PUBLIC DEBT AND ECONOMIC GROWTH: TESTS OF THE REINHART-ROGOFF HYPOTHESIS[1]

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This paper aims to test the hypothesis raised by Reinhart and Rogoff on the relationship between public debt and economic growth. For this, we use an empirical model based on the theoretical neoclassical growth model with some proven relevant economic variables, using panel data on a sample of 86 countries over the period 1983 to 2013. We found evidence confirming in part Reinhart and Rogoff's hypothesis, that public debt has a negative effect on economic growth, but we were unable to find a threshold level of the debt-to-GDP ratio above which the magnitude of that effect is significantly larger.

Keywords: Public Debt. Economic Growth. Crisis.

O presente trabalho tem por objetivo testar a hipótese levantada por Reinhart e Rogoff acerca da relação entre dívida pública e crescimento econômico. Para isso utilizamos um modelo empírico baseado no modelo teórico de crescimento neoclássico acrescido de algumas variáveis econômicas comprovadamente relevantes, utilizando dados em painel numa amostra com 86 países no período de 1983 até 2013. Encontramos evidências que confirmam em parte a hipótese levantada por Reinhart e Rogoff, isto é, a dívida pública apresentou uma relação negativa com o crescimento econômico, no entanto não fomos capazes de encontrar um threshold onde a magnitude de tal efeito fosse aumentada.

Palavras-chave: Dívida Pública. Crescimento Econômico. Crise.

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This paper aims to test the hypothesis raised by Reinhart and Rogoff on the relationship between public debt and economic growth. For this, we use an empirical model based on the theoretical neoclassical growth model with some proven relevant economic variables, using panel data on a sample of 86 countries over the period 1983 to 2013. We found evidence confirming in part Reinhart and Rogoff's hypothesis, that public debt has a negative effect on economic growth, but we were unable to find a threshold level of the debt-to-GDP ratio above which the magnitude of that effect is significantly larger.

1 - INTRODUCTION

The expansionary policies put in place to counter the effects of the worldwide economic crisis sparked by the default in the sub-prime loans in the US has led to increased levels of the ratio of public debt to GDP in several countries. This, in turn, has raised doubts about the long term sustainability of high indebtedness, and sparkled interest on clarifying its impact on the economic growth rate. The discussions of these issues has also become a political debate about the stance of economic policy and kindled public interest in the issue where the technical assessment of the size and direction of the effect of debt on growth plays a crucial role. The controversy regarding that effect centers on the thesis put forward by Carmen Reinhart and Kenneth Rogoff, that the empirical evidence indicates a clear negative effect. This was later disputed by several scholars both in the academic literature and in the broader. This paper is a contribution to the empirical investigation of that effect.

The more recent empirical literature regarding that effect started with Reinhart & Rogoff (2009, 2010a, 2010b) that found that the annual average growth rate of countries with public debt/GDP ratio above 90% is two percentage points lower than the average growth rate of countries with that ratio below 30% (1.7% and 3.7% per year, respectively). However, at intermediate levels of debt/GDP ratio, the growth rate does not seem to be so sensitive to public debt. When countries with a debt/GDP between 30% and 60%, are compared with those with that ratio between 60% and 90%, the difference in the annual average growth rate is only 0.4 percentage points (3% and 3.4%, per year, respectively). They conclude that the relation between public debt and economic growth is non-linear, and propose there is a threshold level of the debt/GDP ratio above which the effect is significantly stronger. They further indicate that the threshold level is equal to 90% for developed countries.

The seminal article Reinhart & Rogoff (2010a) arrived at the conclusions above using simple graphical analysis on a sample of 20 countries over a period from 1946 to 2009. Several studies have later extended the study of that empirical relationship in several directions: (i) by extending the sample, both increasing the number and types of countries, and by considering different time frames, (ii) by improving on the methodology to measure the correlation and, (iii) by exploring the direction of causality. Whereas the structure of the data for these studies is a panel, we rely on the taxonomy proposed by Lee, Pesaran and Smith (1997) to survey this literature in a systematic manner. They classify the methodologies for inference in panels into four major groups: (a) calculating the average over time and estimating a regression of the cross-section type; (b) calculating the average over the cross section and estimating a regression of the time series of these means; (c) estimating a panel regression assuming the homogeneity of coefficients; (d) estimate the coefficients of the individual time series regressions and examining their distribution across groups of countries. We note that the approach in Reinhart and Rogoff is of the type (b), but it has been criticized on grounds of not being rigorous enough. This criticism has been addressed in most recent empirical studies using other types of methodologies.

Broadly speaking, studies of type (c) are panel growth regressions that follow the approach proposed originally in Mankiw, Romer and Weil (1992), that specify an empirical model based on Solow (1956), where the growth rate of output is a function of saving, physical and human capital accumulation and population growth, in a panel with country-specific fixed effects.[4] Barro and Sala-I-Martin (2004, chapter 12) retain the fixed effects panel approach, and include in the basic model several other variables: initial level of per capita GDP; educational level; life expectancy; a measure of international openness; government consumption as proportion of GDP; a subjective indicator of rule of law; a subjective indicator of the extent of democracy; the logarithm of the fertility rate; ratio of real gross domestic investment to real GDP; growth rate of the terms of trade; and inflation rate. However, they conclude that most of these additional variables lack significance. Several other studies have tested yet more variables to improve the fit of the model, at the expense of losing degrees of freedom, which are at a premium in these studies. An example of the approach of type (d) is Bassanini and Scarpetta (2001) which adds other explanatory variables to the growth regression, like institutional development, research and development activities, choices of structural and macroeconomic policies, and financial markets efficiency. They use a pooled mean group estimator, and conclude that their equations estimated explain much of the growth experienced by the countries in their sample. However, these studies do not include public debt among the explanatory variables.

