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Are the government bond yield determinants of developed and developing countries substantially different in- and outside crisis periods and can the bond yields be predicted using rolling-window estimation?

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Abstract

In this thesis we examined whether the determinants of government bond yields of twenty-four developed and ten developing countries worldwide are substantially different in- and outside crisis periods. We observed the ten-year government bond yields (Federal Reserve Bank of St. Louis) for the period 1991 quarter one to 2014 quarter four. We distinguished the yield determinants (Federal Reserve Bank of St. Louis, CSP, IMF, NBER, World Bank) in financial market, real market and political or institutional factors. We estimated three different panel data models (pooled OLS, fixed effects and first-differences) to quantify the relationships between our observed economic variables. We showed that factors from the financial market (e.g. OECD recession and total reserves) and real market (e.g. inflation and export per capita) are important determinants to explain the variation of bond yield series of developed countries. For developing countries, we showed that real market- (e.g. GDP growth and import per capita) and financial market (e.g. government expenditures) factors are important yield determinants. We used rolling-window schemes to forecast the bond yield series and showed that rolling-window forecasting is more accurate than traditional (i.e. out-of-sample) forecasting during crisis periods.

Keywords: panel data, bond yields, financial crisis, rolling-window forecasting, stationarity

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1. Introduction

This thesis sheds some light on the determinants of government bond yields[1]. We hereby categorize the yield determinants in three categories. First, financial market determinants are economic variables related to the markets where governments and corporations are able to get funds (e.g. Foreign Direct Investments). Examples of financial markets are banks, stock- and bond markets. Second, real market determinants are economic variables related to the services- and goods markets (e.g. Gross Domestic Product). Third, political or institutional determinants are economic variables in the political or institutional environments (e.g. Polity regimes). Our research question is whether the bond yield determinants of developed and developing countries are substantially different in- and outside crisis periods.

This research is relevant for three reasons. First, the differences between bond yield determinants of developed and developing countries have not often been researched. We expect political or institutional determinants to have a substantial impact on the bond yields of developing countries and financial market determinants to have a substantial impact on the bond yields of developed countries. Second, the impact of The Financial Crisis (2007-2009) on bond yields has not often been researched. We expect the financial crisis to have a substantial impact on the bond yields of developing countries, due to the financial contagion in stock markets and the impact of the economic turmoil in developed countries on developing countries, see (Velde, 2008). Developing countries are at risk, since their stock markets are trying to integrate into the international financial markets. (Velde, 2008) described the following impacted economic channels for developing markets: trade, remittances, foreign direct investment (FDI) and equity investment, commercial lending, aid and other official flows. One of the developing countries, that is most likely at risk, is Mexico. Mexico depends heavily on exports to crisis affected countries from Europe and The United States. Another example is South-Africa. South-Africa needs to attract foreign direct investment to address its high current account deficits. Third, we use rolling-window schemes to forecast government bond yields for developed and developing countries in- and outside crisis periods. We expect that rolling-window forecasting is more accurate during crisis periods than traditional (i.e. out-

[1] The bond yield is the return an investor gets on a bond issued by a government. Since the coupon of a government bond is fixed, the bond yield is the inverse of the bond price.

of-sample) forecasting. In traditional forecasting, a data model is built using (old) observations (i.e. training set) and the model is used to predict new data points (i.e. test set). During crisis periods the prediction model might under- or overestimate shocks, because the observations in the test set differ substantially from the observations in the training set. Since our observation period includes financial crisis periods, we use rolling-window forecasting schemes to overcome difficulties in pattern shocks (i.e. outliers). In literature there are not many papers describing rolling-window forecasting techniques, except of (Morales-Arias & Dross, 2010). The authors investigated adaptive forecasting of exchange rates with panel data and alternative predictors using rolling-window and recursive forecasting schemes. Their observation period partly covered the financial crisis. The authors found promising results using cyclical and confidence variables when recursive forecasting is employed. Though, the authors suggested to combine forecasts to improve forecasting accuracy.

This study contributes to the literature since we focus on the differences between bond yield determinants of developed and developing countries and thereby predict the bond yields using rolling-window forecasting schemes. The first contribution adds to the existing literature on bond yield determinants since we focus on crisis periods, in particular on the recent financial crisis of 2007-2009. Our study is unique since we examine the impact of the crisis and the differences between developed and developing countries. The second contribution adds to the study of (Morales-Arias & Dross, 2010). We examine countries worldwide instead of only EMU countries. However, we face different exchange rate regimes, which may cause problems in the analysis.

The panel data origin mostly from the Federal Reserve Bank of St. Louis[2]. We observe the ten year government bond yields of twenty-four developed and ten developing countries worldwide within the period 1991 to 2014. The authors showed that economic news about the financial markets in the United States had a direct and large effect on the German bond market. However, the opposite effect (i.e. news about German and Euro area markets on United States' Treasury bonds) was less influential. The authors confirmed a high degree of interdependence between the financial markets of Europe and the United States. But in general they concluded, yield changes are unrelated to economic news. In panel data analysis

[2] Almost 300.000 economic time series are available from 81 sources. This bank observes and gathers data from commonly known sources like Bloomberg, Eurostat, OECD, IMF and the World Bank.

we can use time or individual fixed effects to examine correlation across countries or over time.

This thesis is organized as follows. In the next chapter we describe determinants of bond yields which were found significant in the literature. Based on the literature we state three hypotheses that we are going to test in this thesis. In chapter three we explain our methodology of determining which real market-, financial market- or political or institutional factors are significant yield determinants in our study. In addition, we also explain an uncommonly used methodology to forecast bond yields. In chapter four we explain how we build our panel data set. In this chapter relates to the related literature. In chapter five we discuss the results of our study. We discuss the explanatory effects of the bond yield determinants and illustrate the rolling-window forecasts. In chapter six we compare our insights with that of related literature and conclude by answering our research question. In the final chapter we discuss our approach and results. We also give recommendations on future research how to predict economic variables, especially during crisis periods.

2. Related literature

In this chapter we discuss related studies to refine our research question. We discuss different approaches to study bond yield determinants, we describe the yield determinants which were found significant in the literature and we propose hypotheses to test and to answer our research question.

2.1. Research approach

We are interested to see whether the government bond yield determinants of developed and developing countries are substantially different in- and outside crisis periods. We build upon the papers of (Bernoth, Hagen, & Schuknecht, 2003) and (Afonso, Arghyrou, & Kontonikas, 2015). The determinants of credit risk can broadly be categorized into two groups: political or institutional and fiscal determinants (Bernoth, Hagen, & Schuknecht, 2003). Earlier research on government bond yields covers two periods: prior to and covering the financial crisis (Afonso, Arghyrou, & Kontonikas, 2015).

In the literature one often examines transformations of the bond yield. (Barrios, Iversen, Lewandowska, & Setzer, 2009), (Barbosa & Costa, 2010), (Bernoth & Erdogan, 2010) and (Favero, Pagano, & Thadden, 2010) examined the bond yield spread (i.e. yield differential) as the dependent variable. The yield spread is the difference between two bond yields. The variable is often used by investors and policy makers to assess the spread and intensity of the debt crisis (Afonso, Arghyrou, & Kontonikas, 2015). When examining the bond yield spread one often takes one country as a benchmark. For each other country in the observation sample, the bond yield is measured relative to the benchmark country. Germany is often chosen as a benchmark country, see (Favero, Pagano, & Thadden, 2010) and (Bernoth & Erdogan, 2010) for example. One of the reasons is that Germany was not affected by the financial contagion until 2011, see (Giordano, Linciano, & Soccorso, 2012). However, (Bernoth & Erdogan, 2010) argued that the safe haven status of Germany diminished in the period between 1999 and the end of 2006. Since the onset of the European Monetary Union (EMU), Euro area countries showed a convergence in spreads to Germany. However, this changed drastically due to the financial crisis. For example, Italian bond yields diverged sharply from

German bond yields from January 2010 onwards. The financial crisis showed that the bond yields of some countries were fragile.

In the literature, the European Monetary Union (EMU) is an often chosen arena to examine bond yield spreads. In the EMU, there are no currency complications or bond conventions, but there is liquidity variation (Favero, Pagano, & Thadden, 2010). The general consensus is that government bond yields are significantly influenced by both international and country-specific risk factors, for example liquidity- and default risk premium, see the often cited papers of (Cordogno, Favero, & Missale, 2003), (Bernoth & Erdogan, 2010) and (Afonso, Arghyrou, & Kontonikas, 2015). Though, (Bernoth & Erdogan, 2010) also showed that during the financial crisis, financial markets reacted more heavily to different risk factors than before the crisis. They found that the impact of fiscal policy variables and general investors' risk aversion on bond yield spreads is not constant over time. They contributed to the literature by estimating time-varying coefficient panel models.

2.2. Yield determinants

As already mentioned, related literature can be categorized into two periods: prior to and covering the crisis. (Favero, Pagano, & Thadden, 2010) and (Baldacci & Kumar, 2010) examined the period prior to the crisis. (Favero, Pagano, & Thadden, 2010) explored the determinants of yield differentials between Euro Area sovereign bonds in the period of 2002 to 2003. Their proposed model predicted that yield differentials should both increase in liquidity and risk, while the interaction term of liquidity and risk had the opposite sign. (Baldacci & Kumar, 2010) re-examined the impact of fiscal deficits and public debt on long-term bond yields during 1980 to 2008 for a panel of thirty-one developed and developing countries. The authors found that higher deficits and public debt lead to a significant increase in long-term interest rates. The magnitude of the increase depends on initial institutional, fiscal and other structural conditions, as well as spill overs from global financial markets. Fiscal deterioration puts an upward pressure on sovereign bond yields, especially for developed countries.

(Barrios, Iversen, Lewandowska, & Setzer, 2009), (Haugh, Ollivaud, & Turner, 2009) and (Barbosa & Costa, 2010) examined the determinants of government bond yield spreads in the Euro area during the financial crisis. The general risk perception played a major role in

explaining the government bond yields differentials. (Haugh, Ollivaud, & Turner, 2009) found that the increase in risk aversion also magnified the importance of fiscal performance, especially as measure by debt to tax ratio or the expected fiscal deficits. (Barbosa & Costa, 2010) explained the bonds spreads to Germany by differences in the creditworthiness of the national governments, liquidity in domestic bond markets and risk premium in international financial markets. The general conclusion in these papers was that the impact of the crisis on the public finances and investors' higher risk awareness could keep the government bond yield spreads at a higher level than before the crisis.

(Afonso, Arghyrou, & Kontonikas, 2015), (Constantini, Fragetta, & Melina, 2013) and (Straathof & Swank, 2015) examined the long-term sovereign bond yield spreads covering the financial crisis. (Afonso, Arghyrou, & Kontonikas, 2015) studied a panel of ten euro area countries to assess the long-term sovereign bond yield spreads for the period 1999 to 2010. They analysed the yield spreads in three different time periods: prior to, during and after the financial crisis. They used an extended set of potential yield determinants, such as macroeconomic and expected fiscal fundamentals, international risk, liquidity conditions and sovereign credit ratings[3]. Similar as in (Bernoth & Erdogan, 2010), they found that the yield determinants changed significantly over time. On top of that, they also found that changes in the sensitivity of bond prices to the macroeconomic and expected fiscal fundamentals are important to explain yields over the crisis period. The role of the other yield determinants is statistically significant but limited relative to the fundamentals. (Constantini, Fragetta, & Melina, 2013) examined the determinants of sovereign bond yield spreads in nine EMU countries for the period 2001 to 2011. They found that fiscal imbalances, especially expected government debt-to-GDP differentials, and liquidity risk factors are the main long-term drivers of bond yield spreads. (Straathof & Swank, 2015) showed that cross-border capital flows within the EMU contributed substantially to sovereign bond yield spreads during the financial crisis. Factors that led to this contribution included changes in sovereign fiscal positions, a tight link between the banking sector- and sovereign health, lack of monetary tools and the lack of a country-specific exchange rate mechanism.

[3] (Cantor & Packer, 1996) showed that bond yields tend to rise when credit ratings decline. However, it is obvious to assume credit ratings influence bond yields.

From origin, investors seek for fixed security opportunities (e.g. bonds) to decrease credit risk in their portfolio[4]. This is known as "flights to quality". In crisis periods flights to quality also occurs, when market investors move their money from the financial markets in crisis to financial markets in safe haven. Since money flows in the safe haven markets, the bond prices rise. As a result the bond yields decrease. During crisis periods we expect to see a flow of capital from developing countries to developed countries.

However, (Longstaff, 2002) observed another trend in the financial markets, namely "flights to liquidity", see also (Bernoth, Hagen, & Schuknecht, 2003). In times of "flights to liquidity", investors seek for highly liquid securities (e.g. U.S. Treasury bonds) rather than less liquid securities. (Longstaff, 2002) found that the yield spread between risk-free- and Treasury bonds is significant and directly related to the consumer confidence index, the amount of Treasury bonds repurchased by the state and the change in the amount of funds held in money market- and equity mutual funds.

Though in general, the role of liquidity (risk) factors on government bond yields is ambiguous. Liquid markets are generally seen as desirable, because one may benefit from improved allocation and information efficiency (Sarr & Lybek, 2002). Though, (Bernoth & Erdogan, 2010) found that a liquidity premium did not play a role in explaining bond yield spreads in EMU. An interesting finding is that of (Ahn, Cai, & Yang, 2011), who stated that liquidity may have a greater role in emerging markets than in developed markets. In general liquidity is valued, but less when risk increases (Favero, Pagano, & Thadden, 2010). The risk that a financial asset cannot be traded quickly enough in the market is known as the liquidity risk. (Afonso, Arghyrou, & Kontonikas, 2015) referred liquidity risk to the size and depth of the sovereign bonds market with the possibility to lose capital due to early liquidation or price reductions. The authors also stated that liquidity is difficult to measure empirically. One can proxy liquidity by bid-ask spreads[5], turnover ratios[6], price impact measures, transaction volumes and the share of a country's debt in global sovereign debt (Sarr & Lybek, 2002), (Bernoth & Erdogan,

[4] Investopedia

[5] Difference between bid and ask price of a financial product (e.g. stocks, bonds or options). The bid-ask spread is considered as the best measure for liquidity risk, see (Barrios, Iversen, Lewandowska, & Setzer, 2009) and (Bernoth & Erdogan, Sovereign bond yield spreads: A time-varying coefficient approach, 2010).

[6] The percentage of a financial holding that have been turned over or replaced with other holdings in a given year (Investopedia)

2010), (Favero, Pagano, & Thadden, 2010), (Constantini, Fragetta, & Melina, 2013) and (Afonso, Arghyrou, & Kontonikas, 2015).

(Eichler, 2014) examined the impact of international political system factors on the sovereign bond yield spreads for developing countries in the period 1996 to 2009. He found that presidential regimes face lower yield spreads than parliamentary regimes. Overall, the political impact on sovereign bond yield spreads was more striking in autocratic and closed countries than in democratic and open countries. (Greiner, 2014) also showed that political risks have an impact on the bond yield of developing countries. He claimed that investors are not being properly compensated for all the entailed risks of developing market bonds.

In the 1990s emerging economies have taken crucial steps to improve their government bond markets. This development was required due to the necessity of substantial investments in infrastructure and capital-intensive projects. (Cin, 1998) examined the determinants that influence the yield spreads of new emerging market bond issues. The author found that macroeconomic fundamentals, like low domestic inflation, improved terms of trade and increase foreign assets are linked to lower bond yield spreads. Weak liquidity variables, like high debt to GDP ratios, low foreign assets to GDP ratios, low export growth rate and high debt service ratios are associated with higher yield spreads.

(Eisen, 2014) showed that real market factors might influence bond yields through stock market indices[7], since bonds and stocks are generally negatively correlated. In crisis periods the effect might be even higher, since investors then seek for safe investments like bonds instead of stocks (i.e. flights to quality). However, the stock market often lags the bond market.

(Sirucek, 2012) examined the impact of real market variables on US stock market indices between 1999 and 2012. He found that inflation and unemployment have the most significant (negative) impact on the stock market index change. We expect real market factors to have a minor effect on explaining variations in government bond yields.

In Table 1, we summarize the yield determinants that are found significant in the literature and the expected direction of the relation between the bond yield and its determinants. We

[7] The stock market index (e.g. the AEX in the Netherlands or the CAC in France) is an imaginary portfolio of stocks that measures the change in a stock market. The Standard and Poor's 500 is probably world's most common used benchmark for the stock market.

also add some control variables (e.g. GDP per capita) and political or institutional factor (e.g. war index and the legal rights index).

