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Linear and Non-Linear Effects of Public Debt on Long Term Interest Rate

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Abstract
The main objective of this paper is to reassess the effect of public debt on long-term interest rate using panel data approach. It complements and extends the existing literature and in particular, the empirical framework employed in the paper by Ardagna, Caselli and Lane (2004) through exploring nonlinear effects of large fiscal deterioration by broadening the country sample and using different time horizon. Non-linear effects of public debt on GDP are estimated by calculating threshold value for public debt ratio using the methodology proposed by Hansen (1999). We find strong evidence that during the period of financial trouble or recession, having high public debt results in stronger significant effects on long term interest rates. While investigating the presence of non-linear relationship of Public debt ratio and long-term interest rates, we find strong evidence of non-linearity.
Keywords: Public debt, sovereign rate, non-linear
JEL Classification: E60, E63

1. Introduction

In the wake of the recent financial crisis, sharp increase in fiscal deficits and public debt (particularly in advanced economies) has renewed focus on the importance of a country's net debt position in determining its interest rates and its impact on long-term sovereign bond yields. Some economic theories suggest that the effect of debt on long term interest rates is an important channel through which debt can affect the real sector of the economy through the crowding-out effect. For example, extensive fluctuations in long term rates usually have a strong impact on the interest-sensitive components of private spending such as housing and business fixed investment. However, some contradictory theories, for instance the theory of Ricardian equivalence of debt-neutrality suggests that there will be no impact of government debt on interest rates. Therefore, understanding how debt impacts long term rates is of utmost importance for policy formation among current economists and policymakers.

However, this relationship can be puzzling by the fact that different policy measures, both monetary and fiscal, may impact debt and interest rates simultaneously. For instance, during some recessions long-term interest rates are subject to fall due to monetary easing, while automatic stabilizers raises the level of debt (CBO, 2013). Therefore, this implies a negative correlation between debt and interest rates. Nevertheless, when all other factors are controlled for, the relationship is positive. Thus the dynamics of the relationship between the impacts of debt on long term interest rates is essentially an empirical question and the focus of our investigation in this paper.

While economic theories suggests different patterns in relationship between interest rate and public debt (generally ignoring nonlinear effects of deficits and debt), empirical results have also been much less straight forward. Even though there is a significant amount of existing literature exploring the relationship between public debt and interest rates, there is a multiplicity of findings. While many studies suggest a single-digit rise in the interest rate when government debt increases by one percent of GDP, other studies estimate either much larger effects or find no effect at all. Lack of a clear consensus regarding this topic in the academic world is evident, and this discrepancy in academic opinion has spurred our interest to evaluate the relationship between public debt and interest rates.

Even though the existing literature on this topic has been inconclusive, a potential reason might be that most of the work on public debt and interest rate evaluation was based on time series evidence from small group of countries, typically the US. To address this gap in literature, we have decided to incorporate large cross-country evidences to analyze the relationship between public debt and interest rates with the expectation of finding a more conclusive result.

The main objective of this paper is to reassess the effect of public debt on long-term government bond yields using panel data approach. It complements and adds to the existing literature of the empirical framework employed in the paper by Ardagna, Caselli and Lane (2004) through exploring in particular, nonlinear effects of large fiscal deterioration by broadening the country sample and using a different time horizon. The earlier work uses a panel estimation of 16 OECD countries, covering a time span from 1960 to 2002 found statistically and economically significant effects of fiscal imbalances on long-term interest rates. As one of goals of our paper is to estimate the non-linear effects of public debt on GDP and in consequence, estimate threshold value for Public debt ratio, we will be using the methodology proposed by Hansen (1999) to estimate the threshold values. Since there is no clear consensus with regards to choice of variables, our model will include variables from several key papers in this field. We have chosen variables based on papers by Caselli, Ardagna & Lane (2007), Baldacci & Kumar (2010)

and Baum, Chicherita & Rother (2012).

The paper is organized as follows. The following section will provide a brief summary of the existing literature that has evaluated the relationship between government debt and interest rates over the past twenty years. The next section will discuss a potential theoretical framework on the relationship between debt and interest rates. In the following section, we will provide descriptions of the econometric methods employed in our paper, the rationale for the selection of variables to be included in the analysis, as well as comprehensive description of the data used for our paper. The subsequent section will present detailed interpretations of our regression results and analysis of our findings. Finally, in the last section, we will summarize our conclusions and briefly discuss the potential effects of government debt on the economy in general.

2. Literature Review

There have been numerous studies conducted over the past twenty years that have tried to evaluate the relationship between government debt and interest rates. Despite the volume of work, no universal consensus has emerged on the relationship between government debt and interest rates.

Bernheim (1987, 1989) and Seater (1993) used the Ricardian equivalence theory (debt neutrality), to specify the problem with hypothesis testing where debt neutrality will ensure that changes in debt will not affect long term interest rates. Bernheim argues that the Ricardian equivalence hypothesis should be rejected, which would favour positive relationship between federal government debt and interest rates. However, Seater (1993) in general finds an overall support for the Ricardian equivalence hypothesis, which implies that federal government debt has no effect on interest rates. Barro (1989) takes a similar position as Seater, concluding that the overall empirical results on interest rates support the Ricardian view. Consequently, the paper by Elmendorf and Mankiw (1999) states that the literature has not been able to provide a conclusive finding and further work is required to analyze the relationship between public debt and long term interest rates.

Barro and Sala-i-Martin (1990) and Barro (1991) incorporated the potential effects of increased integration of international financial markets by providing estimates of the effects of economic, fiscal and monetary policy variables on expected real world interest rates across ten major developed economies. They use a structural approach where the world interest rate is determined by investment demand and desired saving. They conclude that current government debt or deficits do not play an important role in the determination of real expected interest rates in these countries.

Many country-specific and cross-country studies have found a diversity of results. In an earlier comprehensive survey, Gale and Orszag (2003) summarized the findings of almost 60 studies: of these, around one-half found a “predominantly positive significant” effect of fiscal deficits on interest rates and the other half a “mixed” or “predominantly insignificant” effect. A similar conclusion was reached by Engel and Hubbard (2004). Concerning the magnitude of the effect, the broad finding appears to be that an increase in deficits by 1 percent of GDP raises long-term interest rates by 30–60 basis points, while an increase in the debt-to-GDP ratio of 1 percentage point is associated with an increase in interest rates of between 2 and 7 basis points as concluded by Engel and Hubbard (2004), Reinhart and Sack (2000) and Kinoshita (2006)

In addition to differences arising due to model specifications, choice of explanatory variables and sample and time periods, the effect of fiscal policy on bond yields also appears to depend to some extent on the budget variable used. It is considerably larger and found more frequently when expected deficits (Feldstein, 1986b) are used. Results also point to a positive relation between fiscal deficits and long-term interest rates when there is uncertainty on the composition of fiscal policy (Balduzzi, Corsetti and Foresi, 2007).

Ardagna (2009) explores the behavior of government (and corporate) bond yields in times of large changes in the fiscal stance for the OECD countries (over the period 1960–2002). She finds that 10-year nominal yields on government bonds increased by more than 180 basis points during years in which the primary fiscal deficit widened by more than 1½ percent of GDP in one year or 1 percent of GDP per year in two consecutive years.

The literature on non-linearity in fiscal policy is relatively new, with the most current and influential paper being Caselli, Ardagna & Lane (2007), Baldacci & Kumar (2010) and Chicherita & Rother (2011). Therefore, specifications and choice of variables for our analysis are based on the papers mentioned above.

Another paper which uses a more conventional Threshold VAR to incorporate non-linearity in fiscal policy is Candelon and Lieb (2011). Although structural VAR specifications have been the workhorse for investigating the impact of fiscal variables on monetary and vice versa (Mountford and Uhlig (2009), Perotti (2002), Engen and Hubbard (2004)), the existence or estimation of non-linearity in their relationship is rare in the literature. One reason could be the small sample size of most fiscal data and the potential empirical issues that researchers might have to encounter with the large number of parameters generated in any non-linear model. However, one good example in this field can be of Checherita and Rother (2010), where they investigate the average impact of government debt on per-capita GDP growth in twelve euro area countries over a period of about 40 years starting in 1970. They find a non-linear impact of debt on growth with a turning point—beyond which the government debt-to-GDP ratio has a deleterious impact on long-term growth—at about 90-100% of GDP.