Section 2 surveys the recent literature on panel growth studies that address the effect of public debt on growth on which the model of this paper is inserted. Broadly speaking, they confirm the Reinhart and Rogoff hypothesis, seen as a negative empirical correlation between the public debt to GDP ratio, and the per capita GDP growth rate. Significant effort is devoted to test whether there is a threshold level for the debt ratio above which the effect is stronger. Other aspect of this literature which can be highlighted is the use of a variety of estimation approaches in an effort to address potentially serious problems in these types of equations: omitted variables, endogeneity of explanatory variables (public debt, in particular) which could lead to correlation with the error term, and measurement errors. It should be pointed out, however, that it can be interpreted that the focus of this branch of the literature is more on showing that there exists a negative correlation, rather than demonstrating the causal relation in a structural model for the transmission mechanism. This point is made by Panizza e Presbitero (2012), that are skeptical with respect to the causality running from public debt to

[4] There is also a large literature that proposes the use of the endogenous growth model as the basis of the empirical equation to be estimated in the panel, and some controversy as to the formulation which displays better adherence to the data, but we do not dwell on this matter here, because we restrict attention on this brief survey to the models of the same lineage as the one we present here.

economic growth, and are unable to reject in their model the null hypothesis that there is no impact.

This discussion in section 2 is used in section 3 to motivate and justify the specification model used here, and our choice of estimation approach. Section 4 discusses the model estimation, and the main results. The last section summarizes our conclusions.

2 - LITERATURE REVIEW

This section surveys the recent literature on growth equations that include a public debt variable, briefly discussing their specification, estimation, and results. Kumar and Woo (2010) did focused on the medium and long-term relationship between the initial level of public debt [5] and economic growth in a sample containing 38 countries in the period from 1970 to 2008 using the specification in equation (1).

$$y_{i,t} - y_{i,t-\tau} = \alpha y_{i,t-\tau} + \beta X_{i,t-\tau} + \gamma Z_{i,t-\tau} + \eta_t + \nu_i + \varepsilon_{i,t} \quad (1)$$

where y is the logarithm of real per capita GDP, Z is initial level of government debt, ν is the country-specific fixed effect, η is the time fixed effect, ε is the unobservable error term, and X is a vector of economic and financial variables that explain economic growth, such as initial levels of per capita GDP, the size of government, trade opening, inflation, and other variables such as an index of banking crises, and the average years of secondary schooling in the population over age 15 in the initial year as a proxy for human capital.

They estimate the model by GLS, and find only four variables to be significant at the 5% level: the initial government debt, with an elasticity of -1.76; the initial level of per capita GDP, with an elasticity of -2.823, indicating that richer countries grow more slowly; the average years of secondary schooling, with an elasticity of 6.82; and the financial development indicator, with an elasticity of 1.59. The existence of an inverse relationship between the initial level of public debt and the subsequent economic growth is confirmed and, on average, an increase of 10 percentage points in the debt/GDP ratio would lead to a decrease of 0.2 percentage points in the growth rate of per capita GDP. They also indicate that the relationship between debt and growth is not linear, and that only high levels of debt, above 90% of GDP, would negatively impact net growth.

Checchetti, Mohanty and Zampolli (2011) that investigate the relevance of public debt in the long-term growth for a sample of 18 OECD countries from 1980 to 2008. The equation estimated by the authors is very similar to (1), but specify threshold levels for the effect of public debt, thus producing a nonlinear relationship between debt and economic growth. Another difference is that they use the current values of public debt, rather than its initial value. To reduce the potential effects of cyclical movements, and allow its analysis to focus on the medium-term growth, they use a 5 years forward average of the per capita GDP growth rate as the dependent variable. They estimate equation (3) for a series of threshold values for the debt-to-GDP ratio, and then select the one that minimizes the sum of squared residuals. They find a threshold value of 85% of GDP, and conclude that an increase of 10% in the debt-to-GDP ratio lead to a decrease of 0.13 percentage points in the per capita GDP growth rate.

Baum, Checherita-Westphal and Rother (2013) estimate an equation also similar to (1) for a sample of 12 countries in the euro area from 1990 to 2010. They use the methodology developed by Caner and Hansen (2004) for the estimation of a dynamic

[5] They, and others, use the initial level of this variable to avoid the problem of reverse causality.

threshold model (with some adjustments), and find a value of 66.4% of GDP. They find that a 1% increase in the debt-to-GDP ratio would *increase* the GDP growth rate in 0.07% when debt is below the threshold, and that the effect is null when it is above it.

Kourtellos, Stengos and Tan (2013) also test the existence of a threshold for public debt in a model based on the Solow (1956) growth model, extended to include the public debt variable in a sample containing 82 countries from 1980 until 2009. It is specified as a Structural Threshold Regression (STR) model, and estimated using GMM and also two-stages least squares, and the results do not indicate the presence of a threshold level of public debt.

Afonso and Jalles (2013) also estimate an equation similar to (1) for a sample of 155 countries for the period 1970-2008, and their results confirm the Reinhart and Rogoff (2010b) hypothesis showing that an increase in public debt has negative effects on economic growth, and found countries with debt above 90% of GDP had a lower rate economic growth, when compared to countries with a public debt below 30% of GDP. They find evidence of a threshold effect: a 10% increase in the debt-to-GDP ratio of the most indebted countries decreases the rate of GDP growth by 0.2 percentage points, while the same debt increase in countries with debt ratio below 30% *increases* the GDP growth rate by 0.1 percentage points. Using the Hansen (2000) technique for endogenous estimation of the debt thresholds values, the authors find a value of 59% when considering the whole sample, 58% for the group of countries within the euro zone, and 79% for emerging countries.

3 - THE MODEL

The empirical model specified here contains the key elements of those found in the literature surveyed in the previous section and, in this sense it finds its justification in it. However, we present below its derivation from a simple theoretical model, as this serves as a framework for the formal justification of the choice of the variables we included in it. Later in this section we discuss the estimation of the model.

3.1 Specification

We take as a starting point the neoclassical growth model as formulated by Mankiw, Romer and Weil (1992) who, for simplicity, use a Cobb-Douglas production function with three factors (labor, and physical and human capital):

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} [A(t)L(t)]^{1-\alpha-\beta} \quad (2)$$

where Y is the product, K the stock of physical capital, H the stock of human capital, L labor and A the level of technology. Assume L and A grow to exogenous rates n e g, respectively.

