ERASMUS SCHOOL OF ECONOMICS

Public debt and economic growth: a question of causality

An inquiry into the link between public debt and growth

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Abstract

In the aftermath of the economic crisis, the eurozone and others have responded to the spectre of high debt by pursuing austerity policies. To assess the prudency of this strategy and optimize future policy, a more thorough understanding of the causal link between public debt and economic growth is paramount. This paper presents a wide ranging overview into the available literature concerning the relationship between public debt and economic growth. This is supplemented by a statistical analysis of this relationship using extensive panel data of 20 OECD countries from 1880 till 2011 employing both a fixed-effect ordinary least squares regression and an instrumental variable approach. Consistent with much of the literature, a negative effect of debt on growth is found. The possible evidence in the literature of debt thresholds beyond which growth reduces sharply is found to lack robustness

Key concepts: growth, public, debt, causality

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1. Introduction

The economic crisis has brought the relationship between public debt and economic growth to the center of our academic and political consciousness. Partly driven by unease concerning the effects of very high public debts on economic growth, many developed nations and particularly the eurozone have pursued a policy of fiscal consolidation during the past few years. The suggestion in some academic papers that this relationship is non-linear and growth deteriorates sharply at high levels of debt, particularly a level of 90 percent of debt to GDP (Reinhart & Rogoff, 2010), has acted as a catalyst and contributed to the implementation of these policies (Hendon et al, 2013, p. 3-4). Whether this course of action has been prudent is an open question as long as the relationship between growth and debt remains uncertain.

This thesis attempts to illuminate the issue, and aims to shine a light on the current collective knowledge concerning this relationship. In addition this knowledge is further augmented by statistical analysis at the end of this paper.

The central question of this thesis is:

What is the causal relationship between public debt over GDP and economic growth in advanced countries?

Considering the heavy emphasis put on the non-linear- or threshold effects of debt on growth by both academics and policy makers in recent years, a secondary question of interest is:

Is there a non-linear effect that runs from debt to growth?

The paper follows a typical structure, after section 1 (the introduction) section 2 will be a literature review. The review of the available literature, both theoretical and empirical, serves as the backbone of this inquiry and constitutes its main part. This study is greatly assisted by the wealth of empirical studies that have become available in recent years. And these studies form the main source in answering the central questions of this paper. Section 3 will cover the novel

statistical research performed here. A wealth of data on economic indicators from the IMF is used that has only become available in recent years (Pescatori et al, 2014, p. 7), going back all the way to 1880. The methodology employed is a panel fixed-effect ordinary least squared regression and finally a instrumental variable approach. As the instrumental variable approach is the method most likely to convincingly prove causal effects one way or the other in absence of experiments, given its ability to deal with endogeneity. In section 4 conclusions are drawn on the basis of both the extensive literature review and the instrumental variable regression.

2. Literature review

As nation states have expanded their centralized governments, budgets and budget deficits over the past two centuries, so too has the relative importance of the government in the economy grown. And over time academic interest in the relationship between public debt and economic growth has increased. In recent years the academic debate concerning the relationship between public debt and growth has been given a boost by the global financial crisis and the sovereign debt crisis in the EU. This chapter will cover both theoretical papers on the relationship between public debt and economic growth as well as the rapidly expanding empirical literature on the subject.

2.1 Theory

In this section some of the theoretical literature on the effects of public debt on economic growth will be reviewed. First the conventional view as defined by Elmendorf and Mankiw (1999) will be explained, drawing from both Keynesian influences in the short run and the neoclassical model in the long run. Further on Peter Diamond's seminal work on overlapping growth models will be reviewed.

The theoretical framework serves to anchor possible expectations of the relationship between public debt and economic growth and as a starting point in understanding the as of yet unclear causal relationship between public debt and economic growth.

2.1.1 Conventional view

Elmendorf and Mankiw describe what they label as the conventional view on public debt and its effects on growth (1999, p. 1627-1634). In this conventional view the Ricardian equivalence does not hold and changes in public saving are not fully compensated by changes in private savings. In the short run the economy is Keynesian and in the long run classical. In the short run, given that government expenditures stay the same, the issuance of public debt in lieu of taxes increases disposable income for households and therefore increases demand for consumption goods and thus aggregate demand for goods and services. The effect of this shift in demand is an increase in national income, because the increase in aggregate demand affect the utilization of the factors of productions through the Keynesian concepts of wage rigidity, sticky prices and/or temporary misperceptions. The farther output is below potential capacity, such as during deep recessions, the larger this increase is likely to be according to Keynesian analysis.

According to Elmendorf and Mankiw's conventional view, things change in the long run. Over time these Keynesian effects disappear, wages and prices can adjust and temporary misperceptions vanish. Therefore it is incumbent to analyze several accounting identities that can explain the long run effect of debt on growth ignoring short term Keynesian effects.

Y (national income) = consumption + private savings + taxes (less government transfer payments).

Y (national output) = consumption + investment + government spending + (exports− imports).

Combining these yields:

private savings + (taxes (- transfers) - government spending) = investment + (exports - imports).

The second term on the left hand side of the equation are government savings. And thus according to this identity, private plus government savings (known together as national savings) must equal investment plus net exports. The next identity to consider is that a country's current account balance must equal the negative of its capital account. Ignoring net investment income by domestic residents and net transfers for simplicity, this leaves net exports on the current account. The negative of the capital account is defined as net foreign investment which is foreign investment by domestic residents minus domestic investment by foreign residents. The resulting accounting identity is:

(exports− imports).= net foreign investment.

Substituting this identity into the previous one yields:

private savings + (taxes (- transfers) - government spending) = investment + net foreign investment.

This last identity shows how national savings on the left, is used on domestic and foreign investment on the right hand side of the equation. So if the government starts running a budget deficit by decreasing taxes, holding spending constant, the identity can be balanced in three ways.

The most obvious way to balance the previous identity is to increase private savings, but because the Ricardian equivalence doesn't hold in the conventional view private savings will not compensate for all the loss in public savings. So either investment and/or net foreign investment has to fall. The effect of a fall in domestic investment is a fall in the capital stock which decreases output and thus national income. A fall in net foreign investment means either that domestic residents own less foreign capital or foreign residents own more domestic capital, both reduce national income. So according to the conventional view as explained by Elmendorf and Mankiw (1999) the issuance of public debt increases national income in the short term but decreases it in the long term. Elmendorf and Mankiw calculate this longer term reduction to be 10 cents per year for each additional dollar of debt.

On the other hand Delong and Summers (2012) argue in their paper that expansionary fiscal policy may be self financing in the long run in a depressed economy when interest rates are up against the zero lower bound. Where the central bank is no longer able to perform it's stabilizing function because interest rates can't go any lower and there is still a large shortfall in potential output. Even when expansionary fiscal policy is not self financing they argue it is still likely to pass an extra output cost-benefit test in such an environment where output is significantly below potential. At least as long as the difference between the government's real borrowing cost and the social rate of time discount is not too large. This suggest that budget deficits during recessions may affect growth positively over the long term too if they are a result of expansionary fiscal policy.

2.1.2 Neoclassical growth model in a overlapping generations framework

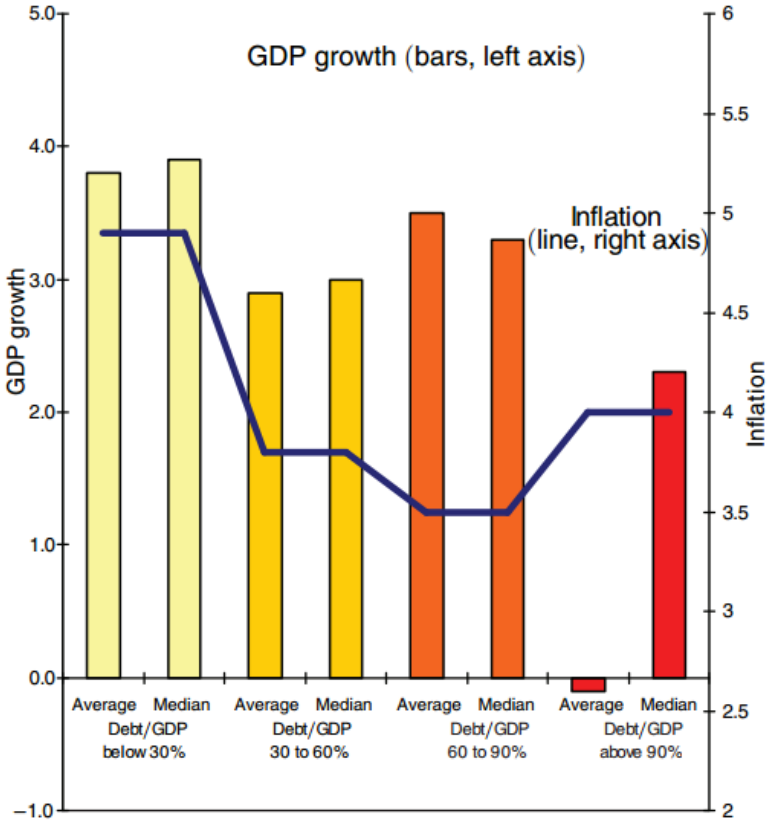
Peter Diamond (1965) expanded on Samuelson's (1958) overlapping generations model to analyze the long term effects of introducing public debt in a neoclassical competitive equilibrium. He did so by introducing capital as the only durable goods. The model works by taking an existing capital stock for granted and having two generations, old and new. Workers work in the first generation and retire in the second on savings/capital gains. For debt a constant debt to labor ratio was assumed because a fixed amount would asymptotically have no effect in a growing economy in the long run. Using this model he showed the possible equilibria and the effects of debt on these equilibria. The Pareto efficient equilibrium was found to be the one in which factors of production, interest on capital and consumption were organized in such a way that interest on capital ***r*** is equal to the natural growth rate of labor ***n***.

