RR is the advantages of reproducible code relative to working spreadsheets. We are grateful to Reinhart and Rogoff for sharing the working spreadsheet, and we will make our simplified version of the spreadsheet and R code that reproduces RR and corrected results available on our website.

RR's incorrect stylized fact has contributed substantially to ensuring that "traditional debt management issues should be at the forefront of public policy concerns" (RR 2010a p. 578). Specifically, RR's findings have served as an intellectual bulwark in support of austerity politics. The fact that RR's findings are wrong should therefore lead us to reassess the austerity agenda itself in both Europe and the United States.

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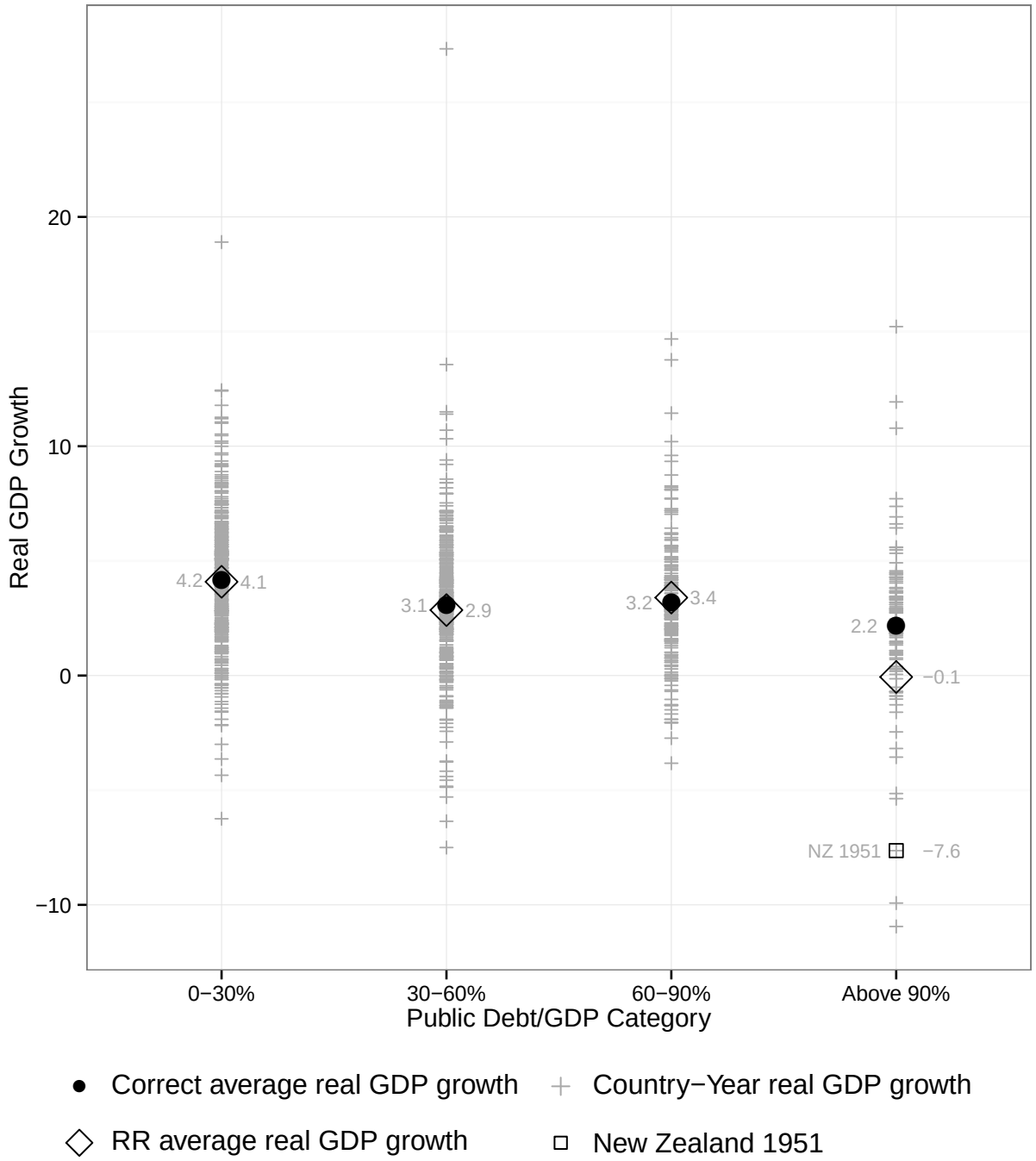
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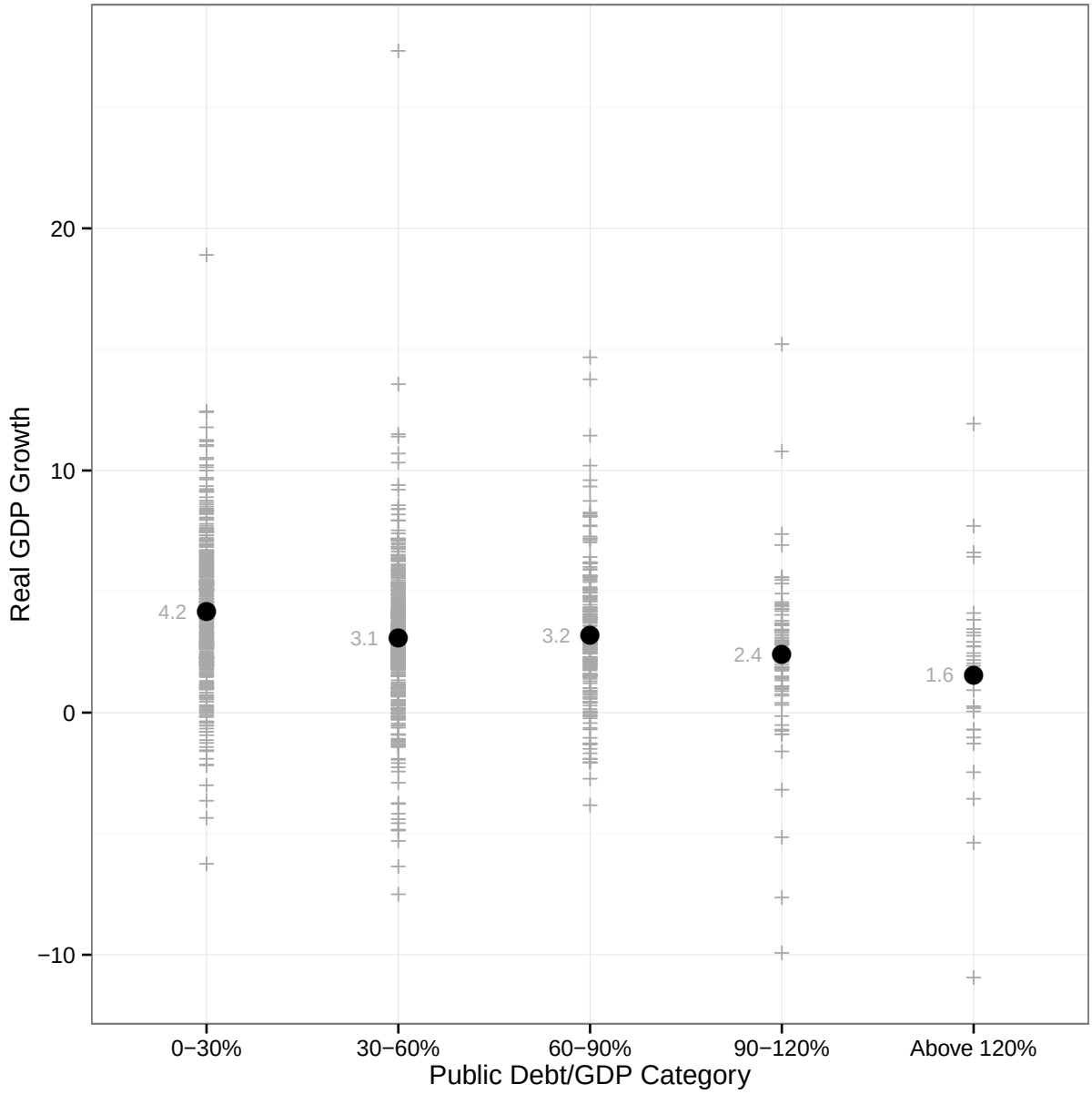
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Figure 1: Real GDP growth by public debt/GDP categories, country-years, 1946–2009