The non-VAR literature includes a relatively higher number of contributions. Laubach (2009) uses a dynamic OLS framework in order to investigate the quantitative effects of government debt and deficits on long-term interest rate for US economy (1976-2006). To overcome the problem of endogeneity, he used variables' projections instead of current values. He found that a 1 per cent increase in the projected deficit/GDP ratio raises the 5-year-ahead 10-year forward rate by 20 to 29 basis points, whereas the same increase in debt/GDP ratio raises the forward rate by 3 to 4 basis points. Ardagna et al. (2007) used a dynamic deficit/GDP ratio associated with a 10 basis points increase in nominal interest rate on 10 years government bond; the cumulative response after ten years is equal to 150 basis points. They also investigated the impact of debt, and found a non-linear effect: the response of long term interest rate is positive and statistically significant only when the existing stock of public debt is above a given threshold.

There is also some evidence on the impact of country-specific fiscal imbalances on a wider level. Along the same line, Faini (2006) used a three-stages least squares focusing on nine EMU countries (over the period 1979-2002) and found that an expansionary fiscal policy in one EMU member has effects both on its spread and on the overall level of interest rate for the currency union (with the latter being stronger than the former). Although less robust, there is also evidence of more significant spillover effects for high debt countries. Bernoth et al. (2004) used a panel data analysis (1991-2002) on 13 EMU nations to investigate the effects of fiscal imbalances (and EMU membership) on spread to German bond. They found that an increase of 1 per cent in the deficit/GDP differential with Germany increases spread by 3.39 basis points although in a non-linear fashion. A 25 per cent differential in debt/GDP ratios corresponds to a 30 basis points, whereas 50 per cent corresponds to 47.5 basis points. However, they found that EMU membership implicated a reduction in spreads.

However, studies using a cross-section of economies indicate a smaller impact than analysis of individual countries. This may be because in the pooling of data, country-specific coefficients tend to be heterogeneously affected by institutional and structural factors, which are generally not explicitly taken into account in many of the studies. Ardagna, Caselli and Lane (2007) found that a deterioration of 1 percent of GDP in the primary balance for a sample of 16 OECD countries leads to an increase in government bond yields by 10 basis points. This is lower than the estimated coefficient found by Dai and Philippon (2005) for the United States using the same fiscal indicator.

Evaluating effects of government debt on interest rates is difficult given the lack of consensus on the appropriate underlying economic model of how federal debt and interest rates should interact. Moreover, variable definitions and other features of the data as well as econometric methodology vary across these studies, making it difficult to make comparisons. As with most of the earlier literature on federal debt and interest rates, it is evident that the existing evidence is quite mixed. Some studies find positive effects of federal debt on interest rates and others do not. Moreover, even among the studies that do find a positive effect of debt on interest rates, the magnitude of the effect on interest rates is still uncertain. However, almost all of this work is based on time series evidence from single and small group of countries, typically the US. This suggests that there might be significant benefits from utilizing larger cross-country evidence to investigate this question. This is one of the goals of our present paper. Our contribution aims at filling this gap in the literature, with an approach to be presented in the following section.

3. Theoretical Framework

It is important to understand the theoretical justification according to which government debt will be affecting interest rates. One of the ways to show positive relationship between interest rates and capital is to assume basic aggregate production function. This production function helps us in understanding the relationship for the economy in which government debt "crowds out" productive physical capital (Ball and Mankiw, 1995; Elmendorf and Mankiw, 1999). The model assumes a Cobb-Douglas production function: $Y=AK^{\alpha}L^{(1-\alpha)}$, where A is the coefficient for multifactor productivity, L denotes labor units, K level of capital, and α is the coefficient on capital in the production function. The interest rate (r) is determined by the marginal product of capital (MPK= $\frac{\partial Y}{\partial K}$). Therefore, a decrease in capital (K) due to increase in government debt (D) (crowding out) would lead to an increase in MPK, and hence in interest rates.

Concerning this model's definition for marginal productivity of capital and consequently, interest rate, we can calculate interest rate by the following formula:

$$MPK = r = a * A * (\frac{L}{K})^{(1-a)}$$

Therefore, considering the case when government debt crowds out the capital ($\frac{\partial K}{\partial D} < 0$), holding other factors constant, an exogenous increase in government debt will cause the interest rate to increase:

$$\frac{\partial r}{\partial K} * \frac{\partial K}{\partial D} = a * (1-a) * \frac{Y}{K^2} > 0, \quad where \ \ (0 < a < 1; K, Y > 0)$$

One of the key proposal of this theoretical framework is that the level of the interest rate is determined by the level of the capital stock and, thus, by the level of government debt. In other words interest rate is affected by the government budget deficit, what is essentially equal to the change in government debt. Even though most empirical work uses a specification different from what is implied by this economic model; that is, the deficit is regressed on the level of the interest rate. It is also important to note that the empirical estimates of the effect on interest rates tend to differ noticeably depending on whether the deficit or debt is used. However, we have used both deficit and debt on our regression to get rid of any preconceived notion.

Key economic theory that counters the previous section is the concept of Ricardian equivalence of debt neutrality. Debt neutrality is said to occur when the real equilibrium of the economy including private consumption, investment etc. is independent of the pattern of government borrowing (bond issuance) and lump-sum taxation over time. In the context of our model, this means that an increase in government debt (keeping marginal tax rates and government consumption constant) will be compensated by the increase in private saving. This means government debt does not crowd out capital from the economy i.e. ($\partial K/\partial D = 0$) and therefore ensures that the capital stock is unchanged from the rise in government debt and hence the interest rate is unaffected (Bernheim 1987, Barro 1989, and Seater 1993).

Two basic economic theories that are explained in this part suggest completely contradictory impacts of government debt on long-term interest rates. Although these theories provide a good benchmark for the potential effect of government debt on interest rates, it must be mentioned that the two theories discussed before have very strong assumptions, and therefore could be in opposite with the real data. Empirical literature on the topic has both these extreme conclusions but yet a proper consensus on the matter is yet to be reached.

4. Baseline model

This section provides description of econometric methods employed in our paper, as well as explanation for the inclusion of various regressors used in our analysis. In addition, data used for our analysis will also be discussed. In line with many other papers in this field, we are using long-term nominal interest rates for government bonds as a dependent variable in our regressions. In order to check our results for robustness, we also used real interest rates and interest rate yields as dependent variables. By long-term interest rate we define interest rate on government bonds with 10 year maturity. The main reason to use long-term interest rates instead of short-term interest rates is to avoid effects of current monetary policy, as latter variable is heavily influenced by monetary shocks, in addition to that time series on 10 year bonds are easily accessible for the most countries in our sample. Unfortunately, even though a lot of research was done in this field, there is no clear consensus with regards to choice of included variables, therefore our choice of inclusion of different economic variables will be based on several major papers in this field. Our choice of variables has been based on papers by Caselli, Ardagna & Lane (2007), Baldacci & Kumar (2010) and Chicherita & Rother (2011). As a result our baseline econometric model is as follows:

$$R_{it}^{10Y} = \alpha_i + \beta_1 R_{it}^{3M} + \beta_2(PD_{it}) + \beta_3\pi_{it} + \beta_4(GD_{it}) + \beta_5 R_{i,t-1}^{\Delta GDP} + \beta_6 Gap_{it} + \beta_7 Capaccount_{it} + Controls_{it} + \varepsilon_{it}$$

In this regression PD_{it} is a public debt as a percentage of GDP in the same time period, and GD_{it} is government deficit divided by GDP. For identification purposes we have included various control variables. R_{it}^{3M} is a 3month interest that we use as a control variable for current stance of monetary policy. Also we control for inflation effects by including π_{it}, which is inflation in period *t.* In order to control for country's cyclical position we also include output gap, capital account and GDP growth in a previous period ($R_{i,t-1}^{\Delta GDP}$). For further controls in our regression analysis, we have included global variables as well country and time fixed effects.

Furthermore we have included "global variables" in order to account for world economic integration in this age of globalization. Every economy in the world could be perversely influenced by developments in world economy and consequently changes in world aggregate economic variables could have a significant impact on interest rate in countries from our sample. Caselli (2007) found statistically significant relationship between global variables and long-term interest rates. Therefore, we decided to use these proxy variables in order to control for these effects. Most of variables are constructed as a weighted by GDP averages of variables in our sample (except inflation and public debt). We assume that countries in our sample cover significant share of movements in global financial markets, and hence can be used as proxies.

5. Threshold approach extension

As one of the main goals of our paper is to study non-linear effects of public debt on interest rates and in consequence estimate threshold value for Public debt ratio, we have to apply additional methodology. The "Threshold" approach that we are going to introduce is widely used in empirical papers nowadays and will better complement the existing literature.

