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Faculty of Social Sciences
Institute of Economic Studies

BACHELOR THESIS

What Drives the Sovereign Bond Spreads in Central and Eastern Europe?

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

The author further declares that the thesis has not been used previously for obtaining any university degree.

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Prague, May 15, 2013

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Abstract

This thesis is devoted to spreads of sovereign bonds in central and eastern Europe relative to German government bonds. In the first part, a widely used government bond spread model is presented. It turns out that its assumption may be relaxed. Next, we show how spreads, inflation and exchange rates interact. Subsequently, we investigate the relationship between spreads and other macroeconomic variables by econometric methods. The most important factors affecting bond spreads in the region are public debt, GDP growth, openness of the economy, current account balance, and inflation. Bond markets in CEE put more weight on total level of public debt than on budget deficits. The effects of these variables differed before and after the year 2008. Two subgroups of central and eastern European countries with similar spread determinants were identified: the first group is formed by Lithuania, Poland, Slovakia, and Slovenia, while to the second one belong Bulgaria, Hungary, Latvia, and Romania. Uncertainty on global financial markets increases bond spreads in CEE as well as in western Europe. Bond spread determinants of the two groups differ from those of western European countries.

JEL Classification C33, G12, G15, H63
Keywords bond yields, bond spreads, central and eastern Europe

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Abstrakt

Tato práce se zabývá spready vládních dluhopisů ve střední a východní Evropě vůči německým vládním dluhopisům. V první části je představen často používaný model spreadů vládních dluhopisů. Ukazuje se, že jeho předpoklady mohou být oslabeny. Dále je zkoumána interakce spreadů, inflace a směnných kurzů. Následně jsou vztahy mezi spready a dalšími makroekonomickými veličinami zkoumány pomocí ekonometrických metod. Nejvýznamnějšími faktory ovlivňujícími spready v dané oblasti jsou výše veřejného dluhu, růst HDP, otevřenost ekonomiky, schodek běžného účtu platební bilance a inflace. Dluhopisové trhy přikládají větší význam celkové výši veřejného dluhu než schodkům státních rozpočtů. Dopad těchto veličin před a po roce 2008 byl odlišný. Byly nalezeny dvě skupiny zemí s podobnými faktory ovlivňujícími spready: první skupina je tvořena Lotyšskem, Polskem, Slovenskem a Slovinskem, zatímco do druhé skupiny patří Bulharsko, Maďarsko, Litva a Rumunsko. Nejistota na světových trzích zvyšuje spready ve střední, východní i v západní Evropě. Determinanty dluhopisových spreadů ve střední a východní Evropě se liší od těch západoevropských.

Klasifikace JEL	C33, G12, G15, H63
Klíčová slova	výnosy dluhopisů, spready dluhopisů, střední a východní Evropa

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Abbreviations and Acronyms

BIS	Bank for International Settlements
CEE	Central and eastern Europe
IMF	International Monetary Fund
BE	Belgium
BG	Bulgaria
CZ	Czech Republic
DK	Denmark
IE	Ireland
EL	Greece
ES	Spain
FR	France
IT	Italy
CY	Cyprus
LV	Latvia
LT	Lithuania
LU	Luxembourg
HU	Hungary
MT	Malta
NL	Netherlands
AT	Austria
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
SK	Slovakia
FI	Finland

Bachelor Thesis Proposal

Author	Josef Růžička
Supervisor	PhDr. Jaromír Baxa, Ph.D.
Proposed topic	What Drives the Sovereign Bond Spreads in Central and Eastern Europe?

Guidelines In my Bachelor's thesis, I will give an overview of factors driving the government bond yields in emerging market economies and present a model explaining the relationship between the spreads and other macroeconomic variables. I am going to use econometric methods to identify key determinants of government bond spreads in the CEE region. After that, I am going to analyze to what extent is the dynamics of bond spreads driven by domestic, regional and foreign factors as well as try to identify subgroups of countries characterized by similar spread determinants. I will investigate whether the regional spread determinants differ from those of the Eurozone countries. Finally, I will provide a comparison of the drivers of sovereign bond spreads in the CEE countries and in other emerging markets.

Preliminary scope of work Government bond yield spreads play an important role in macroeconomy. Proper understanding of their determinants is crucial, because bond markets exert considerable influence over fiscal policy. Moreover, long term interest rate is one of the Euro convergence criteria. After the eruption of sovereign debt crisis in the Eurozone, investors changed their perception of government bonds risks. Although a lot of empirical research has been devoted to recent turmoil on bond markets of the Eurozone countries, impact of this adverse development on sovereign bond yields in Central and Eastern Europe remains unclear.

1. Introduction
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4. Econometric Analysis
5. Discussion of Results
6. Summary and Conclusion

Core bibliography

1. Akitoby, Bernardin and Stratmann, Thomas. “Fiscal Policy and Financial Markets.” The Economic Journal, 2008, 118(533), pp. 1971–85.

2. Alexopoulou, Ioana; Bunda, Irina and Ferrando, Annalisa. “Determinants of Goverment Bond Spreads in New EU Countries.” European Central Bank Working Paper Series, 2009.

3. Baldacci, Emanuele; Gupta, Sanjeev and Mati, Amine. “Is it (Still) Mostly Fiscal? Determinants of Sovereign Spreads in Emerging Markets.” IMF Working Paper, 2008.

4. Bellas, Dimitri; Papaioannou, Michael G. and Petrova, Iva. “Determinants of Emerging Market Sovereign Bond Spreads: Fundamentals vs Financial Stress.” IMF Working Paper, 2010.

5. Bunda, Irina; Hamann, Javier A. and Lall, Subir. “Correlations in Emerging Market Bonds: The Role of Local and Global Factors.” Emerging Markets Review, 2009, 10(2), pp. 67–96.

6. Codogno, Lorenzo; Favero, Carlo and Missale, Alessandro. “Yield Spreads on EMU Government Bonds.” Economic Policy, 2003, 18(37), pp. 503–32.

7. Čihák, Martin and Mitra, Srobona. “The Financial Crisis and European Emerging Economies.” Finance a úvěr-Czech Journal of Economics and Finance, 2009, 59(6), pp. 541–53.

8. Duffie, Darrell; Pedersen, Lasse H. and Singleton, Kenneth J. “Modeling sovereign yield spreads: a case study of Russian debt.” Journal of Finance, 2003, 58(1), pp. 119–59.

9. Eaton, Jonathan; Gersovitz, Mark and Stiglitz, Joseph. “The pure theory of country risk.” European Economic Review, 1986, 30(3), pp. 481–513.

10. Ebner, André. “An empirical analysis on the determinants of CEE government bond spreads.” Emerging Markets Review, 2009, 10(2), pp. 97–121.

11. Eichengreen, Barry; Rose, Andrew K. and Wyplosz, Charles. “Exchange Market Mayhem: The Antecedents and Aftermath of Speculative Attacks.” Economic Policy, 1995, 10(21), pp. 249–312.

12. Manganelli, Simone and Wolswijk, Guido. “What Drives Spreads in the Euro Area Government Bond Market?” Economic Policy, 2009, 24(48), pp. 191–240.

13. Nickel, Christane; Rother, Philipp C. and Rülke, Jan C. “Fiscal Variables and Bond Spreads: Evidence from Eastern European Countries and Turkey.” European Central Bank Working Paper Series, 2009.

14. Rudebusch, Glenn D. and Swanson, Eric T. ”The Bond Premium in a DSGE Model with Long-Run Real and Nominal Risks.” American Economic Journal: Macroeconomics, 2012, 4(1), pp. 105–43.

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Chapter 1

Introduction

Government bond yield spreads play an important role in macroeconomy. They are linked to other key macroeconomic variables such as inflation, exchange rates, and investment. Proper understanding of their determinants is of utmost importance not only for the state as the issuer, but also for investors who buy them. Their level and stability is crucial for the long-run sustainability and management of public debt. Pension funds, banks, insurance companies, municipalities, central banks—they all hold a lot of public debt. But sovereign bond yields also affect private investment: long-term government bond yields are used to assess profitability of investment projects and they affect interest rates of loans too. In some countries bond markets exert considerable influence over fiscal policy. Current sovereign debt crisis shows that this may afflict even the most developed ones. The differences between bond yields, the bond spreads, express expectations about future economic and political developments in a given country. Government bond spreads in the EU tell a lot about economic similarities and dissimilarities of the member states. Last but not least, long term interest rate is one of the Euro convergence criteria.

After the eruption of sovereign debt crisis in the Eurozone, investors changed their perception of government bonds risks. Although a lot of empirical research has been devoted to recent turmoil on bond markets of the Eurozone countries, impact of this adverse development on sovereign bond yields in central and eastern Europe remains unclear. The objective of this thesis is to analyze the post 2008 development on government bond markets in central and eastern Europe. We examine if the government bond spreads in central and eastern Europe are linked to local macroeconomic fundamentals or to global market conditions. We investigate if the countries form a homogenous group in terms of the government bond spread determinants, if there are some subgroups or outliers. Finally, we compare bond spread determinants with western Europe. To do that, we first need clarify the theoretical framework for valuation of bonds under uncertainty in an international setting.

The thesis is structured as follows: Chapter 2 reviews the most relevant empirical literature, in particular the one devoted to CEE, as well as methodology. Chapter 3 focuses on the theory which connects bond spreads with other macroeconomic variables. We present the widely used bond spread model and we propose its generalization. We also show how bond spreads, expected inflation, and expected exchange rate interact. Chapter 4 describes the data and compares bond spreads and macroeconomic fundamentals of EU member states, with special focus on CEE. We compare the situation prior to and during the sovereign debt crisis. Two subgroups of CEE countries with similar bond spreads and macroeconomic fundamentals are identified. Chapter 5 is devoted to an econometric model, its assumptions, specification, and estimation. We compare the bond spread determinants of the two CEE subgroups both before and during the crisis. We also estimate a separate model for western European countries and compare it with CEE. Finally, we compare and interpret the results. Chapter 6 summarizes the work and proposes topics for further research.

Chapter 2

Literature Review

2.0.1 Empirical Studies of Bond Yields and Spreads

The historically first analysis of bond markets in the region was done by International Monetary Fund (2003). They analyzed the bond yields of the Czech Republic, Poland, and Slovakia in their Global Financial Stability Report. The decline of yields in the preceding period was attributed mainly to convergence expectations. No significant relationship between the yields on local bonds and the Bund was identified. The IMF showed that spreads had been influenced mainly by local macroeconomic development, with inflation being the key factor. Such a finding is understandable, since the 1990s were marked by high and unstable inflation. As a result, the uncertainty over the price level prevailed even in the first decade of the 21st century.

Nickel *et al.* (2009) studied the relationship between fiscal variables and bond spreads in the Czech Republic, Hungary, Poland, Russia and Turkey. As opposed to other International Monetary Fund (2003), Ebner (2009) and, Bunda *et al.* (2009), they studied the impact of projected and not real economic variables. This approach reflects the importance of market expectations. Their results varied greatly across individual countries, suggesting the group was not homogenous. They found that deficit of public finances has significant impact on spreads of Russia and Hungary only. The effect of public debt on spreads was not significant, which might be explained by relatively low level of indebtedness.

A more recent study by Ebner (2009) focused on the spreads of 12 CEE countries from 1999 to 2007. The author studied Euro-denominated bonds only, so the effects of exchange rate risk on spreads was largely eliminated. The four principal factors driving the bond spreads were international risk (proxied by implicit volatility of German stock index DAX), ECB reference rate, market liquidity (measured as the difference between the ECB reference rate and EURIBOR) and inflation in the eurozone. While exchange rate turned out to affect the spreads, relation between the other macroeconomic variables and spreads was not proven. This is in line with earlier findings of International Monetary Fund (2003) and Nickel *et al.* (2009).

Another analysis of Euro-denominated bonds was performed by Alexopoulou *et al.* (2010). Their findings in principle confirm those of Ebner (2009). But in contrast to Ebner (2009), they distinguish between short-run and long-run factors through the pooled mean group approach. Apart from that, they include the Emerging Markets Financial Stress Index (developed by Danninger *et al.* (2009)) as explanatory variable. On the one hand, the financial vulnerability and liquidity situation seemed to play an important role in the short run. On the other hand, the macroeconomic variables such as external debt to GDP ratio exerted considerable influence over the spread in the long-run, whereas their short-run effects were much less pronounced. Thus, it is understandable that Ebner (2009) did not find evidence of a relation between fundamentals and spreads, since he worked with short-run effects only.