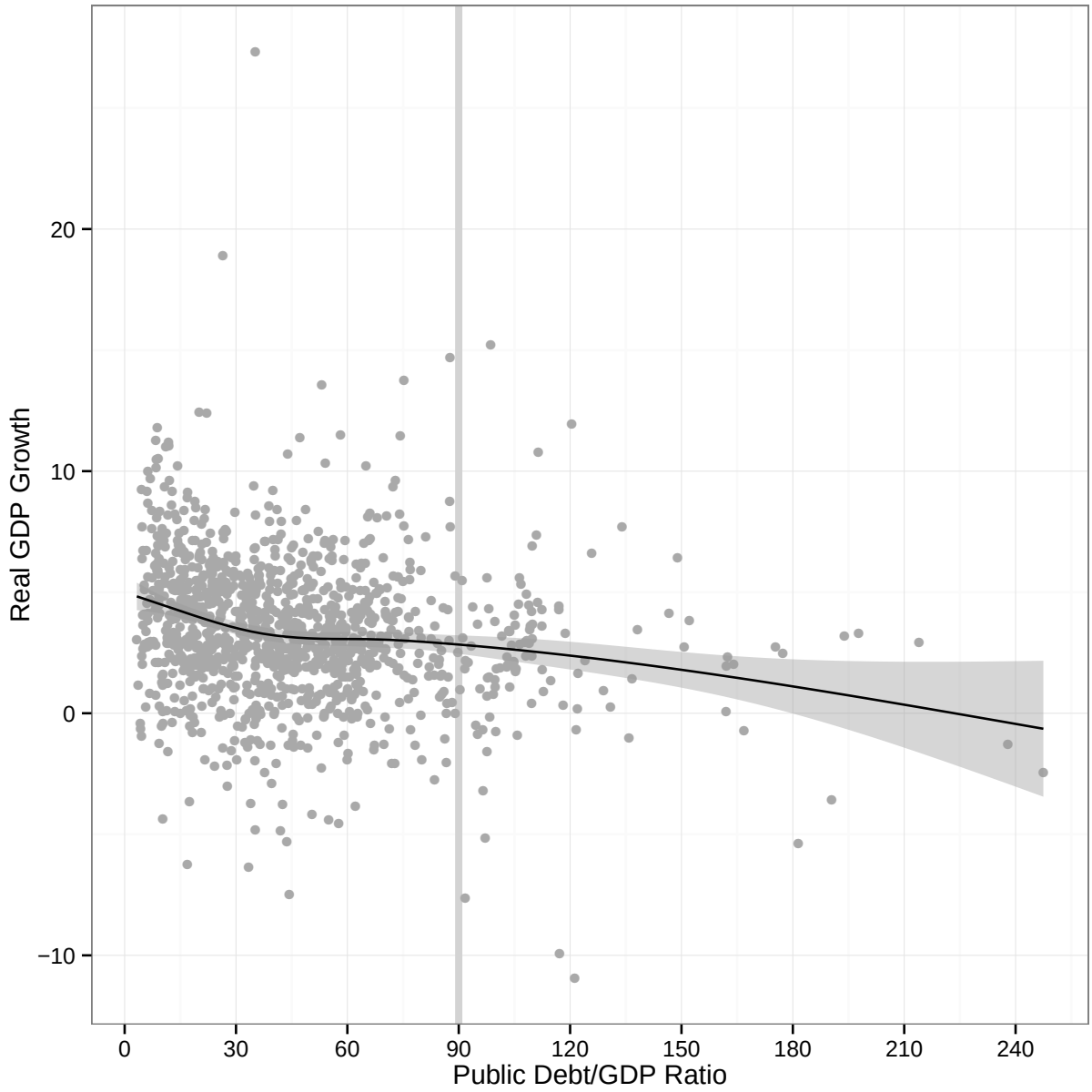
Notes. The unit of observation in the scatter diagram is country-year with real GDP growth plotted against four debt/GDP categories. Our replication of RR published values for average real GDP growth within category are printed to the right. Corrected values for average real GDP growth within category are printed to the left.
Source: Authors' calculations from working spreadsheet provided by RR.