Table 1: Expected signs of relations yield determinants and bond yield

	Yield determinant	**Expected effect on yield**	**Related literature**
Financial market	Fiscal deficits	+	(Baldacci & Kumar, 2010)
	Financial crisis	+	(Bernoth & Erdogan, Sovereign bond yield spreads: A time-varying coefficient approach, 2010), (Barbosa & Costa, 2010)
	Liquidity risk	+	(Cin, 1998), (Sarr & Lybek, 2002), (Bernoth & Erdogan, Sovereign bond yield spreads: A time-varying coefficient approach, 2010), (Favero, Pagano, & Thadden, 2010), (Constantini, Fragetta, & Melina, 2013) and (Afonso, Arghyrou, & Kontonikas, 2015).
	FDI	-	(Velde, 2008)
	Credit rating	-	(Cantor & Packer, 1996), (Afonso, Arghyrou, & Kontonikas, 2015)
	Stock market index	-	(Eisen, 2014), (Sirucek, 2012)
	Government debt	+	(Cin, 1998)
	Investment behaviour	-	(Longstaff, 2002)
	Government Consumption Expenditures	-	*Control variable*
Real market	GDP per capita	-	*Control variable*
	Unemployment	+	(Sirucek, 2012)
	Population growth	+/-	*Control variable*
	Trade	-	(Cin, 1998)
	Inflation	+	(Cin, 1998), (Sirucek, 2012)
Political/instit	War	+	*Control variable*
	Polity regime	-	(Eichler, 2014)
	Legal rights	-	*Control variable*
	Military Expenditures	+	*Control variable*

2.3. Research hypotheses

Based on the related literature described above, we propose three hypotheses that we test to answer our research question. First, we expect political or institutional factors to have a substantial impact on the economic situation of developing countries. Investors fear a higher risk of default when there are political tensions in the reporting country. When investors withdraw money from the government bonds, the bond yield increases due to the law of demand and supply. Developed countries are more focused on the financial market activities. If investors change their investment behaviour on the financial market, this will impact the economic stability in the reporting country.

H1: *Bond yields of developing countries are more influenced by political or institutional factors, whereas the bond yields of developed countries are more influenced by financial market factors*

Second, we expect crisis periods to have a bigger impact on the economy of developing countries, since markets are emerging and not yet stable compared to developed countries. Developed countries can more easily recover from recession periods, due to better currency rates and more flexible tax reformation possibilities.

H2: *Bond yields of developing countries are more influenced by crisis periods than bond yields of developed countries*

Third, with traditional forecasting we are able to predict future crisis periods. However, we expect that the impact of the crisis periods continues to exist. Rolling-window forecasting deletes the oldest observations and therefore neutralises the impact of crisis periods for the whole forecasting period.

H3: *Rolling-window forecasting is more accurate than traditional forecasting during crisis periods*

In the next chapter we explain the methodology for estimating relationships between the economic variables under study. We are interested to see whether the bond yield determinants of developed- and developing countries are substantially different in- and outside crisis periods. In addition, we explain how to forecast government bond yields using rolling-window forecasting schemes.

3. Methodology

In this chapter we describe the methodology of our empirical data study. In section 3.1 we explain how we measure and test statistical relationships between our observed economic variables. In section 3.2 we explain an important concept in time series analysis, namely stationarity. In section 3.3 and 3.4 we explain different panel data models and estimators. In section 3.5 we discuss how we predict future (unknown) bond yield events by rolling-window forecasting schemes.

3.1. Linear regression

In empirical data studies one often is interested in the relationships between economic variables. As already explained in the previous chapter, the variable x_t is the independent variable and y_t is the dependent variable. The simplest relationship between two variables x_t and y_t is a linear relation, given by

$$y_t = \alpha + \beta x_t + \varepsilon_t, \tag{1}$$

where α is the intercept, β is the slope and ε_t is the unobserved error term. All information that is needed to explain y_t other than x_t is kept in the error term. Obviously, the goal is to minimize ε in order to predict y accurately.

In general, there are often multiple variables influencing the dependent variable y. We extend the time series model in (1) to multiple independent variables. The multivariate regression model becomes

$$y_t = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \cdots + \beta_p x_{pt} + \varepsilon_t, \tag{2}$$

where the model intercept α is included as parameter β_0. This model can also be written in matrix notation

$$\boldsymbol{y} = \boldsymbol{X}'\boldsymbol{\beta} + \boldsymbol{\varepsilon},$$

where $\boldsymbol{X}$ is a matrix containing all independent variables x_j and $\boldsymbol{\beta}$ is a vector containing all regression parameters. We estimate parameters $\boldsymbol{\beta}$ using ordinary least squares (i.e. OLS).

In models (1) and (2) it is assumed that x causes y. Though, in order to determine causality, we need to perform a statistical test. A commonly used test is the Granger-causality test. The Granger causality test is a simple F-test (e.g. Wald test) to compare the unrestricted model (i.e. y is explained by the n-th order lags of y and x) and the restricted model (i.e. y is explained by the n-th order lags of y).

$$y_t = a_0 + a_1 y_{t-1} + \cdots + a_p y_{t-p} + b_q x_{t-q} + \cdots + b_p x_{t-p} + u_t,$$

$$y_t = a_0 + a_1 y_{t-1} + \cdots + a_p y_{t-p} + u_t, \quad (3)$$

where $p > q$. We test the null hypothesis $H_0: b_q = b_{q+1} = \cdots = b_p = 0$ against the alternative hypothesis H_1: 'not H_0'. In other words, a rejection of the null hypothesis implies that x Granger-causes y. The same testing procedure holds vice versa; to test if y Granger-causes x. Granger-causality tests only indicates the direction of the relationship between two variables. To measure the strength of the relationship we use the Pearson's correlation coefficient. The correlation coefficient between two variables (x, y) is defined as

$$\rho_{X,Y} = \frac{cov(x,y)}{\sigma_x \sigma_y}, \quad (4)$$

where $cov(x, y)$ is the covariance between x and y and measures how much two random variables change together, and σ_x is the standard deviation and measures the amount of variation in the values of x. The correlation coefficient $\rho_{x,y}$ is between minus one and one. The higher the absolute value of the coefficient, the stronger the correlation between two variables. The significance[8] of the relationship between x and y indicates how likely the relationship might occur. The null hypothesis is that variables x and y are not related. Under the null hypothesis the correlation between x and y is zero.

When two independent variables are highly correlated, including both terms in a regression model might cause multi-collinearity problems. As a result, the coefficient estimates are unstable and difficult to interpret. We measure multi-collinearity[9] in our dataset by the Variable Inflation Factor (VIF):

[8] We use a significance level of 0.05.

[9] Multi-collinearity occurs when two or more independent variables in a regression model are highly correlated. The issue is that the highly correlated independent variables can linearly predict each other, which causes unreliable coefficient estimates in the model.

$$VIF_j = \frac{1}{1-R_j^2}, \quad (5)$$

where VIF_j for variable j is the reciprocal of the R-squared from the regression. We exclude[10] the high collinear (having a value in (5) higher than two) independent variables before building our panel data model.

Though, a high correlation between two variables can also be caused by a third unobserved variable (i.e. confounding variable). When we do not control for the confounded variable in a statistical model, this might cause spurious regression (or in econometric terms endogeneity). In that case, the independent variable x is correlated with the error term ε. The omitted variable is one of the causes of the endogeneity problem, others are measurement errors or strategic behaviour. To avoid endogeneity one can use instrument variables. Instrument variables z correlate with x, but are uncorrelated with the error term. In this study we test for endogeneity using the Durbin-Wu-Hausman test, see section 4.3 for an explanation of the test. In the next section, we describe an important aspect of a time series, namely stationarity.

3.2. Stationarity

In section 3.2., we saw the presence of a (possible) downward trend in the bond yield series of developed and developing countries. In econometrics, time series with trends are said to be non-stationary. Non-stationary time series have statistical properties like means, variances, covariances and autocorrelations[11] that change over time. Other examples of non-stationary processes are cycles and random walks. Standard regression analysis fails when dealing with non-stationary variables, leading to spurious regressions, that suggests relationships even when there are none, and high R-squared and t-test statistics. In order to do statistical analysis and predictive modelling, stationary time series are required (Stadnytska, 2010). Non-stationary time series can be transformed to stationary ones. The data transformation depends on the type of non-stationarity.

[10] https://gist.github.com/fawda123/4717702#file-vif_fun-r for the variable exclusion process based on the VIF.
[11] Autocorrelation or serial correlation is the correlation of a variable at different points in time.

Assume the time series y_t is described by an autoregressive (AR) model of order p

$$y_t = c + \sum_{i=1}^{p} \vartheta_i \, y_{t-i} + \varepsilon_t, \tag{6}$$

where c is a constant term, ϑ_i are parameters and ε_t is unobserved white noise[12]. A random walk is a special case of an auto regression (AR) Model, with $p = 1$ and $c = 0$

$$y_t = y_{t-1} + \varepsilon_t \tag{7}$$

Random walks contain a unit root of order one and are non-stationary. If we want to regress the non-stationary series y_t on the stationary time series x_t, we need to transform y_t by differencing to ensure stationarity. By computing the autocorrelations of y_t, for varying time lags and plotting them, we can check significant lags. When the effect of lags does not die out quickly, this is an indication of non-stationarity. The autocorrelation function (ACF) plots are used to check for randomness in the data, which is an indication of stationarity. The partial ACF plots are useful for model identification of AR models. We also test if our panels are random walks (i.e. contain a unit root). The Levin-Lin-Chu panel unit root test estimates ADF regressions for each time series in the panel. The null hypothesis is the presence of a unit root and the alternative hypothesis is stationarity.

3.3. Panel data models

In the first section we described the time series model and in the second section we described the stationary process of time series. However, in our study, we observe several economic variables of multiple countries over multiple time periods. This type of data is known as panel data. In this section we explain the basic principles of panel data models.

The advantage of using panel data (relative to cross-sectional- or time series data) is the larger number of observations (which leads to increased precision in parameter estimation) and the avoidance of estimation bias due to omitted variables (i.e. unobserved individual heterogeneity).

[12] White noise is a random process of random variables with a zero mean, no correlation between its values and a constant variation.

In our study we are interested in the cross-sectional differences in our panel data set. Suppose we have a panel data set (x_{it}, y_{it}), where $x_{it} = (x_{1it}, x_{2it}, \dots, x_{Kit})'$ for $i = 1, \dots, N$ and $t = 1, \dots, T$. Our goal is to explain y in terms of x. To quantify the relationships between the variables in the panel data set one can set up a general linear panel regression model (without restrictions) as

$$y_{it} = \alpha_{it} + x'_{it}\beta_{it} + u_{it}, \tag{8}$$

where u_{it} is a random (non-observable) error term with zero mean. Obviously, our parameters of interest α_{it} and β_{it} are not estimable with the number of observations. In order to use the model for prediction, some restrictions need to be made. The most restrictive form of equation (8) is the pooled model

$$y_{it} = \alpha + x'_{it}\beta + u_{it}, \tag{9}$$

where u_{it} is assumed to be independent and identically distributed for statistical inferences. The pooled model is known as a parsimonious model, since it is computationally simple to estimate the parameters. In other words, a parsimonious model accomplishes the trade-off between the number of parameters to be estimated and the desired level of explanation. However, the downside of a pooled model is that no heterogeneity is allowed in behaviour. With heterogeneity we mean that individual countries may behave differently relative to another. The individual-specific model allows for more behavioural heterogeneity

$$y_{it} = \alpha_i + x'_{it}\beta_i + u_{it}. \tag{10}$$

The advantage of estimating (10) is that it is computationally simple to estimate the parameters and the model allows for behavioural heterogeneity. Though, the downside is that model is not parsimonious since the model in (10) is more complex than in (9) but is not the most efficient. The efficiency of parameter β is a quantification of the estimation error. The higher the efficiency of β, the lower the estimation error. A simple extension to the general panel data model in (8) is to allow for individual- and time dummies. For example, one can impose the restriction that $\alpha_{it} = \alpha_i + \lambda_t$ (and $\beta_{it} = \beta$) to allow for heterogeneity across individuals and over time. The model then becomes

$$y_{it} = \alpha_i + \lambda_t + x'_{it}\beta + u_{it}. \tag{11}$$

When we restrict $\alpha_{it} = \alpha_i$ (and $\beta_{it} = \beta$) in model (8), we get the individual-specific effects model

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it}, \tag{12}$$

where ε_{it} is the independently and identically distributed error term. The model in (12) is computationally simple, parsimonious and allows for behavioural heterogeneity for individuals via α_i. The individual effects α_i can be treated as a random variable that captures unobserved heterogeneity. Note that in a regression model, one of the individual effects is excluded, since intercept β_0 is also included. There are two types of the individual-specific effects model. First, we have the fixed effects model. In this model, the individual specific effects α_i are correlated with the independent variables x_{it}. The fixed effects model treats all independent variables x_{it} as non-random. We need to assume the intercept to be fixed in order to get consistent estimates of β. We say β to be consistent, when the estimator is getting close to the true value of β. Second, we have the random effects model. In this model, the individual specific effects α_i are not correlated with the independent variables x_{it}. The random effects model treats some or all independent variables x_{it} as random. The intercept is uncorrelated with x_{it}. We assume $\alpha_i \sim i.i.d.(\alpha, \sigma_\alpha^2)$ and $\varepsilon_{it} \sim i.i.d.(0, \sigma_\varepsilon^2)$. The random effects model becomes

$$y_{it} = \alpha + x'_{it}\beta + u_{it}, \tag{13}$$

with $u_{it} = (\alpha_i - \alpha)\varepsilon_{it}$.

As already mentioned, in our study we are interested in the cross-sectional differences in our panel data set. Therefore, we will use fixed effects (countries) in our panel data model. A panel data model can be built using different approaches. We use a stepwise (backward elimination) regression approach. In this approach we start with a model including all independent variables. We remove the independent variable x_j, which has the lowest (insignificant) explanatory effect[13] on the dependent variable. We apply a statistical significance of five per cent, which is often applied in literature. In each step of the building process, we test if we need to exclude an insignificant independent variable from the model. We repeat this process

[13] The relevance of keeping this independent variable in the model

until we cannot improve the model fit and the model only contains significantly relevant variables.

In this section we explained several panel data models and we explained how we build our panel data model. In the next section we discuss several panel data estimation techniques to estimate β.

3.4. Panel data estimators

In this section we discuss several estimators of β. When estimating parameter β, the estimator might be biased when there is a significant difference between the estimator's expected value and the actual value of β. We prefer estimators that are both consistent and efficient. There exist several estimators to estimate β for the panel data models discussed in section 4.2.

The Pooled estimator is simply obtained by estimating β in equation (9) by OLS. The Pooled estimator is consistent when the Pooled or Random Effects model is the correct model, but inconsistent when the Fixed Effects model is the correct model.

The Between estimator only makes use of variation in y and the independent variable x between individuals (over time), by taking the average over time in equation (12)

$$\bar{y}_i = \alpha + \bar{x}_i'\beta + (\alpha_i - \alpha + \bar{\varepsilon}_i). \quad (14)$$

Similar as the Pooled estimator, the Between estimator is consistent when the Pooled or Random Effects model is the correct model, but inconsistent when the Fixed Effects model is the true model.

The Fixed Effects estimator makes use of variation in y and the independent variables x within individuals (over time), by subtracting equation (14) from equation (12)

$$(y_{it} - \bar{y}_i) = (x_{it} - \bar{x}_i)'\beta + (\bar{\varepsilon}_{it} - \bar{\varepsilon}_i). \quad (15)$$

The fixed effect α_i is hereby removed. The Fixed Effects estimator is consistent when the Pooled, Random Effects or Fixed Effects model is the correct model. Note that the Fixed Effects

estimator cannot handle time-invariant independent variables x_k, because the term $(x_{kit} - \bar{x}_{ki})$ cancels out.