Denoting the fraction of income invested in physical and human capital s_k s_h, respectively. The corresponding dynamic equations are as follows:

$$\dot{k}(t) = s_k y(t) - (n + g + \delta)k(t) \quad (3a)$$

$$\dot{h}(t) = s_h y(t) - (n + g + \delta)h(t) \quad (3b)$$

where $k = K/AL$ is the level of physical capital per effective unit of labor, $y = Y/AL$ is the level of output per effective unit of labor, $h = H/AL$ is the level of human capital per effective unit of labor and δ is the depreciation rate of physical and of human capital (they are assumed to be equal, in first approximation, for simplicity). Also, assume that $\alpha + \beta < 1$, which implies diminishing returns for all types of capital. Equations (3a) and (3b) imply that the economy converges to the steady state defined by:

$$k^* = \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n+g+\delta}\right)^{1/(1-\alpha-\beta)} \quad (4a)$$

$$h^* = \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{n+g+\delta}\right)^{1/(1-\alpha-\beta)} \quad (4b)$$

Using equations (4a) and (4b) in (2) and taking logarithms, income per unit of labor in the steady state is:

$$ln\left[\frac{Y(t)}{L(t)}\right] = lnA(0) + gt - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta}\ln(s_h) \quad (5)$$

Solving for s_h as a function of the steady state level of human capital in (4b), and substituting in equation (5), it can be written as a function of the investment rate in physical capital, population growth rate and the level of human capital:

$$ln\left[\frac{Y(t)}{L(t)}\right] = lnA(0) + gt - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + \frac{\alpha}{1-\alpha}\ln(s_k) + \frac{\beta}{1-\alpha}\ln(\mathrm{h}^*) \quad (6)$$

The choice between (5) and (6) for estimation should be made based on the data availability with regards to human capital. In the following development we prefer (5).

Quantitative predictions about the speed of convergence to steady state can also be extracted from the model. Denoting y^* the per capita income in the steady state given by equation (5), and $\mathrm{y}(t)$ the current level at time t, the growth rate around the steady state (the speed of convergence) can be approximated by:

$$\frac{d\ln(y(t))}{dt} = \lambda[\ln(y^*) - \ln(y(t))] \quad (7)$$

where $\lambda = (n+g+\delta)(1-\alpha-\beta)$.

Equation (7) implies that:

$$\ln\big(y(t)\big) = \left(1-e^{-\lambda t}\right)\ln(y^*) + e^{-\lambda t}\ln(y(0)) \quad (8)$$

where y(0) is the per capita income in some initial date. Subtracting $\ln(y(0))$ from both sides of the equation (8) yields:

$$\ln\big(y(t)\big) - \ln\big(y(0)\big) = \left(1-e^{-\lambda t}\right)\ln(y^*) - \left(1-e^{-\lambda t}\right)\ln\big(y(0)\big) \quad (9)$$

Finally, substituting for y^* from equation (5) yields:

$$\ln\big(y(t)\big) - \ln\big(y(0)\big) = \left(1-e^{-\lambda t}\right)\frac{\alpha}{1-\alpha-\beta}\ln(\mathrm{s_k}) + \left(1-e^{-\lambda t}\right)\frac{\beta}{1-\alpha-\beta}\ln(\mathrm{s_h}) - \left(1-e^{-\lambda t}\right)\frac{\alpha+\beta}{1-\alpha-\beta}\ln(\mathrm{n}+\mathrm{g}+\delta) - (1-e^{-\lambda t})\ln(y(0)) \quad (10)$$

Subtracting the equation (10) itself lagged one period, and including the lagged product to characterize the convergence (corresponding to the processing of the last term of (10)), we have that the output growth rate depends on the logarithm of the physical capital saving rate, the logarithm of the human capital saving rate, the logarithm of the sum $(\mathrm{n}+\mathrm{g}+\delta)$ as indicated in (11) where, for simplicity g and δ were taken to be equal for all countries, so that their effect appears in the constant of the equation, leaving only the logarithm of n as explanatory variable. Included in equation (11) is a vector of other explanatory variables seen to be relevant for growth (see the survey in section 2).

$$\ln(y_{i,t}) - \ln(y_{i,t-1}) = \alpha\ln\big(y_{i,t-1}\big) + \beta_1\ln\big(\mathrm{s_{i,t}^h}\big) + \beta_2\ln\big(\mathrm{s_{i,t}^k}\big) + \beta_3\ln\big(\mathrm{n_{i,t}}\big) + \gamma\ln\,(X_{i,t}) + \nu_i + \tau_t + \varepsilon_{it} \quad (11)$$

where y is real per capita GDP; s^h is the human capital accumulation rate; s^k is the physical capital accumulation rate; n is the population growth rate; ν is the specific fixed effect by country; τ is the time fixed effect; ε is the unobservable error term; X is the vector of economic variables that explain the economic growth, in this model they are represented by the debt-to-GDP ratio (Z), the trade openness index (W), and the inflation rate (π). The log transformation is applied to these variables to control for extreme values.

Equation (11) is a panel with fixed effects for countries and for time. The variable τ captures the unobservable aspects specific to each year of the sample, thus considering peculiarities in the global economy in a given period of time that may affect economic growth, such as the global crisis of 2008. The variable ν captures the unobservable country-specific aspects. We avoid country-specific coefficients for other variables (including debt-to-GDP ratio) to be able to interpret them as the average (over all countries) effect of the variable in the growth rate.

The real per capita GDP lagged one period on the right side is a proxy for the distance from the steady state in a given moment in time, and allows the equation to capture the effects of conditional convergence of income between countries.