We decided to determine threshold value by applying methodology, proposed by Hansen (1999). In this paper

author proposes threshold estimation in case of non-dynamic panels with fixed effects. Our model with threshold effect can be represented in a following way:

$$R_{it}^{10Y} = \alpha_i + \beta' X_{it} + \delta_1 PD_{it} Z_{it}^1 (PD_{it} > PD^*) + \delta_2 PD_{it} Z_{it}^2 (PD_{it} < PD^*) + \varepsilon_{it}$$

In this specification X_{it} is a set of independent variables, defined in a previous section, with exception for public debt ratio. Z_{it}^1 is a dummy that takes value of 1 if public debt exceeds certain value. By including these two interaction terms into regression we will be able to identify, whether there is a change in relationship pattern between public debt and interest rates. Here we gave an example, when there is a single threshold value. If there is another threshold, then we also include dummy for the case when public debt ratio is in between both thresholds.

Strategy for finding the threshold consists in three steps. Firstly, we set the grid of possible threshold values, and conduct series of least square minimizations (Model estimation). Then we choose such PD^* so that sum of squared residuals is minimized:

Once threshold value is obtained we have to check threshold for statistical significance. Null and Alternative Hypotheses for absence of threshold effect can be represented in a following way:

$$\begin{cases} H_o: \delta_1 = \delta_2 \\ H_a: \delta_1 \neq \delta_2 \end{cases}$$

Under the null hypothesis of this model coefficient of this model does not exist. Existence of nuisance implies that test statistics distribution should be non-standard (Davies problem). However, according to Hansen (1999) bootstrap procedure should attain first-order asymptotic distribution therefore p-values should be asymptotically correct. In this case we group the set of regression residuals ($\hat{e}^*$) by individual$\hat{e}_i^* = (\hat{e}_{i1}^*; \hat{e}_{i1}^*; \dots \hat{e}_{iT}^*)$. Then we draw from this set a sample of residuals for some size *n* and estimate model for null and alternative hypothesis. Then we repeat this procedure (with replacements) many times and calculate the percentage of ties when calculated statistics is higher than actual one. When distribution is attained, it is possible to compute p-values and check threshold value for statistical significance.

To implement this test we must run regressions under null and alternative hypotheses and compute sum of squared residuals. Finally, we test this threshold value for statistical significance, applying following test:

$$F = \frac{(SSE_0 - SSE(PD^*))}{\widehat{\sigma_2}}$$

In our paper we are also testing for double threshold. In this case, function takes the following form:

$$R_{it}^{10Y} = \alpha_i + \beta' X_{it} + \delta PD_{it} Z_{it} (PD_{it} < PD^*) + \delta PD_{it} Z_{it} (PD^* < PD_{it} < PD^{**}) + \delta PD_{it} Z_{it} (PD_{it} > PD^{**}) + \varepsilon_{it}$$

Here we can implement the same procedure for the sum of squared residuals minimization, as it was in case of single threshold. Therefore, we should find combination of values PD^* and PD^{**} so that sum of squared errors is minimized. However, this method could be computationally cumbersome as it requires approximately $(nT)^2$ regressions to be implemented. Therefore, as it was suggested by Hansen (1999) we employ two-step procedure, where we firstly find first threshold, and then find the second one, by fixing the first one.

6. Description of Data

Data on the most macroeconomic variables and interest rates was mainly obtained from AMECO database, and in some cases supplemented by data from OECD Outlook database and websites of national central banks. Data on inflation, output gap and capital balance was acquired from Eurostat and Datastream databases. Appendix C compromises more implicit description of data sources, as well as descriptive statistics of variables that are used in our baseline model.

Our sample takes period from 1992 to 2013, however our panel is slightly unbalanced as there is no data for long-term interest rate for some eastern European countries in beginning of 90s. Altogether 38 countries are used in our sample and 785 observations are available. Our sample mainly consists of European countries and some developed economies outside the Europe including Australia, Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Estonia, Iceland, Ireland, Italy, Israel, Japan, Latvia, Lithuania, Luxemburg, Malta, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovenia, Slovakia, South Africa, South Korea, Spain, Sweden, Switzerland, United Kingdom, and United States.

It is also important to note that we have separated the sample into two groups. One in which all the countries in the sample are included and the other excluding eastern European economies. Due to their transition from socialistic to market economy during the 90s, Eastern European countries may have significantly different relationship patterns between interest rates and fiscal variables. Furthermore, we have separated the sample into two time frames. One takes a maximum time-span from 1992 to 2013 and the other time span is from 1992 to 2008 in order to get rid of any potential outlier effects from the recent global financial crisis.

Correlations among different variables show considerable pattern in connection amongst various macroeconomic and fiscal variables. Short and long-term interest rates show high positive correlation between each other. Another significant feature is the highly positive relationship between output gap and budget deficit.

Also high output gap is associated with higher capital inflows via transaction balance. In order to check for multicollinearity we implemented Variance Inflation Factor analysis. VIF analysis rejects null hypothesis for excessive multicollinearity among regressors.

Hypothetical problem that we may encounter in current econometric specification is simultaneous bias problem. Changes in long-term interest rates may affect level of public debt, in addition to that interest rates may adversely affect level of government deficit. High interest rates may discourage policymakers from taking additional loans and allowing for budget deficit, but small interest rates could in contrary lead to opposite effects. In order to control for that we also run GMM regressions, where we use lagged variables as instruments.

Another possible issue might be stationarity and cointegration problem. Due to certain macroeconomic trends some of our variables could be non-stationary. Therefore, stationarity properties of our variables were examined, by applying panel data unit root test proposed by Im, Pesaran and Shin (2003). Results of this test showed that some of our variables, especially long-term interest rates and public debt appeared to be non-stationary at 5% confidence level. Therefore, we applied HP filtering in order to de-trend these series. We decided to use HP filtering instead of first-differencing in order to avoid decrease in our number of observations. Unit root test results for all variables are given in the Appendix C.

7. Description of results

For simplicity purposes, we will de-note our samples with the following specific names:

	Full Country Sample	**Short Country Sample (Excluding Eastern European Countries)**
Full Time Period (1992 – 2013)	**Sample A** (No of observations – 785)	**Sample C** (No of observations – 640)
Short Time Period (1992 – 2008)	**Sample B** (No of observations – 556)	**Sample D** (No of observations – 461)

Full Country Sample

Table 1 of columns 1, 2 and 3 shows the results for multivariate regressions of the *nominal* interest rate on 10-year government bonds, on the nominal interest rate on 3-month Treasury bills (short term interest rates), Capital Account as a share of GDP, Public debt as a share of GDP, output gap, budget deficit as a share of GDP and inflation for sample A without fixed effects, with country fixed effects and with time and country effects respectively. Table shows that there is a positive relationship between public debt as a share of GDP and 10-year government bonds interest rate and the result is statistically significant at 1% significant level. The size of the coefficient, however, varies slightly across the different groups from 0.0745 to 0.0605, implying that one percent point increase in the public debt to GDP ratio is associated with an increase of the 10-year government bonds interest rate from a maximum of 7.45 basis points to a minimum of 6.05 basis points. Furthermore, we also detect a similar positive relationship on deficit as a share of GDP but only significant at 10% significant level. Regressing nominal interest yield as the dependant variable (Table 5, column 1, 2 and 3) reduces the statistical significance of public debt as a share of GDP to 10% and deficit as a share of GDP completely weaken. However, statistically significant evidence of nominal short-term interest rate now emerges.

Similarly, Table 2 of columns 1, 2 and 3 show the results of multivariate regressions of the *real* interest rate on 10-year government bonds on the same regressors in the previous section. Similarly to the previous section, we find positive relationship on public debt as a share of GDP and the result is statistically significant at 1% level except for regression with country fixed effects. However, unlike the previous section, real short-term interest rates are statistically significant at 1% and are positively related. Regressing real interest yield as the dependant variable (Table 6, column 1, 2 and 3) gives us a similar result; however, statistical significance evidence of real short-term interest rates is now insignificant.

Considering Sample B, from table 1 of column 4, 5 and 6, we also find positive relationship on public debt as a share of GDP. However, the result is statistically significant at 10% level of significance only. Moreover, we find some evidence for positive relationship between nominal short-term interest rate. Regressing nominal interest yield as the dependant variable (Table 5, column 4, 5 and 6), we find exactly the same results.

Now considering the real interest rate on 10-year government bonds for the same sample (sample B), it is very interesting to see that statistically significant relationship of public debt as a share of GDP completely disappears. However, there still exists some evidence of positive relationship between real short-term interest rate. Regressing real interest yield as the dependant variable (Table 6, column 4, 5 and 6) gives a similar evidence of positive relationship between real short-term interest rate, however, now we observe substantial positive relationship of public debt as a share of GDP statistically significant at 1% level. Inclusion of global variables doesn't change results significantly, however global deficit appears to be positive in several specifications.