With the outbreak of the financial crisis, situation changed and the role of macroeconomic fundamentals seems to have become more important. The impact of the financial crisis on CEE bond spreads was studied by Cihak & Mitra (2009), who considered the time period 2001–2008. They found that during the crisis, financial markets put more weight on macroeconomic fundamentals than in the pre-crisis period. They did not analyze the effect of individual fundamentals, but used a composite index of economic risk instead. The importance of individual macroeconomic variables during/after the financial crisis has not yet been discussed.

The spillover effects between bond spreads can be captured by pairwise correlations of bond spreads of individual countries, as performed by Bunda *et al.* (2009). They show existence of groups of countries with high positive within-group correlations of bond spreads. At the same time, global factors in periods of financial stress do not influence all groups uniformly, but can have different effects on different groups. Moreover, they found that the correlations had increased substantially after the collapse of Lehman Brothers in October 2008. This finding lead them to conclusion that the financial crisis had been associated with much less discrimination of investors among individual countries. Since Alexopoulou *et al.* (2010) divided the new member states into two subgroups with similar spread determinants (the Czech Republic, Lithuania, Poland, and Slovakia being the first one; and Bulgaria, Hungary, Latvia, and Romania the second one), a question that arises is whether the difference between the two groups is still apparent after the crisis started.

If we had at our disposal more observations, it would be possible to disentangle the effects of several fiscal variables. Financial markets differentiate between different types of fiscal adjustments in emerging markets, as showed by Akitoby & Stratmann (2008). Specifically, they found that higher tax revenues decrease spreads more than lower government spending. They also showed that cuts in government spending have higher effect on spreads than cuts in public investment. Finally, they come to the conclusion that investors demand higher risk premia for debt-financed spending than for the revenue-based.

2.0.2 Econometric Models of Bond Spreads

Bond spreads as well as the typically used explanatory variables are often nonstationary and individual observations are far from independent. This implies that more sophisticated estimation methods have to be used. Ebner (2009) estimated model in levels with Newey-West standard errors to control for heteroskedasticity and serial correlation. Petrova *et al.* (2010) and Akitoby & Stratmann (2008) modeled the spreads by fixed effects, again utilizing serial correlation and heteroskedasticity robust standard errors. But estimation of a dynamic model (that is, a model with lagged explained variable as one of the explanatory variables) by standard fixed effects in presence of serial correlation, leads to biased estimates—this was proven by Nickell (1981).

An alternative approach, which relies on different assumptions, is the pooled mean group estimation (for description, see 5.1). This technique was used e.g. by Petrova *et al.* (2010) and Poghosyan (2012). Finally, there are Bayesian methods, which can in certain sense assess the importance of each explanatory variable. Given the number of studies of spreads and their often strikingly different conclusions, Maltritz (2012) suggests that Bayesian model averaging is justified.

Chapter 3

Theoretical Background

3.1 Government Bond Yields and Spreads

Long-term interest rates play key role in the economy. They are linked to expectations of short-term interest rates, to exchange rates and to price stability.

In general, long term interest rates are considered a good gauge of macroeconomic stability, since countries with macroeconomic imbalances tend to experience higher and more volatile long-term interest rates. This was the reason for including long-term interest rates into the Maastricht criteria. In particular, §4 of the 11. Protocol on the convergence criteria requires the average nominal long-term interest rate be higher than the average long-term interest rates of the three countries with lowest inflation by two percentage points at maximum. Any country which is to enter the Eurozone has to fulfill this criterion.

Moreover, these time series are monitored by European institutions. The European Council and the European Commission use them to assess the state of real convergence of all EU countries in accordance with §121¶3 of the Treaty on the Functioning of the European Union.

This thesis focuses on the differentials between bond yields of individual countries and the risk free interest rate. These differentials are shortly refereed to as bond spreads. The notion of a risk-free interest rate plays prominent role in financial mathematics, as it allows to compare different assets. Despite this, the meaning of a risk-free interest rate depends on context. While it is common to use the yield of the treasury bills when pricing options, valuation of government bonds is typically based on the yields of treasury bonds. When comparing the bond yields of different European countries, the accepted practice is to use the yield on German government bonds (the “Bunds”) as the risk-free interest rate. Consequently, the spreads are defined as the difference between the bond yield of a particular country and the yield of a German government bond. Since German government bond yields have been very low and stable in comparison with other European countries, almost all spreads are positive.

The three principal factors driving the bond spreads are the expected probability of default, expected exchange rate changes and expected inflation. Other less important factors include possible liquidity risk and administrative, legal, and tax issues. Both theoretical and empirical literature traditionally focus on the probability of default. While the effect of changes in exchange rate and inflation expectations is straightforward and can be easily formulated in macroeconomic notions, the relationship between spreads and the expected probability of default turns out to be much more complex.

3.1.1 Standard Bond Spread Model

The fundamental, yet not directly observable factor determining the bond yield is the probability π of government default. Given risk-free interest rate i^*, this probability is the major force behind the market-clearing bond spread s.

A standard model of bond risk premia is in fact a transformation of another model—which was originally motivated by the need to empirically analyze debt servicing capacity via logistic regression. This logit model of spreads, developed by Feder & Just (1977), was later used to study the least developed countries in Edwards (1984) and Edwards (1986). Nowadays, the model is usually applied to bond risk premia rather than to the capacity to honor government debt, as e.g. in Akitoby & Stratmann (2008). In other words, the variable of interest is the bond risk premium (i.e. bond spread) rather then the probability of default. An important feature of this model is that logarithms of spreads are taken as the explained variable.

Although this model is used extensively in empirical research, its underlying assumptions are a great simplification of reality. Nevertheless, this model can be justified even in a more general setting. As we show, this model can be used under less strict and more realistic assumptions. We start by presenting the original model of Feder & Just (1977).

The principal idea is as follows: in equilibrium, the yield on the risk free asset i^* is equal to the expected yield to maturity of a bond. We denote i the yield to maturity of a bond. The spread s between i and i^* is an endogenous variable and is defined as

$$s = i - i^*. \tag{3.1}$$

Two mutually exclusive states of the world are considered. Either no default takes place and the bond is serviced in full and in time. Or a default occurs and not a single repayment of the bond is performed—probability of this event is denoted π. Formally, the equilibrium condition take form

$$1 + i^* = (1 - \pi)(1 + i^* + s) \tag{3.2}$$

which gives the equilibrium spread

$$s = \frac{\pi}{1 - \pi} (1 + i^*) . \tag{3.3}$$

An extension of the model by Edwards (1984) addresses the observation that sovereign defaults typically result in debt restructuring and rescheduling and bonds are partially repaid. Hence, the second state of the world is modified accordingly. If a default takes place, the fair value of the bond at time of issuance is reduced to a fraction f of its original fair value. The market equilibrium is now described be the equation

$$1 + i^* = \pi f (1 + i^* + s) + (1 - \pi)(1 + i^* + s) \tag{3.4}$$

which is the same as

$$1 + i^* = (1 - \pi(1 - f))(1 + i^* + s) \tag{3.5}$$

and the equilibrium spread is

$$s = \frac{\pi(1 - f)}{(1 - \pi(1 - f))} (1 + i^*) . \tag{3.6}$$

These two model are in a certain way equivalent: f together with the probability of default in one model uniquely determine the probability of default in the other one. As a result, we can restrict us to the first and simpler model (3.3). Once spreads in this model have been estimated and we have an estimate of f, the estimates can be easily put into the framework of (3.6).

Let us denote x the column vector of factors affecting the probability of default at a given time (these will be the observations) and β the column vector of parameters corresponding to x (which we will want to estimate). (For simplicity, a linear relationship between x and π is assumed. A non-linear relationship can of course be obtained by an appropriate transformation of x.)

The question now is how to relate $\beta^T x$ and the probability of default π. There are two functions which are frequently used in economics to model probability: the cumulative density function of standard normal distribution and the logistic function. There is no clear advantage of one of these function over the other and economists usually choose between these two arbitrarily.

Since we study financial markets data, which tend to have "heavier tails" than the cumulative density function of standard normal distribution, logistic function seems more appropriate. This approach has been adopted by Edwards (1984) and has been common in empirical studies of bond spreads. There is no reason to deviate from this tradition, so we put

$$\pi = \frac{exp(\beta^T x)}{1 + exp(\beta^T x)} \tag{3.7}$$

and we plug this into (3.3):

$$s = \frac{\pi}{(1-\pi)}(1+i^*) = \frac{\frac{exp(\beta^T x)}{1+exp(\beta^T x)}}{(1-\frac{exp(\beta^T x)}{1+exp(\beta^T x)})}(1+i^*) = exp(\beta^T x)(1+i^*). \tag{3.8}$$

The risk free interest rate i^* is close to zero, which justifies the following approximation:

$$s = exp(\beta^T x)(1+i^*) \approx exp(\beta^T x). \tag{3.9}$$

By definition, the spread s expresses the risk premium over a risk free interest rate. Hence, $s > 0$ and it approximately holds

$$ln(s) = \beta^T x. \tag{3.10}$$

This fundamental result of Edwards (1984) determines the functional form for estimation: namely the log-level model.

3.1.2 Bond Valuation under Standard Bond Spread Model

To generalize the original model, we need to work with present values of bonds.

Assumption 3.1 (Bond). Bond with face value F, annual coupon payments of coupon rate c and maturity of n years is a financial flow consisting of n coupon payments $C = cF$ at times $1, 2, \ldots, n$ and face value F at time n.

We analyze fair values at the time of issuance only. Fair values at times of coupon payments can be easily obtained by discounting or by accordingly reducing the number n and using the formula for the fair value at the time of issuance. Fair values at arbitrary time point can then be computed by interpolation, taking into account accrued interest.

Proposition 3.1 (Fair value of bond at time of issuance with possible default). *Expected fair value of bond given effective interest rate of a risk free asset*[1] $i > -1$ *at time of issuance is*

$$E[PV] = (1-\pi)\left(\sum_{t=1}^{n} \frac{C}{(1+i)^t} + \frac{F}{(1+i)^n}\right). \tag{3.11}$$

If furthermore $i \neq 0$, *then*

$$E[PV] = (1-\pi)\left(\frac{C}{i}\left(1 - \frac{1}{(1+i)^n}\right) + \frac{F}{(1+i)^n}\right). \tag{3.12}$$

3.1.3 Original Poisson Default Model

Even though the probability of default as well as the spread vary in time, the expected probability of default over the life span of a bond can be considered a constant. This idea leads to a Poisson process model developed by JP Morgan (2000, pp. 8-11). Bond holder is in case of default paid recovery value, which is proportional to the face value. They assumed that this recovery value is independent of the remaining time to maturity. Moreover, they assumed that at most one default takes place during the bond's lifespan. However, these two assumption do not seem realistic, certainly not for emerging markets.

First, *ceteris paribus*, the later a default occurs, the lower is the loss for the bondholder, since more coupon payments are repaid in full. Second, a country can default on and reschedule its debt more than once in time period shorter than lifespan of a bond.

In contrast with JP Morgan (2000), we relax the two aforementioned assumptions by constructing an alternative model.

[1] Even though negative nominal interest rates have little economic justification, real interest rates can be negative. This analysis can be applied to real interest rate i as well, which is why we allow for negative interest rates.

3.1.4 Generalized Poisson Default Model

Assumption 3.2 (Realignment). A default is followed by a realignment, which reduces the fair value of the debt outstanding at the time of default to a fraction f of its former value, where $0 < f < 1$.

Assumption 3.3 (Defaults have Poisson distribution). For time interval $[t_0, t_1]$, where $0 \leq t_0 < t_1$ and $\lambda > 0$, the following holds:[2]

$$P(k \text{ defaults occur during } [t_0, t_1]) = \frac{(\lambda(t_1 - t_0))^k}{k!} e^{-\lambda(t_1 - t_0)}. \tag{3.13}$$

Equation (3.13) implies that the probability of no default in the time period $[0, t]$ is $e^{-\lambda t}$. The probability of at least one default between time 0 of issuance and time t is $1 - e^{-\lambda t}$. It is reasonable to measure time in years. The parameter λ then expresses the expected number of defaults in one year. Put differently, the defaults occur on average every $\frac{1}{\lambda}$ years.