We use the gross fixed capital formation-to-GDP ratio as a proxy the rate savings related to physical capital accumulation (s^k). A direct measure of the rate of savings related to human capital accumulation (s^k) was not available, so a proxy variable for it was constructed. It is based on the assumption that the proportional change of years of schooling, denoted $e(t)$, is directly related to the net investment in human capital formation. The total investment in human capital is calculated as the sum of the net investment, with depreciation $\delta e(t)$.[6]

The coefficient of the public debt variable (Z) allows us to test the hypothesis we address in this paper. Since it is not country specific, the effect allows general inferences of the same kind made by Reinhart and Rogoff (2010b). A modified version of (11), including the threshold effects, is discussed later.

The trade openness variable (W) captures the possibility that when additional markets for the country's exports are reached, several important mechanisms that lead to output growth kick in: economies of scale in production, greater productivity due to exposure to foreign competition, diffusion of knowledge, absorption of more advanced technology amalgamated in imported of capital goods and, of course, increase in foreign investment.

The inflation variable (π), appears because of its empirical relevance, but it is clear that it can be detrimental to long term economic growth in several ways: the uncertainty and the dispersion in price changes increases the difficulty of evaluating investment decisions; the distortion caused by commodity taxation and the welfare loss is also associated are also enhanced by inflation; and the inflation tax also reduces investment.

3.2 <u>Estimation</u>

We used ordinary least squares to estimate equation (11), avoiding the instrumental variables and GMM approach used in several papers reviewed in the previous section, to take advantage of the robustness, stability and efficiency of this estimation approach, but taking care to avoid pitfalls identified previously in the

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[6] The relevance of the saving rates for physical capital and human capital formation in the growth decomposition equation is supported by several studies on the relative importance of factors versus productivity for growth. This literature is too extensive do be discussed here, so we refer to Ferreira, Pessôa and Veloso (2008) and the references contained therein to support this point of view. They find that in spite of the importance of productivity to explain the dispersion in the level and in the growth rates of per capita GDP between countries, the accumulation of factors (namely, physical and human capital) is responsible for most of the average growth in per capita GDP between 1960 and 2000 for the countries in their sample. We acknowledge, nevertheless, that there is some controversy regarding this issue.

literature. We have examined possible sources of bias whose presence has been suggested by Kumar and Woo (2010) in estimating their model, which is similar to the one described in equation (11). The possibility of the occurrence of first problem they mention, that of having omitted important variables, was avoided by deriving the specification of (11) from a well-founded theoretical model and, also, by including in it all the variables that proved to be statistically significant in previous studies. The second possible source of bias they mention is the occurrence of endogeneity, but we tested for this by verifying that none of the correlations between each of the regressors and the error term were significant. The third possible source of bias mentioned by them, the occurrence of measurement errors, is avoided by taking special care in the construction of the database, as described in the Appendix. Other sources of problems in the estimation raised in the literature are discussed below.

A major concern in analyzing time series data is the possibility of residual autocorrelation, while for cross-section data the major concern is the occurrence of heteroscedasticity. With panel data is necessary to be aware of the possibility of both problems, so we carefully tested for them, and found no evidence of their presence. Another possible source of bias is the existence of a reverse causal relationship between public debt and economic growth, where low growth causes the increase in government debt, as measured by the debt-to-GDP ratio, rather than the assumed causal effect. This possibility was excluded by performing a Granger causality test, varying the number of lags used from 2 to 10, and noting that in all cases the null hypothesis that the growth of real per capita GDP does not Granger-cause the debt is rejected. The hypothesis that debt does not Granger-cause the real per capita GDP growth is also rejected. This leads us to believe in the existence of a reciprocal causality.

Several models in the literature use 5 years averages and 5 year periods for the variables, to reduce the potential impact of cyclical movements. However, we do not consider such movements potential sources of bias in our estimation, and this averaging entails a major loss of the information contained in those variables and considerably reduces the sample size. However, for comparison with those studies we also estimate (11) as five-year period panel. Comparison with the annual data panel allows us to assess the trade-off between the number of degrees of freedom and the possible source bias arising from cyclical movements. Another source of problems raised in the literature is the possibility of the occurrence of a structural break in 2008. Some studies deal with this by excluding that year and the subsequent period from their sample, but we do not do so because it contains precisely the shock which we seek to clarify the relationship between debt and growth.

3.3 The data

As the aim of this work was to make a broader analysis than the previous papers dealing with the same subject, therefore we try to obtain the larger possible sample. Thus, the only restriction to add a country to the sample was the data availability. Regarding the sample period, a similar criteria was followed, but taking into account that data for that time period should be available for all countries selected. We also made a special effort to include in the sample the period of the 2008 debt crisis. Thus, in order to maximize the time and the number of countries analyzed, we arrived at a sample of 86 countries stretching from 1983 to 2013 with annual data. The details of the construction of the database can be found in the Appendix.[7]

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[7] The Data appendix is available from the authors upon request.

We examine the time series properties of all the variables in the specification, with the log transformation specified in (11). It should be pointed out that we used the appropriate panel unit-root tests, which allows us to test both the presence of a unit root in a common stochastic process to all series of cross-section, as well as the presence of a unit root in the individual series of the cross section.[8] The results are reported in Table 1.

Table 1 - P-Value of Unit Root Tests

	$\hat{y}$	Log (Z)	$\log(s^k)$	$\log(s^h)$	$\log(\pi)$	$\log(W)$	$\log(n)$
Null Hypothesis: Presence of a Unit Root (assumes a common unit root process)							
Levin, Lin & Chu t*	0.0000	0.1826	0.0000	0.0069	0.0000	0.0064	0.0283
Null Hypothesis: Presence of a Unit Root (assumes individual unit root processes)							
Im, Pesaran and Shin W-stat	0.0000	0.7515	0.0000	0.0000	0.0000	0.5000	0.6536
ADF - Fisher Chi-square	0.0000	0.6790	0.0000	0.0081	0.0000	0.0132	0.0000
PP - Fisher Chi-square	0.0000	0.8240	0.0000	0.0042	0.0000	0.0330	0.0252

Sample: 1983-2013

Broadly speaking, the presence of common and specific unit roots is rejected for all variables except the log of the debt-to-GDP ratio. Looking at the Im, Pesaran and Shin W-stat tests for individual series we see that the presence of a unit root is also not rejected also for (the log) the openness and the population growth variables. However, the ADF and the PP tests also reject the unit root for those series. However, it is well know that when structural breaks are in the present, the standard unit root tests can reject it, when in fact the series is integrated (see Perron (1997)). This sample includes many instances where the suspicion of the occurrence of structural break that may have affected all these variables is justified: several positive and negative petroleum price shocks, and several worldwide and localized financial (debt) crisis. Unfortunately, however, unit root tests with structural breaks are not available for panel data. We proceed the analysis under the provisional result that the unit root tests are inconclusive, except for the variable Z where its presence is not rejected. As a result, we perform below cointegration tests, under the possibility that the unit root is present in the other variables and, in the next section, estimate (11) using a least-squares based procedure, under the possibility that the variables are stationary.