The first surprising result Diamond found is that in an OLG model the frictionless competitive equilibria need not be Pareto efficient. Interest rates can be either larger or smaller than ***n*** and because of this the effects of debt on total utility are ambiguous depending on the case. In the Pareto efficient case both internal and external debt decrease total utility. However in the Pareto inefficient case internal debt increases total utility, if there is no external debt, and external debt may do so as well.

In the model utility is ultimately derived from production/income and thus increases and decreases in utility can be seen as analogous to economic growth and decline. An increase in total utility thus corresponds to an increase in total production given that the allocation function of income among generations is separate from the production function. Given this it is surprising that even in a *neoclassical* OLG model there are scenarios in which extra government debt, both internal and external, can lead to higher sustained growth. This surprising result of the paper further complicates theoretical predictions on the overall sign of the effect of debt on growth because it presents alternative possibilities.

2.2 Empirical literature

Figure 1: The non-linearity of the debt-growth relationship



Source: Reinhart and Rogoff (2010a)

2.2.1 Nonlinear effects of debt on growth (on the existence of thresholds)

There have been a large number of empirical studies on the relationship between growth and public debt the last few years. Many of whom have found a nonlinear relationship characterized by a threshold, usually around 90 percent public debt to GDP ratio, above which growth drops sharply. A very influential paper in policy circles in both the USA and Europe is the paper by Carmen Reinhart and Kenneth Rogoff (2010) which found such a threshold. The main

result of the paper is that there is a cut-off point at 90 percent public debt to GDP where growth slows dramatically. The study is based on an extensive dataset including 44 countries spanning some 200 years covering a wide array of political systems, monetary arrangements, exchange rates, institutions and historical circumstances.

Between 2007 and 2009 public debt has increased by about 75 percent in real terms in countries hit by systemic financial crisis, well on track to meet or exceed the historic three year deep post-war crisis benchmark of 86 percent found in their earlier paper (Reinhart and Rogoff, 2009a, b). To measure the effects of public debt on growth, country years are grouped into four categories of different debt to GDP ratios: ratios below 30 percent, ratios between 30 percent and 60 percent, ratios between 60 percent and 90 percent and ratios surpassing 90 percent (Reinhart and Rogoff, 2010). Each group has a significant number of observations.

No obvious link between debt and growth is seen in the lower three categories, but at 90 percent or above median growth declines by about 1 percent for advanced economies and average growth is almost 4 percent lower. Results for emerging market economies are largely similar. No apparent link between public debt and inflation is found in the paper. Interestingly Reinhart and Rogoff also looked at the effects of external debt, both private and public, rather than public debt for emerging market economies and find a much more severe threshold at 60 percent external debt and an even further deterioration at ratios exceeding 90 percent. Inflation is also significantly higher in the group where external debt exceeds 90 percent in emerging markets. These results suggest that perhaps the composition of debt is more important than the overall level of public debt.

The study by Reinhart and Rogoff and the conclusion that there is a threshold at 90 percent public debt to GDP above which growth greatly deteriorates was hugely influential in policy circles both in the USA and Europe. Some select quotes are:

- *"It is widely acknowledged, based on serious research, that when public debt levels rise about 90 percent they tend to have a negative economic dynamism, which translates into low growth for many years."* — European Commissioner Olli Rehn.

- *It's an excellent study, although in some ways what you've summarized understates the risks*."— Former US Treasury Secretary Tim Geithner.

- *"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 effect on economic growth."* — Republican vice-presidential candidate Paul Ryan (Ryan, 2013, p. 78).

- *"For example, an influential series of papers by Reinhart and Rogoff (2010, 2012) argues that there is a threshold effect whereby debt above 90 percent of GDP is associated with dramatically worse growth outcomes."* — Pescatori, A., Sandri, D., & Simon (Pescatori et al, 2014, p. 4).

- *"We would soon get to a situation in which a debt-to-GDP ratio would be 100%. As economists such as Reinhart and Rogoff have argued, that is the level at which the overall stock of debt becomes dangerous for the long-term growth of an economy. They would argue that that is why Japan has had such a bad time for such a long period. If deficits really solved long-term economic growth, Japan would not have been stranded in the situation in which it has been for such a long time."* — Lord Lamont of Lerwick, former UK chancellor and sometime adviser to current chancellor George Osborne.

Reinhart and Rogoff also cite an additional 76 high profile features that have cited this paper (Herndon, T., Ash, M., & Pollin, R., 2014).

However, other's have been more critical of the study. A paper by Thomas Hendon, Michael Ash and Robert Pollin (2013) found some serious errors in the Reinhart and Rogoff paper (2010). They found that the result that Reinhart and Rogoff found was mostly driven by unconventional weighing of the data, a coding error which excluded the first five countries from analysis and selective exclusion of data. Correcting for these issues they find no significant difference between average growth in the highest debt category compared to the others. What they find is an average growth rate of 2.2 percent in the 90+ percent GDP group compared to the -0.1 percent that Reinhart and Rogoff reported.

The selective exclusion of four New Zealand years, all in the highest debt category, is of particular importance and changes the average growth rate in the 90+ percent debt category by -0.3 percentage points on its own and by -1.9 percent in combination with the unconventional weighting discussed below. Thus mistakes concerning a single small country already explains almost all of the threshold effect that is Reinhart and Rogoff's main conclusion, not just putting into question the validity and rigor of their study but also the robustness of their method of analysis. Hendon et al also find selective exclusion in the cases of Australia and Canada, though these do not have an effect on Reinhart and Rogoff's findings because of the spreadsheet error discussed further in the text.

Another controversial aspect of the study highlighted by Hendon et al is the unconventional weighting of the data. In the Reinhart and Rogoff study averages for each of the four debt categories are calculated per country and each average is weighed the same in the final result. This is problematic because it weighs results with vastly different numbers of observations the same way. For example for the 19 years that the UK was in the highest debt category it averaged a growth of 2.4 percent while the one year in this category that was not excluded for New Zealand growth was -7.6 percent. Both these results are

weighed the same in the Reinhart and Rogoff paper despite one being based on 19 observations and the other being based on only a single observation.

In addition, Hendon et al identify a spreadsheet error that leads to the exclusion of the first five countries in alphabetical order from Reinhart and Rogoff ‘s analysis. This error, compounded with other errors, is responsible for a -0.3 percent difference in the average growth in the highest debt category, a -0.2 percent difference in the second lowest debt category as well as an overstatement of growth by 0.1 percent in the lowest debt category.

So in summary Hendon et al find no nonlinear effect on growth between the two highest debt categories, thus no threshold. Instead they find that higher public debt is associated with lower growth but this is a gradual effect not a threshold. Another issue that Hendon et al find is that the negative relationship between debt to GDP and growth becomes weaker if the period of analysis is more recent and thus more relevant. This may simply indicate that the relationship isn’t as strong today as it was but it might also point to a relationship between periods, growth and the debt groups chosen. More to the point, it may be that a relatively higher number of countries were in the lower debt categories in the past when they were still more in the process of industrializing or developing and that these periods could also be associated with higher growth in general.