Lemma 3.1. *Under the assumptions (3.1), (3.2) and (3.3) and for $i > -1$, $i \neq e^{-\lambda(1-f)} - 1$,[3] the expected fair value of a bond at the time of issuance is*

$$E[PV] = \frac{C}{(1+i)e^{\lambda(1-f)} - 1}\left(1 - \frac{e^{-\lambda n(1-f)}}{(1+i)^n}\right) + \frac{Fe^{-\lambda n(1-f)}}{(1+i)^n}. \tag{3.14}$$

Proof. Combining (3.11) with (3.13) allows us to write the expected value of bond at time of issuance:

$$E[PV] = \sum_{t=1}^{n}\left(\frac{C}{(1+i)^t}\sum_{k=0}^{\infty}\frac{(\lambda t)^k}{k!}e^{-\lambda t} f^k\right) + \frac{F}{(1+i)^n}\sum_{k=0}^{\infty}\frac{(\lambda n)^k}{k!}e^{-\lambda n} f^k. \tag{3.15}$$

Taylor expansion of the exponential function and some algebra yields

$$\sum_{k=0}^{\infty}\frac{(\lambda t)^k}{k!}e^{-\lambda t} f^k = e^{-\lambda t(1-f)}. \tag{3.16}$$

Plugging (3.16) into (3.15) and applying the formula for the sum of the first n terms of a geometric series completes the proof. □

Proposition 3.2 (Equivalence of the Two Models). *Let us have $n \in N$, $C > 0$, $F > 0$, $f \in (0, 1)$ and $i > 0$. Then, for every $\pi \in (0, 1)$ there exists one and only one $\lambda \in (0, +\infty)$ such that the expected present value of bond in the*

[2] Note that the parameter λ is in practice close to zero.
[3] In particular, this condition is satisfied for $i > 0$.

original model (3.12) is equal to the expected present value of bond in Poisson default model (3.14).

Proof. Let us take fixed π, f, n, C, i and F according to assumptions. Let us denote $g(\lambda)$ the function on the right hand side of the equation (3.14) and PV_0 the expected present value of bond in the original model (3.12). PV_0 is positive.

First, it holds $\lim_{\lambda \to +\infty} g(\lambda) = 0$. Therefore, there exists some $\lambda_2 \in (0, +\infty)$ such that $PV_0 > g(\lambda_2)$. Second, the limit $\lim_{\lambda \to 0^+} g(\lambda)$ exists and is greater than PV_0. So there exists some $\lambda_1 \in (0, +\infty)$ such that $g(\lambda_1) > PV_0$. Third, g is continuous on $(0, +\infty)$, because its derivative exists on $(0, +\infty)$. Fourth, g is decreasing on $(0, +\infty)$, since $\frac{\partial g(\lambda)}{\partial \lambda} < 0$ on $(0, +\infty)$. Therefore, $\lambda_1 < \lambda_2$.

The function g is continuous on $[\lambda_1, \lambda_2] \subset (0, +\infty)$ and $g(\lambda_1) \geq PV_0 \geq g(\lambda_2)$. By the intermediate value theorem, there exists some $\lambda_0 \in [\lambda_1, \lambda_2]$ such that $g(\lambda_0) = PV_0$. Existence is hereby proven. Uniqueness follows by contradiction from the monotonicity of g on $(0, +\infty)$. □

From the aforementioned proposition it follows that we can work with the original bond spread model (because it is easy to estimate) while relying on the assumptions of the generalized Poisson default model (because it is more realistic and it offers sensible and useful interpretation of probabilities of default).

More precisely, if an empirical researcher is interested only in spreads and not in probabilities of default, he can base his analysis on equation (3.2) and rely on the more relaxed assumptions of the generalized Poisson default model only.

If on the other hand there is a need to obtain an estimate of probability of default, it is recommendable to use the original bond spread model first and get estimates of probabilities of default within its framework. These estimates can then be transformed into the framework of the Poisson model through equation (3.14), which can be easily done by software.

If the bonds in question were issued in different currencies, it is necessary to control for the effect of exchange rate changes.

3.2 Expected Inflation and Exchange Rate

The equilibrium condition (3.2) does not take into account expected changes in price levels and exchange rates. Nevertheless, these factors are of crucial importance for bond market players, which is why we incorporate these two phenomena into the theoretical framework.

To see how these variables are related to each another, we denote i_r the real yield, i_n the nominal yield, e the expected domestic inflation, ex_0 the expected exchange rate at time 0 and ex_1 the expected exchange rate at time 1 (both in units of foreign currency per unit of domestic currency). We further denote a the nominal foreign currency appreciation relative to domestic currency, $a = \frac{ex_0}{ex_1} - 1$.

We consider the risk-free interest rate i^* a nominal interest rate, which can be obtained by investing in domestic currency. It would be possible to work with real risk free interest rate as well—investors can hedge against inflation by inflation protected securities. But this type of bonds forms only a small segment of the whole market. The vast majority of investors are far from "inflation-neutral".

The real yield equals the nominal yield minus (domestic) inflation plus foreign currency appreciation relative to domestic currency. To formulate this idea exactly, we start by adjusting the Fisher equation for exchange rate changes:

$$\frac{ex_0}{ex_1}(1 + i_n) = (1 + i_r)(1 + e) \tag{3.17}$$

which is equivalent to

$$(1 + a)(1 + i_n) = (1 + i_r)(1 + e). \tag{3.18}$$

The equation (3.1) now becomes

$$i_n = i^* + s. \tag{3.19}$$

We solve for i_r, which is the real yield of a foreign bond:

$$i_r = \frac{a - e + (i^* + s)(1 + a)}{1 + e}. \tag{3.20}$$

The real yield corresponding to investing in a domestic bond is:

$$i_r^* = \frac{i^* - e}{1 + e}. \tag{3.21}$$

In equilibrium, expected real yields of domestic and foreign bonds are equal to each other (this is the same argument as in (3.2)).

$$1+\frac{i^{*}-e}{1+e}=(1-\pi)\left(1+\frac{a-e+(i^{*}+s)(1+a)}{1+e}\right). \tag{3.22}$$

Finally, the equilibrium spread equals

$$s=\left(\frac{\pi}{1-\pi}-\frac{a}{1+a}\right)(1+i^{*}). \tag{3.23}$$

Predictions of this model are consistent with economic intuition. Equation (3.23) implies that expectations regarding domestic inflation do not have direct effect on foreign bond spread. But expected foreign currency appreciation leads to lower spreads, and vice versa.

Chapter 4

Empirical Analysis: Descriptive Part

4.1 Data Description

Bond yields have been collected for all EU countries except for Estonia. The time series are available since April 2000 for all 26 countries except for the following: for Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, and Slovakia only since January 2001; for Slovenia since March 2003; for Bulgaria since January 2003; and for Romania since April 2005. Last observation included is from January 2013.

4.2 Spreads and Macroeconomic Fundamentals

There is no consensus as to what variables should be used to explain bond spreads—each study considers different set of explanatory variables, which makes comparison and synthesis of their results especially difficult. For a summary of which variables were included in different studies, see Maltritz (2012).

4.2.1 Inflation

Higher inflation leads to currency appreciation in the long-run, which implies, everything else being equal, lower real yield. To keep the real yield unchanged, spreads have to increase. This is a direct consequence of 3.17. (It follows from 3.23, too.) The relationship between inflation and spreads is most likely nonlinear. The higher inflation is, the more it is unstable. Bond market players

Table 4.1: Data description

Variable	Source (Frequency)	Description[1]
Bond yield	Eurostat (M)	Government bond yields with a ten years' maturity and interest rates used for the Maastricht criterion on long-term interest rates.
Budget balance (% of GDP)	EIU[2] (Q, Y)	General government receipts minus General government outlays.
Current account balance (% of GDP)	EIU (Y)	The difference between exports and imports of goods, services, income and current transfers.
Public Debt (% of GDP)	EIU (Q, Y)	Total debt (both local and foreign currency) owed by government to domestic residents, foreign nationals and multilateral institutions such as the IMF.
Money market interest rate	EIU, Eurostat (M)	3-month interbank rate (% per annum).
Real effective exchange rate	BIS (M)	Bilateral exchange rates deflated by consumer price indexes against a panel of 61 countries.[3]
Real gross domestic product	Eurostat (Q)	Gross domestic product at chained 2005 market prices.
Growth of real GDP	Eurostat (Y)	Growth of gross domestic product at chained 2005 market prices.
Inflation	Eurostat (M)	Harmonized index of consumer prices, monthly data at annual rate of change.
Exports	EIU (M)	Exports of goods and services
Imports	EIU (M)	Imports of goods and services
Openness	own calculation (M)	Sum of exports and imports as percentage of GDP.
Spread	own calculation (M)	Difference between the yield on bond of a particular country and the German bond.
CBOE Volatility Index	CBOE Stock Exchange, LLC (M)	Chicago Board Options Exchange Volatility Index.

[1] Variable descriptions are taken from data providers. In some cases, data corresponding exactly to given definitions were not available. If this was the case, other variable of the same economic nature was used as a substitute (e.g. 91-Day Treasury Bills rate en lieu interbank rate for Romania).

[2] Economist Intelligence Unit CountryData of The Economist Newspaper Limited.

[3] Real effective exchange rate for Finland was not available. The variable for the eurozone was used as a substitute.

most likely require special premium for this uncertainty. However, it is not necessary to include second power of inflation to control for this non-linearity, as we work with log-level model.

4.2.2 Exchange Rate

If a government issues bonds in foreign currency, its ability to repay is intrinsically linked to the exchange rate between the domestic currency and the currency in which the bond was issued. a devaluation or depreciation of domestic currency increases the foreign debt expressed in domestic currency, making it more costly to repay.

There does not seem to be a direct relation between the exchange rate regime and its stability. Fixed exchange rates may *prima facie* seem to eliminate exchange rate risk and thus to be associated with lower risk premiums and lower spreads; however, when a country with fixed exchange rate faces an asymmetric demand shock, it either keeps the exchange rate unchanged and risks losing its competitiveness, or it devalues the exchange rate. In either case, credibility of the exchange rate suffers and investors are likely to charge higher risk premium.

Even the currency board, under which every single unit of domestic currency is (in theory) backed by central bank's reserves of foreign currency, does not guarantee exchange rate stability. The most flagrant example is Argentina, which terminated the currency board in December 2001 and devalued the Peso. The unsustainable macroeconomic imbalances lead to the largest sovereign default in history.

Empirical study by Eichengreen *et al.* (1995, pp. 51-52) confirms that the exchange rate regime per se has no effect on the credibility and stability of the exchange rate. This suggests that there is no causal relation between exchange rate regime and bond spreads, whereas part of the relation between macroeconomic fundamentals and bond spreads has to do with the exchange rate credibility. This is why we do not control for different currency regimes or EMU membership.

4.2.3 Output Growth

According to economic theory, yields (as well as spreads) should rise as potential GDP growth increases. Laubach (2009) derived this result from the Ramsey model of optimal growth. There is also empirical evidence which justifies this theoretical result. Poghosyan (2012) showed on a large panel of advanced economies that when potential growth increases by one percent, bond yields increase by about 45 basis points.

Given the length of the period we study and the structural changes CEE economies went through in the past, estimation of a an effect of potential output changes would be challenging. Therefore, we use real GDP growth instead. We expect higher real GDP growth to decrease spreads. Higher GDP growth *ceteris paribus* implies higher budget revenue and thus lower probability of default.

4.2.4 Fiscal Variables

Higher share of public debt on GDP means that relatively more debt will have to be refinanced in the future and that maneuvering of fiscal policy will be more difficult. More debt also implies less investment, lower GDP growth and lower budget revenue in the long-run. Higher public debt should increase bond spreads, which is evident even from the graph B.2.

Nevertheless, this does not hold for all countries. Edwards (1986) found that the for the least developed countries, higher level of public debt is associated with lower spreads. Given the relatively high level of development of the countries we study, this finding is unlikely to apply.

Similarly, higher budget balance should decrease bond spreads. Again, this does not contradict the correlation in B.4.

4.2.5 Global Risk

External factors can be measured by volatility indexes. Although it would be possible to take a European index, as e.g. Alexopoulou *et al.* (2010), who used the Dow Jones Eurostoxx 50, we prefer the Chicago Board Options Exchange Volatility Index as it better captures global risk conditions. This index was used by Petrova *et al.* (2010) when they analyzed emerging market economies. It had an increasing effect on bond spreads.