4 - ESTIMATION

In this section we estimate the model using several different approaches.

4.1 Cointegration tests

In this section we examine the existence of a long-term relationship between the main variables of interest: real per capita GDP growth rate $\hat{y}$, the ratio of public debt-to -GDP ratio (Z), and the savings rate for physical capital accumulation (s^k), without the log transformation.[9] We test for cointegration in spite of the results of the panel unit root tests, as discussed in the previous section, because of the possibility that the results of those tests are inconclusive. We perform the tests with the understanding that the statistics of the equations themselves will allow the reader to judge their relevance as representative of a long term relation between those variables and, therefore, as evidence on the validity of the Reinhart-Rogoff hypothesis.

We perform five cointegration tests: the Kao test, Pedroni's test, and the Fisher test, FMOLS - Panel Fully Modified Least Squares, DOLS - Panel Dynamic Least Squares. The Kao test is basically an ADF test on the residuals of the cointegration

[8] Standard routines of the Eviews 7.1 software package were used.
[9] Running the tests with the log-transformed variables does not change the results significantly.

equation and also strongly rejects the no cointegration hypothesis. The Pedroni (1999) test is also based on the residuals of the cointegration equation, and has the advantage of allowing the heterogeneity of the intercepts and coefficients between members of the panel, and use of several different alternative hypothesis. Both strongly (p-value of 0.000 for the test statistics) reject the hypothesis of no cointegration. The Fischer test is an extension to panels of the Johansen unrestricted cointegration test, and the results are presented in Table 2, in the familiar form for that test. It rejects the hypothesis of no cointegration, and also that there is only one cointegration relation, indicating the existence of *two* cointegration vectors.

Table 2 - Cointegration Test (Fisher)

Series: Real GDP per capita Growth Rate; Debt/GDP; Physical Capital Accumulation Rate Sample: 1983-2013 Observations: 2604				
Nº of Cointegration Vectors (Hypothesis)	Fisher Statistic (Trace Test)	P-Value	Fisher Statistic (Eigen Value Test)	P-Value
None	639.5	0.0000	620.4	0.0000
At most 1	222.8	0.0030	201.5	0.0398
At most 2	144.5	0.9048	144.5	0.9048

The specification of the Panel Fully Modified Least Squares (FMOLS) and Panel Dynamic Least Squares (DOLS) models are adapted to the majority of time series, and allow the assessing the long-term relation between the variables. Chen et al. (1999) suggest that these methods are more efficient because they correct for the endogeneity and serial correlation of the variables, allow immediate visualization of the cointegration vectors, and are usually more robust than the methods based on the Johansen methodology because they are based on least squares estimation. The results of the estimation of these two models are shown in Table 3 and 4.

Table 3 - Cointegration Test (FMOLS)

Dependent Variable: Real GDP per capita Growth Rate Estimation Method: Panel Fully Modified Least Squares (FMOLS) Sample (adjusted): 1985-2013 Cross-Sections: 83 Total Panel (unbalanced) Observations: 2111				
Variables	Coefficient	Standard-Error	T-Statistic	P-Value
Debt/GDP	-2.217766	0.409187	-5.419927	0.0000
Physical Capital Accumulation Rate	4.600280	0.529823	8.682666	0.0000
R^2	0.604158	Mean (dependent variable)		1.732444
Adjusted R^2	0.453386	Standard-Deviation (dependent variable)		3.985715
Standard-Error of Regression	2.946774	Sum of Squared Residuals		13268.35
Durbin-Watson	1.972279	Long-Run Variance		5.486813

Table 4 - Cointegration Test (DOLS)

Dependent Variable: Real GDP per capita Growth Rate Estimation Method: Panel Dynamic Least Squares (DOLS) Sample (adjusted): 1984-2013 Included Periods: 30 Cross-Sections: 83 Total Panel (unbalanced) Observations: 2199				
Variable	Coefficient	Standard-Error	T-Statistic	P-Value
Debt/GDP	-2.299079	0.452106	-5.085267	0.0000
Physical Capital Accumulation Rate	3.706080	0.901828	4.109520	0.0000
R^2	0.794228	Mean (dependent variable)		1.712021
Adjusted R^2	0.669089	Std-Deviation (dependent variable)		4.055347
Standard-Error of Regression	2.332832	Sum of Squared Residuals		7749.557
		Long-Run Variance		2.704886

As shown in Table 3, the FMOLS estimated coefficients of the endogenous variables are statistically significant, and have the expected signs. The $R^2=0.6$ of the regression indicates the included variables explain a significant fraction of the observed variation of the growth rate of the countries in the sample. The results of the estimation of the DOLS model (Table 4) corroborate even more strongly the results of the other cointegration tests ($R^2=0.79$).

In summary, the cointegration tests support the Reihart-Rogoff hypothesis of a stable long term negative relation between economic growth and public debt.

4.2 Results for the basic model

Equation (11) was first estimated using a the least squares panel regression approach, with fixed-effects and time-effects, employing the White method to estimate the covariance coefficient. As indicated previously, the variables are submitted to the log transformation, and in the discussion below this is subsumed.