Other studies that have found similar thresholds. For example a paper by Baum, Checherita and Rother (2013) using a dynamic threshold panel methodology and focusing on 12 euro area countries from 1990-2010. This period was mainly chosen because the debt to GDP was found to be non-stationary over the longer 1980- period included in their robustness section. Baum et al regress real annual GDP growth on lagged debt to GDP using their dynamic threshold model and find a threshold for public debt exceeding 95 percent of GDP, above which growth slows down. Interestingly they also find a threshold of 67 percent under which debt has a positive impact on growth. This is the threshold found when the crisis years are excluded and the sample is 1990-

2007, probably a more generally representative sample. Baum et al argue that this is consistent with positive multiplier effects in Keynesian analysis. This is not entirely convincing as their model is one that looks at the effect of debt *levels,* and a certain debt level does not imply a change in spending on which the Keynesian multiplier relies. In a paper looking at 18 OECD countries from 1980 to 2010 Cecchetti et al (2011) find that public debt above 85 percent of GDP acts to slow down growth, though this augments to 96 percent when controlling for crisis. They estimate their model by using five-year overlapping forward averages of the per capita income growth rate and regressing it on control variables and debt levels.

2.2.2 Causality

Aside from the errors found by Hendon et al (2013), another more fundamental problem with the Reinhart and Rogoff paper and others is the question of causality. If it is true that higher public debt is associated with lower growth, as many papers have found, then this does not prove causation. It is possible that the effect or some of the effect runs the other way. Slow growth might lead to high levels of debt in a recession environment if revenues fall faster than expenditures or if the government follows an expansionary fiscal policy to mitigate some of the negative of lower growth in a recession. In fact the former is what is typically seen during recessions where expenditures do not fall but rise due to automatic stabilizers and revenues fall because of the drop in GDP.

Another issue is that there may be an omitted variable bias, the recessions already mentioned are an obvious source but wars and other crisis are possible sources as well. Another issue to consider is that the rapid industrialization of many nations, when economic growth is particularly high, has largely preceded the creation of the welfare state and the expansion of governments (Flora & Heidenheimer, 1981, p.22). In fact the birth of the early modern welfare state was a direct result of some of the growing pains of rapidly

industrializing nations in the west. And developing countries generally don't have the same access to financial markets as developed nations do (Panizza, Sturzenegger & Zettelmeyer, 2009) so they would naturally start from a lower stock of debt. So this theoretical causal effect would actually stem from high growth, due to industrialization, leading to higher debt due to increased access to financial markets and perhaps to finance part of the expansion of the government and the welfare state. Such an effect would be captured in studies and models measuring the impact of a *change* in debt on growth. But not in papers and models that look into the relation of the overall *level* of public debt on growth. Such studies constitute the majority of those surveyed here as well as the statistical analysis undertaken under section 3, and may thus bias the results somewhat of Reinhart and Rogoff, Woo and Kumar, Pescatori et al and others.

Another issue to consider is that debt to GDP has both a denominator and a numerator, so if GDP falls the ratio will increase but this is an identity, not a causal relationship. This in contrast may affect papers that analyze changes rather than levels. So endogeneity is problematic for this causal relationship, as there are good reasons to believe there is at least some reverse causality in the relationship and credible omitted variables are easy to propose.

However strong evidence for a debt threshold would indicate that most of the causality runs from debt to growth rather than vice versa because it's hard to justify the argument that slow growth causing high debt would create such thresholds.

To solve this issue of causality different papers have taken on different strategies. A paper by Woo and Kumar (2010) run a regression on the relationship between debt and growth in 30 advanced and emerging market economies using data over the period 1970-2007. They focus on a core set of explanatory variables that are consistently associated with economic growth (Doppelhofer et al, 2004). For debt they use the initial value of debt and regress it against subsequent growth to attempt to avoid the reverse causality problem.

To further avoid endogeneity Woo and Kumar instrument their debt value. Given the difficulty of finding appropriate external instrumental variables for initial government debt and other economic variables (Woo & Kumar, 2010, p. 8) they turn to internal instruments, specifically the system generalized method of moments approach (SGMM) popular in econometrics for microeconomic data which uses appropriate lagged first differences and lagged levels of the regressors and their instruments. Using this model they find a negative relationship between debt and growth where a 10 percent increase in the former results in a 20 basis points reduction in economic growth. This is a significant effect consistent with the theoretical model and calculations referenced by Mankiw and Elmendorf (1999). The use of the SGMM estimator is criticized by Panizza and Presbitero (2012) however, because the use of lagged variables is problematic given that debt and growth tend to be persistent and this limits their validity as internal instruments. The coefficients found are also similar to or larger than those obtained by standard fixed-effect regressions or pooled OLS models. Which Panizza and Presbitero find problematic because they argue this indicates that either the SGMM estimations don't correct for endogeneity or that debt is not endogenous, which is unlikely. However if the relationship between debt and economic growth is complex, which all this literature as well as this paper is somewhat of a testament to, then it's not completely out of the question that the true causal relationship is as large or larger than the OLS coefficient even if there is endogeneity.

Checherita-Westphal & Rother (2012) instrument the debt to GDP ratio with the average GDP ratio of the rest of their sample, consisting of 12 euro area countries from 1970-2008. They find that the effect of debt on growth becomes negative at around 90 to 100 percent debt to GDP. The instrument chosen doesn't seem too convincing, if debt is related to growth then using the average debt ratio of neighboring countries as an instrument is implicitly saying that the growth rates of these countries are not correlated with the subject country.

Panizza and Prebistero (2012) instrument the public debt to GDP ratio with the valuation effects originating from the interaction between movements in

the exchange rate and foreign currency debt. They show this instrument to be relevant in the paper but because their model is exactly identified, cannot test the validity of their instrument. Panizza and Prebistero find that the thresholds effects vanish in their instrumented models but ultimately cannot answer the question whether there is a causal relationship between public debt and economic growth. In their conclusion they do caution that this is not an argument for fiscal prolificacy but also as a counterfactual that the debt-growth link should not be used as an argument for fiscal consolidation as the evidence is inconclusive.

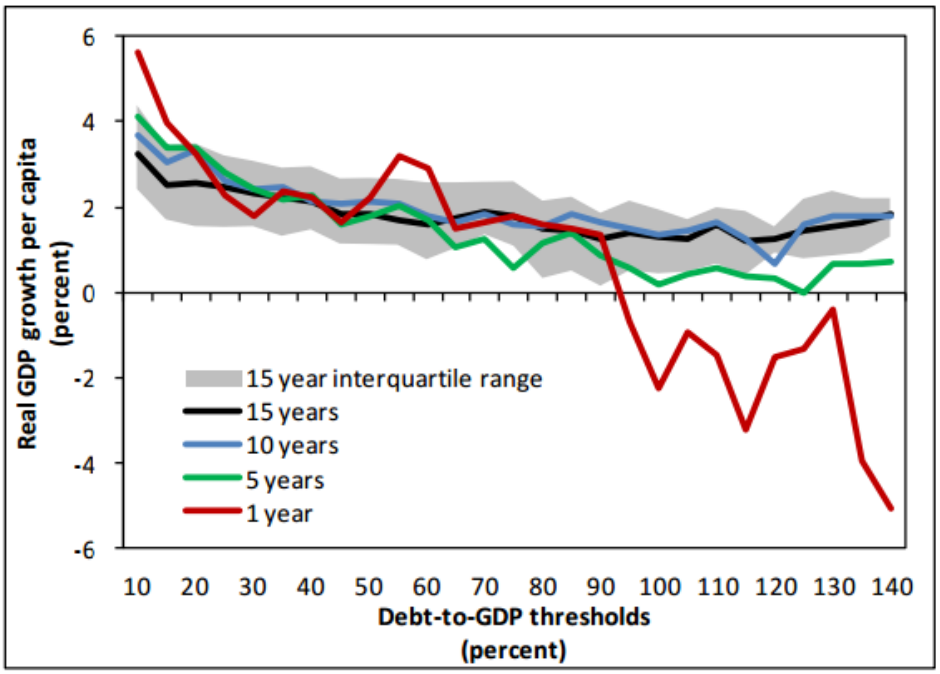
2.2.3 Robustness of thresholds

A recent paper by Andrea Pescatori, Damaino Sandri, and John Simon used a different strategy to estimate the effects of debt on growth (2014). Focusing in particular on longer term effects, effects relative to peers and debt trajectory effects on growth. Looking at advanced economies Pescatori et al used a comprehensive database compiled by the IMF on gross public debt to GDP ratios going back to 1875 covering most of the IMF membership. This data is supplemented with data on other indicators such as interest payments and real GDP. The strategy Pescatori et al employ is focusing on a long-term relationship between debt and growth, this is done to limit the effects of reverse causality. If high debt is a drag on growth then this should be visible over the longer term as debt, being a stock, is relatively stable over time. A fact also demonstrated by Pescatori et al in their paper.