Since the CEE countries cannot be considered “safe havens”, we expect that higher values of the volatility index would be associated with higher spreads.

4.2.6 Other Factors

We further include openness (defined as the sum of exports and imports over real GDP) and current account balance as possible long-run determinants.

Openness has two effects on bond spreads. On the one hand, higher openness means higher dependence on financial and exchange rate markets, which translates into higher vulnerability when these markets become more volatile. On the other hand, higher openness may be a sign of external competitiveness. The total effect depends on which one of these two effects dominates. The graph B.9 does not give any information as to which effect would dominate. However, an intuitive interpretation of B.9 may be that the total effect differs across countries—there is somewhat lower variance of spreads for values around the mean of openness, while the variance seems to become larger for values of openness which are far from the mean of openness.

4.3 Cluster and Principal Components Analysis

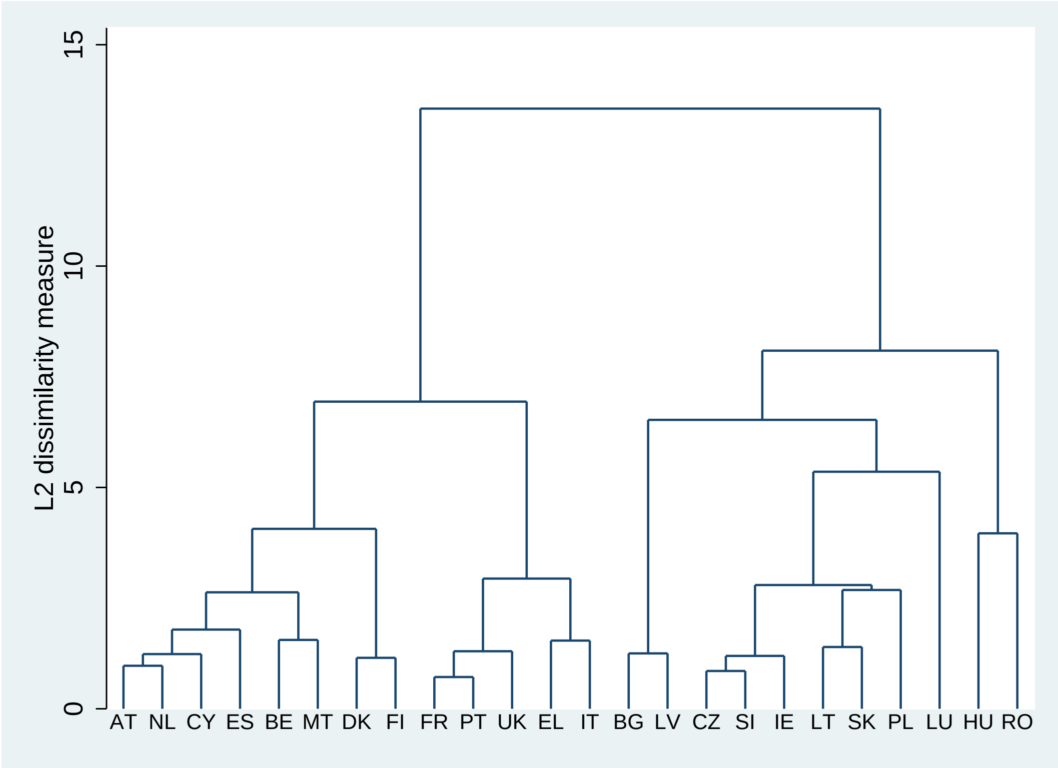
Cluster analysis is a statistical approach to multivariate data. The goal is to identify homogenous subgroups in heterogeneous data. This is done in two phases. Firstly, there needs to be defined an appropriate distance (or proximity) measure between individual observations and groups of observations. Secondly, an algorithm constructs groups in such a way that the groups are as homogenous as possible. For a more technical treatment of the issue, see e.g. Härdle & Simar (2003, pp. 274–291)

The purpose of our cluster analysis is to identify groups of countries which are similar to one another in terms of spreads and other relevant macroeconomic variables. We choose such variables for which there is empirical evidence of their impact on spreads, namely: public debt, budget balance, real GDP growth, inflation, and openness. We perform the analysis on these five variables and the spreads, making it 6 variables in total. We apply Euclidean distance (in R^6) and we choose Ward's linkage. According to Everitt *et al.* (2011, pp. 83–84), this hierarchical method works well when the clusters do not differ too much in their sizes and gives results with sensible interpretation.

We continue with principal components analysis. This descriptive method provides a deeper insight into the structure of the data. We report and interpret the first two principal components (PCs) only since in all cases considered they are the only PCs which explain more than the average part of variance (which is in our case 1/6.)

We analyze the variables in two time periods: before the European sovereign debt crisis (years 2006 and 2007) and during the crisis (2010 and 2011). We work with longer, two-year periods and we average each variable over time in

Figure 4.1: Dendrogram for cluster analysis (2006 and 2007), EU



both periods in order to attenuate the effect of unobserved disturbances. And we of course divide each variable by its sample standard deviation. (Otherwise, the units would not be comparable and interpretation would be infeasible.)

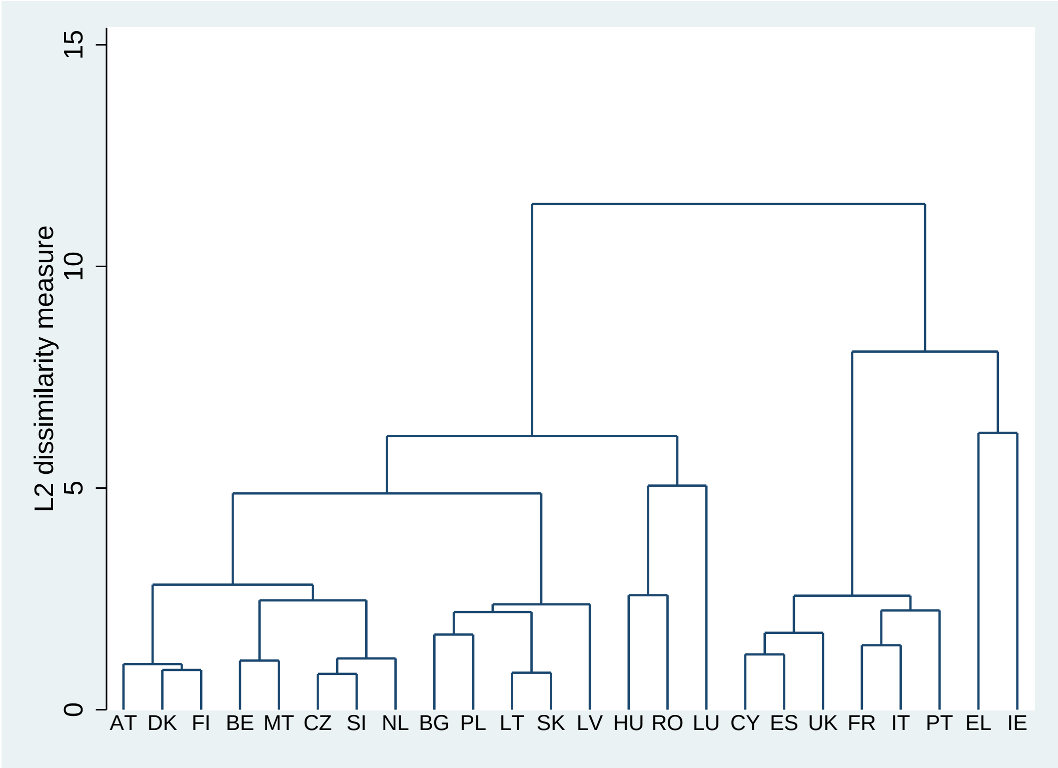
We apply this analysis on 24 EU countries. (We exclude Germany—we consider spreads on German bonds, Sweden—openness is not available, and Estonia—bond yields are not available). Next, we repeat the procedure on the 9 CEE countries only.

4.3.1 CEE Countries—a Subgroup of EU Member States?

Dendrogram 4.1, which refers to the pre-crisis development, clearly separates the new EU member countries (to the right) from other EU members (to the left). The only exceptions are Ireland and Luxembourg, both of which can be considered special cases among the other EU countries. These two countries were put into the cluster of the new members. The countries in question form two distinct groups with respect to the six chosen variables: a group of CEE countries and a group of other EU members.

The situation of this set of countries four year later is completely different. Roughly the left part of the graph 4.2 indicates that macroeconomic

Figure 4.2: Dendrogram for cluster analysis (2010 and 2011), EU



fundamentals of some new member states (Bulgaria, Poland, Latvia, Czech Republic, Slovenia, Lithuania, and Slovakia) are similar to some western European countries (Austria, Denmark, Finland, Germany, Belgium, Malta, and the Netherlands). Hungary and Romania do not belong to the main cluster of CEE countries.

Some of the countries which were hit by the debt crisis and which found it difficult to service their debt can be found in the cluster to the right: Portugal, Ireland, Italy, Greece, Cyprus, and Spain. The two newly emerged subgroups are the eurozone's "troublemakers" (to the right) and countries not as hardly affected by the crisis (to the left). The difference between CEE and other European countries is not as pronounced as in the past.

To demonstrate this shift graphically, we provide graphs 4.3 and 4.4. These graphs allow us to compare similarity and dissimilarity of relevant macroeconomic variables in terms of first two PCs. These graphs reduce the six dimensional observations into two dimensions, so some information got lost in the process. In principle, the graphs are in accordance with the cluster analysis.

The interpretation of estimated principal components in table 4.2 is not straightforward. In the pre-crisis data set, the PC1 is related especially to the