Small Country Sample (Excluding Eastern European Countries)

Table 3 of columns 1, 2 and 3 shows the results of multivariate regressions of the nominal interest rate on 10-year

government bonds excluding Eastern European countries from the sample (Sample C) using the same regressors as in the previous section. Unlike the full country sample, the statistical significance of public debt as a share of GDP is smaller. However, we find statistically significant positive relationship of nominal short-term interest rate at 1% significant level. Moreover, evidence of positive relationship of capital account as a share of GDP is observed. Regressing nominal interest yield as the dependant variable (Table 7, column 1, 2 and 3) we find similar statistical significance of public debt as a share of GDP; however, no evidence of nominal short-term interest rate is observed.

Simultaneously, observing real long term interest rates from Table 4 for the same sample (Sample C), statistical significance of public debt as a share of GDP and real short-term interest rate is also observed. However, like in the previous section we find no evidence of capital account as a share of GDP. In addition, evidence of positive relationship of GDP growth and negative relationship of output gap is observed at 1% significant level. Regressing real interest yield as the dependant variable (Table 8, column 1, 2 and 3) we find similar results for GDP growth; however, the statistical relationship in no longer evident.

Considering Sample D (shorter time-span) gives us exactly the same finding as for Sample C for both the nominal and real interest rate on 10-year government bonds. Similarly when regressing nominal interest yield as the dependent variable (Table 7, column 4, 5 and 6) as well as regressing nominal interest yield as the dependent variable (Table 8, column 4, 5 and 6), we find exactly the same results except that output gap is no longer statistically significant.

8. Interpretation of the results

As shown in our empirical results, there is a significant difference in outcomes across our samples. The first notable difference is the significant discrepancy in results for the samples that include/exclude period of world financial crisis (2007-2010). As it is seen from Table 1 and Table 2, results for shorter time sample are considerably less significant, than for the sample that included all years. It is interesting to note that basically all variables in our regression show lower t-values, and R-squared dropped almost twofold.

However, if we look at coefficient values for short-term interest rates we see that in case of shorter time, sample coefficients for nominal interest rates are considerably higher than in case of longer sample. Basically, in case of pre-crisis period short-term interest rates had much more effect on long-term interest rates, than it was earlier. Considering short-term nominal rate is a conventional alternative for current stance of monetary policy and we figured out the following interpretation.

In pre-crisis times, when macroeconomic condition of countries in our sample was considerably stable and balanced, country's monetary policy was playing a much more significant role in determining its long-term interest rate. As during the pre-crisis times overall risks were considerably lower, a country's fiscal stance was not considered as a strong predictor of its sovereign risk by the market. That leads us to the conclusion that fiscal balances (public debt, deficit) are much better predictors for long-term interest rates in time of financial pressure. ***As a result, effect of having high public debt is much stronger during the period of financial trouble or recession***. This result also persists for the case of samples C and D (excluding Eastern European countries) and is presented in Appendix A.

Another interesting topic to discover is to assess differences between sample with and without Eastern European countries. Intuition says that Eastern European countries may be considered as more risky countries to invest compared to the Western European countries. Therefore Eastern European countries may become outliers in our sample and thereby bias our results.

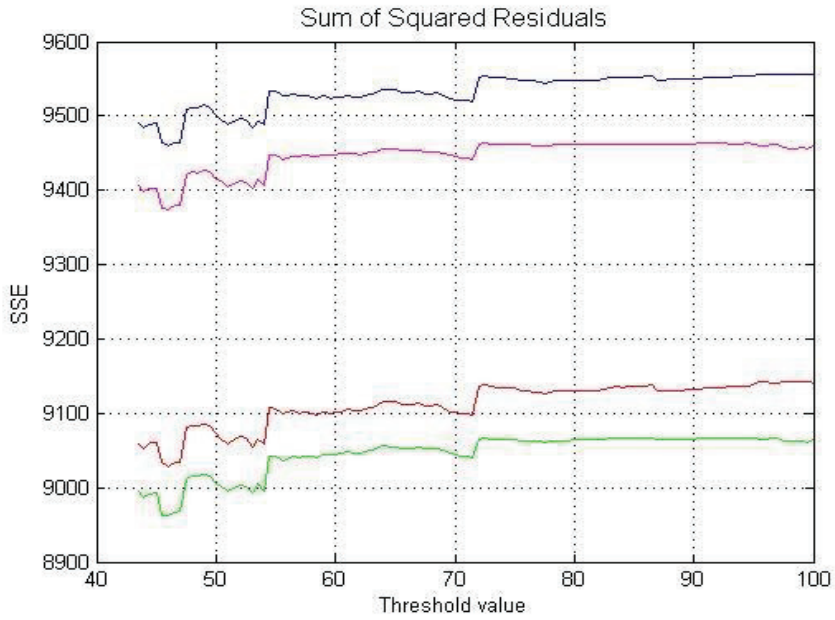
If we exclude the Eastern European countries in our sample we see that effect of current fiscal position becomes weaker. It is especially notable when we analyze only pre-crisis times. T-values for short-term interest rates become much more significant. Basically, results for tables 2 and 3 are in line with our argumentation as presented earlier. In case of sample C and D we omitted these countries; those could be considered as the riskiest in our sample. We again received higher values for short-term interest rate, and less significant results for fiscal policy variables. Therefore, we again can conclude that in case of higher sovereign risks and financial turmoil, public debt effects become more significant.

Also we tried to change our dependent variable for some other alternatives (real interest rates, interest rate yield) in order to check for robustness. As seen from the tables 5-8 our results are quite robust across various dependent variables. However, there is significant difference for inflation coefficient between the cases when we use nominal interest rates and when use real interest rates. Results show strong and negative relationship between inflation and real interest rates. Nonetheless, this issue is widely discussed in empirical literature. Inclusion of global variables doesn't change results significantly. Results for GMM regressions (tables 9 and 10, Appendix A) are similar to linear regression, where relationship between interest rates and public debt becomes insignificant, when we evaluate regression at pre-crisis period.

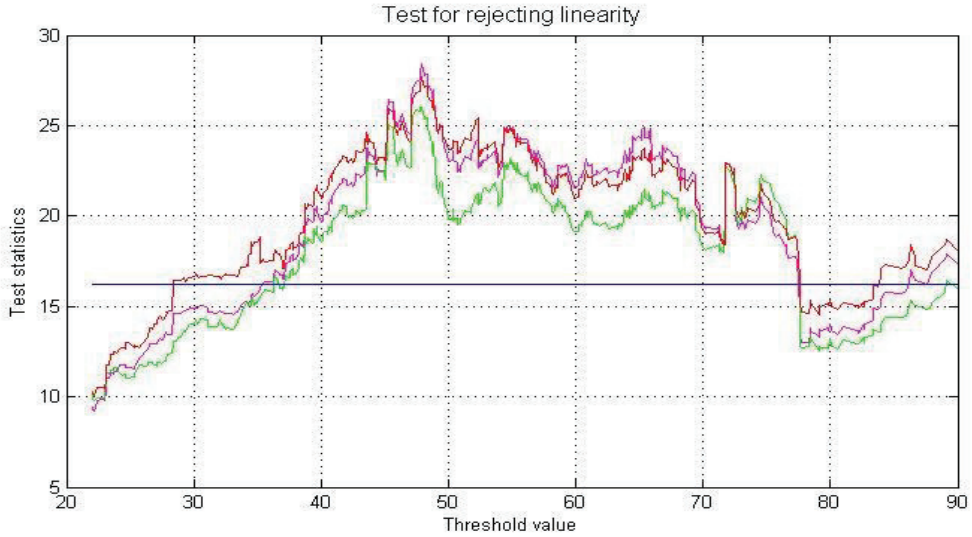
9. Threshold estimation

In this section we will implement threshold testing in order to capture non-linear effects of public debt on long-term interest rates. The process consists of two steps: firstly we run regressions for the grid of possible threshold values and then distinguish such threshold values that give us the lowest sum of squared residuals. Then these threshold values are checked for statistical significance applying Likelihood Ratio test, where asymptotic distribution is derived from bootstrap procedures (in our case we make 2000 iterations).