The methodology used by Pescatori et al is to take the stock of debt to GDP in a given year, ***bt***, and comparing this to the real GDP growth in the next ***h*** years, with intervals for ***h*** of 1, 5, 10 and 15 compared. Starting years for these episodes are chosen based on a sample country crossing a chosen threshold of debt to GDP, countries can have multiple but not overlapping episodes. This is done to ensure that each country is only allowed to have relatively fewer episodes, so that some of the weighting issues like the ones in the Reinhart and Rogoff paper (2010) discussed by Hendon et al (2013) can be avoided.

Figure 2 plots the growth performance for country-episodes when crossing a given threshold for varying subsequent periods ***h*** corresponding to the different lines in the graph.

Figure 2: Debt and Growth over the Medium Run



Source: Pescatori et al (2014)

What is immediately noticeable about the graph in figure 2 is that growth deteriorates particularly quickly the first year after a country reaches a debt to GDP ratio of around 90 percent. Growth averages around 2 percent in countries with debt below 90 percent and falls to around -2 percent when they exceed this threshold, a result consistent with the Reinhart and Rogoff paper (2010). It should be noted that the interquartile range for first year growth (not shown here to save on space) exceeding thresholds at 90 percent and above is quite large and unduly influenced by outliers such as wars and crisis. What is even more noticeable in the graph is that most of this effect disappears when extending the subsequent growth horizon to 5 years. There is still a negative relationship between debt and subsequent annual growth but there is no longer a clear threshold at 90 percent and above. Countries below a given threshold outperform those above it but the relationship appears linear.

When extending the horizon to 10/15 years this negative relationship becomes even weaker and seems to disappear entirely from debt thresholds exceeding 60 percent, which is the range relevant for current austerity policy.

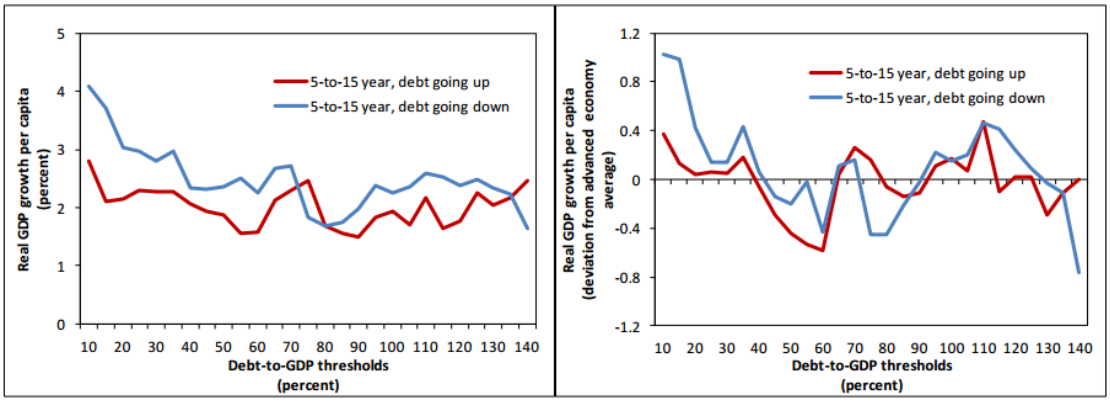
The possibility that the weakening relationship for larger horizons are driven by the fact that debt ratios might fall sharply after exceeding very high thresholds is also analyzed. Reflecting the possibility that such countries might be pushed into debt reduction or have arrived at such very high levels of debt due to temporary crisis and wars. This is done by comparing debt thresholds to the average debt over the varying periods mentioned before. Debt turns out to be quite stable over time, for example countries that exceed 140 percent debt to GDP (the maximum threshold) average 130 percent debt to GDP over the next 15 years, so this explanation is rejected.

Another aspect considered by Pescatori et al (2014) is the question whether the debt trajectory has any effect on subsequent growth. That is the question whether there is a difference between countries with the same level of debt but on a different debt trajectory, increasing debt or decreasing. This is analyzed by the same method described before but adding episodes where a threshold is reached from above. They find that those countries with a decreasing trajectory of debt outperform the others in the first subsequent year for almost all levels of debt, except for the very lowest ranges below about 25 percent debt to GDP and between about 60- and 75 percent. For the 15 year subsequent growth episodes the decreasing trajectory countries outperform their peers on the entire range of debt to GDP thresholds except at round 75 percent.

To check for robustness of these results the analysis was redone looking at relative growth rather than absolute growth in the 15-year episodes (results not reproduced here to save on space). Subtracting average growth for all countries during an episode from the absolute growth rate in the sample, Pescatori et al find that growth rates between high debt countries and their peers are fairly close, with average growth rates generally deviating less than half a percent at all but the lowest debt levels of less than about 20 percent.

To further limit the effects of reverse causality, growth rates and relative growth rates of the 15-year episodes were also compared excluding the first 5 years from the analysis. The results are reproduced below.

Figure 3: Growth Performance from 5 to 15 years after crossing debt thresholds



Source: Pescatori et al (2014)

Removing the first 5 years makes the relationship between debt and growth even weaker as demonstrated in the figure. As seen on the right panel in figure 3, there is no clear consistent sign for the deviation in growth rates between threshold countries and their peers above the very lowest of thresholds at around 20 percent. This suggests that whatever causality exists between debt and growth, it exists mainly in the short term. Where endogeneity is more problematic because cause and effect are closer together and more difficult to statistically distinguish.

Lastly while the evidence for a non-linear relationship between debt and growth is weak in the Pescatori paper, they do find some indication that output volatility and debt are positively related. Suggesting that growth rates in countries with high debt levels might be more unstable. It should be noted that this might also be related to the outliers Pescatori et al mentioned in the beginning of their paper. Wars, crisis and recovery intuitively lead to very broad ranges of growth correlated with high levels of debt. And while there is evidence for a relationship between volatility and debt, there is no threshold.

3. Empirical research

To study the relationship between debt and growth, in this section a broad IMF dataset is analyzed using both a ordinary least squared regression and an instrumental variable approach.

3.1 Data

For this study 20 OECD countries were chosen based on historical economic development, historical political stability and economic relevance which should be understood to mean that larger economies were preferred over smaller economies all other things being equal. Recent performance on these criteria is weighed heavier than criteria further in the past. The focus on stable developed countries might limit the external validity of the results but will probably increase validity and reliability for the economies that do match the criteria. These countries also happen to be the ones with the most complete historical statistics for the variables of interest which is certainly a boon.

The data included in the analysis consists of gross public debt-, public expenditures-, public revenues-, interest on public debt- all in percentages of GDP, in addition real long term bond yield and the real GDP growth rate are included. All data is taken from the International Monetary Fund and the period of analysis is 1880 till 2011.

All analysis and figures in section 3 and the appendix cover this entire period unless stated otherwise.

The 20 countries included in the OECD sample are:

Australia	**Italy**
Austria	**Japan**
Belgium	**Korea, Republic of**
Canada	**Netherlands**
Denmark	**New Zealand**
Finland	**Spain**
France	**Sweden**
Germany	**Switzerland**
Greece	**United Kingdom**
Ireland	**United States**

All analysis and figures in section 3 and the appendix cover this entire sample of countries.

Figure 4 group descriptive statistics individual samples

20 OECD 1880-2011

	GDP_YIELD	DEBT	EXPEN	REVENUES	BOND_YIELD	I_DEBT
Mean	3.017978	57.38362	24.71030	22.58643	2.269256	2.422915
Median	3.061650	48.02250	20.40135	18.56450	2.834520	1.806510
Maximum	69.80770	269.7980	71.72040	60.54720	24.27240	12.65910
Minimum	-58.67770	1.595230	0.684444	0.771179	-337.7240	-0.914668
Std. Dev.	6.327261	42.02700	16.15400	14.83093	9.925371	2.108292
Skewness	0.242399	1.400182	0.528055	0.592813	-22.56083	1.665563
Kurtosis	29.64467	5.505882	2.128662	2.224523	750.3497	6.345768
Jarque-Bera	75663.06	1369.196	181.6798	195.0208	43280489	2076.737
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	7716.969	133531.7	57476.16	52671.57	4204.930	5417.638
Sum Sq. Dev.	102327.5	4108340.	606712.9	512718.5	182446.1	9934.343
Observations (#missing data)	2557 (83)	2327 (313)	2326 (314)	2332 (308)	1853 (787)	2236 (404)

Figure 4 gives some descriptive statistics of the data used. All variables are in percentages of GDP except for those listed as yield. So for example I_DEBT is interest payments on public debt as a percentage of GDP which are on average about 2.4 percent of GDP in the sample. DEBT would be public debt, EXPEN are public expenditures and REVENUES are public revenues all in percentages of GDP. The yield statistics are growth percentages in percentage points, GDP_YIELD is annual real GDP growth and BOND_YIELD is interest on long term government bonds.