Figure 4.3: Principal components score plot (2006 and 2007), EU

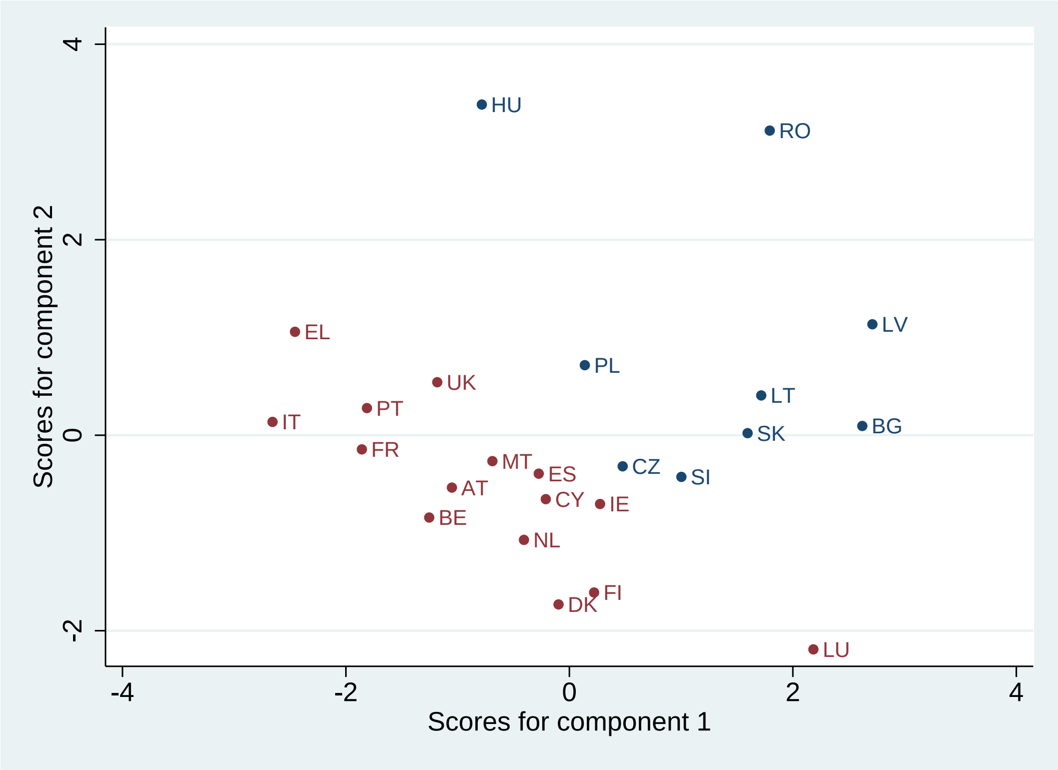


Figure 4.4: Principal components score plot (2010 and 2011), EU

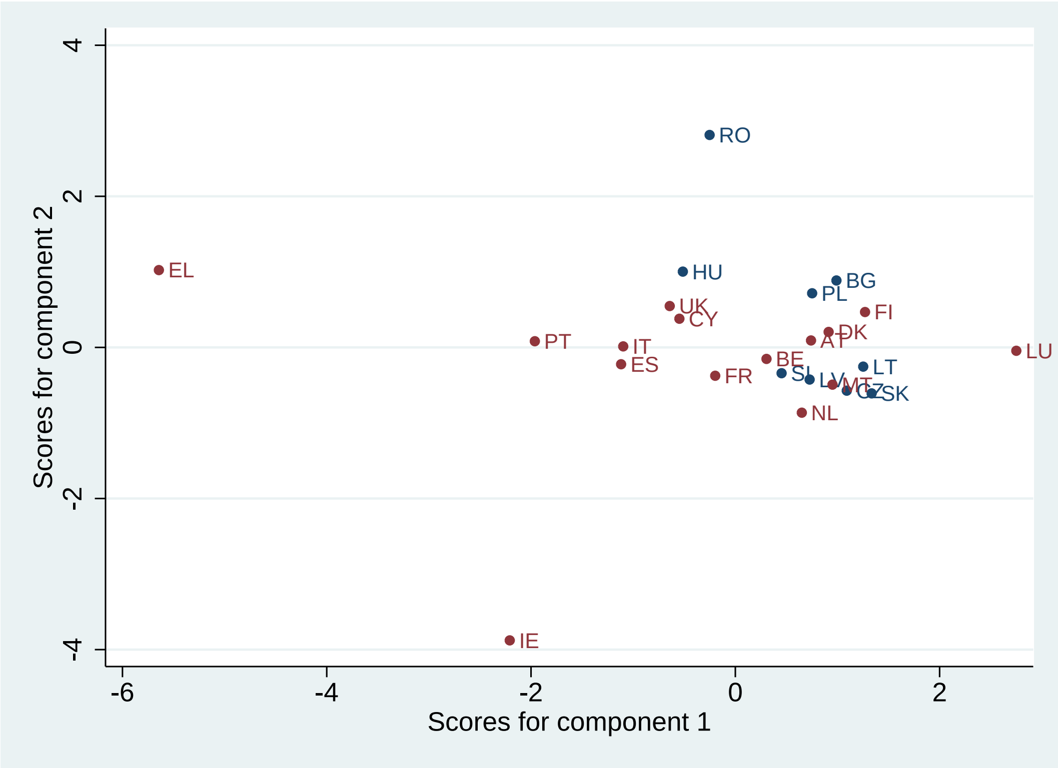


Table 4.2: Principal components, EU

	2006–2007			2010–2011		
	PC1	PC2	unexpl. variance	PC1	PC2	unexpl. variance
proportion	0.394	0.280		0.456	0.212	
public debt	−0.589	0.104	0.163	−0.512	−0.148	0.256
budget balance	0.349	−0.488	0.314	0.431	0.423	0.266
GDP growth	0.530	0.113	0.313	0.505	−0.130	0.282
inflation	0.395	0.465	0.269	−0.049	0.817	0.144
openness	0.291	−0.265	0.681	0.305	−0.318	0.617
spread	0.096	0.673	0.218	−0.450	0.121	0.427

difference between GDP growth and public debt. PC2 expresses essentially the difference between the "real spread" and budget balance, where the "real spread" is the spread minus inflation. Thus, countries with higher PC1 can be fast growing countries with low debt, while countries with higher budget deficits and higher real spreads can be characterized by higher PC2.

This makes sense: new member countries (to the right and top) had low public debt, they grew fast, but paid higher risk premia for their debt. Interestingly, Greece, Italy, and Portugal, which were later hit by the crisis, had low PC1 and high PC2. This corresponds with their lower openness, higher risk premia, slower growth and a lot of debt already before the the crisis.

While the role of the spread in the PC1 before the crisis was negligible, it was not so in the crisis period. In fact, when we proxy the ability of a state to repay its debt by GDP growth, budget balance and negatively taken debt, then PC1 is the difference between the ability to service the debt and bond spread. As a result, countries which are less likely to default and which pay low risk premia are located to the right. On the other hand, states with high bond spreads and with severe fiscal problems are to the left. These are Greece, Ireland, Portugal, Spain, and Italy. The second PC is mainly driven by inflation. This relates to comparatively higher inflation in Romania, Hungary, Bulgaria, Poland, and in Greece.

To sum up, the difference between the traditional and new member states was apparent only before the crisis. During the crisis, the EU countries split into two groups: one which was hit by the crisis, and another one which was not.

Figure 4.5: Dendrogram for cluster analysis, CEE

2006 and 2007 2010 and 2011

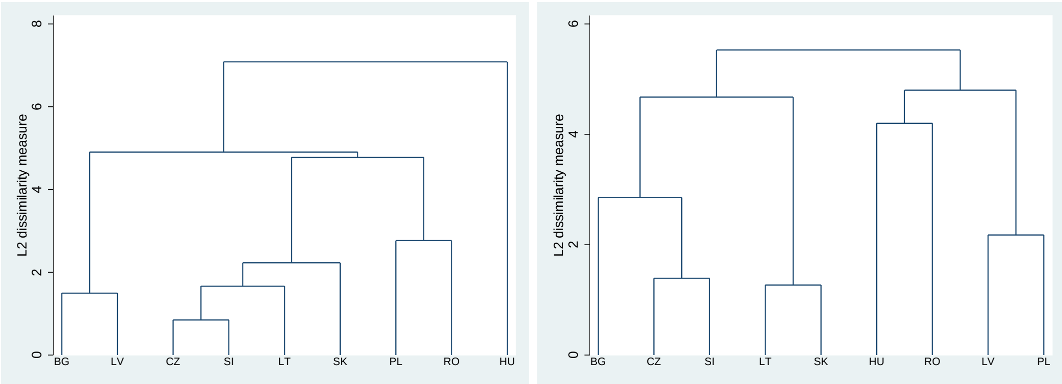
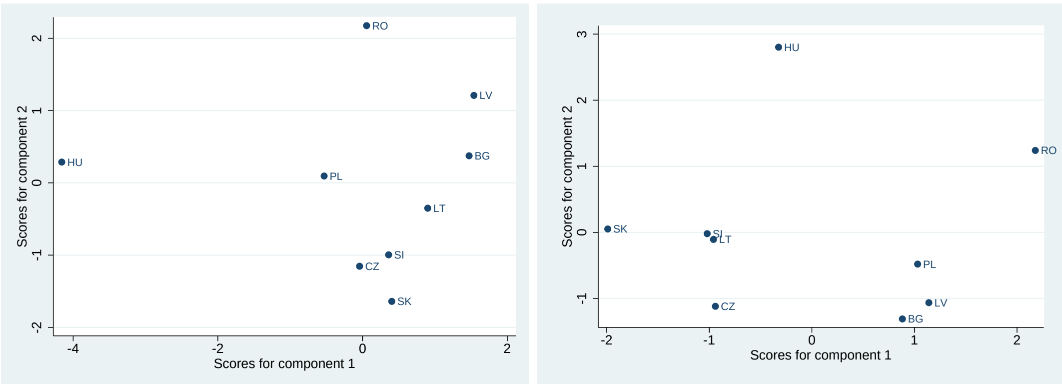


Figure 4.6: Principal components score plot, CEE

2006 and 2007 2010 and 2011



4.3.2 CEE—a Homogenous Group?

Even though 4.1 indicates that the CEE countries differed a lot from other EU states before the crisis, this does not *per se* imply that the CEE group was homogenous. As can be seen in 4.5, there was another more or less homogenous subgroup within the CEE countries (Czech Republic, Slovenia, Lithuania, Slovakia), while the remaining five countries (and, most notably, Hungary), did not fit into this subgroup.

The situation in 2010 and 2011 again differs from the pre-crisis period. Graph 4.5 suggests that the CEE countries could be further divided into two subgroups, i.e. Bulgaria, Czech Republic, Slovenia, Lithuania and Slovakia forming the first one; and Hungary, Latvia, Poland and Romania the second one.

Graphical analysis of the first two PCs in 4.3 and 4.4 brings further two

Table 4.3: Principal components, CEE

	2006–2007			2010–2011		
	PC1	PC2	unexpl. variance	PC1	PC2	unexpl. variance
proportion	0.484	0.241		0.308	0.286	
public debt	−0.546	−0.088	0.123	−0.139	0.558	0.431
budget balance	0.521	0.128	0.189	0.359	−0.451	0.413
GDP growth	0.499	−0.092	0.265	−0.036	−0.270	0.873
inflation	0.091	0.556	0.530	0.408	0.520	0.229
openness	−0.164	−0.584	0.430	−0.628	0.229	0.180
spread	−0.382	0.564	0.118	0.538	0.301	0.310

important observations. There are two countries which can be regarded as outliers both before and during the crisis: Romania and Hungary. Very low PC1 of Hungary before the crisis correspond to worse fiscal position and higher risk premium. High PC2 of Romania before the crisis has to do with higher inflation and spreads. Similarly, High PC1 and PC2 of Hungary and Romania may be attributed particularly to higher inflation and higher spread. Overall, the homogeneity of the subgroup of CEE countries without Romania and Hungary before the crisis was less pronounced in 2010 and 2011 since the differences between these countries became larger.

4.3.3 Conclusion of the Multivariate Analysis

Although the two statistical approaches we used are descriptive and do not provide as sound evidence as e.g. hypotheses testing, they brought some important findings.

We restricted us to six for our study relevant variables (spreads, public debt, budget balance, real GDP growth, inflation and openness). In terms of these variables prior to the sovereign debt crisis, CEE countries differed a lot from other EU members. In 2010 and 2011, this difference was much less pronounced. This can be confirmed by sample means in the table 4.4, too. In fact, except for Hungary and Romania, the CEE countries took after some western European countries. Hungary and Romania differed substantially from other CEE countries both before and during the crisis.

We can now combine the information acquired thus far and divide the new member states into two subgroups we will work with in chapter 5. The first group comprises the Czech Republic, Slovenia, Lithuania, Slovakia, and Poland;

the second one Bulgaria, Hungary, Latvia, and Romania. Although 4.5 indicates otherwise, we believe Poland fits better into the first group than into the second group, mainly for economic and political reasons.

Table 4.4: Sample means by clusters

	2006 and 2007		2010 and 2011	
	CEE	EU, not CEE	CEE	EU, not CEE
public debt	28.377	57.071	41.509	81.469
budget balance	−1.035	−0.532	−4.437	−5.728
GDP growth	6.199	2.912	2.137	0.439
inflation	4.784	2.237	3.017	2.503
openness	29.846	28.032	32.286	28.955
spread	1.071	0.178	3.120	2.148
CEE	group 1	group 2	group 1	group 2
public debt	27.454	29.530	40.703	42.518
budget balance	−1.346	−0.645	−4.754	−4.039
GDP growth	6.812	5.433	2.505	1.677
inflation	3.095	6.896	2.423	3.758
openness	30.952	28.464	33.791	30.403
spread	0.483	1.806	2.042	4.468

Countries in CEE group 1: CZ, LT, PL, SI, SK; in CEE group 2: BG, HU, LV, RO;
in EU, not CEE: AT, BE, CY, DK, FI, FR, EL, IE, IT, LU, MT, NL, PT, ES, UK.

Chapter 5

Empirical Analysis: Inferential Part

5.1 The Pooled Mean Group Estimator

Panel data models used in microeconometrics (such as fixed effects) are appropriate when the number of time periods T is much smaller than the number of panels N. These models rely on the assumption that the slope coefficients are the same for all (or at least for a large number) of observations. Unfortunately, these assumptions are not adequate in many applications. For example in macroeconomics it is often the case that the number of industries or countries N is smaller than T. Moreover, the assumption of homogenous slope coefficients is often not met and, as showed by Pesaran & Smith (1995), its violation generally leads to inconsistency.

Suppose we have a panel data set in which N and T are large (in the sense that it is possible to estimate the model for each time series separately.) Further suppose that we suspect the coefficients differ across panels. In such a case, we can run a regression for each individual panel and then average the estimated coefficients. This is called the mean group (MG) approach and its statistical properties are discussed in Pesaran & Smith (1995). This method can be used even for estimation of dynamic models, which contain both short-run and long-run coefficients. These coefficients may differ across panels. The equality of coefficients across panels can easily be tested by the Lagrange multiplier test or by the F test.