The First-Differences estimator is obtained by subtracting the one-period lagged equation (12) from equation (12)

$$(y_{it} - y_{i,t-1}) = (x_{it} - x_{i,t-1})'\beta + (\varepsilon_{it} - \varepsilon_{i,t-1}). \quad (16)$$

The fixed effect α_i is hereby removed. Note that the time-invariant independent variables also drop out of the model. The First-Differences estimator is consistent when the Pooled, Random Effects or Fixed Effects models is the correct model. The First-Differences estimator is suitable for non-stationary data series as first differencing can help to stabilize the mean.

The Random-effects estimator can be obtained by estimating β in model (13). The estimator is both consistent and efficient when the individual specific effects from α_i are uncorrelated with the independent variables x. In that case the Random effects model is the correct model.

In Table 2, we summarize the properties of the panel data estimators. As already explained, the chosen panel data models and estimators do not have to correspond (e.g. the Random Effects estimator is consistent in the Pooled model). However, the estimator is only efficient when the estimator corresponds to the assumed model. The Fixed Effects estimator is consistent, irrespective of correlation between α_i and x_{it}. The Random Effects estimator is only consistent, when α_i is not correlated with x_{it}.

Table 2: Overview asymptotic properties/efficiency panel data estimators of β

Estimator of β	Assumed model		
	Pooled	RE	FE only
Pooled OLS	consistent/efficient	consistent/inefficient	inconsistent/-
Between Estimator	consistent/inefficient	consistent/inefficient	inconsistent/-
FE Estimator	consistent/inefficient	consistent/inefficient	consistent/efficient
First Differences	consistent/inefficient	consistent/inefficient	consistent/inefficient
RE Estimator	consistent/inefficient	consistent/efficient	inconsistent/-

* Inconsistent estimators cannot be measured on their efficiency

A Durbin-Wu-Hausman test can be used to test whether the Fixed Effects- and Random Effects estimators are significantly different. As a result the test also shows whether the fixed- or random effects model is preferred. The test evaluates the consistency of an estimator and compares that to an alternative less efficient estimator, which is already known to be consistent. The null hypothesis of the test is that the random effects model is preferred due to higher efficiency. There are two estimators for β: b_0 and b_1. Under the null hypothesis both estimators are consistent, but b_1 is efficient. If we reject the null hypothesis, it means that b_0 is consistent and b_1 is not.

To measure the 'goodness of fit' of a statistical model the most commonly known measure in regression analysis is the coefficient of determination (i.e. R-squared). This measure indicates how much of the variation in y can be explained by the independent variables. So, the better the regression model fits the data, the higher the R-squared.

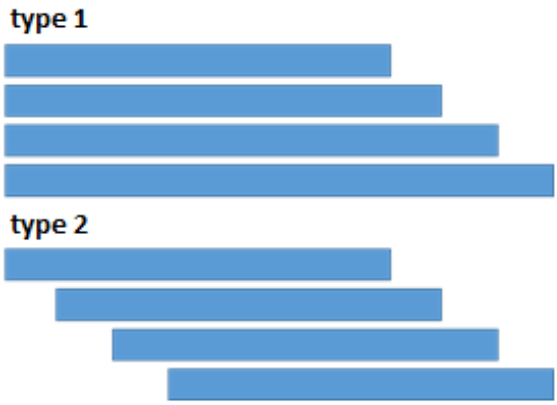
The next section is about prediction. We describe how we can forecast bond yield series in- and outside periods using rolling-window forecasting schemes.

3.5. Panel data prediction

Forecasting in economics is an important topic for decision making. A researcher always aims to have a statistical model fitting the data and having a high prediction accuracy. However, there is a trade-off between parsimony and plurality, also known as the Occam's razor. This theory states that too few independent variables in a model cause bias and too many variables cause efficiency loss (even when all variables are relevant). Therefore, it is important to assess a prediction model using validation techniques. In traditional forecasting one often uses a fixed window approach to assess the forecasting performance of a data model. All available data is split in a training set (i.e. set to build the model), a test set (i.e. set used for forecasting) and sometimes a validation set (i.e. set used to validate predictions). Though, the fixed window approach is only effective if the data are stationary (i.e. statistical measures like mean, variance are all constant over time). In our study we do not expect our data to be stationary, since we have crisis periods in the data sample. Therefore, we use rolling-windows instead of fixed windows. There are two types of rolling-window models, see Figure 1. The first type of model rolls the data forward including all data behind. There is a constant starting point with

ever increasing size, for example $1{:}\,4$, then $1{:}\,5$, then $1{:}\,6$, etcetera. The size of a window m defines the number of consecutive observations per window. The window size depends on the sample size T. Longer window sizes tend to yield smoother estimates than shorter sizes. We are interested in the second type of model, which deletes the oldest data points as it adds the newest. There is a constant size with ever increasing starting point, for example $1{:}\,4$, then $2{:}\,5$, then $3{:}\,6$, etcetera.

Figure 1: Rolling-window model



We use rolling-window analysis to assess the stability and the forecast accuracy of our panel data model over time and across countries. We choose rolling windows of size $m = 4$ (since we have quarterly observed data). We observe $T = 24$ quarters in our data sample. So, we need to partition our data set into $N = 21$ subsamples[14]. We also use the rolling-window approach to forecast the bond yields. The advantages of using the rolling-window panel data model is that causal changes in the data (e.g. financial crisis periods) might not permanently affect the predictions. The downside is that the rolling-window model might lose valuable information by dropping the oldest observations.

The rolling-window regression code can be found in Appendix 6A. To indicate the prediction accuracy we measure the root mean squared error (RMSE) of a prediction. The RMSE of a prediction is given by

$$RMSE_k = \sqrt{\sum_{i=1}^{h}(\hat{y}_i - y_i)^2}, \tag{20}$$

[14] $N = T - m + 1$

where k is the number of experiments[15], h is the forecast horizon and $\hat{y}$ is the predicted value of the dependent variable y.

In the next chapter we describe our dataset to test our hypotheses and to answer the research question.

[15] m divided by h

4. Data

In the related literature (chapter 2) we found significant yield determinants that might be relevant in our study. In this chapter we describe our data set. In section 4.1 we describe the observed economic variables. In section 4.2 and 4.3 we explain how we build our panel data set. At the end of section 4.3 we summarize with

4.1. Panel data set

In our study we examine repeated data on certain variables for N countries at T time periods. In econometrics, this type of data is known as panel data. We mainly observe the panel data, at a quarterly frequency, from the Federal Reserve Bank of St. Louis. This bank is the centre of the eight district of the Federal Reserve System in The United States. The bank offers a wealth of economic and financial data of countries worldwide. The quarterly observed data can either be in units (e.g. Foreign Direct Investment) or in percentages (e.g. Bond Yield). The quarterly data are observed as the sum (e.g. 2014Q1 is the sum of January, February and March 2014), except for variables observed in percentage points. For percentage data the average (e.g. 2014Q1 is the average of January, February and March 2014) is taken. The remainder data are observed at an annual frequency from the Centre for Systematic Peace (CSP), International Monetary Fund (IMF), National Bureau of Economic Research (NBER) and the World Bank.

We observe thirty-four developed and developing countries worldwide in the period 1990 Q1 to 2014 Q4. To define whether a country is developed or developing, we use the credit rating of a country, also known as the sovereign credit rating. The sovereign credit rating is a forward looking opinion about a country's ability to repay its loan. Credit ratings are assigned by credit rating agencies[16], see Appendix 1A for a detailed overview of the credit ratings[17]. In our study, a developed country is a country that is having a credit rating above "lower medium grade", see Appendix 2A. We only use the credit ratings to define developed and developing countries. For simplicity, we take the credit rating before our observation period starts[18] and assume it

[16] The tree main credit rating agencies (a.k.a. the Big Three) are Standard and Poor's, Moody's and Fitch. Together they account for a 95% market share.
[17] Note that each symbol of Moody's has its counterpart in Standard and Poor's rating scale.
[18] In case there is no credit rating available we take the year closest to the beginning of our observation period.

to be constant over time. This is not entirely true, since credit ratings usually worsen after financial crises for example.

Before doing the data analysis we build our panel data set. Our panel is unbalanced, since we do not observe all variables for all time periods. Also, as previously mentioned, we do not observe all data at the same frequency; namely at a quarterly- and annual frequency. So, in order to do build our dataset, we need to transform the data. We can either aggregate the quarterly observed data or interpolate the annually observed data. We expect less seasonality[19] in the yearly observed data. However, we observe less data points than with quarterly data, which may cause estimators to be inconsistent. Since we do not want to lose any observations, we initially choose to interpolate annually observed data. We hereby use a linear interpolation approach[20]. We examine both quarterly- and annually observed data when estimating panel data models.

The government bond yield (section 3.2) is our dependent variable. The set of independent variables consists of real market, financial market and political or institutional factors (section 3.3). Summary statistics can be found in Appendix 3A.

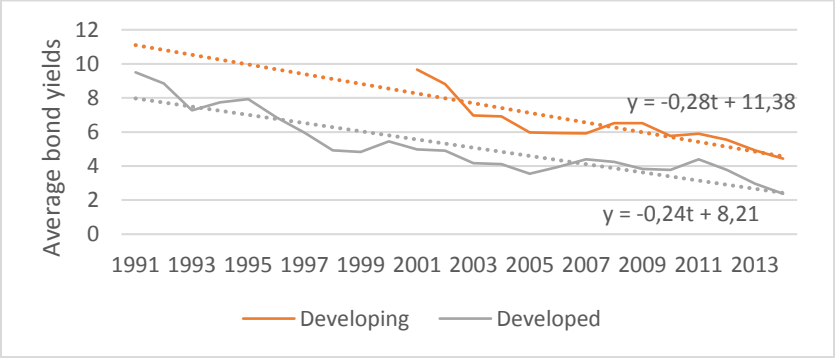
4.2. Bond yields

Our dependent variable y is the ten year[21] government bond yield. The bond yield series are observed for twenty-four developed and ten developing countries. The bond yield series of developing countries are subjected to data limitations[22] and outlying observations around the year 1999[23]. Therefore, we decide to observe developing countries as of 2001Q1. The bond yield series seem to have a downward trend, see Figure 2. In econometrics, time series with a trend, are non-stationary processes. Non-stationary processes are unpredictable and cannot

[19] Patterns in the data that repeat over fixed periods in time.
[20] The annually observed data give the end of a year status (i.e. quarter four). With linearly interpolation we compute the intermediate values for quarter one to three.
[21] Initially we were interested in the short-term bond yields, since we expect those to be more sensitive to changes in economic market information or political changes. Though, there was limited data available.
[22] Only South Africa is completely observed.
[23] That year was part of the Russian financial crisis (started in 1998Q3). The crisis resulted in the Russian government defaulting on its debt (Wiel, 2013). However, Russia made a quick comeback due to a rapidly rising world oil price.

be modeled[24]. In the previous chapter, we explained in detail how we deal with non-stationary time series. Obviously, the average of the bond yields of developing countries (6.86) is higher[25] than that of developed countries (5.02). We also see from Figure 2 that both yield series seem to converge, since the developing bond yield series declines faster than the developed series. The financial crisis of 2007 and 2009 did not seem to have an enormous impact on both bond yield series, see Figure 2. We see that the yield series of developing countries increase by around ten per cent[26] in the period 2007 to 2009. In the period 2010 to 2012, we see an increase of sixteen per cent in the yield series of developed countries, which seems to be caused by the Greek government debt crisis late 2009. Greece suffered hard from the crisis and failed to repay its debt to IMF.

Figure 2: Average bond yield series of developed- and developing countries in our panel.



4.3. Bond yield determinants

The bond yield determinant is notated as x. We observe multiple bond yield determinants x_j, where $j = 1, \dots, p$. The yield determinants are the variables of interest and are also known as the independent variables. We use the determinants to explain possible differences in the bond yield series of developed and developing countries and in- and outside crisis periods. We

[24] Investopedia
[25] The difference seems small, but the developing countries are observed from 2001 onwards. So the average of developing countries is underestimated.
[26] Bond yield growth rate computed as $\frac{y_t}{y_{t-1}}$.

hereby categorize the determinants into three groups: financial market, real market and political or institutional yield determinants.

4.3.1. Financial market yield determinants

We expect financial market determinants to have a significant impact on the bond yields of developed countries. As we saw in literature, large fiscal deficits are expected to have a significant impact on long-term yields via national savings, see (Baldacci & Kumar, 2010). In a standard neo-classical model, fiscal deficits reduce (ceteris paribus) national savings and increase aggregate demand. This creates an excess supply of government debt, leading to higher yields. We proxy the government's deficits[27] by the current account balance[28]. Fiscal deficits tend to reduce the government's current account balance via the national savings. Summarized, we expect that a decrease of the current account balance (through an increase of the fiscal deficits) leads to an increase of the bond yield.

In literature, liquidity (risk) is an often mentioned determinant that influences the bond yields. (Longstaff, 2002) observed a flights-to-liquidity phenomenon in the financial markets. He found that some investors moved towards highly liquid investments in crisis periods. The government bond yields are expected to increase with liquidity risk. Since assets cannot be easily traded, the prices of bonds drop while the yields increase. Since it is empirically difficult to measure liquidity (risk), we proxy liquidity risk by using the share of the general government's debt[29] as a percentage of the global[30] general government debt (Favero, Pagano, & Thadden, 2010)

$$LIQ\_RISK_{i,t} = \frac{GOVT\_GROSS\_DEBT_{i,t}}{GOVT\_GROSS\_DEBT\_TOT_t}. \quad (21)$$

From Appendix 3A, we see that developed countries have on average a higher liquidity risk (4.7) than developing countries (0.41). Developed countries have on average higher debt

[27] The difference between a country's savings and investments (Investopedia). The variable signals a country's economic health.

[28] Current Account Balance = Export – Import + Net Income abroad + Net current transfers

[29] The total gross government debt, observed by OECD

[30] Total government gross debt for the countries in our sample.

levels (1.5 Trillion US $) than developing countries (160 Billion US $), so the relative debt share (i.e. proxy for liquidity risk) is higher as well.

We use the OECD recession indicator (i.e. dummy variable) for individual countries to measure the turning points of recessions and expansions (i.e. 1=recession, 0=expansion). We see high recessions in the early years of the twenty-first century and the years during and after the financial crisis, see Appendix 4A. We also include dummy variables for the global financial crisis (2007Q3 to 2009Q2) and the sovereign debt crisis (2009Q3 to 2012Q2), where we partly follow (Afonso, Arghyrou, & Kontonikas, 2015). The literature states that foreign direct investment (FDI) and trade are impacted economic channels for developing countries during crisis periods (Velde, 2008). During crisis periods, investors search for safe haven investment opportunities (i.e. flights-to-quality phenomenon) and capital flows out of the risky markets. We measure the FDI net inflows[31], which are the direct investments made in the reporting country. We expect to see a negative relation between FDI net inflows and bond yields during crisis periods. Trade is covered by the imports and exports. We expect that trade has a negative impact on the bond yield, especially for developing countries. Developing countries depend on trade. When there is less trade, those countries need to issue debt to finance investments, which increases the bond yield.

The total reserves (excluding gold) is the sum of all deposits that banks are allowed to take into account. We use this variable to proxy the investment behaviour of a country's population. Our hypothesis is that the more deposits the banks hold, the less will be invested. We also expect FDI and total reserves to be highly correlated, because the more reserves the higher the amount of FDI contracts that can be taken up by the host country (Devi, 2014).

To measure the national income of a country we examine the gross domestic product (GDP). The GDP calculated through the expenditure method is probably the most commonly known approach:

$$Nominal\ GDP\ =\ Consumer\ Expenditure\ (C) + Government\ Expenditure\ (G)\ + Government\ Investment\ (I)\ +\ Net\ Exports\ (NX). \quad (22)$$

[31] We expect the total reserves to be highly correlated to the FDI net inflows, since a part of the FDI net inflows is deposit for the banks.

In literature, GDP and population are often used to transform economic variables. We use the GDP to transform the fiscal variables (e.g. debt to GDP ratio) and financial variables (e.g. total reserves to GDP ratio) in our panel regression analysis. The debt to GDP ratio is an indication of the healthiness of an economy and a key factor for the sustainability of a government finance. A low debt to GDP indicates that the economy produces and sells a sufficient amount of goods and services to pay back debts without incurring more debt. We expect a positive effect of debt to GDP on the bond yield, since higher government debt increases solvency- and liquidity risk, which results in a higher risk premium (i.e. bond yield). We see from Appendix 3A that the average debt to GDP ratio of developed countries (75.2) is somewhat higher than the ratio of developing countries (63.2). We use the population to transform the fiscal variables (e.g. debt per capita) and financial variables (e.g. FDI per capita). The GDP per capita of developed countries (28.3) is more than twice the ratio of developing countries (11.5). The debt per capita is often used as a measure of a country's indebtedness.