Much of the missing data is earlier in the sample in countries that were less developed at the time than the rest of the sample. In the debt data for example there is no record for Korea before 1958, and for Ireland there are only two entries before 1936, together they are responsible for 132 out of 313 missing values. In the expenditure-, revenue- and interest samples the situation is virtually analogous, with Korea and Ireland being responsible for 125 out of 314- and 308 missing values for revenues and expenditures respectively, as well as 126 for interest. Almost all of the missing data that isn't clustered in the beginning is centered around the second world war.

In so far as missing data is a function of extraordinary circumstances like war the quality of the model may not suffer, as the model is meant less to generalize for such circumstances. To the extent that the missing data reflects a lack of development among countries earlier in the sample, and thus institutions that do meticulous record keeping, the model might also not suffer too much as the focus is on advanced developed economies.

3.2 Methodology

The strategy employed is a panel fixed-effect regression. First the ordinary least squared methodology is used to build the baseline model and explore the relationship between debt and growth in such a model. A other model is also explored in the form of a instrumental variable regression to limit endogeneity and make sure that the relationship found between debt and economic growth is a causal one.

For the dependent variable of economic growth real GDP growth is used because the data on this is much more extensive than per capita figures, going back all the way till 1875. In addition it is judged to be more relevant for policy because they tend to be the headline figures. As for the period over which growth is measured a single year is chosen to maximize the number of observations.

To further limit reverse causality and in accordance with other studies the initial level of debt is used to regress with economic growth. As Pescatori et al showed (2014) debt is a relatively stable stock variable and most of the effect and potential endogeneity between GDP growth and debt over GDP is probably seen in the first year of subsequent growth. Therefore the debt covariate is lagged twice.

The existence of fixed period and cross-period effects is also analyzed and implemented. As it is almost certain the model won't capture all or even very much of the country specific heterogeneity and there are good arguments to be made for period specific affects in the form of wars, crisis and rapid development mentioned earlier in the text.

The baseline OLS model can be described algebraically as follows:

$$G_{i,t} = C + \beta_1 * X_{1,t} \ldots + \beta_i * X_{i,t} + \mu_i + v_t + \varepsilon_{i,t}$$

Where $G_{i,t}$ is the independent variable, economic growth, and X_1 is the independent variable of interest: debt. X_i Are the control variables, other

covariates chosen that also help to explain economic growth. The other terms are explained at the end of this section.

The final instrumental variable model, with the terms included for simplicity, can be described as follows:

The structural model is:

$$GDP\_YIELD_{i,t} = C + \beta_1 * DEBT(-2)_{i,t} + \beta_2 * BOND\_YIELD_{i,t} + \mu_i + v_t + \varepsilon_{i,t}$$

The reduced form, with the instruments for the lagged instrumental variable is:

$$DEBT(-2)_{i,t} = EXPEN_{i,t} + REVENUES_{i,t} + I\_DEBT_{i,t} + \varepsilon_{i,t}$$

Where:

$GDP\_YIELD_{i,t}$:	Annual real GDP growth in percentages
C :	A constant term
$\beta_1 * DEBT(-2)_{i,t}$:	Instrumental variable for twice lagged public debt to GDP, β_1 to be computed
$\beta_2 * BOND\_YIELD_{i,t}$:	Control variable: long term bond rate in percentages, β_2 to be computed
μ_i :	Country fixed-effects
v_t :	Time fixed-effects
$\varepsilon_{i,t}$:	Error term
$EXPEN_{i,t}$:	Public expenditures to GDP, percentage
$REVENUES_{i,t}$:	Public revenues to GDP, percentage
$I\_DEBT_{i,t}$:	Interest payments on public debt to GDP, percentage

3.3 Results

Figure 5 correlations 20 OECD 1880-2011

	GDP_YIELD	DEBT	EXPEN	REVENUES	BOND_YIELD	I_DEBT
GDP_YIELD	1.000000	-0.179417	-0.094130	-0.066053	0.120387	-0.133629
DEBT	**-0.179417**	1.000000	0.215769	0.148700	-0.003831	0.616911
EXPEN	**-0.094130**	**0.215769**	1.000000	0.960222	-0.009752	0.542940
REVENUES	**-0.066053**	**0.148700**	0.960222	1.000000	0.064278	0.492752
BOND_YIELD	0.120387	-0.003831	-0.009752	0.064278	1.000000	0.109280
I_DEBT	**-0.133629**	**0.616911**	0.542940	0.492752	0.109280	1.000000

The correlations in figure 5 show that none of the variables are particularly strongly correlated with real GDP growth but debt over GDP is most strongly correlated at -.18. What's also noticeable is that expenditures, revenues and especially interest on debt are strongly correlated with debt, in particular relative to GDP. What follows is the panel OLS fixed-effects regression in figure 6.1, this is compared to the same regression with debt twice lagged to address some of the endogeneity in figure 6.2. And the fixed-effects assumption is tested in figure 6.3 on the 6.2 model.

Figure 6.1 OLS baseline model

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 19:25
Sample: 1880 2011
Periods included: 132
Cross-sections included: 19
Total panel (unbalanced) observations: 1759

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.568926	0.403974	11.30995	0.0000
DEBT	-0.025471	0.004049	-6.291034	0.0000
I_DEBT	0.126817	0.081274	1.560354	0.1189
REVENUES	-0.016650	0.029111	-0.571963	0.5674
EXPEN	-0.011117	0.025157	-0.441929	0.6586
BOND_YIELD	0.078205	0.009328	8.383876	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.357471	Mean dependent var	2.925797
Adjusted R-squared	0.295782	S.D. dependent var	3.911859
S.E. of regression	3.282742	Akaike info criterion	5.299227
Sum squared resid	17285.34	**Schwarz criterion**	**5.781454**
Log likelihood	-4505.670	Hannan-Quinn criter.	5.477442
F-statistic	5.794719	Durbin-Watson stat	1.762283
Prob(F-statistic)	0.000000		

Figure 6.2 OLS baseline model debt lagged twice

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 19:45
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1737

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.612539	0.410685	11.23133	0.0000
DEBT(-2)	-0.008468	0.003903	-2.169809	0.0302
I_DEBT	-0.075409	0.080329	-0.938757	0.3480
REVENUES	-0.013496	0.029936	-0.450822	0.6522
EXPEN	-0.030574	0.025401	-1.203667	0.2289
BOND_YIELD	0.076391	0.009442	8.090964	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.342552	Mean dependent var	2.916205
Adjusted R-squared	0.279464	S.D. dependent var	3.889983
S.E. of regression	3.301989	Akaike info criterion	5.310887
Sum squared resid	17270.56	**Schwarz criterion**	**5.791812**
Log likelihood	-4459.505	Hannan-Quinn criter.	5.488734
F-statistic	5.429713	Durbin-Watson stat	1.739285
Prob(F-statistic)	0.000000		

Figure 6.3 test for fixed effects

Redundant Fixed Effects Tests
Equation: Untitled
Test cross-section and period fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	2.716417	(18,1591)	0.0001
Cross-section Chi-square	52.729941	18	0.0000
Period F	5.470921	(129,1591)	0.0000
Period Chi-square	639.543568	129	0.0000
Cross-Section/Period F	5.126980	(147,1591)	0.0000
Cross-Section/Period Chi-square	675.513162	147	0.0000

As seen in figure 6.1 and 6.2 both models perform largely similar, with the non lagged model performing slightly better explaining about 36 percent of the observed variance compared to 34 percent for the lagged model. Lagging once doesn't improve the model significantly (see appendix A) and the improvements

in relation to endogeneity resulting from lagging twice are preferred. Lagging three times does decrease the quality of the model significantly as the coefficient for the lagged debt variable is no longer significant (see appendix A).

Testing for cross-section fixed effects and period fixed effects shows both to be highly and jointly significant as can be seen by the relevant F and Chi-square tests in figure 6.3.

Alternative specifications of model 6.2 can be seen in appendix A where different covariates are removed from the model. Neither the Schwarz nor the AIC criterion are improved by removing any covariates, though removing single covariates doesn't significantly negatively impact the model either except for removing the long term interest on bonds covariate (I_DEBT). Seeing as model 6.2 (marginally) has the best Schwarz and AIC compared to the other lagged specifications, it is judged to be adequate.

3.3.1 Relevance of the instruments

To address the endogeneity problem an IV estimator model follows. Expenditures, revenues and interest are variables that correlate relatively strongly with debt but weakly with growth (see figure 5). The relevance and strength of expenditures-, revenues- and/or interest payments to GDP as instruments for debt to GDP can be assessed by correlating them and then restricting the model for the instruments with the Wald Test. A large F-value (F>10) is evidence against weak instruments. All of them are used to instrument for debt(-2) in the model.