After running regressions for different specifications, we end up with 47% and 72.1% thresholds for public debt. Another significant result is the threshold at 54.5%, however we decided to omit this threshold, due to its close proximity to our first threshold result. Results for the sum of squared residuals are as follows:



Our results are slightly different from results obtained by Ardagna, Caselli & Lane (2007), who discovered threshold at 62%-66% levels. However our result is in line with results by Rother, Checherita-Westphal & Baum (2012) where authors found a threshold at 72.8% level. Then we tested values of our thresholds for statistical significance. Tests for single threshold values between 78% and 40% and are statistically significant on a 95% level:



Different econometric specifications show consistent results, where values for the first threshold vary from 46% to 49% and second one gives even more robust result of 71-72%. Results for real interest rates show results with higher significance, and inclusion of interaction dummies lead to more significant decrease in sum of squared residuals. Results for real interest rates show fairly similar results, where threshold values lie around values of 47% and 72%. If we add fixed effects, then both real and nominal interest rates show very close estimates for the threshold.

In order to interpret threshold coefficients, we create three interaction dummies, one for case when public debt is lower than 45% (low level of public debt), one for the case when it is higher than 72% (high level of public debt) and the third one when the value for public debt is in between those two values (medium level of public debt). Therefore our econometric specification will look as follows:

$$R_{it}^{10Y} = \alpha_i + \beta' X_{it} + \delta PD_{it} Z_{it}(PD_{it} < PD_{it}^{*}) + \delta PD_{it} Z_{it}(PD_{it}^{*} < PD_{it} < PD_{it}^{**}) + \delta PD_{it} Z_{it}(PD_{it} > PD_{it}^{**}) + \varepsilon_{it}$$

Results for Sample A show negative relationship between public debt and interest rates for low public debt values, and positive for medium ones. Results for other samples are given in appendix B.

If we analyze sample with Eastern European countries, then we see that our results are in line with results of Ardagna, Caselli & Lane (2004). We receive significant results for the cases, when debt/GDP ratio becomes higher than 72% and less significant or negative if public debt is lower. What is especially interesting is that public debt values below 72.1% often correspond to negative coefficient values.

Our paper is not the first one to find a presence for negative relationship between long-term interest rates and public debt. Ardagna, Caselli & Lane (2004) as well as other authors such as Baum, Checherita & Rother (2012) also present evidences that low levels of public debt may correspond to decrease in interest rates. Interpretation for this issue was presented by Caporale and Williams (2002). According to them negative coefficient could appear due to so-called portfolio effect. The authors state that, in case government issues high-quality bonds some investors switch to them from riskier ones. As the demand for these new bonds is very high, it creates downward pressure on the price, leading to decrease in interest rates. At the same time, level of public debt could serve as a predictor of bond riskiness; therefore low public debt rates are going to have negative relationship with interest rates. Results for Sample C are as follows:

Dependent variable: nominal long-term rate

Model	Interaction term	Coefficient value	T-value
OLS	D(z<z*)	-0.0568	-1.22
FE	D(z<z*)	-0.0418	-0.62
FE	D(z<z*)	-0.0769	-1.18
OLS	D(z*<z<z**)	0.0202	-1.21
FE	D(z*<z<z**)	-0.0214	-0.93
FE	D(z*<z<z**)	-0.00571	-0.21
OLS	D(z>z**)	0.0205	-0.98
FE	D(z>z**)	0.0516*	1.84
FE	D(z>z**)	0.005*	1.954

By z* and z** are defined thresholds with values of 47% and 72.1 % respectively. *,** and *** denote 90%, 95% and 99% level of significance. Heteroskedastic errors are applied

Dependent variable: real long-term rate

Model	Interaction term	Coefficient value	T-value
OLS	D(z<z*)	-0.0124*	-1.69
FE	D(z<z*)	-0.07	-1
FE	D(z<z*)	-0.05	-1.07
OLS	D(z*<z<z**)	-0.044	-1.61
FE	D(z*<z<z**)	0.0590*	2.1
FE	D(z*<z<z**)	0.06*	1.93
OLS	D(z>z**)	0.036	0.82
FE	D(z>z**)	0.0767*	1.69
FE	D(z>z**)	0.0741*	1.07

By z* and z** are defined thresholds with values of 47% and 72.1 % respectively. *,** and *** denote 90%, 95% and 99% level of significance. Heteroskedastic errors are applied

All in all, our results are slightly robust for different left-hand side variables; however effect of medium debt levels is stronger in case of real interest rate. Nonlinearity pattern is much more observable if Eastern European countries are excluded, what can be attributable to argumentation that was presented in previous section.

Based on the results that we got in this section we reach our second conclusion: ***public debt ratio has non-linear relationship pattern with long-term interest rates, where low values of debt have negative correlation with long-term interest rates and higher values of debt correspond to positive correlation.*** However, our results are not suggestive of a definitive conclusion with regards to medium level of debt.

10. Conclusions

The existing literature has shown to be rather inconclusive on the issue of this topic. Most of the work was based on time series evidence from small group of countries, typically the US. This spurred our interest in exploring this relationship bringing large cross-country evidence to analyse this question and contributing by filling this gap in the literature.

This paper has tried to empirically evaluate the impact of public debt on long-term interest rates over the last two decades. Our analysis took into account a wide range of country-specific factors, for a panel of 38 advanced and emerging market economies. In order to investigate the linear relationship, we used long-term interest rates for government bonds as a dependent variable in our regression and strong evidence of correlation was established. Furthermore, we came across notable differences in results for the samples that include period of world financial crisis (2007-2010) and also for samples that include Eastern European economies (riskier) in the form of greater degree of significance. As a result, we find that the effect of having high public debt is much stronger during the period of financial trouble or recession and also with higher sovereign risk. This leads us to our first conclusion

that fiscal balances namely public debt and deficit show stronger correlation with long-term interest rates in times of financial pressure and also for higher sovereign risk economies.

In addition to investigating the linear relationship, another goal of our paper was to study non-linear effects of public debt on interest rates and we came across empirical evidence in favour of significant non-linearity in the debt-interest rate relationship. Using the methodology of Hansen (1999), we find 47% (low-regime) and 72.1% (high-regime) threshold values for public debt which is in line with results obtained by Rother, Checherita-Westphal & Baum (2012). We find a negative relationship between long-term interest rates and public debt for the low-regime which we explain as a consequence of portfolio effect. The high-regime gives a positive relationship between long-term interest rates and public debt. Thus this leads to our second conclusion, public debt ratio has non-linear relationship pattern with long-term interest rates; where low values of debt have negative correlation with long-term interest rates and higher values of debt corresponds to positive correlation. Both the results obtained were significant and robust.

The results obtained from our paper should not only be interesting to policymakers in designing debt stabilization strategies but also suggest some motivating proposition for future research in this field. For instance, it be could be interesting to examine relationship between fiscal and monetary variables in times of low and high degree of risk aversion. We believe, with supplementary empirical analysis testing this relationship using various approaches; the debate of conflicting predictions about the effects of debt on interest rates will be settled across different macroeconomic models.

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Appendix (A)

Table 1

	Nominal long-term interest rate					
	Sample A			Sample B		
Nominal short-term interest rate	0.2377193	0.4477589	0.1659258	0.8688189	1.103891	1.226509
	[1.32]	[2.54]**	[0.94]	[1.46]	[1.68]*	[1.81]*
Capital Account/GDP	-0.0458773	-0.0502972	-0.0066186	-0.0551834	0.1551489	0.1048283
	[-1.54]	[-1.51]	[-0.21]	[-0.52]	[0.97]	[0.77]
Public debt/GDP	0.06532611	0.074475	0.0605049	0.036381	0.034243	0.038425
	[9.18]***	[7.62]***	[8.27]***	[1.68]*	[1.76]*	[1.65]*
Output gap	-0.2471892	-0.1849624	-0.1432707	0.3157144	0.5084545	0.0690233
	[-1.87]*	[-1.68]*	[-0.99]	[1.08]	[1.27]	[0.23]
Budget deficit/GDP	0.236098	0.2216399	0.1654809	-0.1355473	-0.3554344	0.0106531
	[1.96]**	[1.71]*	[0.94]	[-0.83]	[-1.18]	[0.06]
Inflation	-0.0506971	-0.3613933	-0.0235959	-0.8412391	-1.077679	-1.131059
	[-1.30]	[-3.17]***	[-0.59]	[-1.22]	[-1.39]	[-1.46]
Constant	5.269557	2.172927	2.172927	-2.587088	-3.520569	-2.465
	[2.79]***	[1.72]*	[1.72]*	[-1.85]*	[-2.21]**	[1.71]**
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Observations	785	785	785	556	556	556
R^2	0.4975	0.5744	0.5655	0.2678	0.2595	0.3101

Table for regressions on nominal long-term interest rate. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity

Table 2

	Real long-term interest rate					
	Sample A			Sample B		
Real short-term interest rate	0.7423215	0.8225789	0.8043835	1.023858	1.303914	1.327291
	[5.03]***	[9.47]***	[4.18]***	[1.49]	[1.77]*	[1.72]*
Capital Account/GDP	0.0386489	0.0733212	0.0525545	-0.1628069	0.192848	0.2518727
	[1.12]	[2.75]***	[1.79]	[-1.41]	[1.72]*	[1.38]
Public debt/GDP	0.037211	0.010982	0.041459	0.030161	0.03123	0.045669
	[3.83]***	[0.56]	[4.79]***	[1.32]	[1.50]	[1.61]
Output gap	0.0540421	0.1054543	-0.06685	0.0898355	0.2870349	0.0346667
	0.59	[1.15]	[0.73]	[0.30]	[0.75]	[0.12]
Budget deficit/GDP	-0.1440852	-0.164308	-0.1536791	-0.0539661	0.0463981	0.0032445
	[-1.00]	[-1.29]	[-0.98]	[-0.35]	[0.39]	[0.02]
Inflation	-0.2465108	-0.234568	-0.1888848	-0.3821898	-0.4911771	-0.5612327
	[-3.30]***	[-2.99]***	[-2.77]***	[-3.59]***	[-4.09]***	[-4.45]***
Constant	-2.445688	-2.559462	-1.621878	-1.661026	-2.084142	-38.06928
	[-4.67]***	[-2.59]***	[-1.57]*	[-0.95]	[-1.16]	[-2.72]***
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Observations	785	785	785	556	556	556
R^2	0.8327	0.82	0.846	0.3242	0.2958	0.3074

Table for regressions for real long-term interest rate. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity

Table 3

	Nominal long-term interest rate (Excluding Eastern European Countries)					
	Sample C			Sample D		
Nominal short-term interest rate	0.3743731	0.48103	0.7267851	0.4628012	0.6219396	0.7864781
	[4.27]***	[5.60]***	[10.82]***	[3.99]***	[6.12]***	[8.90]***
Capital Account/GDP	0.0501555	0.0541437	0.037851	0.062665	0.0645618	0.0363522
	[2.41]*	[1.88]*	[2.48]**	[2.49]**	[3.13]***	[1.47]
Public debt/GDP	0.04208	0.03717	0.0186	0.03721	0.04189	0.01385
	[2.05]*	[1.20]	[0.00]	[1.61]*	[1.37]	[0.39]
Output gap	-0.0590342	-0.0081244	-0.0143676	0.031586	0.1334634	-0.009748
	[-1.44]	[-0.19]	[-0.56]	[0.94]	[4.69]***	[-0.24]
Budget deficit/GDP	-0.0528414	-0.1278822	-0.0143076	0.0426757	-0.0056935	-0.0165713
	[-1.25]	[-3.13]**	[-0.36]	[0.62]	[-0.81]	[-0.90]
Inflation	-0.134051	-0.1002325	-0.1734247	-0.198292	-0.107212	-0.1450625
	[-2.40]*	[-1.71]*	[-3.03]**	[-2.87]***	[-1.67]*	[-2.37]**
GDP growth	-0.0265908	-0.0390076	-0.023736	-0.0203209	-0.0364298	-0.016041
	[-0.92]	[-1.47]	[-1.70]*	[-0.62]	[-1.68]*	[-1.26]
Constant	-1.826668	-2.379624	-2.138762	-2.757804	-3.94566	-3.149689
	[-4.66]***	[-8.38]***	[-6.75]***	[-4.02]***	[-9.10]***	[-5.02]***
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Observations	640	640	640	461	461	461
R^2	0.4119	0.3915	0.5149	0.4743	0.4262	0.4258

Table for regressions for nominal long-term interest rate. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity

Table 4

Real long-term interest rate (Excluding Eastern European Countries)

	Sample C			Sample D		
Real short-term interest rate	0.1356666	0.1804543	0.2729436	0.1847745	0.2953016	0.2877572
	[2.51]*	[2.69]*	[2.14]*	[2.14]*	[2.75]***	[1.98]*
Capital Account/GDP	-0.0113799	0.0432934	0.0298909	-0.0203996	0.0647257	0.0588296
	[-0.53]	[0.85]	[0.59]	[-0.70]	[0.93]	[0.81]
Public debt/GDP	0.01451	0.01197	0.0587	0.03088	0.04985	0.0578
	[4.39]***	[0.62]	[0.02]	[1.63]*	[1.45]	[1.56]
Output gap	-0.2169265	-0.2118382	-0.2447734	-0.1242913	-0.1142054	-0.1159698
	[-4.77]***	[-4.43]***	[-3.96]***	[-2.66]***	[-1.72]***	[-1.71*]
Budget deficit/GDP	-0.0752598	-0.0858509	-0.0522311	-0.0286904	0.0441284	-0.05742256
	[-2.39]*	[-1.90]*	[-0.94]	[-0.83]	[0.93]	[0.47]
Inflation	-0.2725586	-0.3593762	-0.4160206	-0.1129875	-0.1818802	-0.1981566
	[-3.12]**	[-3.09]**	[-3.07]**	[-1.76]*	[-1.96]*	[-2.16]**
GDP growth	0.0675582	0.0486217	0.0467903	0.0654985	0.0241127	0.0265089
	[4.39]***	[2.60]**	[2.69]**	[3.49]***	[0.93]	[0.96]
Constant	-0.0706633	0.0147216	-0.056283	-0.5697635	-0.8437234	-0.5913511
	[-0.33]	[0.05]	[-0.11]	[-1.72]*	[-2.01]	[-0.82]
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Observations	640	640	640	461	461	461
R^2	0.1956	0.1766	0.224	0.1143	0.134	0.1722

Table for regressions for real long-term interest rate. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity

Table 5

Nominal Interest Rate Yield

	Sample A			Sample B		
Nominal short-term interest rate	1.234302	1.310861	1.584645	0.5304281	0.6983716	0.6817335
	[1.50]*	[1.55]*	[1.59]*	[0.58]	[1.64]*	[0.70]
Capital Account/GDP	-0.1207694	0.1114443	0.0711596	-0.0614094	0.300635	0.3979001
	[-1.17]	[0.98]	[0.62]	[-0.46]	[1.88]*	[2.14]*
Public debt/GDP	0.1670789	0.0969061	0.1531647	0.0026104	0.0026058	0.0038528
	[1.64]*	[1.71]*	[1.68]*	[1.65]*	[1.64]*	[1.71]*
Output gap	0.079045	0.1909042	0.0173994	-0.1195526	0.035037	0.0115769
	[0.32]	[0.67]	[0.07]	[-0.69]	[0.41]	[0.04]
Budget deficit/GDP	0.0209229	0.0296126	-0.0898669	0.008471	0.1000469	0.1748191
	[0.17]	[0.28]	[0.59]	[0.06]	[0.83]	[0.94]
Inflation	-0.7790435	-0.1909042	-1.076683	-1.01683	-1.254024	-1.298605
	[-0.96]	[0.67]	[-1.19]**	[-1.14]	[-1.35]	[-1.39]
GDP growth	-0.4299799	0.0296126	-0.1036419	-0.218564	-0.2375395	-0.2403075
	[-1.30]	[0.28]	[-0.62]	[-1.30]	[-1.37]	[-1.37]
Constant	-1.324235	-1.022541	-0.4633936	1.19017	1.106757	-20.50046
	[-1.32]	[-0.78]	[-0.47]	[0.46]	[0.41]	[-1.90]*
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Observations	778	778	778	552	552	552
R^2	0.3597	0.3929	0.406	0.1425	0.1502	0.1608

Table for regressions for nominal interest rate yield. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity

Table 6

Real Interest Rate Yield

	Sample A			Sample B		
Real short-term interest rate	1.620	1.308	1.218	1.459	1.608	1.782
	[1.63]*	[1.50]	[1.44]	[1.58]	[1.71]*	[1.77]*
Capital Account/GDP	0.0476	0.123	-0.0735	-0.0447	0.141	0.0854
	[0.44]	[1.05]	[-0.85]	[-0.36]	[0.83]	[0.59]
Public debt/GDP	0.0682	0.0441	0.0528	0.00791	0.00944	0.012
	[3.02]***	[3.47]***	[3.19]***	[3.00]***	[3.71] ***	[3.06]***
Output gap	-0.000123	0.0565	-0.0324	0.237	0.34	-0.0447
	[-0.00]	[0.25]	[-0.18]	[0.81]	[0.96]	[-0.13]
Budget deficit/GDP	0.104	-0.0227	-0.0183	0.141	0.201	0.229
	[0.66]	[-0.22]	[-0.15]	[0.70]	[1.27]	[1.23]
Inflation	-0.762	-0.767	-0.79	-0.881	-0.892	-0.882
	[-8.78]***	[-9.94]***	[-9.66]***	[-8.01]***	[-9.78]***	[-12.70]***
GDP growth	-0.303	-0.509	-0.523	0.614	-0.563	-0.0999
	[-1.89]*	[-1.99]*	[-1.67]*	[-1.44]	[-1.69] *	[-0.52]
Constant	1.761	0.0150	-0.0958	-2.686	-4.011	-5.118
	[2.03]*	[0.01]	[-0.07]	[-1.04]	[-1.31]	[-1.47]
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Observations	778	778	778	552	552	552
R^2	0.3974	0.416	0.4646	0.4735	0.459	0.4636