We use the total share prices for all shares of a country[32] to evaluate a country's financial market. The share price index (SPI) measures the return of investing in a basket of shares. The variable we observe is indexed in 2010. So, the index measures how the value of the stocks has changed compared to 2010. The total share price index (TSPI) of country i at period t can be calculated as:

$$TSPI_{i,t} = \frac{\frac{1}{n}\sum_{i=0}^{n} SPI_{i,t}}{\frac{1}{n}\sum_{i=0}^{n} SPI_{i,2010}}. \quad (23)$$

We expect a negative relation between the TSPI and the bond yield. In general the stock- and bond market move in opposite directions. The more value an investor might get when investing in stocks, the less is invested in bonds. As a result, bond prices decline and bond yields increase vice versa.

[32] According to OECD

4.3.2. Real market yield determinants

A common used determinant in literature to evaluate the real market is the inflation. The inflation is typically defined as the change in prices of a basket of goods and services that is typically bought by specific groups of households. We look at the growth rate (compared to previous period) of the consumer price index (CPI) of all items[33]. The CPI growth rate compared to the previous period is defined as:

$$CPI\_GR_{i,t} = \frac{CPI_{i,t} - CPI_{i,t-1}}{CPI_{i,t-1}}, \tag{24}$$

where $CP_{i,t}$ is the consumer price index of a basket of goods and service for country i at period t. From Appendix 3A, we see that the average CPI growth rate of developing countries (1.03%) is twice that of developed countries (0.58%). We expect that inflation has a positive effect on the bond yield, since investors demand higher interest rates to get compensated for the decrease in real return (due to higher inflation).

We also observe the government final consumption expenditures (GFCE). The GFCE is a purchase of goods and services from the national accounts to satisfy individual- or collective consumption directly. We expect countries, satisfying individual- or collective consumption more, are low yield countries. So, we expect to see a negative effect of GFCE on the bond yields. We define the government final consumption expenditure for country i as the growth rate of the GDP by expenditure in period t compared to period $t-1$:

$$GFCE_{i,t} = \frac{(GDP\_EXP_{i,t} - GDP\_EXP_{i,t-1})}{GDP\_EXP_{i,t-1}}. \tag{25}$$

4.3.3. Political or institutional yield determinants

We expect political or institutional factors to be relevant yield determinants, particularly for developing countries. Polity regimes might impact the bond yields, since extreme regimes might burden trade negotiations or frighten foreign investors. We observe the polity regime trends, except for Iceland. Individual country regime trends are defined as Autocracy (-10 to -6), Closed Anocracy (-5 to 0), Open Anocracy (1 to 5), Democracy (6 to 9) and Full Democracy (10). The majority of countries is a full democracy, see Appendix 5A, and the average polity

[33] Including the prices for food, clothing, education and others. Observed by Federal Reserve Bank of St. Louis.

regime trends of developed (9.80) is a bit higher than developing countries (9.10). We also see that there were no open anocracies in the early years of the twenty-first century. Mexico, from origin an open anocracy, transited successfully to a democracy during the 1980s and 1990s due to an electoral stage. We expect that democracies face lower bond yields than anocracies. Anocracies face higher human right violations, political instability and ineffectiveness than democracies. As a result, investors may avoid those countries more often and therefore the capital flow falters.

Next to polity regimes, we also indicate a state's fragility and warfare in the global system. The war index variable is categorized as extreme (20-25), high (16-19), serious (12-15), moderate (8-11), low (4-7), little or no (0-3) or not included (NA). From Appendix 3A, we see that the average war index for developing countries (5.07) is much higher than the average for developed countries (1.40). Similar as with the regime variable, we expect investors avoid countries in war. So, we expect the bond yield to increase with the war situation of a country.

Related to the war index variable we also observe the military expenditures (as percentage of GDP). We expect the higher the military expenditures to GDP ratio, the higher the bond yield. Though, we expect the positive effect to be relatively small, since low yield countries (e.g. United States) also have a high military expenditures to GDP ratio. From Appendix 3A, we see that the military expenditures as a percentage of the GDP is higher for developing countries (2.42) than developed countries (1.66).

Finally, we also examine the legal rights of countries. Strength of legal rights index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and thus facilitate lending. The legal rights variable is marked on a scale (0 = weak to 12 = strong) to indicate the strength of the legal rights index. We see that developing countries have in general lower legal rights (average=6.12) than developed countries (average=6.73). We expect that legal rights and polity regimes are highly correlated.

5. Results

In this chapter we discuss the results of our empirical study. In section 5.1 we discuss the relationships between our observed economic variables and their relations to the bond yield series. In Appendix 7A one can find the variables' model abbreviations and explanations. Additionally, we do statistical tests to measure distortion (e.g. multi-collinearity, unit roots) in our panel data set. In section 5.2 we estimate linear panel regression models. Statistical measures like correlations help in determining which variables might be relevant in our data model. Our goal is to build a model that fits the data accurately. In section 5.3 we test our data model on its predictive power by using traditional forecasting and rolling-window forecasting schemes.

5.1. Statistical relationships

As explained in the previous chapter, the correlation coefficient measures the strength of a relationship between two variables, the Granger-Causality test statistic indicates the direction of causality and the autocorrelation measures the correlation between a variable's observations.

The correlation matrix shows interesting (significant) relationships between our observed economic variables for developed and developing countries, see Appendix 8A. For developed countries, the government bond yield series is highly negative correlated with the *GDP per capita* (-0.55) and *inflation* (-0.44). The first relation seems to indicate that richer developed countries issue lower bond yield bonds than poorer developed countries. The second relation shows that low bond yield developed countries face higher inflation numbers than high yield developed countries. For developing countries, we see for example that the bond yield series is highly negative correlated with the *import*- (-0.46) and *export per capita* (-0.43). This seems to indicate that developing countries with higher trade activities have lower bond yields. The political or institutional variables are not highly correlated with the bond yield. However, we see that the *polity regime index* is highly negatively correlated with financial market variables. The effect of polity regimes on bond yield might be indirect, for example when the polity regime is a democracy. The benefit of a democracy is legal protection for the country's

citizens. This might stimulate the investment behaviour of companies and decrease the need to import products and services. Though, negative relationships between the *polity regime index* and the *FDI* or *exports* are not as we expected. One possible reason might be low variation in the observations of the *polity regime index*.

We perform Granger-causality tests for developed and developing countries separately, see Appendix 9A. We see that *import* and the *government gross debt* both significantly cause[34] the government bond yield series for developed countries with one lag including. Remarkably, the test doesn't show Granger-causality of political or institutional yield determinants for developing countries. The *FDI per capita* significantly causes the bond yield series of developing countries including one lag in the unrestricted model.

From the (partial) autocorrelation graphs we can see if the effect of a shock remains effective after a number of lags. In the *bond yield* series the shock remains effective after twenty lags, see Appendix 10A. This finding suggests non-stationarity in the bond yield series. We also find non-stationarity in the series of *import, export, inflation* and *total reserves*[35]. Additionally, we perform a panel unit root test. The Levin-Lin-Chu test[36] shows that the *government bond yield, population, GDP, Inflation, total reserves, import* and *export series* all contain a unit root in the developed countries data set, see Appendix 11A. For the developing countries data set, we see unit roots in the panels of the *government bond yield, GDP, inflation, total reserves, government gross debt, current account balance* and *liquidity risk*, see Appendix 11A. As already explained, we estimate first-differences panel regressions to transform the non-stationary variables to stationary series.

5.2. Panel data model results

In the previous chapter we explained how we build our panel data model (section 4.3) and we discussed that the model parameters can be estimated using several panel data estimators (section 4.4.). In chapter 3 we explained that we initially focus on quarterly[37] observed data,

[34] Vice versa, the bond yield series does not cause the import and government gross debt series.
[35] Not included in Appendix
[36] The test includes an intercept. H_0: unit root versus H_a: stationary series
[37] Some data are annually observed. We linearly interpolate annually data at intermediate values.

but in this chapter we also investigate our yearly[38] observed data. We estimate the Pooled OLS, the country fixed effects[39] and the first-differences[40] regression models. In Table 3 we show the estimated signs of our proxy variables in the different panel data models. Some proxies do not have an estimated sign (we only estimate models including significant determinants) and some proxies have a negative and positive sign. For the quarterly observed data[41] we also examine the time fixed effects regression model to examine whether we can explain the bond yield differences between countries in crisis- and non-crisis periods. In Appendix 12A we show the estimation results using quarterly observed data and in Appendix 13A the results using yearly observed data. Note that for each panel data model we use a "backward elimination" approach to select only the relevant (i.e. significantly different from zero) variables in our model. Note that certain determinants that are not relevant in one model can be relevant in the other.

5.2.1. Quarterly observed data

Using the quarterly observed panel data we estimated different panel data models. We examine the total sample and the developed and developing countries separately. The Pooled OLS regression model (Appendix 12A) for the total sample shows the estimated signs of the independent variables as we expected to see according to the related literature. For example, we see a negative coefficient for the *development* dummy variable. Developed countries have ceteris paribus[42] bond yields that are 1.13 percentage point lower than developing countries. Developing countries have on average a higher risk of default and thus need to issue bonds with higher yields than developed countries to attract investors.

We also observe a significant negative explanatory effect for the *total share price index* and *government consumption expenditures*. In a healthy economy, investors buy stocks instead of government bonds. The more demand, the lower the supply of stocks, which drives up the

[38] The first quarter of the quarterly observed data is taken as yearly observation.
[39] In the country fixed effects estimator we include a dummy variable for countries (i.e. fixed effects).
[40] First differencing is a method to transform non-stationary time series to stationary ones. We estimate the panel data model using first-differences because some of our observed economic variables are highly autoregressive (e.g. the bond yield, import and export series).
[41] Due to small set of observations, we don't estimate time fixed effects regressions for yearly observed data.
[42] All others remaining equal.

price (and lowers the yield). Governments can spend more on consumption or paying off their debts, which leads to less bond issued and lower yields.

For real market yield determinants, we see a positive effect for *unemployment* and the *CPI growth rate*. When the *unemployment rate* increases by one percentage point, ceteris paribus, the bond yield increases by 0.06 percentage point. In case of high unemployment numbers, an economy is in a bad health. Governments usually have exceeding deficits and need to issue more bonds, which decreases the bond price but increases the bond yield. The exceeding deficits also lead to a greater money base growth, which can create inflationary pressure (Nelson & Buol, 2004). The effect of an increase in the *CPI growth rate* of one percentage point has a 0.49 percentage point increase of the bond yield (ceteris paribus). So, when the inflation of period t increases compared to period $t-1$, then the bond yield increases as well.

The *financial crisis* dummy has a positive effect on the bond yield. During a financial crisis investors avoid investing in risky countries, without getting a reward for the risk. Therefore, the bond yields increase, to attract investors to buy bonds.

In the first differences regression (total sample) we see a positive impact of the first-differenced *CPI growth rate* variable and *export per capita* variable, see Appendix 12A1[43]. We also see that the dummy[44] variables for quarter two and three variables have a significant positive effect on the dependent variable, which shows seasonality effects for the transition between Q1 and Q2 (i.e. first difference Q2) and between Q2 and Q3 (i.e. first difference Q3).

In the country fixed-effects regression we find all estimated signs as we expected, for example a positive effect for the *financial crisis* dummy variable. In a financial crisis, the bond yield is expected to be higher than when there is no financial crisis (ceteris paribus). Since we are interested to see whether the bond yields of developed and developing countries are substantially different in- and outside crisis periods, we also check the fixed effects regression model with time fixed effects instead of country fixed effects. We hereby split the data sample into a pre-crisis (1991Q1-2007Q2), crisis (2007Q3-2012Q2) and a post-crisis (2012Q3-2014Q4) subsample. Unless the small subsamples, we see that in crisis periods, the financial market

[43] Note from section 4.4 that the unobserved fixed effect (captured in the intercept) and all observed time-invariant effects cancel out when using the first-difference estimator (or within estimator).
[44] Since we left out quarter one in the regression, the dummy variables need to be interpreted relative to quarter one.

seems to be key in explaining the bond yield series. Before and after the crisis periods we observe explanatory effects from various types of determinants.

We perform an F test for the individual effects, by comparing the pooling- and fixed effects model. The F test statistic[45] shows that the individual effects are significantly different from zero and thus the fixed effects model is preferred over the pooling regression model. We also estimate the individual effects model with random effects. The Hausman F test that the null hypothesis (i.e. random effects model is preferred) needs to be rejected. So, we support the alternative hypothesis that the fixed effects model is preferred.

We also estimate data models for the developed- and developing panels separately, see Appendix 12A3 to 12A6. One of the reasons is that we do not observe developing countries for the whole observation period (1991-2014), but only from 2001-2014, due to data limitations. The other reason is our research question. We are interested to see whether the yield determinants are different between developed- and developing countries and within or outside crisis periods. From Appendix 12A3, we see that financial market- and real market yield determinants are significantly impacting the bond yields of developed countries, which is in line with our hypothesis. In the time fixed effects regression, we see that in general the financial- and real market determinants are relevant, which is in line with our hypothesis, see Appendix 12A4. However, the explanatory effect of political or institutional yield determinants is less available in the developing panel, see Appendix 12A5. We only see a negative estimated effect on the bond yield for the *polity regime* variable in the country fixed effects regression. When the political situation in a developing country worsen, the bond yield increases. Investors avoid political instable countries, since the risk of default increases. In the time fixed effects regression, we see that real market- and political or institutional factors are relevant in crisis periods for explaining the bond yields of developing countries, which is in line with our hypothesis, see Appendix 12A6.

[45] F statistic is 2.36 and highly significant

5.2.2. Yearly observed data

In the pooled regression (total sample) we see the estimated signs that we expected (Appendix 13A1). The explanatory effect of the *total share price index* is higher than expected, compared to the pooled regression (total sample) estimation with quarterly observed data. When the *total share price index* increases by one percentage point, ceteris paribus the bond yield decreases by 0.40 percentage points, compared to 0.12 percentage points with quarterly observed data.

The first differences estimation also shows a remarkable impact of the *total share price index* variable. When the first difference of the *total share price index* increases by one percentage point, ceteris paribus the first difference of the *bond yield* decreases by 0.61 percentage points. The stock- and bond market are substitutes in theory. When the share in stocks is high, less is invested in bonds. As with any free-market economy, bond prices are affected by supply and demand. The price of bonds increases, where the yield decreases.

We also estimate the yearly panel data models for developed- and developing countries separately, see Appendix 13A2 and 12A3 respectively. The Pooled OLS regression for the developed countries yearly data set shows the importance of financial market, real market and political or institutional determinants. The *liquidity risk* variable seems to be important for explaining variation in the *bond yield*, but the estimated sign is not as expected. When the *liquidity risk* increases by one percentage point, ceteris paribus the *government bond yield* decreases by 0.17 percentage points. We also did not expected the negative estimated signs of *unemployment* and *inflation*. In the first-differences estimation we also estimate that *liquidity risk* is important in explaining the bond yield difference. In the fixed effects estimation, *unemployment* seems to be quite relevant, when *unemployment* rises by one percentage point the *bond yield* increases by 0.20 percentage points. An increasing unemployment rate is an indication of a bad state of the economy. Countries often have larger fiscal deficits and issue more government bonds. The bond prices decrease but the yield increases.

Finally, we also estimate yearly panel data models for the developing countries. The models show that financial market and real market yield determinants are important in explaining the variation of the dependent variable. Though, the political or institutional determinants do not seem to have a significant explaining effect.

Summarized, almost all estimated signs of the determinants are as we expected, see below Table 3. The opposite sign for the *war index* variable in the yearly observed panel of developed countries is not as expected. However, the *war index* variable is not much fluctuating[46] for developed countries, because the chance of war is small for developed countries.