Figure 2: Real GDP Growth by Expanded Debt/GDP Categories, Country-Years, 1946–2009



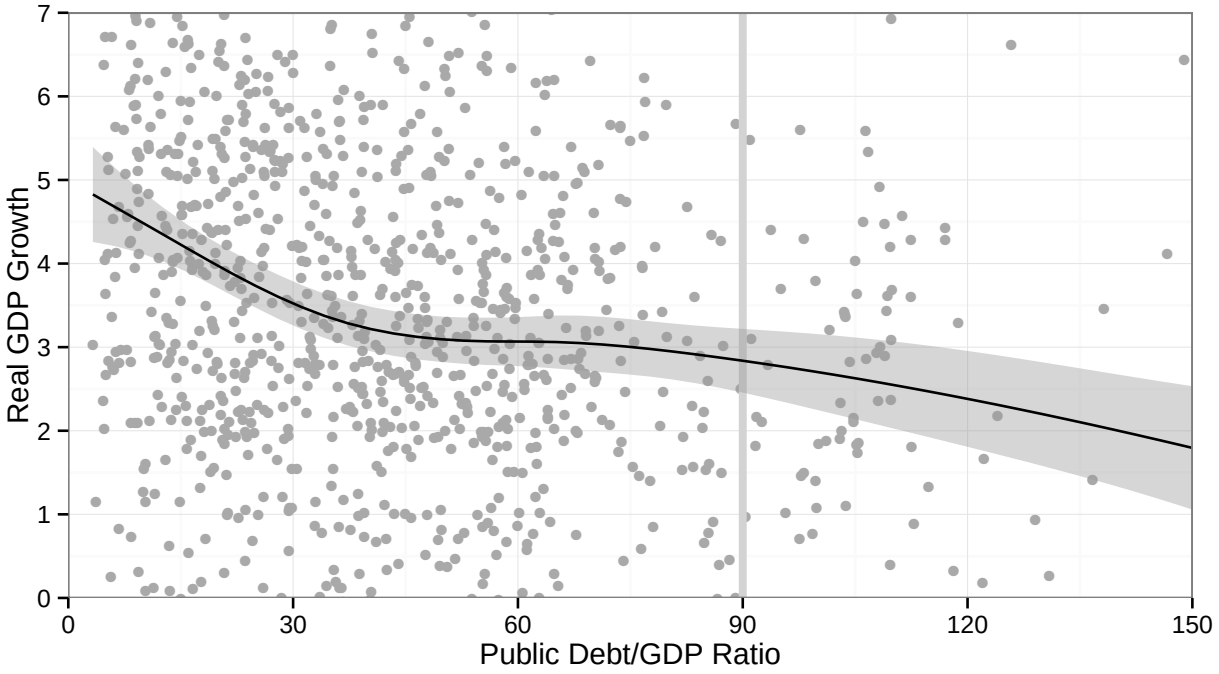
Notes. As in Figure 1, the unit of observation in the scatter diagram is country-year with real GDP growth plotted, in this case, against five debt/GDP categories. Average real GDP growth within category are printed and indicated with a filled circle.
Source: Authors' calculations from working spreadsheet provided by RR.

Figure 3: Real GDP growth *vs.* public debt/GDP, country-years, 1946–2009



Notes. Real GDP growth is plotted against debt/GDP for all country-years. The locally smoothed regression function is estimated with the general additive model with integrated smoothness estimation using the `mgcv` package in R. The smoothing parameter is selected with the default cross-validation method. The shaded region indicating the 95 percent confidence interval for mean real GDP growth. Alternative methods, e.g., loess, and smoothing parameters produced substantively similar results.
Source: Authors' calculations from working spreadsheet provided by RR.

Figure 4: Real GDP growth *vs.* public debt/GDP, country-years, 1946–2009 (close-up)



Notes. Figure 4 is a close-up on a region of Figure 3. Real GDP growth is plotted against debt/GDP for all country-years. The locally smoothed regression function is estimated with the general additive model with integrated smoothness estimation using the `mgcv` package in R. The smoothing parameter is selected with the default cross-validation method. The shaded region indicating the 95 percent confidence interval for mean real GDP growth. Alternative methods, e.g., loess, and smoothing parameters produced substantively similar results. As in Figure 3 , all available data were used in producing Figure 4.
Source: Authors' calculations from working spreadsheet provided by RR.