Figure 7.1 regressing endogenous variable debt(-2) on covariates

Dependent Variable: DEBT(-2)
Method: Panel Least Squares
Date: 08/11/14 Time: 23:47
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1742

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.299452	2.633130	0.873277	0.3826
BOND_YIELD***	-0.236785	0.060446	-3.917301	0.0001
EXPEN***	-0.631744	0.162596	-3.885358	0.0001
REVENUES***	1.507248	0.188752	7.985342	0.0000
I_DEBT***	12.45478	0.411737	30.24938	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.730987	Mean dependent var	56.11805
Adjusted R-squared	0.705439	S.D. dependent var	39.14261
S.E. of regression	21.24405	Akaike info criterion	9.033243
Sum squared resid	717582.7	Schwarz criterion	9.509905
Log likelihood	-7715.955	Hannan-Quinn criter.	9.209488
F-statistic	28.61252	Durbin-Watson stat	0.118185
Prob(F-statistic)	0.000000		

Figure 7.2 Wald test for weak instruments

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic***	501.2858	(3, 1590)	0.0000
Chi-square***	1503.857	3	0.0000

Null Hypothesis: C(3)=0, C(4)=0, C(5)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(3)	-0.631744	0.162596
C(4)	1.507248	0.188752
C(5)	12.45478	0.411737

Restrictions are linear in coefficients.

H0 that all instruments are irrelevant is rejected. F-statistic = 501.2858 (F>10).

So, these are strong and relevant instruments.

3.3.2 Validity of the instruments

To test the validity of the instruments the residuals of the instrumented two-stage least squared regression are obtained and subsequently the instruments are regressed on these residuals to check if they are uncorrelated.

Figure 8.1 instrumented regression model TSLS

Dependent Variable: GDP_YIELD
Method: Panel Two-Stage Least Squares
Date: 08/12/14 Time: 00:04
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1737
Instrument specification: C EXPEN REVENUES I_DEBT
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C***	3.926526	0.243080	16.15325	0.0000
DEBT(-2)***	-0.022740	0.005142	-4.422374	0.0000
BOND_YIELD	0.113151	0.074998	1.508713	0.1316

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.327275	Mean dependent var	2.916205
Adjusted R-squared	0.264115	S.D. dependent var	3.889983
S.E. of regression	3.336974	Sum squared resid	17671.87
F-statistic	4.775285	Durbin-Watson stat	1.744124
Prob(F-statistic)	0.000000	Second-Stage SSR	18137.37
Instrument rank	151		

Figure 8.2 regressing residuals on instruments

Dependent Variable: RESID01
Method: Panel Least Squares
Date: 08/11/14 Time: 23:53
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1737

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EXPEN	-0.011479	0.016949	-0.677244	0.4983
REVENUES	0.007039	0.017719	0.397259	0.6912
I_DEBT	0.030995	0.042186	0.734724	0.4626
C	0.056668	0.152873	0.370685	0.7109

R-squared	0.000627	Mean dependent var	-1.28E-17
Adjusted R-squared	-0.001103	S.D. dependent var	3.190556
S.E. of regression	3.192315	Akaike info criterion	5.161670
Sum squared resid	17660.78	Schwarz criterion	5.174243
Log likelihood	-4478.910	Hannan-Quinn criter.	5.166319
F-statistic	0.362699	Durbin-Watson stat	1.746587
Prob(F-statistic)	0.779955		

NR^2=1.089099, Chi^2 (1 df), critical value is 3.84

H0: all surplus moment conditions are valid. The null is not rejected.

No evidence for correlation between instruments and residuals. So these are valid instruments.

3.3.3 Testing for endogeneity between debt and growth

Finally the possible endogeneity between the debt variable and the economic growth variable is assed with Hausman's test for endogeneity. The result of which will be used to choose between the unrestricted OLS model given in 6.2 (or a different specification of this model) if endogeneity turns out not to be a problem or the instrumental variable regression given in 8.1 if endogeneity is established.

Figure 9 Hausman test for endogeneity

Residuals obtained from equation 7.1 -> RESIDV, test coefficient on residuals.

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/12/14 Time: 01:04
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1737

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C***	3.923873	0.240172	16.33777	0.0000
DEBT(-2)***	-0.021058	0.004019	-5.239589	0.0000
BOND_YIELD***	0.074030	0.009290	7.968847	0.0000
RESIDV*	**0.012593**	**0.005598**	**2.249460**	**0.0246**

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.340279	Mean dependent var	2.916205
Adjusted R-squared	0.277884	S.D. dependent var	3.889983
S.E. of regression	3.305606	Akaike info criterion	5.312035
Sum squared resid	17330.27	Schwarz criterion	5.786674
Log likelihood	-4462.502	Hannan-Quinn criter.	5.487557
F-statistic	5.453649	Durbin-Watson stat	1.733211
Prob(F-statistic)	0.000000		

Test coefficient on residuals

H0: output is exogenous and LS is applicable,

The null is rejected, use instrumented TSLS regression model R.1

So it appears debt to GDP is indeed endogenous with real GDP growth, and the instrumental variable appears to be exogenous so the TSLS model in 8.1 can be used to estimate the effects of debt on growth. According to the resulting model, for every 10 percent increase in public debt to GDP economic growth slows by about 22 basis points. Consistent with Woo and Kumar's findings (2010) and Elmendorf and Mankiw's conventional theory calculations (1999).

3.4 Robustness checks

To test the validity and applicability of the model it's important to consider the assumptions made for the regression and how it responds to different, more recent, time periods.