Table 3: Estimated signs of the relation between proxy variable and bond yield

	Yield determinant	**Proxy variable**	**Expected effect on yield**	**Estimated effect on yield**
Financial market	Fiscal deficits	Current account balance*	-	-
	Financial crisis	Recession Dummy & Financial Crisis Dummy	+	+
	Liquidity risk	Liquidity risk	+	N/A
	FDI	FDI*	-	-
	Credit rating	Development dummy	-	-
	Stock market index	Total share price index	-	-
	Government debt	General government debt*	+	N/A
	Investment behaviour	Total reserves*	+	-
	Government Consumption Expenditures	Government Final Consumption Expenditures	-	-
Real market	GDP	GDP growth	-	+/-
	Unemployment	Unemployment	+	+
	Population growth	Population growth	+/-	+
	Trade	Imports and exports*	-	-
	Inflation	CPI growth rate	+	+
Political/institutional	War	War index	+	-
	Polity regime	Polity regime index	-	+/-
	Legal rights	Legal rights index	-	-
	Military Expenditures	Military Expenditures (as % of GDP)	+	N/A

* and transformations (e.g. FDI per capita) of the proxy variable.

[46] Either low (4-7) or little to no (1-3).

5.3. Panel data prediction

In the previous section we discussed the estimation results of the pooled, first-differences and fixed effects (time and country) panel models. We used quarterly- and yearly observations. We examined the total sample and the developed- and developing panels separately. In this section we discuss how we predict unknown bond yield events.

As already mentioned, we deal with unbalanced panel data since not all attributes are entirely observed. For this reason, we examine rolling-window forecasting for time series instead of unbalanced panels[47]. By predicting time series, we also do not face issues with different exchange rate regimes (Morales-Arias & Dross, 2010). We also examine traditional forecasting to test whether rolling-window forecasting is more accurate than traditional forecasting during crisis periods.

We observe the developed countries for the period 1991Q1 to 2014Q4 (i.e. ninety six quarters) and the developing countries for the period 2001Q1 to 2014Q4 (i.e. fifty six quarters). For our rolling-window regression we choose a window size ($m = 60$ quarters) for the developed countries sample and ($m = 36$ quarters) for the developing countries sample. We choose a forecasting horizon h of four quarters, to avoid seasonality across the quarters. We run $k = 9$ experiments for the developed countries sample and $k = 5$ experiments for the developing countries sample. For traditional forecasting we choose training set with the same sizes ($m = 60$ quarters) for the developed countries sample and ($m = 36$ quarters) for the developing countries.

We estimate the linear regression model for developed countries (26) and developing countries (27) as

$$Yield_t = \alpha + \beta_1 Export\ cap_t + \beta_2 Unempl_t + \varepsilon_t \quad (26)$$

$$Yield_t = \alpha + \beta_1 Yield_{t-4} + \beta_2 OECD_t + \varepsilon_t. \quad (27)$$

We estimate the first-differenced linear regression model for developed countries (28) and developing countries (29) as

[47] Little to no literature found on rolling-window forecasting for panel data and no literature found on unbalanced panels

$$Yield_t - Yield_{t-1} = \beta_1(Export\ per\ capita_t - Export\ per\ capita_{t-1}) + \beta_2(Unemployment_t - Unemployment_{t-1}) + (\varepsilon_t - \varepsilon_{t-1}) \quad (28)$$

$$Yield_t - Yield_{t-1} = \beta_1(Yield_{t-4} - Export\ per\ capita_{t-5}) + \beta_2(Polity_t - Polity_{t-1}) + (\varepsilon_t - \varepsilon_{t-1}). \quad (29)$$

We estimate the autoregressive (AR) model of order one as

$$Yield_t = \alpha + \beta_1 Yield_{t-1} + \varepsilon_t. \quad (30)$$

The $AR(1)$ model is used as a benchmark[48] and the Root Mean Squared Error (RMSE) is used to measure the prediction accuracy of the different prediction models. We test if rolling-window forecasting is more accurate than traditional forecasting, see Table 3 and 4. Next to that we test if the prediction models (normal regression and first-differences) are significantly different from the benchmark $AR(1)$ model.

Table 3: RMSE measures of developed countries

	Linear model		First-differences		$AR(1)$	
	Traditional	Rolling-window	Traditional	Rolling-window	Traditional	Rolling-window
France	0,93%	0,47%	0,30%	0,30%	0,30%	0,29%
Czech	5,25%	1,38%	0,51%	0,52%	0,37%	0,34%
Netherlands	0,83%	0,55%	0,29%	0,32%	0,30%	0,29%
USA	5,41%	1,06%	0,41%	0,32%	0,40%	0,34%
Austria	2,25%	1,19%	0,30%	0,35%	0,30%	0,30%
Australia	1,39%	1,10%	0,42%	0,67%	0,41%	0,40%
UK	2,25%	0,90%	0,36%	0,35%	0,34%	0,33%
Belgium	0,86%	0,69%	0,33%	0,33%	0,34%	0,33%

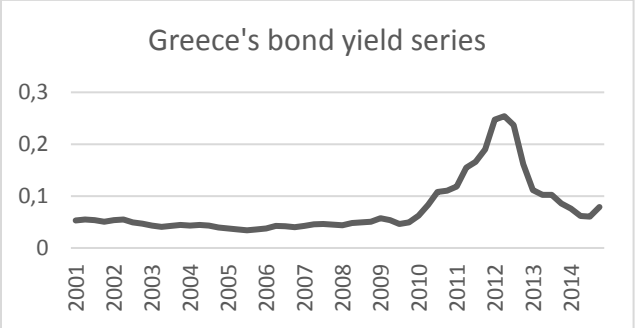
Table 4: RMSE measures of developing countries

	Linear model		First-differences		$AR(1)$	
	Traditional	Rolling-window	Traditional	Rolling-window	Traditional	Rolling-window
Greece	8,58%	10,57%	3,04%	3,26%	3,03%	2,82%
Russia	0,78%	0,69%	0,39%	0,38%	0,39%	0,36%
Chile	1,31%	0,82%	0,35%	0,55%	0,52%	0,40%
Polen	1,16%	1,03%	0,44%	0,43%	0,47%	0,40%

[48] Autoregressive models and random walks are often used as a benchmark model in literature

From Table 3 and 4 we see that rolling-window forecasting is in general more accurate (i.e. lower RMSE) than traditional forecasting, except for some countries using the first-differences model and Greece using the linear model. The RMSE measures of the linear regression model are the highest, compared to the first-differences and $AR(1)$ model. On average, the RMSE measures of the first-differences and the $AR(1)$ model are similar. The highest RMSE measures are computed for Greece, because Greece's bond yields grew enormously after the financial crisis, see Figure 3. After the financial crisis (2007 to 2009) the European sovereign debt crisis started, because Greece among others was unable to repay their government debt.

Figure 3: Peak in Greece's bond yield series during the European sovereign debt crisis.



We also visualize the RMSE measures of the rolling-window predictions over time, see Appendix 14A. For the linear regression model we see peaks of the RMSE for most developed countries in 2012. For Czech (2007) and the United Kingdom (2009) a peak occurs during the financial crisis. In the first-differences model we see peaks for most developed countries in 2009 and for the $AR(1)$ model in 2012.

6. Conclusion

In this thesis we studied the determinants of ten-year government bond yields worldwide. We employed two panels. The first panel consisted of twenty-four developed countries (Australia, Austria, Belgium, Canada, Czech, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Korea Republic, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States) using quarterly data over the period 1991Q1 to 2014Q4. The second panel contained ten developing countries (Chile, Greece, Hungary, Israel, Mexico, Poland, Russia, Slovak Republic, Slovenia, South Africa) using quarterly data over the period 2001Q1[49] to 2014Q4. We examined whether the bond yield determinants of developed and developing countries are substantially different in- and outside crisis periods. We hereby categorized the yield determinants into three types: financial market-, real market- and political- or institutional factors. We used dummy variables to examine the effects of the financial crisis (2007Q3 to 2009Q2) and the global debt crisis (2009Q3 to 2012Q2).

We used panel data mainly[50] from the Federal Reserve Bank of St. Louis the Centre to answer our research question whether the bond yield determinants of developed and developing countries are substantially different in- and outside crisis periods. We proposed three hypotheses in order to answer our research question:

H1: *Bond yields of developing countries are more influenced by political or institutional factors, whereas the bond yields of developed countries are more influenced by financial market factors*

H2: *Bond yields of developing countries are more influenced by crisis periods than bond yields of developed countries*

H3: *Rolling-window forecasting is more accurate than traditional forecasting during crisis periods*

[49] Due to data limitations.

[50] The remainder was observed from the Centre Systematic Peace (CSP), International Monetary Fund (IMF), National Bureau of Economic Research (NBER) and the World Bank.

We estimated several panel data models and found that financial market factors (e.g. *government expenditures* and *total reserves*) and real market factors (e.g. *inflation* and *import-* and *export per capita*) are important yield determinants. Both developed and developing countries heavily rely on the financial- and real market, also during crisis periods. Causality tests showed that the financial market factors influence the bond yields. From our descriptive analysis and our panel data models, we saw that the financial crisis only had a small positive effect on the bond yield. When estimating the time fixed effects model, we saw the important of fiscal variables (*liquidity risk* and *debt-to-GDP ratio*) during crisis periods, which is in line with (Constantini, Fragetta, & Melina, 2013). During crisis periods, developed countries are mainly influenced by financial market and real market factors. Whereas developing countries are mainly impacted by the bond yield in the same period of the previous year. Similar as in (Bernoth & Erdogan, 2010) the significant yield determinants changed over time. We only found a few explanatory effects of the political or institutional factors for the developing countries panel, for example the polity regime (Eichler, 2014). Summarized, the financial market and real market factors were the main influencers for both the developed and the developing countries in- and outside crisis periods. During crisis periods, we saw some explanatory effects of the political or institutional factors for developing countries.

In the last part of our data analysis we examined an uncommonly used forecasting approach (rolling-window forecasting) and compared it with traditional (i.e. out-of-sample) forecasting. We showed that rolling-window forecasting is in general more accurate than traditional forecasting during crisis periods. However, a limitation of rolling window forecasting is the loss of information, because the oldest observations are removed due to the rolling windows. We examined the predictions of the linear model and the first differences model and benchmarked the predictions against the first order autoregressive model. The first differences regression and autoregressive forecasts were the most accurate based on the RMSE measures.

Our thesis contributes to the literature because we indicated important yield determinants for developed and developing countries in- and outside crisis periods. Our findings are interesting for pension funds (often invest on the bond market), investors seeking for safe investment opportunities (during crisis periods) and portfolio managers of fixed-income securities (to optimize risk in bond portfolio), especially during crisis periods. During the

Financial Crisis, credit rating agencies provided misleading credit ratings. Our thesis showed that it is possible to predict bond yields accurately during crisis periods using publicly available information and rolling-window forecasting schemes. Further research is needed to optimize the rolling-window forecasting algorithm (Appendix 6A), so it can be adapted on (unbalanced) panel data. The main limitation in our research is the data. We dealt with unbalanced panel data sets and interpolated annually observed yield determinants to strengthen our data analysis.

Appendix 1A: Credit ratings provided by the Big Three credit rating agencies: Fitch, Moody's and Standard & Poor's.

	Prime	High grade			Upper medium grade			Lower medium grade			Non-investment grade	Speculative		Highly speculative			Substantial risks	Extremely speculative	Default imminent with little	Prospect for recovery		In default		
Fitch	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC					DDD	DD	D
Moody's	Aaa	Aa1	Aa2	Aa3	A1	A2	A3	Baa1	Baa2	Baa3	Ba1	Ba2	Ba3	B1	B2	B3	Caa1	Caa2	Caa3	Ca		C	/	
S&P	AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	BB+	BB	BB-	B+	B	B-	CCC+	CCC	CCC-	CC	C	D		

Appendix 2A: Overview of selected countries and sovereign credit ratings (http://www.tradingeconomics.com/country-list/rating).

Developed countries	Sovereign Credit Rating
Austria	AAA (S&P: Jun 26 1989)
Australia	AA (S&P: Jun 26 1989)
Belgium	AA (S&P: Jun 26 1989)
Canada	AAA (S&P: Jun 26 1989)
Czech Republic	AA- (S&P)
Denmark	AA (S&P: Jun 26 1989)
Finland	AAA (S&P: Jun 26 1989)
France	AAA (S&P: Jun 26 1989)
Germany	AAA (S&P: Jun 26 1989)
Iceland	A (S&P: Jun 26 1989)
Ireland	AA- (S&P: Oct 12 1989)
Italy	AA+ (S&P: Jun 26 1989)
Japan	AAA (S&P: Jun 26 1989)
The Republic of Korea	AA- (S&P)
Luxembourg	Aaa (Moody's Sep 20 1989)
Netherlands	AAA (S&P: Jan 25 1990)
New Zealand	AA (S&P)
Norway	AAA (S&P: Jun 26 1989)
Portugal	A (S&P: Oct 26 1989)
Spain	AA (S&P: Jun 26 1989)
Sweden	AAA (S&P: Oct 31 1990)
Switzerland	AAA (S&P: Jun 26 1989)
United Kingdom	AA (S&P)
United States	AA+ (S&P)

Developing countries	Sovereign Credit Rating
Chile	BBB (S&P: Aug 17 1992)
Greece	Baa1 (Moody's: Jul 19 1990)
Hungary	Ba1 (Moody's: Jul 18 1990)
Israel	BBB- (S&P: Jun 26 1989)
Mexico	Ba2 (Moody's: Dec 18 1990)
Poland	Baa3 (Moody's: Jun 01 1995)
Russian Federation	Ba2 (Moody's: Oct 07 1996)
Slovak Republic	BB- (S&P: Feb 15 1994)
Slovenia	B3 (Moody's: May 08 1996)
South Africa	BBB- (S&P)

Appendix 3A: Data summary of our observation sample.

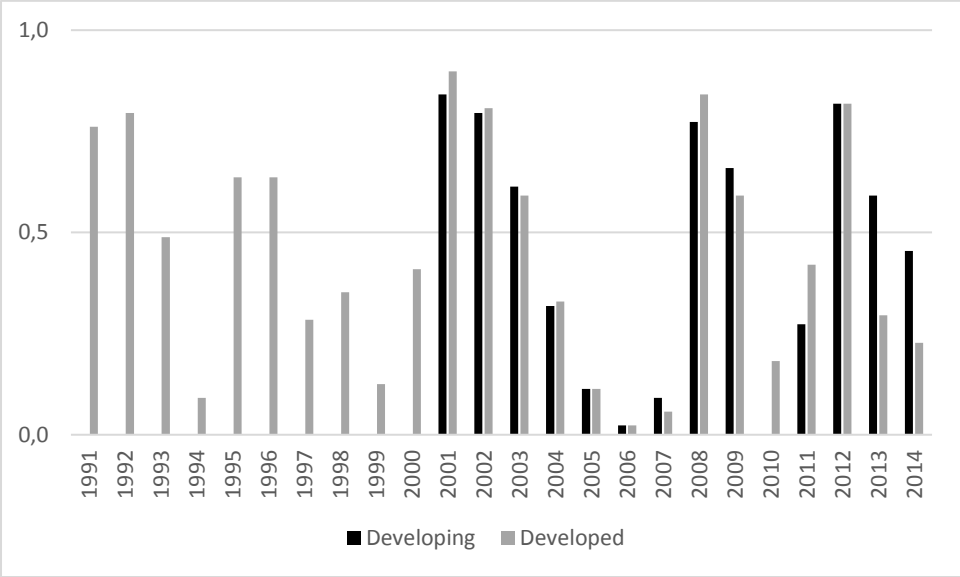
The table shows the data summary of the developed countries panel 1991Q1-2014Q4 (n=24, T=96) and developing countries panel 2001Q1-2014Q4 (n=10, T=56). We show both the mean and median to indicate how skewed our data panels are.