Table 5 - Regression Results

Dependent Variable: Real GDP per capita Growth Rate				
Estimation Method: Least Squares (Panel)				
Sample: 1984-2013				
Cross-Sections: 83				
Observations: 2291				
Variable	Coefficient	Standard-Error	T-Statistic	P-Value
Constant	38.76160	8.471785	4.575376	0.0000
Per Capita GDP(-1)	-6.500665	0.923895	-7.036155	0.0000
Debt/GDP	-0.765107	0.227782	-3.358947	0.0008
Physical Capital Accumulation Rate	3.610051	0.599878	6.017977	0.0000
Human Capital Accumulation Rate	0.004255	0.260414	0.016338	0.9870
Trade Openness	3.164274	0.597467	5.296145	0.0000
Inflation	-0.509833	0.123686	-4.122001	0.0000
Population Growth	-0.263074	0.163775	-1.606311	0.1084
R^2	0.333957	Mean (dependent variable)		1.712021
Adjusted R^2	0.297772	Std-Deviation (dependent variable)		4.055347
Standard-Error of Regression	3.398341	Akaike		5.334996
Sum of Squared Residuals	25083.82	Schwarz		5.632977
Log Likelihood	-5992.238	Hannan-Quinn		5.443658
F-Statistic	9.229245	Durbin-Watson		1.633665
P-Value(F-Statistic)	0.000000			

The estimation result is shown in Table 5. The $R^2=0.33$ is relatively low, but that does not invalidate the equation because much is being asked from it, since the only variable that varies by country is the fixed-effects in the intercept and the coefficients of the independent variables are applied to all countries. Thus, it is not surprising that the model's explanatory power is small, given the diversity between the countries included in the sample. Several studies, some of them mentioned in the first section, reduce this heterogeneity restricting the sample to more homogeneous groups of countries. Examples would be those that uses only OECD countries, or the poorest countries or those in the euro-zone. We do not do this, because our goal is a quantitative assessment of the public debt impact on growth that can be generalized to the set of all countries in the sample.

Nevertheless, other indicators support the validity of the equation. The F-statistic equal to 9.22 indicates that it is highly significant, and all variables included in it, without exception, display the expected signs and, with the exception of the human capital accumulation rate and the population growth rate, are statistically significant at the 5% level. The Durbin-Watson statistic equal to 1.63 indicates that the residue has no significant autocorrelation, making it unnecessary to estimate this system in two stages.

Furthermore, it ensures that the use of the lagged dependent variable in the right side of the equation, measuring the speed of convergence to the steady state, does not introduce bias into the equation. We examine the equation coefficients below.

The sign of the lagged real per capita GDP shows the rate of growth decreases as the country becomes richer. As this variable is a proxy for the proximity of the steady state, this supports the neoclassical story of a slow approach to the steady state, and also captures the effects of conditional convergence. The value of its coefficient can be used to calculate the "half-life" of that process which is equal to 10 years. This means that the countries used in our sample would take, on average, 10 years to reduce in half their distance to the steady state.[10]

The sign of the estimated coefficient of the debt-to-GDP ratio is negative, confirming in part the effect pointed out by Reinhart and Rogoff (2010b) and others. Its magnitude indicates that a 1% increase in it would entail a reduction of 0.76% in the real per capita GDP growth rate.

The physical capital accumulation rate variable displays the largest positive coefficient in the model, thus indicating its importance for economic growth. A 1% increase in it would lead to an 3.61% increase in the per capita GDP growth rate.

The human capital accumulation rate variable was not statistically significant even at the 10% significance level. The low significance of the variable is not surprising, since its changes are small and its behavior is too smooth to be able to contribute to the explanation of the observed variations in the real per capita GDP growth rate.

The inflation variable also showed the expected signal and is statistically significant confirming, for example, the finding in Eggoh and Khan (2014). An increase of 1% in the inflation rate would on average over the time span of the sample, lead to a decrease of approximately 0.5% in the real per capita GDP growth rate.

The population growth variable, was not statistically significant, confirming the finding in most other growth decomposition equations.

The trade openness variable also had the expected sign and its magnitude indicates that a 1% increase in its index would lead to a 3.16%. increase of the real per capita GDP growth rate. This result is very similar to the impacts caused by the physical capital accumulation rate in economic growth. This phenomenon has been widely observed in the growth literature, but it still lacks a good model to explain it. Maldonado, Tourinho and Valli (2007) suggest that this is a dynamic effect of internationalization reciprocal reinforcement between with increase in exports of the inflow of foreign direct investment.

4.2 Estimation of variations of the basic model

Several variations of the basic model were tested, such as a version without the temporal fixed effect (A), another using five years annual data (B), one contemplating the existence of a threshold for the debt (C), and a model with a specific speed of convergence to the steady state for every country in the sample (D). The result of these tests are briefly commented below.

(A) The objective of the version of the model without the temporal fixed effect was to ascertain if the lack of significance of the human capital accumulation rate and population growth dependent variables. It is, therefore, a panel regression with fixed effects for countries. In this case we used a generalized least squares method (GLS), to

[10] See Barro & Sala-i-Martin (2004).

try to control for heteroscedasticity and improve on the efficiency of the estimation. We used a panel variance-covariance matrix where weights were assigned to the equation of each country is inversely proportional to the standard deviation of the respective error. The results obtained are discussed below.

Comparing to the estimation of the model in the previous section, there is a small drop in $R^2=0.30$, but the F-statistic increased to 10.98, indicating an improvement in significance. The Durbin-Watson statistic has remained unchanged, indicating the removal of the temporal dummy did not introduce residual autocorrelation. Some estimated coefficients change, but the qualitative conclusions are not affected. The major changes are in the human capital accumulation rate and population growth, which became statistically significant. The value of former indicates that its increase by 1% would result in a increase of 0.38% in real per capita growth rate. However, since this variable is measured by the net change in average schooling, even a 1% change is "large". The coefficient of the latter indicates that a 1% increase in the population growth rate would produce a decrease of 0.36% in the real per capita GDP growth rate.