Even though the assumption of homogenous coefficients is often questionable, in some application it may not be unrealistic that the long-run coefficients are the same across some group of panels. If this was indeed the case, the MG estimator would still be consistent. But it would not be efficient, because it would not take advantage of the homogenous long-run coefficients. The Pooled mean group estimator of Pesaran *et al.* (1999) addresses precisely this situation. It fixes the long-run coefficients across panels, while still allowing the short-run coefficients and variances of disturbances to differ across panels. Thus, the PMG estimator has more strict assumptions than the MG estimator.

The PMG or MG estimators are appropriate given our model and data. Some variables, such as exchange rates or short-term interest rates, have an immediate effect on bond spreads and may differ in their effect across countries. Other variables, e.g. real GDP growth and openness, have only a limited immediate impact, but play an important role in the long-run. Recent theoretical results of Rudebusch & Swanson (2012) confirm that bond spread determinants have both short-run and long-run effects.

5.1.1 The Hausman test

We use the Hausman test (Hausman (1978)) to compare properties of PMG and MG estimators. Under the null hypothesis, both estimators are consistent, but PMG estimator is efficient, while MG is not. Under the alternative, PMG is inconsistent, while MG remains consistent.

The classical Hausman test may not be feasible if the difference of the two variance matrix estimates is not positive definite (this often happens in finite samples). Therefore, we use an alternative version of the test, as recommended in Cameron & Trivedi (2009, pp. 260), which derives both variance matrices from the PMG estimates. (Cameron & Trivedi (2009) notes that it is possible to take variance matrices from the MG estimates too and that all three tests are asymptotically equivalent.)

Nevertheless, even this alternative test may produce negative chi-square statistic. If this was the case, we would follow the recommendation of Greene (2003) and we would not reject H_0. (There is some evidence that this approach may not be always correct. Schreiber (2008) proposes to reject H_0 in sufficiently large samples if the p-value corresponding to the absolute value of the chi-square statistic surpasses the critical value of the test.)

5.2 Model Specification

The long-run effect of fundamentals on spreads can be described by the equation

$$ln(s_{it}) = \theta_{0i} + \sum_{j=1}^{k} \theta_{ji} x_{jit} + u_{it} \tag{5.1}$$

for $i = 1, 2, \ldots, N$ and $t = 1, 2, \ldots, T$. The spread of country i at time t is s_{it}. The macroeconomic fundamentals and other explanatory variables are x_{jit} for $j = 1, 2, \ldots, k$. u_{it} are the unobserved disturbances, which may have serial correlation of the form $AR(1)$. We will estimate (5.1) as an $ARDL(1, 1, \ldots, 1)$ model

$$ln(s_{it}) = \mu_i + \alpha_i ln(s_{i,t-1}) + \sum_{j=1}^{k} \beta_{ji} x_{jit} + \sum_{j=1}^{k} \gamma_{ji} x_{ji,t-1} + \epsilon_{it} \tag{5.2}$$

Equation 5.2 can be rearranged into an error-correction form

$$\Delta ln(s_{it}) = \phi_i (ln(s_{i,t-1}) - \theta_{0i} - \sum_{j=1}^{k} \theta_{ji} x_{i,t}) - \sum_{j=1}^{k} \gamma_{ji} \Delta x_{i,t} + \epsilon_{it} \tag{5.3}$$

where

$$\phi_i = -(1 - \alpha_i), \theta_{0i} = \frac{\mu_i}{1 - \alpha_i}, \theta_{ji} = \frac{\beta_{ji} + \gamma_{ji}}{1 - \alpha_i}. \tag{5.4}$$

and $\{\epsilon_{it}\}_{t=1}^{\infty}$ is a sequence of independent and identically distributed random variables with zero mean and variances $\sigma_i^2 > 0$ and with distribution independent of explanatory variables. $\{x_{jit}\}_{t=1}^{\infty}$ are assumed to be either stationary or $I(1)$ for $i = 1, 2, \ldots, N$, $j = 0, 1, \ldots, k$. We further assume that that the long-run coefficients are the same for all countries, that is

$$\theta_{ji} = \theta_j, i = 1, 2, \ldots, N, j = 0, 1, \ldots, k. \tag{5.5}$$

This assumption might seem restrictive at first, but in fact it is not. In particular, Pesaran *et al.* (1999) notes that it allows for seasonal dummies and time trends. It does, however, exclude the possibility to treat the coefficients as random. This is in contrast with the MG estimator, which allows all coefficients to vary across groups. (It can do so because the MG estimator runs a separate regression for each time-series in the panel. This guarantees consistent estimation of the expected value of coefficients.)

Pesaran *et al.* (1999) postulates that the PMG estimators require several more technical assumptions for consistency, e.g. $\{\epsilon_{it}\}_{t=1}^{\infty}$ must have finite fourth-order moments and there may be no perfect collinearity. These are unlikely to be violated in practice.

We denote the θ the vector of long-run coefficients and γ_i the vector of short-run coefficients for $i = 1, 2, \ldots, N$.

Table 5.1: Explanatory variables and their expected effect on spread

variables	long-term effect on spread
public debt	+
budget balance	−
GDP growth	−
current acc. bal.	−
openness	+
inflation	+
VIX	+
control variables	**short-term effect on spread**
money market i.r.	+
effective ex. rate	+/−

5.3 Estimation of the Model

A crucial assumption for the correct estimation of the PMG model is homogeneity of the long-term coefficients. Given the heterogeneity of the group of CEE countries, as discussed in chapter 4, pooling all CEE countries into one group might imply inconsistent estimation if the long-run coefficients differed across the CEE countries. However, in chapter 4 we have identified two subgroups of the CEE countries with similarities in terms of relevant macroeconomic variables. The first group ("CEE group 1") is formed by the Czech Republic, Slovenia, Lithuania, Slovakia and Poland. The second one ("CEE group 2") consists of Bulgaria, Hungary, Romania and Latvia. (The second group differs from the first one particularly in inflation and spreads, see 4.4.) We can use this prior information and assume that the long-run coefficients are the same for the countries in the same group.

32 out of 1953 observations of spreads of CEE countries are negative, which corresponds to about 1.6%. Since we work with the log-level model, these observations had to be excluded. Given their low proportion in the sample, the

possibly induced selection bias would be negligible. However, in 3682 observation of spreads in the remaining EU countries, about 9% of spreads were negative. Basically, there are two possible approaches to tackle this issue. The first one is to use the spreads as the explained variable, as e.g. von Hagen *et al.* (2011) and Alexopoulou *et al.* (2010) did—but this contradicts the theory of bond valuation under uncertainty, see equation (3.10). The second possible approach (which we adopt), used by e.g. Nickel *et al.* (2009) and Petrova *et al.* (2010), is to use the logarithmic transformation of spreads. The "negative" spreads then have to be excluded. This action is justified, since "negative" spreads are inconsistent with the theory on which the model estimation and interpretation is based. Within this framework, "negative" spreads are erroneous observations.

Public debt, budget balance and GDP growth are not collected on monthly basis, so we follow Ebner (2009) and Alexopoulou *et al.* (2010) and we linearly interpolate the missing values.

We start by estimating 5.3 separately for these two groups. After that, we estimate models which allow for a structural break due to the financial crisis. We compare the results and decide if the population coefficients changed. Next, we compare the estimates of the two CEE groups to find out if it is possible to merge the two groups. We also estimate 5.3 for those EU countries which do not belong to CEE and which have not yet been severely hit by the debt crisis. These countries are: Austria, Belgium, Denmark, Finland, France, Italy, Luxembourg, Malta, the Netherlands, and the UK (we are forced to exclude Sweden, since openness is for this country unavailable). Although it is imprecise, we denote this group for simplicity "traditional EU members". For this group of countries, we use longer time series, starting in January 1995. This means that the data set contain the period of the creation of the Economic and Monetary Union. This should not be a major problem, since Codogno *et al.* (2003) did not find evidence of a structural break caused by the introduction of the EMU.

Explanatory variables can be found in table 5.1. We are particularly interested in estimates of the long-run coefficients. The short-run coefficients as well as the speed of adjustment are estimated for each country individually. We report only group averages of estimates of short-run coefficients and of the speed of adjustment. We will take advantage of the finding of Pesaran *et al.* (1999) that the long-run PMG estimators are asymptotically normally distributed.

When we estimated the model for CEE group 1, the speed of adjustment for the Czech Republic was insignificant and even positive. For the Czech Republic there is no evidence of a long-run relationship between the macroeconomic fundamentals and bond spreads, so this country cannot be described by the proposed model. Therefore, we take the Czech Republic out from CEE group 1 and we reestimate the model—new estimates are in table 5.2 (2).

Budget deficit and GDP growth are individually insignificant, which suggests they do not have a major impact on bond spreads of the group. We exclude them and we reestimate the model to find out if they are jointly significant. The p-value of the likelihood-ratio test is 0.4944. We cannot reject the hypothesis that both coefficients are zero.

Estimates of the model for CEE group 2 can be found in table 5.3. Again, public debt and GDP growth are jointly insignificant (p-value 0.3152).

The estimation of the model for the traditional EU members 5.4 (1) raises the same issue as CEE group 1. The estimate of the speed of adjustment is negative for all countries except for Finland. We have no other choice but to exclude this state from the model, as the relationship between spreads and other variables of this economy differs substantially from other traditional EU members. (Considering the peculiarities of recent finish economic history, this finding is understandable.) Once Finland has been taken out, the logarithm of empirical likelihood increased dramatically, see 5.4 (2).

Since we have at our disposal many more observation than for the CEE countries, we can control much better for the non-linear effect of the volatility index.

Table 5.2: Fundamentals and spreads, CEE group 1

	(1)		(2)	
	Coef.	(Std. err.)	Coef.	(Std. err.)
long-run coefficients				
public debt	0.10728***	(0.01115)	0.10588***	(0.01132)
budget balance	0.02927	(0.02299)		
GDP growth	−0.00963	(0.03069)		
current acc. bal.	0.07523**	(0.03214)	0.07301**	(0.03193)
openness	−0.11026***	(0.01838)	−0.10528***	(0.01821)
inflation	0.16663***	(0.02785)	0.17554***	(0.02751)
VIX	0.05814***	(0.02115)	0.06107***	(0.02033)
VIX^2	−0.00044	(0.00036)	−0.00050	(0.00036)
speed of adjustment	−0.33098***	(0.09321)	−0.32418***	(0.08592)
short-run coefficients				
Δpublic debt	−0.17100**	(0.08368)	−0.17944**	(0.08632)
Δbudget balance	0.02523	(0.01778)	0.02206*	(0.01292)
ΔGDP growth	−0.19434**	(0.09447)	−0.20802**	(0.10099)
Δmoney market i.r.	0.13805	(0.15763)	0.14160	(0.15943)
Δcurrent acc. bal.	0.04433	(0.20807)	0.06632	(0.19692)
Δopenness	0.03104	(0.03879)	0.02656	(0.03951)
Δeffective ex. rate	0.00101	(0.01608)	0.00329	(0.01410)
Δinflation	−0.02666	(0.02282)	−0.03134	(0.02331)
ΔVIX	−0.00479	(0.00796)	−0.00449	(0.00778)
ΔVIX^2	0.00001	(0.00012)	0.00001	(0.00012)
constant	−0.34362***	(0.10781)	−0.43687***	(0.10485)
log-likelihood	−21.21822		−21.92272	
number of obs.	496		496	
countries	LT, PL, SI, SK			

Stars denote p-values of the test of the null hypothesis that the coefficient is zero against the two-sided alternative as follows: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5.3: Fundamentals and spreads, CEE group 2