	Developed countries					Developing countries				
STATISTIC	N	MIN	MEAN	MEDIAN	MAX	N	MIN	MEAN	MEDIAN	MAX
Population* (in Millions of people)	2,285	25.5E-2	38.1	10.5	3.19E+2	560	1.99	3.93	13.3	1.46E+2
Recession dummy	2,117	0.0	0.45	0.0	1.0	530	0.0	0.45	0.0	1.0
Legal rights index*	976	2.0	6.73	7.0	12.0	410	3.0	6.12	6.0	10.0
War index*	803	0.25	1.40	1.0	4.0	390	0.25	5.07	5.0	12.0
Polity regime index*	2,197	6.0	9.8	10.0	10.0	560	4.0	9.10	10.0	10.0
Imports (in Billion US $)	2,304	30.6E-2	62.0	31.1	5.92E+2	560	2.52	25.0	17.1	1.01E+2
Imports per capita* (in thousand US $)	2,285	45.4E-2	2.72	2.02	18.3	560	86.2E-3	1.35	1.05	5.09
Exports (in Billion US $)	2,304	33.7E-2	59.1	32.7	4.12E+2	560	2.12	26.7	15.2	1.39E+2
Exports per capita* (in thousand US $)	2,285	35.5E-2	2.82	2.06	14.6	560	14.3E-2	1.25	87.3E-2	4.64
Current account balance (in Billion US $)	2,140	15.8	1.91	36.7E-2	57.9	514	-9.70	5.41E-2	13.4E-2	6.94
Current account balance per capita* (in thousand US $)	2,129	97.1E-2	0.37	4.61E-2	17.0	514	-79.9E-3	81.3E-3	15.4E-3	62.2E-2
FDI (in Billion US $)	2,027	-41.2	7.07	1.93	2.04E+2	514	-4.63	2.51	1.14	22.2
FDI per capita* (in thousand US $)	2,016	-5.85	2.72	11.8E-2	39.8E+2	514	-48.7E-2	10.2E-2	65.9E-3	90.7E-2
Total reserves* (in Billion US $)	2,289	6.41E-2	59.4	23.6	1.26E+3	560	34.4E-2	59.5	27.0	4.87E+2
Total reserves per capita * (in thousand US $)	2,278	11.9E-2	2.68	1.29	62.1	560	30.7E-3	1.92	1.10	10.5
GDP* (in Trillion US $)	2,285	6.27	1.30E+3	4.04E+2	1.74E+4	560	20.6	3.63E+2	2.15E+2	2.08E+3
GDP per capita* (in thousand US $)	2,285	5.76	35.1	31.3	1.19E+2	560	1.86	13.5	12.0	37.2
General government debt* (in Billion US $)	1,598	2.87	1.53E+3	3.24E+2	2.13E+4	404	6.89	1.64E+2	1.23E+2	6.2E+2
General government debt per capita* (in thousand US $)	1,598	99.1E-2	28.3	25.6	1.1E+2	404	1.14	11.5	7.53	39.9
Government bond yield (in %)	2,190	0.45	5.02	4.78	13.9	534	1.33	6.86	6.38	25.4

Total share price index (in %)	2,252	0.94	96.7E-2	90.8E-2	13.5	560	11.5E-2	89.8E-2	90.2E-2	3.0
Government expenditures (in %)	2,134	-6.96	48.7E-2	46.5E-2	15.8	542	-10.9	56.0E-2	62.1E-2	12.4
Unemployment (in %)	1,762	1.93	6.81	6.30	26.2	545	2.55	10.5	8.69	29.3
CPI (in %)	2,280	-3.05	58.7E-2	50.9E-2	11.9	557	-2.44	1.03	92.4E-2	6.67
GDP growth* (in %)	2,261	-10.9	1.17	1.25	8.26	550	-8.22	2.02	1.95	12.9
Imports/GDP* (in %)	2,285	1.35	7.55	6.48	25.7	560	3.0	9.58	7.21	22.5
Exports/GDP* (in %)	2,285	1.57	7.78	6.68	26.1	560	1.58	9.31	7.65	23.3
Current account balance/GDP* (in %)	2,129	-3.69	52.1E-2	16.6E-2	15.4	514	-85.8E-2	31.9E-2	14.5E-2	2.83
FDI/GDP* (in %)	2,016	-8.92	3.34	45.8E-2	3.74E+2	514	-2.13	84.7E-2	65.6E-2	13.5
Total reserves/GDP* (in %)	2,278	28.5E-2	7.46	4.76	72.4	560	9.65E-2	14.9	14.3	35.9
General government debt/GDP* (in %)	1,598	11.6	75.2	66.3	2.47E+2	404	11.3	63.2	55.6	1.79E+2
Liquidity risk* (in %)	1,598	1.0E-2	4.7	1.11	38.2	404	3.4E-2	41.3E-2	29.1E-2	1.2
Military expenditures/GDP* (in %)	2,143	12.3E-2	1.66	1.48	5.12	530	40.6E-2	2.42	1.80	9.10
Population growth* (in %)	2,261	-0.44	0.17	0.14	0.85	550	-18.9E-2	0.14	60.5E-3	59.9E-2
log(Imports)	2,304	19.5	24.1	24.1	27.1	560	21.7	23.6	23.6	25.3
log(Exports)	2,304	19.6	24.2	24.1	26.7	560	21.5	23.5	23.4	25.7
log(Current account balance)	1,355	13.3	21.1	21.5	24.8	560	15.6	20.2	20.2	22.7
log(FDI)	1,758	10.8	21.7	22.9	26.0	462	13.8	21.0	21.1	23.8
log(Total reserves*)	2,289	18.0	23.7	23.9	27.9	560	19.7	23.7	24.0	26.9
log(GDP*)	2,285	22.6	26.8	26.7	30.5	560	23.8	26.1	26.1	28.3
log(Government gross debt*)	2,183	22.6	24.6	24.7	26.2	560	22.1	24.4	24.5	25.9
log(Population*)	2,285	12.5	16.4	16.2	19.6	560	14.5	16.7	16.4	18.8

* Linearly interpolated on a quarterly basis

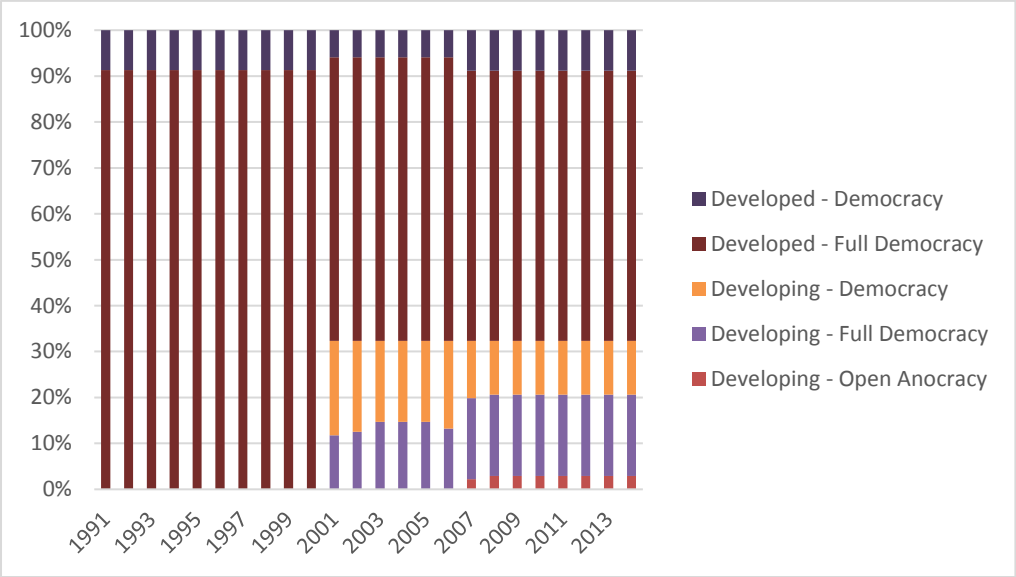
Appendix 4A: Crisis* dummy (averaged) for developed and developing** countries in our observation sample.



* 1 = crisis; 0 = expansion

** Developing countries observed as of 2001

Appendix 5A: Polity regimes of developed and developing countries* in our observation sample.



* Developing countries observed as of 2001

Appendix 6A: Rolling-window regression code (example France)

```
#Example country
dd         <-  test_France

windowsSize <- if (nrow(dd)==96) { 60 } else { 36 }     # training data size (developed: 60; developing: 36)
testsize  <- 4                                          # number of observations to forecast (quarterly: 4)
nr_exp <- ((nrow(dd)-windowsSize)/testsize)-1           # number of experiments-1

# load variables from the data set (example below for France)
X11     # Yield determinant 1
X21     # Yield determinant 2
X31     # Yield determinant 3
X41     # Yield determinant 4
Y1      # Yield
RMSE    <- matrix(0,(nr_exp+1),1)

for(k in 0:nr_exp)                              # number of experiments
{
 A       <- k*testsize + 1
 B       <- A + windowsSize - 1
 start_obs <- A
 end_obs   <- B

 X1      <- X11[A:B]
 X2      <- X21[A:B]
 X3      <- X31[A:B]
 X4      <- X41[A:B]
 Y       <- Y1[A:B]

 llmm           <- lm(Y~X1 + X2 + X3 + X4, na.action=na.omit)               # initiate linear regression
 intercept      <- coef(llmm)[1]
 co_X1          <- coef(llmm)[2]
 co_X2          <- coef(llmm)[3]
 co_X3          <- coef(llmm)[4]
 co_X4          <- coef(llmm)[5]

 A           <- B + 1
 B           <- B + testsize
 X1          <- X11[A:B]
 X2          <- X21[A:B]
 X3          <- X31[A:B]
 X4          <- X41[A:B]
 Y           <- Y1[A:B]
 predict_EXT   <- matrix(0, testsize, 1)
 SSE         <- 0

 for(i in 1:testsize)                # do the forecast based on LM results
 {
  predict_EXT[i] <- intercept + (X1[i]*co_X1) + (X2[i]*co_X2) + (X3[i]*co_X3) + (X4[i]*co_X4)

  SSE <- SSE + (predict_EXT[i] - Y[i])^2
 }
 RMSE[k+1] <- sqrt(SSE/testsize)

 print(RMSE[k+1])

 }
```

Appendix 7A: Variable explanations

Variable	Abbreviation
Government bond yield	GOVT_BND_YLD
Government bond yield (lag X)	GOVT_BND_YLD_LAGX
Population	POPL
Development dummy (1=developed)	DEV_DUM
GDP	GDP
Imports	IMPORT
Exports	EXPORT
Total share price index	TOT_SHR_P
Government consumption expenditures	GVT_EXP
Current account balance	CURR_ACC_BAL
Foreign domestic investments	FDI
Recession dummy (1=recession)	OECD_DUM
Unemployment	UNEMPL
Polity regime index	POLITY
War index	WAR
Inflation	INFL
Government gross debt	GOVT_GROSS_DEBT
Government gross debt total	GOVT_GROSS_DEBT_TOT
Liquidity risk	LIQ_RISK
Legal rights index	LEGAL
Total reserves	TOT_RES
Military expenditures as % of GDP	MIL_EXP_GDP
Population growth	POPL_GROWTH
GDP growth (previous period)	GDP_GROWTH
GDP growth (same period previous year)	GDP_GROWTH_SP
GDP per capita	GDP_CAP

Variable	Abbreviation
Current account balance as % of GDP	CURR_ACC_BAL_GDP
Imports per capita	IMPORT_CAP
Imports as % of GDP	IMPORT_GDP
Exports per capita	EXPORT_CAP
Exports as % of GDP	EXPORT_GDP
Total reserves per capita	TOT_RES_CAP
Total reserves as % of GDP	TOT_RES_GDP
FDI per capita	FDI_CAP
FDI as % of GDP	FDI_GDP
Government gross debt per capita	GOVT_GROSS_DEBT_CAP
Government gross debt as % of GDP	GOVT_GROSS_DEBT_GDP
Current account balance per capita	CURR_ACC_BAL_CAP
Current account balance as % of GDP	CURR_ACC_BAL_GDP
Quarter X dummy (1=quarter X)	QX_DUM
Financial crisis dummy (1=crisis)	FIN_CRISIS_DUM
Debt crisis dummy (1=crisis)	DEBT_CRISIS_DUM
Log exports	LOG(EXPORT)
Log imports	LOG(IMPORT)
Log GDP	LOG(GDP
Log current account balance	LOG(CURR_ACC_BAL)
Log FDI	LOG(FDI)
Log total reserves	LOG(TOT_RES)
Log government gross debt	LOG(GOVT_GROSS_DEBT)
Log population	LOG(POPL)

Appendix 8A: Correlation matrix of developed and developing countries.

The correlation matrix shows the correlations ≥ 0.40 and significant for all the observed economic variables. In grey highlighted, the (high) correlations between the bond yield series and the yield determinants.

Developed countries			
Variable 1	**Variable 2**	**corr.**	**p**
GOVT_BND_YLD	GDP_CAP*	-0.55	(***)
MIL_EXP_GDP*	EXPORT_CAP*	-0.49	(***)
MIL_EXP_GDP*	IMPORT_CAP*	-0.45	(***)
GOVT_BND_YLD	INFL*	-0.44	(***)
GOVT_GROSS_DEBT*	POPL_GROWTH*	-0.42	(***)
MIL_EXP_GDP*	EXPORT_GDP*	-0.41	(***)
GOVT_BND_YLD	IMPORT_CAP*	-0.41	(***)
GOVT_BND_YLD	EXPORT_CAP*	-0.41	(***)
LIQ_RISK	POPL_GROWTH*	-0.40	(***)
FDI_GDP*	GDP_CAP*	0.40	(***)
WAR*	MIL_EXP_GDP*	0.40	(***)
TOT_RES*	TOT_RES_GDP*	0.40	(***)
FDI	CURR_ACC_BAL_GDP*	0.40	(***)
CURR_ACC_BAL	FDI	0.41	(***)
EXPORT	GOVT_GROSS_DEBT*	0.41	(***)
IMPORT	FDI	0.41	(***)
GDP_CAP*	FDI_CAP*	0.41	(***)
FDI	CURR_ACC_BAL_CAP*	0.43	(***)
CURR_ACC_BAL_GDP*	EXPORT_CAP*	0.46	(***)
WAR*	LEGAL*	0.46	(***)

Developing countries			
Variable 1	**Variable 2**	**corr.**	**p**
POLITY*	INFL*	-0.86	(***)
POLITY*	TOT_RES*	-0.85	(***)
EXPORT	POLITY*	-0.80	(***)
EXPORT	CURR_ACC_BAL	-0.73	(***)
CURR_ACC_BAL	TOT_RES*	-0.70	(***)
CURR_ACC_BAL	INFL*	-0.63	(***)
FDI	POLITY*	-0.62	(***)
IMPORT	POLITY*	-0.60	(***)
CURR_ACC_BAL	FDI	-0.58	(***)
IMPORT	CURR_ACC_BAL	-0.54	(***)
WAR*	IMPORT_GDP*	-0.52	(***)
IMPORT	GOVT_GROSS_DEBT_GDP*	-0,52	(***)
GOVT_BND_YLD	TOT_SHR_P	-0,50	(***)
EXPORT	GOVT_GROSS_DEBT_GDP*	-0,50	(***)
EXPORT	CURR_ACC_BAL_GDP*	-0,49	(***)
EXPORT	GOVT_GROSS_DEBT_CAP*	-0,47	(***)
IMPORT	GOVT_GROSS_DEBT_CAP*	-0,46	(***)
GOVT_BND_YLD	IMPORT_CAP*	-0,46	(***)
FDI	GOVT_GROSS_DEBT_GDP*	-0.44	(***)
FDI	GOVT_GROSS_DEBT_CAP*	-0.44	(***)