(B) The estimate of the basic model using five years annual data instead of the annual data was performed to allow comparison of our results to other studies in the literature. We estimate the model by GLS. The main differences were the (significant) increase in the $R^2=0.51$, the drop in F-statistics to 4.2, and an increase in the Durbin-Watson statistic to 2.53. Again all the variables retain their expected signs, and only the human capital accumulation rate is, again, not statistically significant. The estimated elasticities are smaller (in module) than in the original model, as expected, except for the population growth.

(C) The second variation of the model is meant to test the existence of a threshold of the public debt variable that, above which its impact on the growth rate is stronger. This is specified including in the equation a multiplicative index variable which is dependent on a chosen threshold value. We estimate several versions of the model with GMM, one of each different value for the threshold of the debt-to-GDP ratio, from 50% to 100%, with intervals of 10 percentage points. In none of these specifications we could reject the hypothesis that the public debt effects on the real per capita GDP growth rate were equal when the debt-to-GDP ratio was above or below the threshold. All estimated coefficients, F-statistic, Durbin Watson statistic and the R^2 values were similar to those obtained in the original model.

(D) The final model variation takes into account the differences between countries in the speed of convergence to the steady state, making the first variable in the RHS of (14) country-dependent. The model is estimated by GLS and the results are shown in Table 6 for a threshold of 80%. The main differences from the original model were the increase in the $R^2=0.39$, and an increase (in module) of the estimated public debt coefficients (-1.21), physical capital accumulation rate (4.04), human capital accumulation rate (0.56) and trade openness (4.42). All variables retained their expected signs, and the only variable that was not statistically significant was the population growth.

Table 6 - Model with Debt threshold at 80% of GDP

Dependent Variable: Real GDP per capita Growth Rate				
Estimation Method: Panel Estimated Generalized Least Square (Cross-Section Weights)				
Sample: 1984-2013				
Cross-Section: 83				
Observations: 2291				
Variable	Coefficient	Standard-Error	T-Statistic	P-Value
Constant	31.28462	5.908835	5.294550	0.0000
Per Capita GDP(-1)	-5.864271	0.795456	-7.372214	0.0000
Debt/GDP(<80%)	-0.806463	0.129750	-6.215517	0.0000
Debt/GDP(>80%)	-0.863635	0.127955	-6.749534	0.0000
Physical Capital Accum Rate	3.845748	0.512263	7.507375	0.0000
Human Capital Accum Rate	0.362003	0.159275	2.272812	0.0231
Trade Openness	3.620095	0.518369	6.983619	0.0000
Inflation	-0.370964	0.113428	-3.270473	0.0011
Population Growth	-0.370225	0.139745	-2.649287	0.0081
Weighted Statistics				
R²	0.307901	Mean (dependent variable)		2.325172
Adjusted R²	0.279588	Std-Deviation (dependent variable)		4.242430
Standard-Error of Regression	3.500744	Sum of Squared Residuals		26961.46
F-Statistic	10.87484	Durbin-Watson		1.632056
P-value(F-Statistic)	0.000000			
Unweighted Statistics				
R²	0.279573	Mean dependent variable		1.712021
Sum of Squared Residuals	27131.97	Durbin-Watson		1.649172

The results of the Wald test in Table 7 do not reject the null hypothesis of equality between the coefficients of the debt variables below and above the assumed threshold.

Table 7 - Wald Test for threshold on the Debt/GDP variable

Test Statistic	Value	d.f.	Prob.
T-Statistic	0.440634	2200	0.6595
F-Statistic	0.194158	(1, 2200)	0.6595
X²	0.194158	1	0.6595
Null Hypothesis: Debt/GDP(<80%)=-0.86363529494			
Summary of Null Hypothesis:			
Normalized Restriction(= 0)		Value	Standard-Error
0.86363529494 + Debt/GDP(<80%)		0.057172	0.129750

The existence of a threshold can also be tested with the likelihood ratio test by considering the sample divided into two groups: one with low debt and the other high debt. The so called F-test is performed comparing the residual sum of squares of the restricted equation (RRSS) with that of the unrestricted equation (URSS). The test statistic for this test is:

$$F_{(k, n_1+n_2-2k)} = \frac{(RRSS-URSS)/k}{URSS/n_1+n_2-2k} \tag{12}$$

It has an F distribution where k is the total number of parameters, n_1 is the number of observations contained in the first group (debt-to-GDP ratio $\leq \tau$), n_2 is the number of observations contained in the second group (debt-to-GDP ratio $> \tau$). Calculating, we find F= 0,2137. Since the critical value for the degrees of freedom in our equations, considering a 5% significance level is 1.26, we cannot reject the null that the tested restriction is binding. This means that we cannot guarantee that the coefficients of the equation with a threshold are statistically different from those in our basic equation. Therefore, there is no empirical evidence regarding the presence of a 80% threshold level, in spite of the fact that the point estimate of the coefficients is different. The same exercise was performed for other threshold levels, varying from 50% to 100% in 10% intervals, with similar results. Therefore, we conclude that the threshold effect is not observed from our sample.

4.3 Summary of the results

The results obtained from the estimation of equation (11), both in the mid-term and in the long term, support the argument raised in Reinhart and Rogoff (2010b) that the public debt has an inverse relationship with economic growth. Taking as the starting point the neoclassical growth model, that considers as determinants of growth the human capital accumulation rate, the physical capital accumulation rate and the population growth, we added other variables that, according to the existent literature, are relevant on determining economic growth, such as inflation, trade openness, public debt and also the lagged per capita GDP, adopted as a proximity measure to the steady state, thus removing any possibility of bias due to the omission of relevant variables.

All variables included in the model had the expected signs and were statistically significant. In addition, there is no sign of the presence of heteroskedasticity or residual autocorrelation according to the results obtained from the statistical tests.

In summary, an increase in public debt reduces the per capita GDP growth rate, confirming the initial hypothesis of Reinhart and Rogoff (2010b). We conclude that a 1% increase in the debt-to-GDP ratio would produce, on average, a reduction 0.92% in the per capita GDP growth rate of a given country. We have found no threshold value of the debt-to-GDP ratio above which this is effect is significantly larger.