	(1)		(2)	
	Coef.	(Std. err.)	Coef.	(Std. err.)
long-run coefficients				
public debt	0.00687	(0.00726)	0.00363	(0.00616)
budget balance	−0.01083	(0.01302)		
GDP growth	−0.01396	(0.04098)		
current acc. bal.	0.06768***	(0.01449)	0.07482***	(0.01036)
openness	0.02392	(0.01763)	0.01899	(0.01714)
inflation	−0.02545	(0.02792)	−0.02167	(0.02754)
VIX	0.13767***	(0.03123)	0.13176***	(0.03018)
VIX^2	−0.00170***	(0.00051)	−0.00156***	(0.00047)
speed of adjustment	−0.21822	(0.15411)	−0.21879	(0.15287)
short-run coefficients				
Δpublic debt	−0.15387**	(0.06949)	−0.14125**	(0.06473)
Δbudget balance	−0.07680	(0.07925)	−0.07294	(0.07365)
ΔGDP growth	0.03071	(0.05860)	0.04172	(0.06264)
Δmoney market i.r.	0.01510	(0.01860)	0.01469	(0.01863)
Δcurrent acc. bal.	0.04740	(0.06401)	0.05502	(0.06742)
Δopenness	−0.05497	(0.03678)	−0.05399	(0.03649)
Δeffective ex. rate	−0.01205	(0.00937)	−0.00858	(0.00826)
Δinflation	0.02392**	(0.01084)	0.02047**	(0.00798)
ΔVIX	0.00339	(0.00381)	0.00344	(0.00393)
ΔVIX^2	−0.00007*	(0.00004)	−0.00007*	(0.00004)
constant	−0.34067	(0.29659)	−0.28431	(0.25475)
log-likelihood	195.26996		194.89138	
number of obs.	483		483	
countries	BG, HU, LV, RO			

Stars denote p-values of the test of the null hypothesis that the coefficient is zero against the two-sided alternative as follows: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5.4: Fundamentals and spreads, traditional EU members

	(1)		(2)	
	Coef.	(Std. err.)	Coef.	(Std. err.)
long-run coefficients				
public debt	0.06538***	(0.00778)	0.04820***	(0.00933)
budget balance	0.03053	(0.02973)	−0.11321**	(0.05124)
GDP growth	−0.15089***	(0.04362)	−0.06452	(0.06670)
current acc. bal.	−0.01981	(0.02096)	−0.11992***	(0.03433)
openness	0.02255	(0.02361)	0.08203***	(0.03075)
inflation	−0.00150	(0.05454)	0.08321	(0.06789)
VIX	0.92684***	(0.30738)	1.20181***	(0.38106)
VIX^2	−0.04094**	(0.01634)	−0.05680***	(0.02033)
VIX^3	0.00079**	(0.00036)	0.00117***	(0.00045)
VIX^4	$-5.4 \cdot 10^{-6}$**	$(2.7 \cdot 10^{-6})$	$-8.4 \cdot 10^{-6}$**	$(3.4 \cdot 10^{-6})$
speed of adjustment	−0.18112	(0.14082)	−0.31033***	(0.11046)
short-run coefficients				
Δpublic debt	−0.00472	(0.13297)	−0.11479*	(0.06890)
Δbudget balance	−0.32314	(0.21536)	−0.27462	(0.19652)
ΔGDP growth	−0.03753	(0.17184)	0.01051	(0.19287)
Δeffective ex. rate	0.01375	(0.02712)	−0.00256	(0.02062)
Δmoney market i.r.	−0.00041	(0.12094)	0.19468***	(0.07430)
Δcurrent acc. bal.	0.31076	(0.41374)	0.29669	(0.58246)
Δopenness	0.32346***	(0.11440)	0.32007**	(0.12907)
Δinflation	0.08690**	(0.04104)	0.08655*	(0.04770)
ΔVIX	−0.12641	(0.09233)	−0.26203**	(0.11006)
ΔVIX^2	0.00394	(0.00394)	0.01088***	(0.00415)
ΔVIX^3	−0.00004	(0.00009)	−0.00019**	(0.00007)
ΔVIX^4	$8.2 \cdot 10^{-8}$	$(6.9 \cdot 10^{-7})$	$1.2 \cdot 10^{-6}$**	$(5.2 \cdot 10^{-7})$
constant	−3.41615	(2.19073)	−6.23984**	(2.54413)
log-likelihood	-649.23398		-440.15716	
number of obs.	1555		1383	
countries	AT, BE, DK, FI FR, IT, LU, MT NL, UK		AT, BE, DK FR, IT, LU, MT NL, UK	

Stars denote p-values of the test of the null hypothesis that the coefficient is zero against the two-sided alternative as follows: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.4 Impact of the Financial Crisis

We will test for a possible structural break at the time of the start of the financial crisis, by which we understand the bankruptcy of the Lehman Brothers. (Obviously, it would be better to test for a structural break without *a priori* specifying its time rather than to choose it arbitrarily as we did. But it is not known how to do it in the PMG framework.) Before the Lehman Brothers, the financial turmoil was mostly restricted to the sub-prime mortgage market. The collapse of the investment bank affected not only the global economy, but also the subjective perception of risk of many investors. It can be considered a plausible structural break.

Let us denote LB a dummy equal to one since September 2008, and zero otherwise. We will estimate the model with the vector of long-run coefficients

$$\tilde{\theta} = (\theta, \theta \cdot LB) \tag{5.6}$$

and vector of short-run coefficients

$$\tilde{\gamma_i} = (\gamma_i, \gamma_i \cdot LB) \tag{5.7}$$

Estimates can be found in tables 5.5, 5.6 and 5.7. Unfortunately, the estimation of the model with long-run coefficients $(\theta, \theta \cdot LB)$ failed due to a technical issue—the numerical algorithm maximizing empirical log-likelihood did not converge. We were only able to estimate the model when some two variables of $(\theta, \theta \cdot LB)$ were excluded. We decided to exclude $LB \cdot VIX$ and $LB \cdot VIX^2$. We will check in section 5.6 if subsequent inclusion of these two variables into a restricted model somehow changes our results. Again, the Czech Republic had to be excluded, as its estimate of the coefficient of adjustment $\hat{\phi}$ was positive. (It remained negative and significant at the 0.1% level for the remaining for four countries of the group CEE 1.)

We will test for the structural change separately for CEE group 1 and CEE group 2. If there was no structural break, the newly added variables $\theta \cdot LB$ and $\gamma_i \cdot LB$ should be jointly insignificant. More precisely, we test $H_0 : \theta \cdot LB = 0^T, \gamma_i \cdot LB = 0^T$ against $H_a : \theta \cdot LB \neq 0^T$ or $\gamma_i \cdot LB \neq 0^T$. This can be done by the Likelihood ratio test. Under H_0, LR has asymptotically χ^2_{30} distribution (the unrestricted model contains 6 more long-run parameters and $6 \cdot 4$ short-run parameters).

$$LR = 2(ln(L)_{ur} - ln(L)_r) = 2(-8.006699 - (-21.21822)) = 26.423042 \quad (5.8)$$

The p-value of the test is 0.6534. We cannot reject the hypothesis of no structural change in the six variables for CEE group 1.

$$LR = 2(ln(L)_{ur} - ln(L)_r) = 2(217.03874 - 195.26996) = 43.53756 \quad (5.9)$$

The p-value is 0.0525. We reject the hypothesis of no structural change of CEE group 2 at the 10% significance level.

We conclude that the financial crisis of 2008 was a structural break for CEE group 2, but not necessarily for CEE group 1. Once have asserted the occurrence of a structural change, we investigate what variables does the change relate to.

5.4.1 CEE Group 1

The following interacting terms in 5.5 (1) are not significant at any reasonable significance level: public debt, budget balance, openness and inflation. One of the possible reasons for this might be that the population coefficients on these variables were not affected by the structural change—unfortunately, it is impossible to test this idea statistically. But what we can do is to test the contrary. We consider the null hypothesis that the coefficients on the interacting terms of public debt, budget balance, openness and inflation (long-run as well as short-run) are all equal to zero against the alternative that at least one of them is non-zero.

$$LR = 2(ln(L)_{ur} - ln(L)_r) = 2(-13.27295 - (-8.696867)) = 9.152166 \quad (5.10)$$

The corresponding p-value (via χ^2_{20}) is 0.9811. We cannot reject the hypothesis that there was no structural change in public debt, budget balance, openness and the inflation at the 10% significance level.

5.4.2 CEE Group 2

The only individually insignificant variables which interact with LB are budget balance and inflation. We test if they are jointly significant.

$$LR = 2(ln(L)_{ur} - ln(L)_r) = 2(217.03874 - 215.716) = 2.64548 \tag{5.11}$$

The p-value of the test is 0.9886 (we used χ^2_{10}). We cannot reject the hypothesis that there was no structural change in budget balance and inflation.

Table 5.5: Fundamentals and spreads, CEE group 1

	(1)		(2)	
	Coef.	(Std. err.)	Coef.	(Std. err.)
long-run coefficients				
public debt	0.11853***	(0.02216)	0.11085***	(0.00991)
budget balance	0.04452	(0.03596)		
GDP growth	0.07711	(0.05426)		
current acc. bal.	0.11759***	(0.04491)		
openness	−0.05888**	(0.02967)	−0.09579***	(0.02211)
inflation	0.20647***	(0.04047)	0.20541***	(0.02963)
VIX	0.13674***	(0.03175)	0.09905***	(0.02566)
VIX^2	−0.00187***	(0.00057)	−0.00117***	(0.00045)
LB · public debt	−0.00707	(0.01865)		
LB · budget balance	−0.03317	(0.05120)		
LB · GDP growth	−0.18257**	(0.07579)	−0.06740*	(0.03584)
LB · current acc. bal.	−0.22296*	(0.13020)		
LB · openness	−0.01063	(0.02710)		
LB · inflation	−0.00987	(0.08739)		
speed of adjustment	−0.35572***	(0.10686)	−0.32621***	(0.09146)
short-run coefficients				
Δpublic debt	−0.07995**	(0.03508)	−0.11271*	(0.06753)
Δbudget balance	0.14691	(0.13981)	0.36644	(0.34726)
ΔGDP growth	−0.13903	(0.12789)	−0.12243	(0.13229)
Δmoney market i.r.	0.13455	(0.15387)	0.14692	(0.16144)
Δcurrent acc. bal.	0.14999	(0.19269)	0.19786	(0.14223)
Δopenness	0.02364	(0.07390)	0.02102	(0.06596)
Δeffective ex. rate	−0.00764	(0.01448)	−0.00344	(0.01278)
Δinflation	−0.03403	(0.02312)	−0.04628	(0.03255)
ΔVIX	−0.03134	(0.02562)	−0.02261	(0.02430)
ΔVIX^2	0.00056	(0.00048)	0.00042	(0.00047)
ΔLB · public debt	−0.17721	(0.17197)	−0.28858	(0.20373)
ΔLB · budget balance	0.00592	(0.34266)	−0.19778	(0.51884)
ΔLB · GDP growth	0.12556	(0.27020)	0.07392	(0.28389)
ΔLB · current acc. bal.	0.20753	(0.46589)	0.05624	(0.52666)
ΔLB · openness	0.21351	(0.20704)	0.26415	(0.22452)
ΔLB · inflation	−0.94686	(0.94711)	−1.16982	(1.19095)
constant	−1.46007***	(0.41120)	−0.86042***	(0.17391)
Log-likelihood	-8.00670		-12.37024	
Number of obs.	496		496	
countries	LT, PL, SI, SK			

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.6: Fundamentals and spreads, CEE group 2