IMPORT	MIL_EXP_GDP*	0.46	(***)	IMPORT_GDP*	POPL_GROWTH*	-0.44	(***)
CURR_ACC_BAL	MIL_EXP_GDP*	0.48	(***)	EXPORT_GDP*	POPL_GROWTH*	-0.43	(***)
EXPORT	INFL*	0.48	(***)	GOVT_BND_YLD	EXPORT_CAP*	-0.43	(***)
CURR_ACC_BAL_CAP*	EXPORT_CAP*	0.49	(***)	POLITY*	WAR*	-0.41	(***)
CURR_ACC_BAL	INFL*	0.50	(***)	EXPORT	CURR_ACC_BAL_CAP*	-0.40	(***)
IMPORT	CURR_ACC_BAL	0.51	(***)	TOT_RES*	GOVT_GROSS_DEBT_GDP*	-0.40	(***)
IMPORT_CAP*	FDI_CAP*	0.51	(***)	FDI	CURR_ACC_BAL_GDP*	-0.40	(***)
CURR_ACC_BAL_GDP*	GDP_CAP*	0.51	(***)	POLITY*	CURR_ACC_BAL_CAP*	0.40	(***)
FDI_GDP*	IMPORT_CAP*	0.52	(***)	TOT_RES_CAP*	FDI_CAP*	0.40	(***)
CURR_ACC_BAL_CAP*	GDP_CAP*	0.55	(***)	POLITY*	GOVT_GROSS_DEBT*	0.41	(***)
GOVT_GROSS_DEBT*	TOT_RES*	0.58	(***)	WAR*	POPL_GROWTH*	0.41	(*)
FDI	FDI_GDP*	0.59	(***)	POLITY*	LIQ_RISK	0.41	(***)
EXPORT_GDP*	IMPORT_CAP*	0.60	(***)	WAR*	MIL_EXP_GDP*	0.41	(***)
FDI	FDI_CAP*	0.60	(***)	GOVT_GROSS_DEBT_GDP*	IMPORT_CAP*	0.42	(***)
IMPORT	INFL*	0.60	(***)	CURR_ACC_BAL_CAP*	IMPORT_CAP*	0.42	(***)
IMPORT_GDP*	EXPORT_CAP*	0.66	(***)	MIL_EXP_GDP*	GDP_CAP*	0.44	(***)
CURR_ACC_BAL_GDP*	IMPORT_CAP*	0.68	(***)	LEGAL*	TOT_RES_CAP*	0.45	(***)
IMPORT_GDP*	IMPORT_CAP*	0.69	(***)	CURR_ACC_BAL_GDP*	IMPORT_CAP*	0.45	(***)
CURR_ACC_BAL_CAP*	IMPORT_CAP*	0.70	(***)	POLITY*	GOVT_GROSS_DEBT_CAP*	0.45	(***)
EXPORT_GDP*	EXPORT_CAP*	0.71	(***)	POLITY*	IMPORT_GDP*	0.46	(***)
CURR_ACC_BAL_GDP*	FDI_CAP*	0.71	(***)	IMPORT_GDP*	GOVT_GROSS_DEBT_CAP*	0.47	(***)
CURR_ACC_BAL_GDP*	FDI_GDP*	0.71	(***)	CURR_ACC_BAL_GDP*	GOVT_GROSS_DEBT_GDP*	0.47	(***)
IMPORT_CAP*	GDP_CAP*	0.72	(***)	GDP_CAP*	TOT_RES_CAP*	0.47	(***)
EXPORT_CAP*	GDP_CAP*	0.73	(***)	LIQ_RISK	GDP_CAP*	0.48	(***)
FDI_GDP*	CURR_ACC_BAL_CAP*	0.74	(***)	POLITY*	IMPORT_CAP*	0.48	(***)
CURR_ACC_BAL_CAP*	FDI_CAP*	0.77	(***)	LIQ_RISK	GOVT_GROSS_DEBT_CAP*	0.48	(***)
TOT_RES_GDP*	TOT_RES_CAP*	0.83	(***)	CURR_ACC_BAL	GOVT_GROSS_DEBT_CAP*	0.50	(***)
GOVT_GROSS_DEBT*	LIQ_RISK	0.86	(***)	IMPORT	INFL*	0.50	(***)
IMPORT_GDP*	EXPORT_GDP*	0.92	(***)	EXPORT_CAP*	GDP_CAP*	0.51	(***)

IMPORT_CAP*	EXPORT_CAP*	0.93	(***)
IMPORT	EXPORT	0.94	(***)
CURR_ACC_BAL_GDP*	CURR_ACC_BAL_CAP*	0.95	(***)
GOVT_GROSS_DEBT_GDP*	GOVT_GROSS_DEBT_CAP*	0.95	(***)
FDI_GDP*	FDI_CAP*	0.97	(***)

GOVT_GROSS_DEBT*	GOVT_GROSS_DEBT_CAP*	0.52	(***)
GOVT_GROSS_DEBT*	GDP_CAP*	0.53	(***)
POLITY*	CURR_ACC_BAL_GDP*	0.53	(***)
IMPORT_GDP*	GOVT_GROSS_DEBT_GDP*	0.54	(***)
FDI	INFL*	0.54	(***)
MIL_EXP_GDP*	TOT_RES_CAP*	0.54	(***)
CURR_ACC_BAL	GDP_CAP*	0.57	(***)
EXPORT_CAP*	GOVT_GROSS_DEBT_CAP*	0.63	(***)
CURR_ACC_BAL_CAP*	GOVT_GROSS_DEBT_CAP*	0.64	(***)
GDP_CAP*	GOVT_GROSS_DEBT_CAP*	0.65	(***)
IMPORT	FDI	0.66	(***)
EXPORT_GDP*	IMPORT_CAP*	0.67	(***)
CURR_ACC_BAL_GDP*	GDP_CAP*	0.67	(***)
IMPORT_CAP*	GDP_CAP*	0.68	(***)
CURR_ACC_BAL_GDP*	GOVT_GROSS_DEBT_CAP*	0.70	(***)
LIQ_RISK	CURR_ACC_BAL_CAP*	0.71	(***)
CURR_ACC_BAL	LIQ_RISK	0.71	(***)
CURR_ACC_BAL	GOVT_GROSS_DEBT*	0.72	(***)
TOT_RES_GDP*	TOT_RES_CAP*	0.72	(***)
FDI	TOT_RES*	0.72	(***)
IMPORT	TOT_RES*	0.73	(***)
IMPORT_CAP*	GOVT_GROSS_DEBT_CAP*	0.73	(***)
LIQ_RISK	CURR_ACC_BAL_GDP*	0.74	(***)
EXPORT	FDI	0.74	(***)
GOVT_GROSS_DEBT_GDP*	GOVT_GROSS_DEBT_CAP*	0.74	(***)
EXPORT	INFL*	0.75	(***)
GOVT_GROSS_DEBT*	CURR_ACC_BAL_CAP*	0.75	(***)
GOVT_GROSS_DEBT*	CURR_ACC_BAL_GDP*	0.76	(***)
FDI_GDP*	FDI_CAP*	0.77	(***)

CURR_ACC_BAL_CAP*	GDP_CAP*	0.77	(***)
IMPORT_GDP*	IMPORT_CAP*	0.77	(***)
CURR_ACC_BAL	POLITY*	0.78	(***)
CURR_ACC_BAL	CURR_ACC_BAL_CAP*	0.78	(***)
EXPORT_GDP*	EXPORT_CAP*	0.80	(***)
IMPORT_GDP*	EXPORT_CAP*	0.82	(***)
CURR_ACC_BAL	CURR_ACC_BAL_GDP*	0.82	(***)
EXPORT	TOT_RES*	0.90	(***)
INFL*	TOT_RES*	0.90	(***)
IMPORT_GDP*	EXPORT_GDP*	0.93	(***)
CURR_ACC_BAL_GDP*	CURR_ACC_BAL_CAP*	0.93	(***)
IMPORT	EXPORT	0.93	(***)
IMPORT_CAP*	EXPORT_CAP*	0.96	(***)
GOVT_GROSS_DEBT*	LIQ_RISK	0.96	(***)

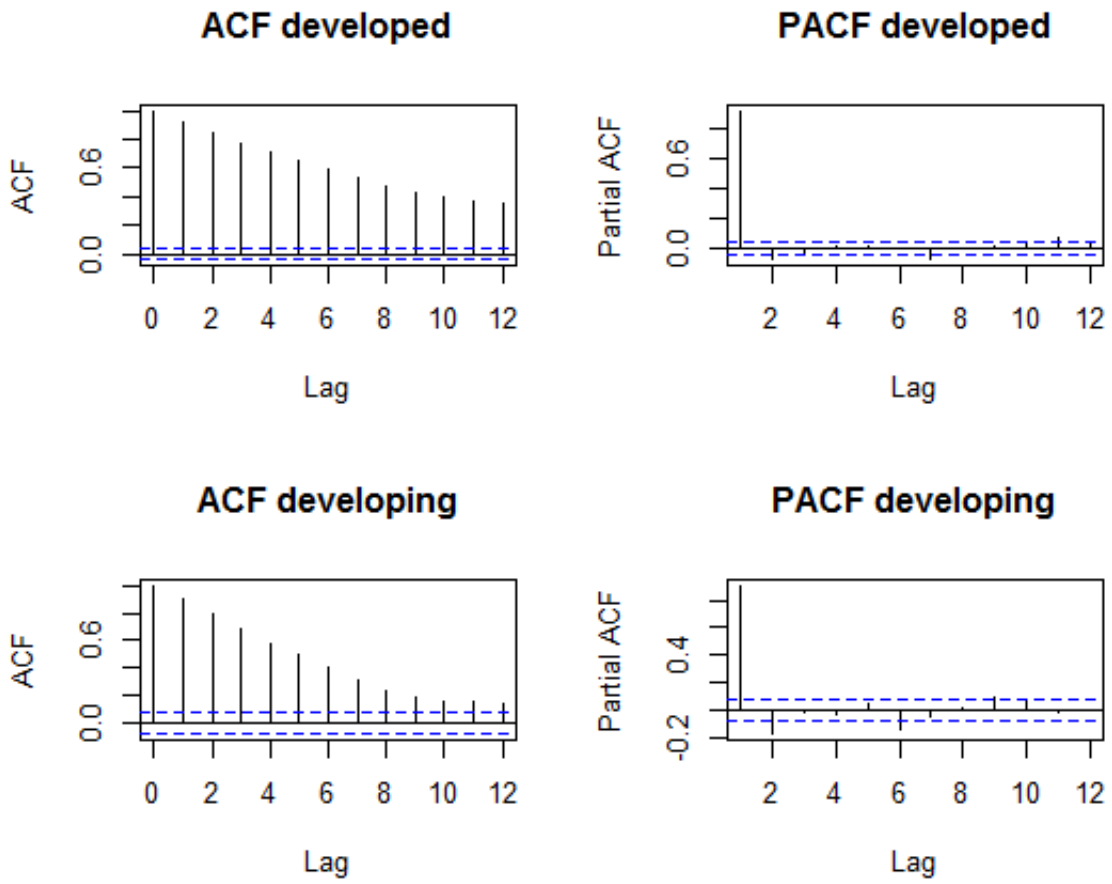
Appendix 9A: Granger-causality tests.

The table presents the results of the panel Granger-causality tests. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

	Developed countries		Developing countries	
	F-test	Order of lags	F-test	Order of lags
Imports	6.57*	1		
Exports	6.28**	2		
Total share price index	23.01***	2	4.27*	2
Government expenditures	2.98*	1		
FDI	9.67**	1		
OECD Dummy	11.11***	1		
Inflation	17.18***	1		
Government gross debt	8.94**	1		
Exports as % of GDP	4.79**	1		
Total reserves as % of GDP			8.39**	1
FDI as % of GDP	5.75*	1		
Imports per capita	20.59***	2	4.29*	2
Exports per capita	8.90**	1	3.4*	2
GDP per capita	8.27***	2		
GDP growth	3.13*	4		
Total reserves per capita				
FDI per capita	5.51*	1	5.47*	1
Population growth	5.5*	1		

Appendix 10A: (partial) Autocorrelation functions of the government bond yield series

(with 5% statistical significance limits for the autocorrelations)



Appendix 11A: Panel unit root test – developed and developing countries

The table presents the p-values of the Levin-Lin-Chu panel unit root test, including an intercept. We use a 5% significance level to test the null hypothesis that the panel contains a unit root.

	Developed countries	Developing countries
Government bond yield	0.2023	0.7645
Population	0.5809	0.0052
GDP	0.6275	0.4493
Inflation	0.6739	0.0836
Total reserves	0.3859	0.6679
Import	0.1895	0.0099
Export	0.4743	0.0302
Government gross debt	0.008	0.3211
Current account balance	0.0033	0.4493
Liquidity risk	3.42E-05	0.0887

Appendix 12A1: Panel data models – total sample (quarterly observations)

The table presents the results of regressions of financial market, real market and political or institutional yield determinants on the government bond yields. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

Pooled OLS $y_{it} = \alpha + X_{it}'\beta + \varepsilon_{it}$		**First-differences** $(y_{it} - y_{it-1}) = (X_{it} - X_{it-1})'\beta + (\varepsilon_{it} - \varepsilon_{it-1})$		**Country fixed effects** $(y_{it} - \bar{y}_i) = (X_{it} - \bar{X}_i)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_i)$	
(Intercept)	6.55E-02 (***)				
DEV_DUM	-1.13E-02 (***)	EXPORT_CAP	2.03E-06 (***)	UNEMPL	0.22 (***)
TOT_SHR_P	-0.4 (***)	Q2_DUM	8.26E-04 (***)	TOT_SHR_P	-0.19 (**)
GVT_EXP	-5.88E-02 (*)	Q3_DUM	9.97E-04 (***)	CPI_GR	0.42 (***)
UNEMPL	5.81E-02 (***)	CPI_GR	3.62E-02 (**)	TOT_RES	-4.74E-14 (***)
CPI_GR	0.49 (***)			LOG(FDI)	-2.47E-03 (***)
TOT_RES	-3.56E-14 (***)			FIN_CRISIS_DUM	3.86E-03 (**)
EXPORT_CAP	-3.29E-06 (***)				
FIN_CRISIS_DUM	3.73E-03 (**)				
R-Squared:	0.4128	0.0332		0.2414	
Adj. R-Squared:	0.4110	0.0332		0.2359	
Unbalanced Panel: N=2139	n=34, T=20-96,	n=34, T=41-96, N=2698		n=34, T=17-89, N=1764	

Appendix 12A2: Panel data models – total sample (quarterly observations) – crisis periods

The table presents the results of time fixed effects regressions of financial market, real market and political or institutional yield determinants on the government bond yields. The pre-crisis period is 1991Q1 to 2006Q4, the crisis period is 2007Q3 to 2012Q2 and the post-crisis period is 2012Q3 to 2014Q4. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

Pre-crisis $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$		**Crisis** $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$		**Post-crisis** $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$	
DEV	-2.3E-02 (***)	LIQ_RISK	-2.65E-02 (***)	TOT_SHR_P	-3.36 (***)
TOT_SHR_P	-0.17 (***)	GOVT_BND_YLD_LAG4	1.18 (***)	GVT_EXP	-0.54 (**)
CPI_GR	0.29 (***)	GVT_EXP	-0.10 (*)	WAR	7.46 (***)
UNEMPL	-0.1 (***)	UNEMPL	0.14 (***)	TOT_RES_GDP	-3.31E-02 (**)
LEGAL	8.91E-04 (**)	GEN_GOVT_DEBT_GDP	9.13E-03 (***)	POPL_GROWTH	-3.31 (**)
TOT_RES	-1.68E-14 (***)				
IMPORT_GDP	-4.39E-02 (***)				
GDP_GROWTH	0.14 (***)				
LOG(FDI)	1.51E-03 (***)				
POPL_GROWTH	1.65 (***)				
R-Squared:	0.6215	0.7884		0.4674	
Adj. R-Squared:	0.5786	0.7539		0.423	
Unbalanced Panel:	n=34, T=2-11, N=304	n=30, T=5-20, N=572		N=17, T=4-10, N=158	

Appendix 12A3: Panel data models – developed countries (quarterly observations)

The table presents the results of regressions of financial market, real market and political or institutional yield determinants on the government bond yields. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

Pooled OLS $y_{it} = \alpha + X_{it}'\beta + \varepsilon_{it}$		**First-differences** $(y_{it} - y_{it-1}) = (X_{it} - X_{it-1})'\beta + (\varepsilon_{it} - \varepsilon_{it-1})$		**Country fixed effects** $(y_{it} - \bar{y}_i) = (X_{it} - \bar{X}_i)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_i)$	
(Intercept)	0.11 (***)				
OECD_DUM	2.87E-03 (***)	OECD_DUM	7.38E-04 (**)	OECD_DUM	2.47E-03 (***)
CPI_GR	0.51 (***)	CPI_GR	4.53E-02 (***)	CPI_GR	0.49 (***)
TOT_RES	-4.23E-14 (***)	EXPORT_CAP	1.89E-06 (***)	TOT_SHR_P	-0.85 (***)
EXPORT_CAP	-2.32E-06 (***)	GDP_GROWTH	2.70E-02 (***)	EXPORT_CAP	-6.14E-06 (***)
UNEMPL	6.54E-02 (***)	Q2_DUM	1.10E-03 (***)	UNEMPL	0.13 (***)
TOT_SHR_P	-1.01 (***)	Q3_DUM	1.12E-03 (***)	FIN_CRISIS_DUM	7.37E-03 (***)
LOG(FDI)	-2.24E-03 (***)				
R-Squared:	0.4466	0.0753		0.4169	
Adj. R-Squared:	0.4438	0.0751		0.4092	
Unbalanced Panel:	n=23, T=17-89, N=1,289	n=23, T=54-92, N=1990		n=23, T=18-93, N=1569	