3.4.1 Residuals

Figure 10.1 residuals plot

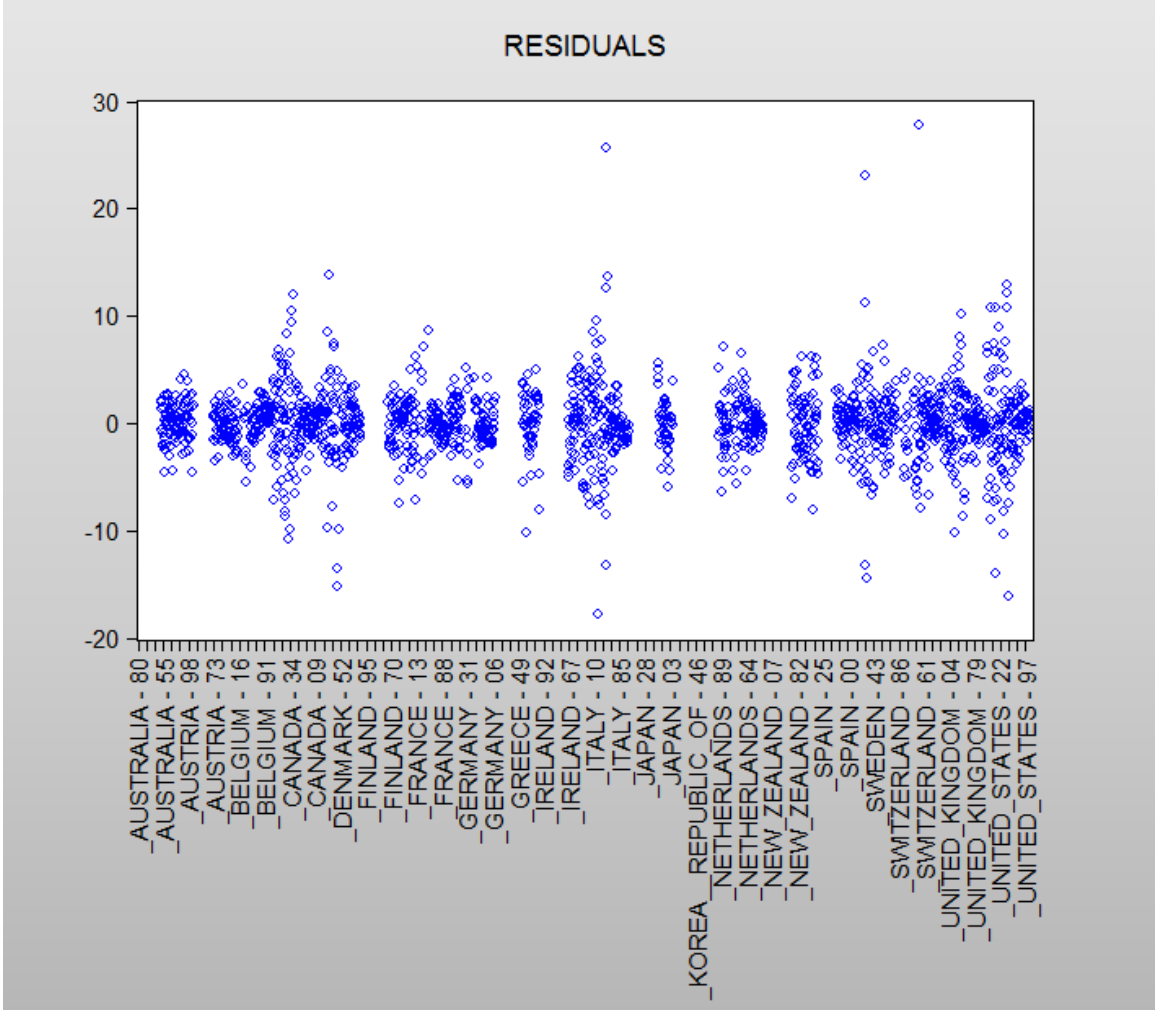


Figure 10.2 standardized residuals histogram

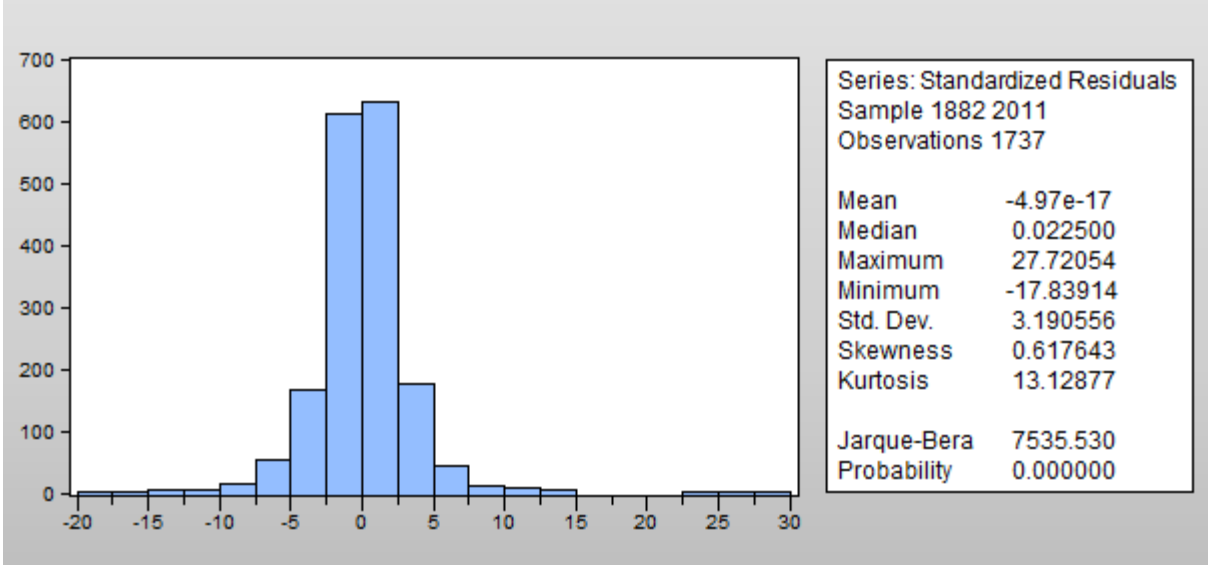


Figure 10.2 shows that the residuals are right skewed. The Kurtosis value is very high as well giving a leptokurtic distribution, a sharper than a normal distribution with values concentrated around the mean and thicker tails. This means high probability for extreme values as is clearly visible in the plot.

The chosen statistical tools do not allow for heteroskedasticity tests for panel data of the sort we've used. So turning to the residual plots in figure 10.1 it can be seen that there are indications for heteroskedasticity, though it is hard to tell. It seems like the residuals are larger toward the middle of the century, the time of the war and post-war boom. Another possible problems could be the almost certain existence of auto-correlation, it stands to reason that growth in a given year is highly conditional on growth in the previous year.

3.4.2 More recent periods

Limiting the model to more recent periods increases the coefficient of the instrumented debt variable from a 24 basis point decrease on growth for every 10 percent increase in debt to GDP since 1950, till about an 8 basis points *increase*

on growth since 1990 (see appendix B). Suggesting that the negative effect of debt on growth found might not exist anymore under present circumstances.

3.5 Discussion

The results suggest the specified instrument to estimate the effect of debt on growth is effective and valid. However some caution in interpreting these results is advised. In particular concerning the likely existence of heteroskedasticity and auto-correlation. This would mean the model is no longer the *best* linear unbiased estimator, and a more efficient specification should be possible. The fact that the coefficient of debt(-2) switches from negative to positive in the instrumental variable model if more recent periods are analyzed is also noteworthy.

On the other hand, it's reassuring that the negative effect of debt on growth and it's magnitude found in the regression is consistent with multiple other studies.

A more general problem with linear regression models is that they simplify what is probably a complex relationship. Certainly the threshold studies and others suggesting a non-linear relationship complicate matters. The causal link between debt and growth probably varies over different levels as seen in the threshold studies, and might also differ with respect to different *changes* in the debt variable.

The instrumental variable model of figure 8.1 suggest a drop of about 23 basis points per 10 percentage points growth in debt to GDP, the baseline model in 6.2 however suggest a drop of only 8.5 basis points. The criticism of Panizza and Presbitero (2012) on Kumar and Woo (2010) concerning the unlikelihood of the exogenous coefficient being larger than the endogenous coefficient doesn't necessarily apply here because both models use a different set of controls.

4. Conclusions

Both our OLS model and IV model suggest that there is a negative relationship between debt and growth. As this result is largely consistent with the available literature, both empirical and theoretical, public debt is certainly not something which should be ignored by policymakers or academics going forward. However not all studies have found such a negative causal link. Among papers that also use an instrumental variable estimation, the Panizza and Presbitero paper (2012) in particular is worth a look.

The negative effect found is not robust for more recent time periods. And in fact the model estimates a positive impact of public debt on growth since 1990. For policymakers and others such details are certainly relevant and highlight the importance in being careful about generalizing models and studies that cover such a large historical period.

The evidence for non-linear relationship between debt and growth seems to vanish upon further analysis as shown by Hendon et al (2013) and Pescatori et al (2014). Thresholds do not seem to be a sound argument for fiscal consolidation, the likes of which undertaken by the eurozone. As there doesn't appear to be any convincing evidence that stands up to further scrutiny or can overcome the endogeneity problem. In any case thresholds should not be treated as a fact, because the available evidence simply is not conclusive. The importance of causality on policy can be illustrated by a simple thought experiment: many economists would argue that the austerity policies pursued by the eurzone have had a detrimental effect on growth over the past few years, in so far as these policies are based on debt thresholds these thresholds become self-fulfilling prophecies precisely because policy makers assume they exist.

Going forward, in absence of any experiments, natural or otherwise, it seems like the instrumental variable approach is the one most likely to yield any definitive answers concerning the relationship between debt and growth. And so far studies employing them have given conflicting answers.

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Source of analysis data: http://www.imf.org/external/Datamapper/index.php

Appendix A: OLS model specification

All covariates

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 19:25
Sample: 1880 2011
Periods included: 132
Cross-sections included: 19
Total panel (unbalanced) observations: 1759

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.568926	0.403974	11.30995	0.0000
DEBT	-0.025471	0.004049	-6.291034	0.0000
I_DEBT	0.126817	0.081274	1.560354	0.1189
REVENUES	-0.016650	0.029111	-0.571963	0.5674
EXPEN	-0.011117	0.025157	-0.441929	0.6586
BOND_YIELD	0.078205	0.009328	8.383876	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.357471	Mean dependent var	2.925797
Adjusted R-squared	0.295782	S.D. dependent var	3.911859
S.E. of regression	3.282742	Akaike info criterion	5.299227
Sum squared resid	17285.34	**Schwarz criterion**	**5.781454**
Log likelihood	-4505.670	Hannan-Quinn criter.	5.477442
F-statistic	5.794719	Durbin-Watson stat	1.762283
Prob(F-statistic)	0.000000		

All covariates, debt lagged once 1.1

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 20:34
Sample (adjusted): 1881 2011
Periods included: 131
Cross-sections included: 19
Total panel (unbalanced) observations: 1752

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.500178	0.375986	11.96901	0.0000
DEBT(-1)	-0.011971	0.003967	-3.017543	0.0026
I_DEBT	-0.036201	0.081552	-0.443895	0.6572
EXPEN	-0.035763	0.015099	-2.368553	0.0180
BOND_YIELD	0.074805	0.009315	8.030401	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