Table 2: Years and real GDP growth with public debt/GDP above 90 percent, by country

	Count of years with public debt/GDP above 90 percent						
		RR Exclusion of early years for Australia, Canada, and	RR Spreadsheet error excluding Australia, Austria Belgium, Canada	**Weights**		**GDP Growth**	
	Correct	New Zealand	and, Denmark	Country-Years	RR	Correct	RR
Australia 1946–50	5	0	0	4.5	0.0	3.8	
Belgium 1947, 1984–2005, 2008–09	25	25	0	22.7	0.0	2.6	
Canada 1946–50	5	0	0	4.5	0.0	3.0	
Greece 1991–2009	19	19	19	17.3	14.3	2.9	2.9
Ireland 1983–89	7	7	7	6.4	14.3	2.4	2.4
Italy 1993–01,2009	10	10	10	9.1	14.3	1.0	1.0
Japan 1999–2009	11	11	11	10.0	14.3	0.7	0.7
New Zealand 1946–49,1951	5	1	5	4.5	14.3	2.6	−7.9
UK 1946–64	19	19	19	17.3	14.3	2.4	2.4
US 1946–49	4	4	4	3.6	14.3	−2.0	−2.0
						Average GDP Growth	
	Count of country-years and countries with public debt/GDP above 90 percent			Country-year weights and correct GDP			
Country-Years	110	96	75	growth data		2.2	
Countries	10	8	7	RR equal weights and RR GDP growth data			−0.1

Notes. Years that each country spent in the highest debt/GDP category are listed. The Years columns show the count of years that each country spent in the highest debt/GDP category. The Correct column uses all available data for 1946–2009. The Exclusion column excludes available early years of data for Australia (1946–1950), Canada (1946–1950), and New Zealand (1946–1949). The Spreadsheet column reflects the spreadsheet error that omits Australia, Austria, Belgium, Canada, and Denmark. The Weights columns show the alternative weightings to compute average real GDP growth. The Year column shows weights proportional to country-years. The RR weight column shows equal weighting of country averages. GDP shows real average GDP growth for each country in the years in which it appeared in the highest debt/GDP category for all available years. The value of -7.9 for New Zealand in parentheses reflects both the exclusion of 1946–1949 and a transcription error of −7.6 to −7.9.
Source: Authors' calculations from working spreadsheet provided by RR.

Table 3: Published and replicated average real GDP growth, by public debt/GDP category

Method/Source	Public debt/GDP category			
	Below 30 percent	30 to 60 percent	60 to 90 percent	90 percent and above
Corrected results				
Country-year weighting, all data	4.2	3.1	3.2	2.2
Replication elements				
Separate effects of RR calculations				
Spreadsheet error only	4.2	3.0	3.2	1.9
Selective years exclusion only	4.2	3.1	3.2	1.9
Country weights only	4.0	3.0	3.0	1.9
Interactive effects of RR calculations				
Spreadsheet error + Selective years exclusion	4.2	3.0	3.2	1.7
Spreadsheet error + Country weights	4.1	2.9	3.4	1.4
Selective years exclusion + Country weights	4.0	3.0	3.0	0.3
Spreadsheet error + Selective years exclusion + Country weights	4.1	2.9	3.4	0.0
Spreadsheet error + Selective years exclusion + Country weights + Transcription error	4.1	2.9	3.4	−0.1
RR Published Results				
RR 2010a Figure 2 (approximated)	4.1	2.9	3.4	−0.1
RR 2010b Appendix Table 1	4.1	2.8	2.8	−0.1

Notes. Average real GDP growth by public debt/GDP category calculated using alternative methods. Spreadsheet error refers to the spreadsheet error that excluded Australia, Austria, Belgium, Canada, and Denmark from the analysis. Country weights refers to the RR averaging country averages rather than averaging country-years. Selective years exclusion refers to the exclusion of available data for 1946–50 for Australia, Canada, and New Zealand. Transcription error refers to a transcription error in the case of New Zealand's average real GDP growth. All permutations of Spreadsheet, Exclusion, and Weights are shown.
Sources: Authors' calculations from working spreadsheet provided by RR, RR 2010a, and RR 2010b. Values from bar chart in RR 2010a Figure 2 are approximate.