Appendix 12A4: Panel data models – developed countries (quarterly observations) – crisis periods

The table presents the results of time fixed effects regressions of financial market, real market and political or institutional yield determinants on the government bond yields. The pre-crisis period is 1991Q1 to 2006Q4, the crisis period is 2007Q3 to 2012Q2 and the post-crisis period is 2012Q3 to 2014Q4. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

Pre-crisis $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$		**Crisis** $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$		**Post-crisis** $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$	
POPL_GROWTH	2.19 (***)	FDI	-1.16E-13 (***)	TOT_RES	-2.64E-14 (***)
TOT_SHR_P	-0.1 (***)	WAR	4.41E-03 (***)	EXPORT_GDP	8.38E-02 (***)
CPI_GR	0.15 (**)	TOT_RES	-1.19E-13 (***)	POPL_GROWTH	-2.61 (***)
UNEMPL	4.41E-02 (***)	EXPORT_GDP	-3.02E-02 (**)		
POLITY	-4.22E-03 (***)				
TOT_RES	-1.93E-14 (***)				
IMPORT_CAP	-6.76E-07 (***)				
GDP_GROWTH_SP	1.24E-02 (*)				
R-Squared:	0.5773	0.517		0.2763	
Adj. R-Squared:	0.5342	0.4520		0.2612	
Unbalanced Panel:	n=23, T=2-62, N=938	n=12, T=1-20, N=191		N=24, T=9-10, N=239	

Appendix 12A5: Panel data models – developing countries (quarterly observations)

The table presents the results of regressions of financial market, real market and political or institutional yield determinants on the government bond yields. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

Pooled OLS $y_{it} = \alpha + X_{it}'\beta + \varepsilon_{it}$		**First-differences** $(y_{it} - y_{it-1}) = (X_{it} - X_{it-1})'\beta + (\varepsilon_{it} - \varepsilon_{it-1})$		**Country fixed effects** $(y_{it} - \bar{y}_i) = (X_{it} - \bar{X}_i)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_i)$	
(Intercept)	3.21E-02 (***)				
GOVT_BND_YLD_LAG4	0.59 (***)	GOVT_BND_YLD_LAG4	-9.3E-02 (*)	GOVT_BND_YLD_LAG4	0.50 (***)
OECD_DUM	8.57E-03 (***)	TOT_SHR_P	-1.36 (***)	OECD_DUM	6.79E-03 (***)
GVT_EXP	-0.18 (***)			TOT_RES_GDP	-2.59E-02 (*)
TOT_RES_GDP	-2.5E-02 (**)			POLITY	-7.6E-03 (**)
IMPORT_CAP	-3.56E-06 (***)			GVT_EXP	-0.17 (***)
				POPL_GROWTH	-4.79 (**)
R-Squared:	0.5349	0.0454		0.3975	
Adj. R-Squared:	0.5279	0.0452		0.3836	
Unbalanced Panel:	n=10, T=33-49, N=457	n=10, T=36-52, N=492		n=10, T=33-49, N=457	

Appendix 12A6: Panel data models – developing countries (quarterly observations) – crisis periods

The table presents the results of time fixed effects regressions of financial market, real market and political or institutional yield determinants on the government bond yields. The pre-crisis period is 1991Q1 to 2006Q4, the crisis period is 2007Q3 to 2012Q2 and the post-crisis period is 2012Q3 to 2014Q4. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

Pre-crisis $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$		**Crisis** $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$		**Post-crisis** $(y_{it} - \bar{y}_t) = (X_{it} - \bar{X}_t)'\beta + (\varepsilon_{it} - \bar{\varepsilon}_t)$	
LOG(CURR_ACC_BAL)	-3.24E-03 (**)	GOVT_BND_YLD_LAG4	1.15 (***)	GOVT_BND_YLD_LAG4	0.38 (***)
FDI	4.15E-03 (***)	OECD_DUM	1.07E-02 (**)	GVT_EXP	-0.39 (**)
POPL_GROWTH	2.72 (**)	UNEMPL	7.6E-02 (**)	TOT_RES	4.12E-14 (**)
GDP_GROWTH_SP	-5.17E-02 (**)	MIL_EXP_GDP	0.15 (*)	GDP_GROWTH	-0.66 (***)
		GDP_GROWTH	-0.29 (***)		
R-Squared:	0.3812		0.7202		0.7014
Adj. R-Squared:	0.2999		0.6274		0.6022
Unbalanced Panel:	n=7, T=5-21, N=122		n=10, T=17-20, N=194		N=10, T=9-10, N=99

Appendix 13A1: Panel data models – total sample (yearly observations)

The table presents the results of regressions of financial market, real market and political or institutional yield determinants on the government bond yields. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

Pooled OLS		**First-differences**		**Fixed effects**	
(Intercept)	2.5E-02 (***)				
GOVT_BND_YLD_LAG4	0.63 (***)	GOVT_BND_YLD_LAG4	-0.17 (***)	GOVT_BND_YLD_LAG4	0.51 (***)
TOT_SHR_P	-0.46 (**)	TOT_SHR_P	-0.67 (*)	CPI_GR	0.30 (***)
OECD_DUM	2.52E-03 (*)	OECD_DUM	3.2E-03 (**)	UNEMPL	7.41E-02 (**)
TOT_RES	-1.35E-14 (***)	UNEMPL	0.18 (**)	EXPORT_CAP	-3.01E-06 (***)
FIN_CRISIS_DUM	4.10E-03 (*)	FIN_CRISIS_DUM	4.79E-03 (*)	GDP_GROWTH	5.80E-07 (**)
DEV	-3.64E-03 (*)	CPI_GR	0.29 (***)	FIN_CRISIS_DUM	3.17E-03 (**)
CPI_GR	0.20 (**)	TOT_RES	-5.50E-14 (*)		
EXPORT_CAP	-1.05E-06 (***)				
R-Squared:	0.7231	0.1005		0.5140	
Adj. R-Squared:	0.7123	0.099		0.4744	
Unbalanced Panel:	n=33, T=7-23, N=602	n=33, T=4-23, N=508		n=34, T=4-23, N=520	

Appendix 13A2: Panel data models – developed countries (yearly observations)

The table presents the results of regressions of financial market, real market and political or institutional yield determinants on the government bond yields. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

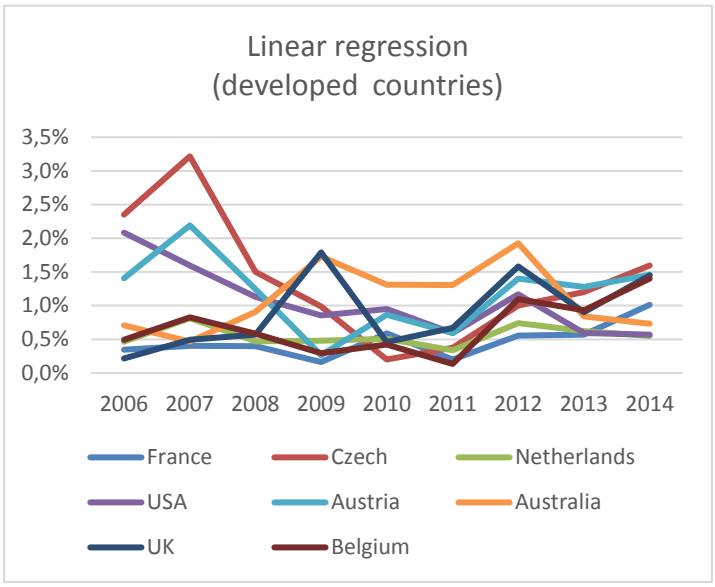
Pooled OLS		**First-differences**		**Fixed effects**	
(Intercept)	4.52E-03 ()				
OECD_DUM	7.19E-03 (**)	OECD_DUM	3.06E-03 (***)	OECD_DUM	6.21E-03 (***)
TOT_RES	-6.05E-14 (*)	CPI_GR	0.44 (***)	WAR	-4.96E-03 (*)
POLITY	7.51E-03 (**)			TOT_RES	-5.03E-14 (*)
FDI_CAP	-2.21E-07 (**)			LOG(CURR_ACC_BAL)	-3.51E-03 (**)
CPI_GR	0.99 (***)			CPI_GR	0.74 (***)
LOG(CURR_ACC_BAL)	-1.7E-03 (*)				
R-Squared:	0.2378	0.1012		0.3345	
Adj. R-Squared:	0.2322	0.1008		0.2915	
Unbalanced Panel:	n=20, T=3-24, N=296	n=23, T=14-24, N=515		n=13, T=1-19, N=140	

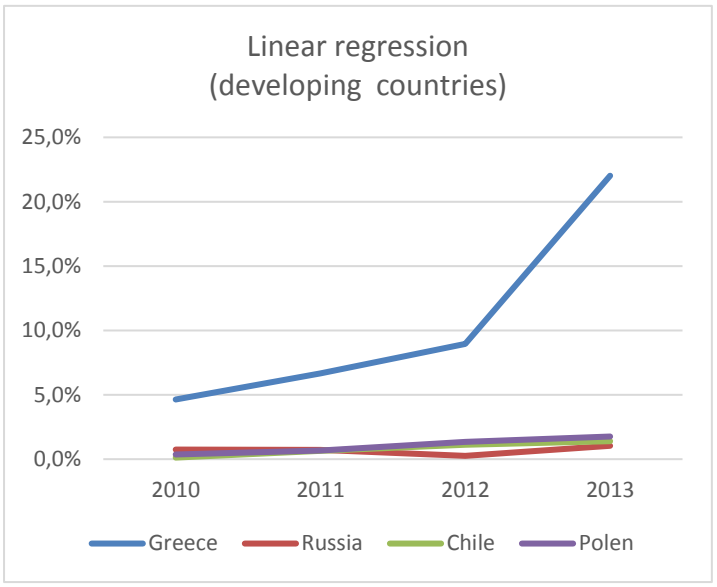
Appendix 13A3: Panel data models – developing countries (yearly observations)

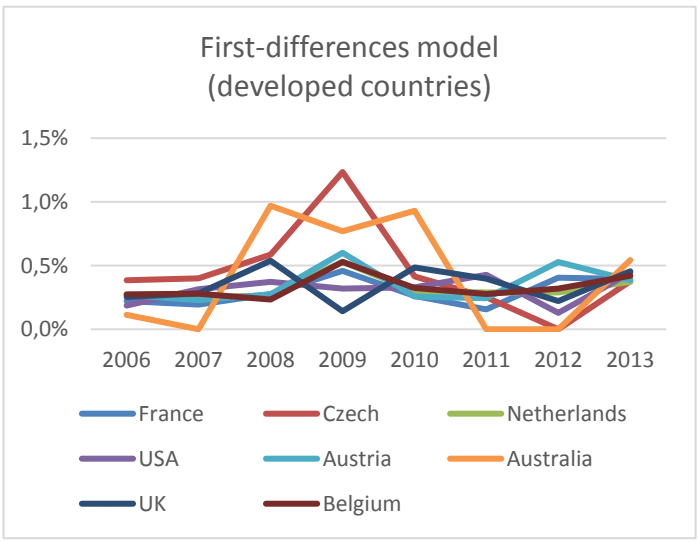
The table presents the results of regressions of financial market, real market and political or institutional yield determinants on the government bond yields. We used the correlation and Variable Inflation Factor (VIF) to exclude multi-collinearity in the independent variables set. The statistical significance is shown in parentheses in the table. ***,**,* denote statistical significance at a 0.1%, 1% and 5% level respectively.

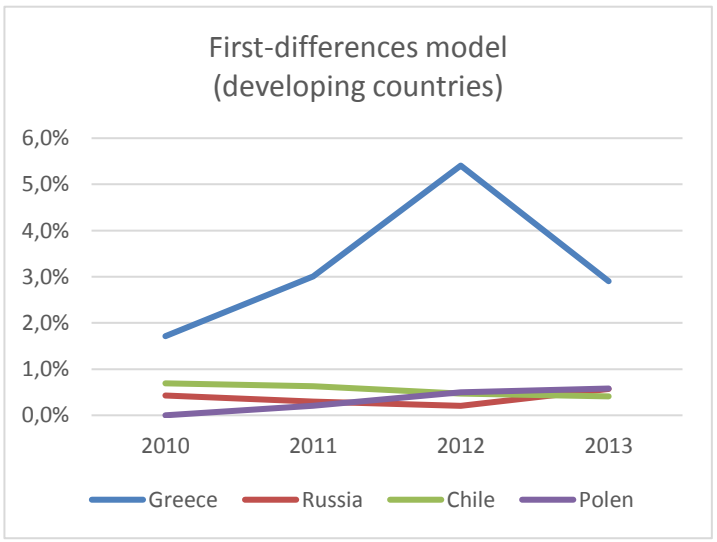
Pooled OLS		**First-differences**		**Fixed effects**	
(Intercept)	8.87E-02 (***)				
IMPORT_CAP	-1.20E-05 (***)	IMPORT_CAP	-2.11E-05 (***)	IMPORT_CAP	-1.71E-05 (***)
GDP_GROWTH	-0.19 (**)			LOG(CURR_ACC_BAL)	7.14E-03 (*)
				TOT_RES_GDP	-0.12 (***)
R-Squared:	0.24223	0.1725		0.41	
Adj. R-Squared:	0.23627	0.1711		0.36357	
Unbalanced Panel:	n=10, T=9-13, N=122	n=6, T=19-24, N=129		n=6, T=10-22, N=78	

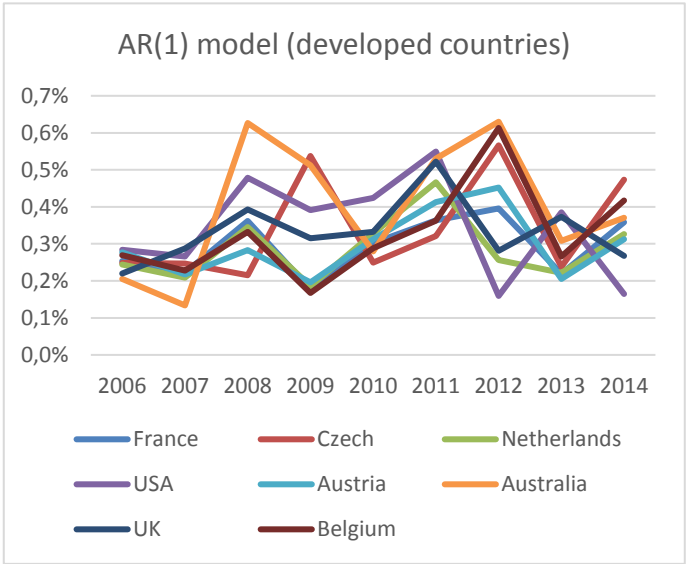
Appendix 14A: RMSE calculations linear regression, AR (1) and first-differences regression.

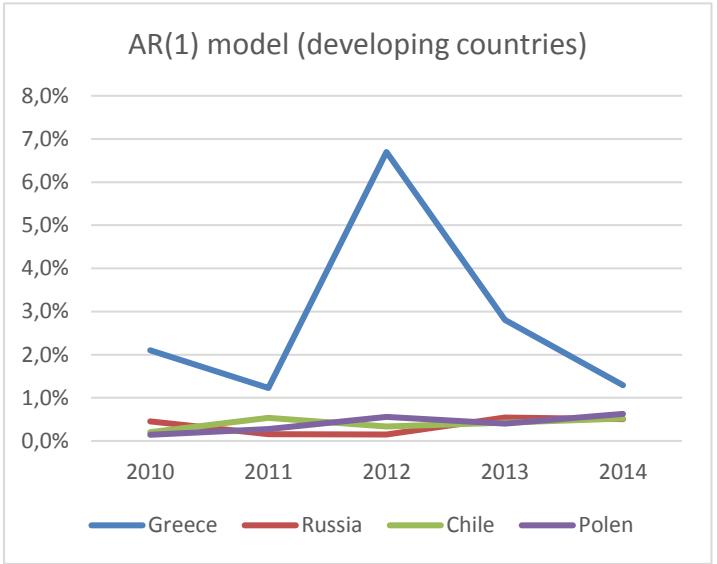












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