All covariates, debt lagged once 1.2

R-squared	0.342376	Mean dependent var	2.915633
Adjusted R-squared	0.279863	S.D. dependent var	3.893787
S.E. of regression	3.304303	Akaike info criterion	5.311606
Sum squared resid	17458.55	**Schwarz criterion**	**5.789165**
Log likelihood	-4499.967	Hannan-Quinn criter.	5.488132
F-statistic	5.476847	Durbin-Watson stat	1.754304
Prob(F-statistic)	0.000000		

All covariates, debt lagged thrice

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 20:35
Sample (adjusted): 1883 2011
Periods included: 129
Cross-sections included: 19
Total panel (unbalanced) observations: 1721

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.543622	0.384008	11.83211	0.0000
DEBT(-3)	**-0.005023**	**0.003700**	**-1.357598**	**0.1748**
I_DEBT	-0.124263	0.078855	-1.575851	0.1153
EXPEN	-0.042656	0.015046	-2.835099	0.0046
BOND_YIELD	0.075930	0.009337	8.132246	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.341107	Mean dependent var	2.906414
Adjusted R-squared	0.278156	S.D. dependent var	3.889621
S.E. of regression	3.304677	Akaike info criterion	5.312204
Sum squared resid	17145.80	**Schwarz criterion**	**5.790444**
Log likelihood	-4420.152	Hannan-Quinn criter.	5.489141
F-statistic	5.418570	Durbin-Watson stat	1.726124
Prob(F-statistic)	0.000000		

All covariates, debt lagged twice

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 19:45
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1737

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.612539	0.410685	11.23133	0.0000
DEBT(-2)	-0.008468	0.003903	-2.169809	0.0302
I_DEBT	-0.075409	0.080329	-0.938757	0.3480
REVENUES	-0.013496	0.029936	-0.450822	0.6522
EXPEN	-0.030574	0.025401	-1.203667	0.2289
BOND_YIELD	0.076391	0.009442	8.090964	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.342552	Mean dependent var	2.916205
Adjusted R-squared	0.279464	S.D. dependent var	3.889983
S.E. of regression	3.301989	Akaike info criterion	5.310887
Sum squared resid	17270.56	**Schwarz criterion**	**5.791812**
Log likelihood	-4459.505	Hannan-Quinn criter.	5.488734
F-statistic	5.429713	Durbin-Watson stat	1.739285
Prob(F-statistic)	0.000000		

Remove interest on debt 1.1

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 19:27
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1742

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.670216	0.406688	11.48352	0.0000
DEBT(-2)	-0.010657	0.003107	-3.429832	0.0006
REVENUES	-0.010512	0.029917	-0.351378	0.7254
EXPEN	-0.037757	0.024793	-1.522902	0.1280
BOND_YIELD	0.074922	0.009388	7.980614	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

Remove interest on debt 1.2

R-squared	0.342898	Mean dependent var	2.926880
Adjusted R-squared	0.280494	S.D. dependent var	3.897503
S.E. of regression	3.306007	Akaike info criterion	5.312572
Sum squared resid	17378.20	**Schwarz criterion**	**5.789233**
Log likelihood	-4475.250	Hannan-Quinn criter.	5.488817
F-statistic	5.494797	Durbin-Watson stat	1.757930
Prob(F-statistic)	0.000000		

Remove revenues

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 19:28
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1737

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.541687	0.379328	11.97297	0.0000
DEBT(-2)	-0.008814	0.003826	-2.303864	0.0214
I_DEBT	-0.073868	0.080236	-0.920637	0.3574
EXPEN	-0.039803	0.015035	-2.647272	0.0082
BOND_YIELD	0.075727	0.009323	8.122140	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.342468	Mean dependent var	2.916205
Adjusted R-squared	0.279826	S.D. dependent var	3.889983
S.E. of regression	3.301159	Akaike info criterion	5.309864
Sum squared resid	17272.78	**Schwarz criterion**	**5.787645**
Log likelihood	-4459.617	Hannan-Quinn criter.	5.486548
F-statistic	5.467073	Durbin-Watson stat	1.740128
Prob(F-statistic)	0.000000		

Remove expenditures

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 19:29
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 19
Total panel (unbalanced) observations: 1738

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.533667	0.406226	11.16046	0.0000
DEBT(-2)	-0.006530	0.003875	-1.685258	0.0921
I_DEBT	-0.100985	0.078688	-1.283355	0.1996
REVENUES	-0.045120	0.017773	-2.538719	0.0112
BOND_YIELD	0.076997	0.009395	8.195201	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.339250	Mean dependent var	2.921747
Adjusted R-squared	0.276341	S.D. dependent var	3.895720
S.E. of regression	3.314018	Akaike info criterion	5.317593
Sum squared resid	17418.58	**Schwarz criterion**	**5.795151**
Log likelihood	-4468.989	Hannan-Quinn criter.	5.494190
F-statistic	5.392722	Durbin-Watson stat	1.732782
Prob(F-statistic)	0.000000		

Remove long term bond rate 1.1

Dependent Variable: GDP_YIELD
Method: Panel Least Squares
Date: 08/19/14 Time: 19:29
Sample (adjusted): 1882 2011
Periods included: 130
Cross-sections included: 20
Total panel (unbalanced) observations: 2149

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.968869	0.409917	9.682121	0.0000
DEBT(-2)	-0.005661	0.003832	-1.477205	0.1398
I_DEBT	-0.093431	0.090590	-1.031353	0.3025
REVENUES	0.024690	0.029793	0.828729	0.4074
EXPEN	-0.034972	0.025227	-1.386266	0.1658

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

Remove long term bond rate 1.2

R-squared	0.249319	Mean dependent var	3.107767
Adjusted R-squared	0.192153	S.D. dependent var	4.607311
S.E. of regression	4.141067	Akaike info criterion	5.748318
Sum squared resid	34228.27	**Schwarz criterion**	**6.152195**
Log likelihood	-6023.568	Hannan-Quinn criter.	5.896075
F-statistic	4.361304	Durbin-Watson stat	1.868114
Prob(F-statistic)	0.000000		

Appendix B more recent periods

Dependent Variable: GDP_YIELD
Method: Panel Two-Stage Least Squares
Date: 08/12/14 Time: 08:14
Sample: 1950 2011
Periods included: 62
Cross-sections included: 19
Total panel (unbalanced) observations: 1066
Instrument specification: C EXPEN REVENUES I_DEBT
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.867899	0.722596	8.120576	0.0000
DEBT(-2)	**-0.023519**	**0.005923**	**-3.970829**	**0.0001**
BOND_YIELD	-0.554332	0.224098	-2.473614	0.0135

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.166318	Mean dependent var	3.130727
Adjusted R-squared	0.097692	S.D. dependent var	2.732318
S.E. of regression	2.595426	Sum squared resid	6628.454
F-statistic	11.93836	Durbin-Watson stat	1.145595
Prob(F-statistic)	0.000000	Second-Stage SSR	4010.036
Instrument rank	83		

Dependent Variable: GDP_YIELD
Method: Panel Two-Stage Least Squares
Date: 08/12/14 Time: 08:17
Sample: 1970 2011
Periods included: 42
Cross-sections included: 19
Total panel (unbalanced) observations: 797
Instrument specification: C EXPEN REVENUES I_DEBT
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.836498	1.388750	4.922770	0.0000
DEBT(-2)	**-0.014845**	**0.012250**	**-1.211833**	**0.2260**
BOND_YIELD	-1.201550	0.474719	-2.531074	0.0116

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	-0.945027	Mean dependent var	2.554280
Adjusted R-squared	-1.106451	S.D. dependent var	2.517055
S.E. of regression	3.653156	Sum squared resid	9808.981
F-statistic	11.63151	Durbin-Watson stat	0.852626
Prob(F-statistic)	0.000000	Second-Stage SSR	2566.028
Instrument rank	63		

Dependent Variable: GDP_YIELD
Method: Panel Two-Stage Least Squares
Date: 08/12/14 Time: 08:18
Sample: 1990 2011
Periods included: 22
Cross-sections included: 19
Total panel (balanced) observations: 418
Instrument specification: C EXPEN REVENUES I_DEBT
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.756197	1.026411	1.711007	0.0879
DEBT(-2)	**0.083325**	**0.023814**	**3.499057**	**0.0005**
BOND_YIELD	-1.514684	0.323213	-4.686335	0.0000

Effects Specification

Cross-section fixed (dummy variables)
Period fixed (dummy variables)

R-squared	0.020944	Mean dependent var	2.128340
Adjusted R-squared	-0.085815	S.D. dependent var	2.475601
S.E. of regression	2.579637	Sum squared resid	2502.103
F-statistic	16.58742	Durbin-Watson stat	1.012317
Prob(F-statistic)	0.000000	Second-Stage SSR	909.8857
Instrument rank	43		