Table 4: Regression of GDP growth on public debt/GDP categories

Debt/GDP Category	**Difference in average real GDP growth Relative to 0–30 percent public debt/GDP**	
	Highest category is above 90 percent	Highest two categories are 90–120 percent and and above 120 percent
30–60 percent	−1.08	−1.08
	(0.20)	(0.20)
60–90 percent	−0.99	−0.99
	(0.25)	(0.25)
Above 90 percent	−2.01	
	(0.31)	
90–120 percent		−1.77
		(0.36)
Above 120 percent		−2.61
		(0.54)
R-squared	0.04	0.04

Notes. Table entries are average GDP growth differences for each category with standard error in parentheses. Each column represents a regression of real GDP growth by country-year on a set of indicator variables for debt/GDP category by country-year. The first column shows the growth difference associated with the higher debt/GDP categories relative to the 0–30 percent debt/GDP category. The second column shows the growth difference associated with the expanded, five debt/GDP categories relative to the 0–30 percent debt/GDP category. An F-test on the joint hypothesis that the coefficient on 60–90 percent and the coefficient on 90–120 percent are both the same as the coefficient on 30–60 percent in column 2 fails to reject (p-val = 0.11).
Source: Authors' calculations from working spreadsheet provided by RR.

Table 5: Real GDP growth by public debt/GDP category, alternative periods

	Public debt/GDP category			
Period	Below 30 percent	30 to 60 percent	60 to 90 percent	90 percent and above
1950–2009	4.1	3.0	3.1	2.1
1960–2009	3.9	2.9	2.8	2.1
1970–2009	3.1	2.7	2.6	2.0
1980–2009	2.5	2.5	2.4	2.0
1990–2009	2.7	2.4	2.5	1.8
2000–2009	2.7	1.9	1.3	1.7

Notes. Table entries by debt/GDP category indicate the average real GDP growth rate for country-years in that category computed for alternative periodizations.
Source: Authors' calculations from working spreadsheet provided by RR.

Table A-1: Average real GDP growth and years by country and debt/GDP category

Country		Public debt/GDP category			
		Below 30 percent	30 to 60 percent	60 to 90 percent	90 percent and above
Australia	Years	37	13	9	5
	GDP growth	3.2	4.9	4.0	3.8
Austria	Years	34	27	1	0
	GDP growth	5.2	3.4	−3.8	
Belgium	Years	0	17	21	25
	GDP growth		4.2	3.1	2.6
Canada	Years	3	42	14	5
	GDP growth	2.5	3.5	4.5	3.0
Denmark	Years	23	16	17	0
	GDP growth	3.5	1.7	2.4	
Finland	Years	44	16	4	0
	GDP growth	3.8	2.4	5.5	
France	Years	24	20	10	0
	GDP growth	5.1	2.6	3.0	
Germany	Years	48	11	0	0
	GDP growth	3.9	0.9		
Greece	Years	13	5	3	19
	GDP growth	4.0	0.3	2.7	3.1
Ireland	Years	10	14	32	7
	GDP growth	4.2	4.5	4.0	2.4
Italy	Years	26	6	17	10
	GDP growth	5.4	2.1	1.8	1.0
Japan	Years	22	17	4	11
	GDP growth	7.3	4.0	1.0	0.7
Netherlands	Years	17	34	2	0
	GDP growth	4.1	2.6	1.1	
New Zealand	Years	9	33	17	5
	GDP growth	2.5	2.9	3.9	2.6
Norway	Years	51	12	1	0
	GDP growth	3.4	5.1	10.2	
Portugal	Years	42	9	7	0
	GDP growth	4.5	3.5	1.9	
Spain	Years	5	36	1	0
	GDP growth	1.5	3.4	4.2	
Sweden	Years	18	35	11	0
	GDP growth	3.6	2.9	2.7	

Continued

Table A-1: continued

Country		Public debt/GDP category			
		Below 30 percent	30 to 60 percent	60 to 90 percent	90 percent and above
UK	Years	0	39	6	19
	GDP growth		2.2	2.5	2.4
US	Years	0	37	23	4
	GDP growth		3.4	3.3	−2.0
Country-years		426	439	200	110
Countries		17	20	19	10

Source: Authors' calculations from working spreadsheet provided by RR.