Table 8 presents a short summary comparing the results obtained here with the results found in the works previously reviewed. We notice that our sample is larger than all the other studies, both in the cross section and time dimensions, a fact shown by the number of degrees of freedom in column 5 of the table. Cross-section wise, we use all countries for which data was available, thereby avoiding any selection bias that could arise by considering a sub-set of countries, like some of the counties in the table.

Table 8 - Comparison with other studies

Author	Count-ries	Years Sample	Estimation Method	D.F.	R^2	Debt Elasticity	Threshold
Kumar & Woo (2010)	38	1970-2007 (5 years)	BE SGMM	118	0,78	-1,58 -1,76	Do not test
Cecchetti, et al (2011)	18	1980-2010 (5 years av.)	LSDV	354	0,77	-1,19	96%
Kourtellos et al. (2013)	82	1980-2009 (10 years)	GMM LS	238	-	-0,029 -0,511	Do not find
Baum, et al. (2013)	12	1990-2010 (Annual)	2SLS	233	-	-0,00411 Semi-Elasticity	66,4%
Afonso &Jalles (2013)	155	1970-2008 (5 years av.)	OLS LSDV IV-GLS SGMM	821 803 757 821	0,21 - 0,26 -	-1,18 -0,59 -1,18 -0,59	59%
This paper	86	1983-2013 (Annual)	GLS	2200	0,3	-0,92	Do not find

The results are general, and apply to all types of countries, of all stages of development and all regions of the world. In the temporal dimension we also excel, because we use annual data rather than 5-year or 10-year data, and do not average our data, and consider a wide time frame extending to 2013 and, therefore, including not only the sub-prime crisis of 2009, but also its effects. We also note that, while we were conservative in the choice of estimation methodology, avoiding instrumental variables approaches and the inevitable arbitrariness of choice of instruments, our estimate for the debt elasticity is similar to that of Kumar & Woo (2010), Cecchetti, Mohanty & Zampolli (2011), and Afonso & Jalles (2013), but is slightly smaller because these studies use 5 and 10 year interval data. We believe that choosing a robust estimation approach has paid off.

5 - CONCLUSIONS

In this paper we examined the existence of a negative relationship between public debt and economic growth. The incentive to do so at this particular juncture in time is the fact that recent debt crisis in the euro zone drew attention to an issue that had been not a problem since the late 80s: the increasing public debt in most countries around the world, and its effects on economic growth.

The approach used here to test this hypothesis differs in several ways from previous studies of this issue. We constructed a database that covers almost the entire universe, and is broader than other published studies which test that hypothesis for uniform groups or countries, aggregate along the time dimension. Our database contains 86 countries, with annual observations extending from 1983 to 2013 which allows us to observe the global impact of the sovereign debt crisis that hit the eurozone, and check their developments.

A careful and comprehensive review of the literature on economic growth, from both theoretical and empirical point of view, and their interaction with fiscal and debt variables, allowed us to specify the model used in this paper. The estimated model contains the following variables: real per capita GDP; the human capital accumulation rate; the physical capital accumulation rate; the population growth rate; specific country fixed-effects; the unobservable error term; and economic variables that explain the economic growth, represented in this model by the trade openness, the inflation rate and the public debt. It has been tested to the panel data above, and estimated as both a mid-term and a long-term relationship.

To test the long-term relationship we performed cointegration tests between its main variables: the per capita GDP growth rate, the physical capital accumulation rate and the public debt. Several tests were done, and we confirmed the existence of at least one cointegration vector between them with a significant negative effect of public debt on growth. The shorter term reference equation, with all the variables listed above, was estimated using the generalized least squares with correction for heteroscedasticity and adopts the White specification for the covariance coefficients. This method is preferred because of its robustness.

The results indicate that increases in public debt reduce the rate of economic growth, thus confirming the initial hypothesis. The estimated average elasticity over the sample is 0.92. This implies that the effects of a 10 percentage points increase in the debt-to-GDP ratio on economic growth are as indicated in Table 9.

Table 9 - Effects of an increase of 10 p.p in the debt-to-GDP ratio different countries

Country group for different Debt-to-GDP ratios	Average debt / GDP	Change in the debt / GDP ratio	Change in the average GDP growth rate	Average annual GDP growth rate	Change in the GDP growth rate (in p.p.)
>90%	123.49%	8.09%	-7.44%	1.85%	-0.15
>60% ≤90%	68.89%	14.52%	-13.36%	2.85%	-0.44
>30% ≤60%	45.20%	22.13%	-20.36%	2.80%	-0.72
≤30%	18.70%	53.49%	-49.21%	2.21%	-2.15

The third column of Table 9 represents the percentage change corresponding to an increase of 10 percentage points in the average debt level of the countries in the corresponding group. The fourth column represents the percentage change in the annual rate of growth of GDP. The last column is the impact measured percentage points. They are different for different levels of indebtedness not because the elasticity is different between them, but because the average level of the two variables are different.

We also tested in this paper the existence of a threshold in public debt, i.e. a value above which the magnitude of the effects of an increase in public debt would have a larger impact in the rate of per capita GDP growth. Thus, an alternative version of our basic model which included the presence of a threshold effect for the public debt variable, using several distinct values for the threshold were tested. These tests could not confirm the existence of thresholds in the relationship between public debt and economic growth.

It is possible that our conclusions are, at least partly, due to the larger sample, when compared to other studies in the literature, especially along the temporal dimension. It is also possible that the rejection of the existence of a debt threshold came from the fact that we tested the existence of a universal threshold, and that this phenomenon occurs for a subsample of countries. Exploration of these possibilities is left for further work. Also, other future developments for this model are possible, such as the differentiation between the public debt raised to finance productive expenditures (public investment) and unproductive expenses (government consumption), as suggested by economic theory. Such investigations, however, depend on refinements of the data before they can be tackled.

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