Table for regressions on real interest rate yield. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity

Table 7

Nominal Interest Rate Yield (Excluding Eastern European Countries)

	Sample C			Sample D		
Nominal short-term interest rate	1.620	1.308	1.218	0.4628012	0.6219396	0.7864781
	[1.63]*	[1.50]	[1.44]	[3.99]***	[6.21]***	[8.90]***
Capital Account/GDP	0.0476	0.123	-0.0735	0.062665	0.0645618	0.0363522
	[0.44]	[1.05]	[-0.85]	[2.49]**	[3.13]**	[1.47]
Public debt/GDP	0.0682**	0.0441**	0.0528**	0.03721	0.04189	0.01385
	[3.02]	[3.47]	[3.19]	[1.51]	[1.37]	[0.39]
Output gap	-0.000123	0.0565	-0.0324	0.031586	0.1334634	-0.009748
	[-0.00]	[0.25]	[-0.18]	[0.94]	[4.69]***	[-0.24]
Budget deficit/GDP	0.104	-0.0227	-0.0183	0.0426757	-0.0056935	-0.0165713
	[0.66]	[-0.22]	[-0.15]	[0.62]	[-0.18]	[-0.90]
Inflation	-0.762***	-0.767***	-0.790***	-0.19822	-0.107212	-0.1450625
	[-8.78]	[-9.94]	[-9.66]	[-2.87]**	[-1.67]*	[-2.37]*
GDP growth	-0.303	-0.509	-0.523	-0.0203209	-0.0364298	-0.016041
	[-1.89]	[-1.99]	[-1.67]	[-0.62]	[-1.68]*	[-1.26]
Constant	1.761*	0.0150	-0.0958	-2.757804	-3.94566	-3.149689
	[2.03]	[0.01]	[-0.07]	[-4.02]***	[-9.10]***	[-10.86]***
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Observations	755	755	755	461	461	461
R^2	0.3974	0.416	0.4646	0.4743	0.4262	0.4258

Table for regressions on nominal interest rate yield. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity

Table 8

Real Interest Rate Yield (Excluding Eastern European Countris)

	Sample C			Sample D		
Real short-term interest rate	0.1847745	0.2953016	0.2877572	1.700	1.937*	2.254*
	[2.14]*	[2.75]*	[1.98]*	[1.73]	[2.05]	[2.37]
Capital Account/GDP	-0.0203996	0.0647257	0.0588296	0.0449	0.246	0.115
	[-0.70]	[0.93]	[0.81]	[0.29]	[1.01]	[0.50]
Public debt/GDP	0.03088	0.04985	0.0578	0.0153	0.0170	0.0229
	[1.62]*	[1.45]	[1.56]	[1.67]*	[1.60]	[1.77]*
Output gap	-0.1129875	-0.1142054	-0.1159698	-0.147	0.0151	-0.566*
	[-1.76]*	[-1.72]*	[-1.67]*	[-1.06]	[0.07]	[-2.10]
Budget deficit/GDP	-0.0286904	0.0441284	0.05245875	0.065871	0.035478	0.052478
	[-0.70]	[0.93]	[0.58]	[0.71]	[1.36]	[0.98]
Inflation	-0.1129875	-0.1818802	-0.1981566	-1.294	-1.24	-1.053
	[-1.76]*	[-1.96]*	[-2.16]*	[-2.13]*	[-2.30]*	[-1.78]*
GDP growth	0.0654985	0.0241127	0.0265086	0.0142782	0.025482	0.0452587
	[3.49]***	[0.93]	[0.96]	[0.45]	[1.54]	[1.24]
Constant	-0.5697635	-0.8437234	-0.5913511	-6.368	-7.932	-7.03
	[-1.72]*	[-2.01]*	[-0.82]	[-1.85]*	[-2.02]*	[-2.12]*
Country fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Observations	755	755	755	461	461	461
R^2	0.1705	0.134	0.1722	0.1954	0.1658	0.1985

Table for regressions on real interest rate yield. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity

Table 9

GMM Estimation

	Sample A			Sample B		
	Nominal	**Real**	**Yield**	**Nominal**	**Real**	**Yield**
Short-term interest rate	0.0121	0.0126	0.788	-0.171	0.0936	0.851
	[2.51]*	[2.65]**	[14.56]***	[-0.84]	[0.64]	[11.6]***
Capital Account/GDP	0.0023	-0.00441	0.0834	-0.0673	0.0998	0.226
	[1.43]	[-1.74]*	[1.79]*	[-0.83]	[0.50]	[2.17]*
Public debt/GDP	0.0211	0.0211	0.0394	0.00360	0.0214	-0.0705
	[8.66]***	[8.95]***	[15.37]***	[2.11]*	[0.10]	[-2.02]*
Output gap	-0.00385	-0.00687	-0.0596	0.600	0.0169	0.164
	[-1.1]	[-2.10]*	[-0.95]	[1.57]	[0.04]	[-2.04]*
Budget deficit/GDP	0.00470	0.00545	-0.0647	-0.235	-0.0870	0.0350
	[1.94]*	[2.29]*	[-1.26]	[-1.26]	[-0.48]	[0.48]
Inflation	-0.00953**	0.00254	0.0270	0.215	-0.615***	0.181
	[-2.71]	[1.38]	[0.33]	[1.85]*	[-5.18]	[1.95]
GDP growth	0.961	-0.0012	-0.0746	0.124	-0.112	-0.0816
	[2.01]*	[-0.72]	[-1.24]	[2.13]*	[-0.72]	[-1.24]
Constant	-0.0651	-0.0730	3.566	-0.105	2.380	5.488
	[-0.87]	[-0.98]	[9.40]***	[-0.12]	[3.33]***	[7.06]***
Observations	709	709	709	476	476	476

Table for regressions on nominal long-term interest rate. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity, Dynamic GMM estimation is applied, Public debt and Deficit are instrumented by their lags

Table 10

GMM Estimation

	Sample C			Sample D		
	Nominal	**Real**	**Yield**	**Nominal**	**Real**	**Yield**
Short-term interest rate	0.0122	0.15	0.413	0.0144	0.0153	0.818
	[0.33]	[3.13]***	[3.45]***	[3.26]***	[3.05]***	[14.61]***
Capital Account/GDP	-0.00311	0.00851	-0.0464	-0.00888	-0.0120	-0.0353
	[-0.10]	[0.25]	[-1.75]*	[-3.07]***	[-3.36]***	[-0.87]
Public debt/GDP	-0.0118	0.00714	-0.0500	-0.00847	-0.0542	0.00498
	[-0.47]	[0.32]	[-2.63]***	[-0.52]	[-2.57]*	[1.81]*
Output gap	-0.0593	-0.220	-0.252	-0.0162	-0.0154	-0.222
	[-1.23]	[-3.41]***	[-5.16]***	[-5.71]***	[-4.35]***	[-3.44]***
Budget deficit/GDP	-0.0736	-0.0695	0.0122	0.00486	0.00450	0.136
	[-2.03]*	[-1.88]*	[0.25]	[1.60]	[1.47]	[1.93]*
Inflation	0.0284	-0.221	0.121	0.0113	0.0239	0.269
	[0.90]	[-3.54]***	[1.22]	[1.73]*	[1.65]*	[1.83]*
GDP growth	0.0121	0.0477	0.0362	0.0296	0.0014	0.0177
	[0.76]	[2.12]*	[1.57]	[1.41]	[0.41]	[1.51]
Constant	-0.0979	0.184	2.266	0.0296	0.0943	2.399
	[-0.55]	[1.00]	[6.54]***	[0.41]	[1.62]	[4.51]***
Observations	580	580	580	424	424	424

Table for regressions on nominal long-term interest rate. By nominal long-term interest we government bonds with 10 years maturity.
By short-term rates we define interest rates with 3 month maturity. Output gap is the difference between current and potential GDP.
T-statistics are given in the brackets, where *,**,** define statistical significance on 90, 95 and 99% level of significance.
Errors are adjusted for heteroskedasticity, Dynamic GMM estimation is applied, Public debt and Deficit are instrumented by their lags

Appendix (B)

Table 1

Sample A

Dependent variable: nominal long-term rate

Model	Interaction term	Coefficient value	T-value
OLS	D(z<z*)	-0.00203	-1.31
FE	D(z<z*)	-0.02	-1.24
FE	D(z<z*)	-0.00176	1.14
OLS	D(z*<z<z**)	0.0777***	6.99
FE	D(z*<z<z**)	0.0784***	7.38
FE	D(z*<z<z**)	0.0732***	5.21
OLS	D(z>z**)	0.00399	1.09
FE	D(z>z**)	0.042	1.1
FE	D(z>z**)	0.00452	-1.03

By z* and z** are defined thresholds with values of 47% and 72.1 % respectively. *,** and *** denote 90%, 95% and 99% level of significance. Heteroskedastic errors are applied

Dependent variable: real long-term rate

Model	Interaction term	Coefficient value	T-value
OLS	D(z<z*)	-0.019	-1.55
FE	D(z<z*)	-0.019	-1.16
FE	D(z<z*)	-0.012	-0.9
OLS	D(z*<z<z**)	-0.03***	-3.73
FE	D(z*<z<z**)	-0.029**	-2.5
FE	D(z*<z<z**)	-0.04***	-4.17
OLS	D(z>z**)	0.027	0.99
FE	D(z>z**)	0.38	1.04
FE	D(z>z**)	0.04	1.1

By z* and z** are defined thresholds with values of 47% and 72.1 % respectively. *,** and *** denote 90%, 95% and 99% level of significance. Heteroskedastic errors are applied

Table 2

Sample B

Dependent variable: nominal long-term rate

Model	Interaction term	Coefficient value	T-value
OLS	D(z<z*)	0.05228	1.371
FE	D(z<z*)	0.0054	1.47
FE	D(z<z*)	0.051577	1.17
OLS	D(z*<z<z**)	0.025873	1.53
FE	D(z*<z<z**)	0.031*	1.69
FE	D(z*<z<z**)	0.029229*	1.57
OLS	D(z>z**)	0.006446	1.34
FE	D(z>z**)	0.03741*	1.61
FE	D(z>z**)	0.012539	1.29

By z* and z** are defined thresholds with values of 47% and 72.1 % respectively. *,** and *** denote 90%, 95% and 99% level of significance. Heteroskedastic errors are applied

Dependent variable: real long-term rate

Model	Interaction term	Coefficient value	T-value
OLS	D(z<z*)	-0.0156	-0.50
FE	D(z<z*)	-0.0125	-0.26
FE	D(z<z*)	-0.0767	-1.69
OLS	D(z*<z<z**)	0.024	1.08
FE	D(z*<z<z**)	0.059*	2.10
FE	D(z*<z<z**)	0.0741*	1.93
OLS	D(z>z**)	0.0798	1.44
FE	D(z>z**)	0.123*	2.24
FE	D(z>z**)	0.0872*	2.10

By z* and z** are defined thresholds with values of 47% and 72.1 % respectively. *,** and *** denote 90%, 95% and 99% level of significance. Heteroskedastic errors are applied

Table 3

Sample C

Dependent variable: nominal long-term rate

Model	Interaction term	Coefficient value	T-value
OLS	D(z<z*)	-0.0568	-1.22
FE	D(z<z*)	-0.0418	-0.62
FE	D(z<z*)	-0.0769	-1.18
OLS	D(z*<z<z**)	0.0202	-1.21
FE	D(z*<z<z**)	-0.0214	-0.93
FE	D(z*<z<z**)	-0.00571	-0.21
OLS	D(z>z**)	0.0205	-0.98
FE	D(z>z**)	0.0516*	1.84
FE	D(z>z**)	0.005*	1.954

By z* and z** are defined thresholds with values of 47% and 72.1 % respectively. *,** and *** denote 90%, 95% and 99% level of significance. Heteroskedastic errors are applied

Dependent variable: real long-term rate

Model	Interaction term	Coefficient value	T-value
OLS	D(z<z*)	-0.0124*	-1.69
FE	D(z<z*)	-0.07	-1
FE	D(z<z*)	-0.05	-1.07
OLS	D(z*<z<z**)	-0.044	-1.61
FE	D(z*<z<z**)	0.0590*	2.1
FE	D(z*<z<z**)	0.06*	1.93
OLS	D(z>z**)	0.036	0.82
FE	D(z>z**)	0.0767*	1.69
FE	D(z>z**)	0.0741*	1.07

By z* and z** are defined thresholds with values of 47% and 72.1 % respectively. *,** and *** denote 90%, 95% and 99% level of significance. Heteroskedastic errors are applied

Appendix (C)

Correlations:

	10Y Rate	3M rate	Yield	Cap_account	Debt/GDP	Output gap	Deficit	Inflation
10Y Rate	1							
3M rate	0.5913	1						
Yield	0.6748	-0.1961	1					
Cap_account	-0.0136	-0.0393	0.0195	1				
Debt/GDP	-0.0203	-0.0874	0.0552	0.1121	1			
Output gap	-0.0924	-0.0137	-0.0999	-0.2571	-0.1474	1		
Deficit	-0.141	-0.1224	-0.0594	-0.0937	-0.1207	0.4163	1	
Inflation	0.3382	0.8225	-0.3414	-0.1476	-0.0153	-0.0027	-0.0973	1

Descriptive statistics:

	Obs	Mean	Std. Dev.	Min	Max
10y_nom	785	6.737387	10.6165	0	269.99
3m_nom	785	5.935964	7.98967	0	142.98
Yield	785	0.801424	8.73094	-97.848	202.41
Cap_account	785	-0.76454	6.05981	-25.247	16.481
Debt/GDP	785	62.30116	52.5951	0	387.2
Output gap	785	-0.20194	2.85964	-12.58	12.395
Deficit	785	1.792659	3.5404	-17.7	22.9
Inflation	785	3.739214	6.9141	-1.7	121.608

By 10y_nom is defined interest rate on 10Y government bond. 3m_nom is interest ra
on 3month bonds. Yield is the difference between Domestic and U.S interest rate

VIF analysis:

	VIF	1/VIF
3m_nom	4.25	0.23552
Inflation	4.13	0.24212
Debt/GDP	1.34	0.74352
Deficit	1.3	0.76777
Output gap	1.28	0.78158
Cap_account	1.13	0.88832
Mean VIF	**2.24**	

Stationarity test

Im Pearson and Shin stationarity test (2000)

Deficit	**Debt/GDP**	**y_nom**	**m_nom**	**Yield**	**Cap_account**	**Output gap**
-2.5332***	-0.6523	-1.6123	-2.62***	-2.769***	-3.513***	-2.713***

*** Indicates that the null hypothesis for non-stationarity was rejected at 1% level

By 10y_nom is defined interest rate on 10Y government bond. 3m_nom is interest rat
on 3month bonds. Yield is the difference between Domestic and U.S interest rate

Variable description

Variable	Source	Definition
10 year nominal interest rate	AMECO, OECD Outlook, Central Banks	10 year rate on government bonds
10 year real interest rate	AMECO, OECD Outlook, Central Banks	10 year rate on government bonds adjusted by GDP deflator
3 month nominal interest rate	AMECO, OECD Outlook, Central Banks	3-month rate on government bonds
3 month real interest rate	AMECO, OECD Outlook, Central Banks	3-month rate on government bonds adjusted by GDP deflator
Capital Account	AMECO	Net change in ownership of national assets
Public Debt/GDP	AMECO	Public debt divided by GDP
Output Gap	AMECO, OECD Outlook	Difference between actual and potential (trended) GDP
Budget deficit	AMECO, OECD Outlook	Government deficit in corresponding period
Inflation	Eurostat, OECD Outlook	Annual CPI Inflation
GDP Growth	World Bank Databse	Change in GDP over previous period
Interest Rate Yield	OECD Outlook, authors calculation	Difference between domestic rate and rate for corresponding U.S bonds

List of countries

Belgium	Lithuania	Iceland
Bulgaria	Luxembourg	Norway
Czech Republic	Hungary	Switzerland
Denmark	Malta	United States
Germany	Netherlands	Japan
Estonia	Austria	Canada
Ireland	Poland	Australia
Greece	Portugal	Korea
Spain	Slovenia	Mexico
France	Slovakia	New Zealand
Italy	Finland	Israel
Cyprus	Sweden	South Africa
Latvia	United Kingdom	

*38 countries in total