	(1)		(2)	
	Coef.	(Std. err.)	Coef.	(Std. err.)
long-run coefficients				
public debt	0.05735***	(0.01340)	0.04825***	(0.00617)
budget balance	−0.02178*	(0.01311)	−0.01677	(0.01121)
GDP growth	0.04358	(0.04038)		
current acc. bal.	−0.02163	(0.02798)		
openness	−0.00120	(0.02210)		
inflation	−0.02010	(0.02485)		
VIX	0.13583***	(0.02671)	0.12954***	(0.02515)
VIX^2	−0.00199***	(0.00045)	−0.00185***	(0.00043)
LB · public debt	−0.06819***	(0.01440)	−0.05755***	(0.00765)
LB · budget balance	0.00663	(0.02612)		
LB · GDP growth	−0.11894**	(0.04998)	−0.07846**	(0.03703)
LB · current acc. bal.	0.10245**	(0.04791)	0.09186***	(0.03497)
LB · openness	0.10901***	(0.02529)	0.08767***	(0.00955)
LB · inflation	0.03247	(0.04167)		
speed of adjustment	−0.30485**	(0.14933)	−0.29847**	(0.14721)
short-run coefficients				
Δpublic debt	−0.80743	(0.62635)	−0.67643	(0.43626)
Δbudget balance	−0.16643	(0.17025)	−0.14864	(0.15167)
ΔGDP growth	−0.34839	(0.21987)	−0.24155	(0.15807)
Δmoney market i.r.	0.01497	(0.01458)	0.01752	(0.01340)
Δcurrent acc. bal.	0.01274	(0.18029)	0.02021	(0.16363)
Δopenness	−0.07564	(0.07606)	−0.06491	(0.07059)
Δeffective ex. rate	−0.02180***	(0.00599)	−0.02094***	(0.00542)
Δinflation	0.02567**	(0.01028)	0.02535**	(0.00988)
ΔVIX	−0.00205	(0.00187)	−0.00050	(0.00131)
ΔVIX^2	0.00005**	(0.00002)	0.00002	(0.00002)
ΔLB · public debt	0.26046***	(0.08607)	0.21704***	(0.07102)
ΔLB · budget balance	0.20063	(0.19782)	0.15435	(0.15213)
ΔLB · GDP growth	0.50170**	(0.24806)	0.36904***	(0.13986)
ΔLB · current acc. bal.	0.53061	(0.40762)	0.40732	(0.27300)
ΔLB · openness	0.03355	(0.05231)	0.02426	(0.04759)
ΔLB · inflation	−0.01894	(0.01404)	−0.01600	(0.01266)
constant	−0.97445	(0.69744)	−0.77143	(0.56451)
Log-likelihood	217.03874		215.65179	
Number of obs.	483		483	
countries	BG, HU, LV, RO			

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5.7: Fundamentals and spreads, traditional EU members

	Coef.	(Std. err.)
long-run coefficients		
public debt	0.02951***	(0.00911)
budget balance	−0.09248*	(0.05110)
GDP growth	0.07982	(0.06802)
current acc. bal.	−0.04949*	(0.02703)
openness	−0.03740	(0.03068)
inflation	0.12558*	(0.06537)
VIX	0.16428***	(0.02895)
VIX^2	−0.00226***	(0.00055)
LB · public debt	0.00647	(0.00573)
LB · budget balance	−0.06868	(0.10241)
LB · GDP growth	−0.19910*	(0.10951)
LB · current acc. bal.	−0.01889	(0.03395)
LB · openness	0.00571	(0.01120)
LB · inflation	0.12079	(0.13006)
speed of adjustment	−0.39319***	(0.13257)
short-run coefficients		
Δpublic debt	0.14685	(0.20531)
Δbudget balance	−0.59247	(0.42269)
ΔGDP growth	−0.17601	(0.32181)
Δmoney market i.r.	0.03946	(0.07791)
Δcurrent acc. bal.	0.33759	(0.51078)
Δopenness	0.10843	(0.25168)
Δeffective ex. rate	−0.00739	(0.01516)
Δinflation	0.09653*	(0.05860)
ΔVIX	−0.02206**	(0.01037)
ΔVIX^2	0.00029**	(0.00012)
ΔLB · public debt	−0.37991	(0.50394)
ΔLB · budget balance	0.29406	(0.62979)
ΔLB · GDP growth	0.15777	(0.39218)
ΔLB · current acc. bal.	2.75879	(2.29625)
ΔLB · openness	−0.07540	(0.23226)
ΔLB · inflation	−0.02662	(0.08057)
constant	−4.21115*	(2.51409)
Log-likelihood	-407.61342	
Number of obs.	1383	
countries	AT, BE, DK, FR, IT, LU, MT, NL, UK	

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

We reestimate the model, excluding those variables for which there was no evidence of change of their coefficients. When we did this, current account balance as well as its interacting term for CEE group 1 became insignificant, so we excluded them as well. We still allow for change in the short-run coefficients—they could have changed for some countries. The estimates are in tables 5.5 (2) and 5.6 (2).

5.4.3 Do the Two Group Really Differ?

Let us denote θ_{CEE1}, θ_{CEE2}, and θ_{TEU} the vectors of long-run coefficients of CEE group 1, CEE group 2, and of the traditional EU members, respectively.

As explained earlier, we allowed the long-run coefficients of CEE group 1 (let us denote them θ_{CEE1}) to differ from the those one of CEE group 2 (θ_{CEE2}). We test if there is a justification for this approach—if the population coefficients were the same, we could pool both samples and get better estimates. Moreover, if $\theta_{CEE1} = \theta_{CEE2}$ indeed did hold, CEE countries would form a homogenous group with respect to long-run bond spread determinants. We perform the test separately for the period before and after the bankruptcy of Lehman Brothers.

We consider $H_0 : \theta_{CEE1} = \theta_{CEE2}$ against the alternative $H_a : \theta_{CEE1} \neq \theta_{CEE2}$ before the crisis, i.e. when $LB = 0$. We perform the test as follows. First, we estimate the model in 5.2 (1) pooling all CEE countries (except the Czech Republic). Logarithm of empirical likelihood of this model is $ln(L)_r = 26.70016$. Second, we include the variables $\theta \cdot CEE2$ into the previous model, i.e. we add eight variables. Logarithm of empirical likelihood of this model is $ln(L)_{ur} = 48.1060$. We then apply the likelihood-ratio test.

$$LR = 2(ln(L)_{ur} - ln(L)_r) = 2(48.10604 - 26.70016) = 42.81176 \tag{5.12}$$

We repeat the test for the second period. (Estimation of the model under H_0 was not feasible for technical reasons, so we perform the test on the period from January 2009 to January 2013—this should have a negligible impact on the p-value.)

$$LR = 2(ln(L)_{ur} - ln(L)_r) = 2(369.2986 - 358.4605) = 21.6726 \tag{5.13}$$

Under H_0, LR has asymptotically χ^2_8 distribution. The p-values of the two tests are 0.0000 and 0.0056, respectively. We reject H_0 and we conclude that the long-run bond spread determinants of CEE group 1 differed from those of CEE group 2 both before and during the crisis.

5.4.4 Has There Been a "Convergence" of Spread Determinants?

In the past, a lot of attention was paid to the process of economic convergence of new member countries and the rest of the EU. Is there a systematic difference between bond spread determinants in traditional EU countries and CEE? We have already showed that the two CEE subgroups differ in their spread determinants. For geographic and historical reasons, the CEE group 1 has more intensive economic relations with the traditional EU members. So if there really was a convergence of bond spread determinants, it should be traceable between the traditional EU members and CEE group 1. Let us denote θ_{TEU} the vector of long-run coefficients of the traditional EU members.

We test $H_0 : \theta_{CEE1} = \theta_{TEU}$ against the alternative $H_0 : \theta_{CEE1} \neq \theta_{TEU}$ (To make the test feasible, we do not include VIX^3, VIX^4, $LB{\cdot}VIX^3$, $LB{\cdot}VIX^4$ as long-run determinants, so the p-value is only approximate, as the model suffers from omitted variable bias. We believe this bias to be small, since excluding VIX^3 and VIX^4 from 5.4 has a negligible impact on the size and p-values of other coefficients.) The procedure is analogous to the one in subsection 5.4.3. Again, we perform the test for each period. Up to August 2008:

$$LR = 2(ln(L)_{ur} - ln(L)_r) = 2(-398.8232 - (-414.7428)) = 31.8392 \quad (5.14)$$

Estimation of the unrestricted model since September 2008 was for technical reasons not feasible, so we perform the test on a smaller data set, starting in January 2009.

$$LR = 2(ln(L)_{ur} - ln(L)_r) = 2(-501.9769 - (-515.5144)) = 27.075 \quad (5.15)$$

The p-values corresponding to likelihood ratios and χ^2_8 are 0.0001 and 0.0007, respectively. We reject the null hypothesis at the 1% significance level and we infer that the bond spread determinants of CEE group 1 differed from those of the traditional EU members, before and during the crisis.

5.5 Interpretation of Results

We found that the bond spread determinants between the three groups differed before the crisis. This result is in line with earlier findings of Bunda *et al.* (2009). We found that this difference is significant even after September of 2008. This heterogeneity can be attributable to the structural differences of economies within these groups.

We found strong evidence that September 2008 presents a change in the relationship between the fundamentals and spreads. However, a causal interpretation of this result is not straightforward. The financial crisis was probably one of the forces behind that, as the abrupt change in sovereign bond valuation in western Europe most likely had some impact on the CEE bond markets. At the same time, the new member countries had attracted a lot of foreign investment and had grown rapidly before the crisis. This means that the change may be partly attributable to higher level of economic development and different risk perception as a result.

Sings of statistically significant variables are reported concisely in table 5.8.

Note that the interpretation of estimates of coefficients is in the sense of the log-level model, so e.g. a 100% increase of spread means that the spread doubles.

5.5.1 Fiscal Variables

We did not find any evidence of the long-run *ceteris paribus* impact of budget balances on bond spreads. In general, bond market players seem to be interested in total levels of public debt rather than in current fiscal positions. This makes sense: public debt together with potential GDP growth and bond yield comprise the principal determinants of fiscal sustainability in the long-run. Even though budget balances determine public debt, they are subject to many local and short-term factors, which are possibly beyond understanding of many investors.

Before the crisis, when public debt rose by one percent, this was associated with an approximate increment of spread by: 11% in case of CEE group 1, 5% for CEE group 2, and 3% for the traditional EU members. During the crisis, the estimate for CEE group 1 remained practically the same, while no evidence of an impact of public debt on spreads of CEE group 2 has been found. The corresponding additional risk premium for the traditional EU members during the crisis has been about 1.5% higher than before the crisis. This confirms and earlier finding of von Hagen *et al.* (2011) that since the start of the crisis, investors demand higher risk premia for public debt.

5.5.2 GDP Growth

Before the crisis, there was no evidence of a systematic relation between real GDP growth and spreads for any of the three groups. Interestingly, the second period we studied provides evidence for a diminishing effect of higher output growth on spreads. When real GDP growth increases by one percent, then, everything else being the same, we would expect the spreads of CEE countries to decrease by about 8% and those of the traditional EU countries by about 20%. Although it may be tempting to claim that the impact of GDP growth on spreads only became apparent because of the crisis, the GDP growth became significant only at the 5 or 10 percent significance levels. The evidence in support of this claim is not strong enough to make a sound conclusion.

5.5.3 Inflation

The increasing effect of inflation on spreads was only significant for CEE group 1 and traditional EU members. When inflation goes one up 1%, the spread would be expected to rise by about 20% in CEE group 1 and by 13% in the traditional EU members.

5.5.4 Global Factors

We measured the external factors by the “fear index”, i.e. by the Chicago Board of Exchange Volatility Index. This variable was strongly significant in all models we considered. In contrast with Ebner (2009), Petrova *et al.* (2010) and Alexopoulou *et al.* (2010), we partly controlled for the non-linear relationship between the logarithm of spread and the volatility index by including its second power. For the typical values of the volatility index, an increase in the index is associated with higher spreads. (According to our estimates, e.g. for the CEE group 1 (see 5.5 (2)), spreads are an increasing function of the index for the values of the index lower than about 36.6, and decreasing for higher values. About 95% of observations of the volatility index were less than 36.6.)

5.5.5 Openness and Current Account Balance

Higher openness for CEE group 1 tended to decrease the risk premia in both studied periods. This means that the effect of higher external vulnerability associated with higher openness subdued to the effect of higher external competitiveness. In other words, the benefits of higher openness exceed its possible disadvantages. This result contrasts with the one for CEE group 2—higher openness is expected to increase bond spreads in this group of countries. It may be due to comparatively lower economic integration of the group into the EU economy and higher dependence on economic situation in the rest of the world.

Although bond markets penalize the traditional EU countries for running current account deficits by higher spreads, this finding does not apply to CEE. The relation between current account balance and spreads for the CEE group 1 could not be determined. Surprisingly, current account deficits lower bond spreads in CEE group 2 countries. It is not entirely clear why it is so; it may be a temporary anomaly, or there might also be some more complicated relationship between the current account balance, openness, spreads, and possibly even exchange rate, which is not captured in our model.

5.5.6 Comparison with Other Emerging Markets

Given the myriad of studies of emerging markets bond spreads, we provide comparison only with the most recent papers.

We found that the bond spread determinants differed across the two groups and that they changed after 2008. This result confirms earlier findings of Comelli (2012), who analyzed bond spreads of 28 emerging economies. In spite of working with only 13-year dataset, he found evidence that bond spread determinants indeed change in time. He attributed this variability to changes in investor's perception of the effect of fundamentals. Comelli (2012) used indexes of political and economic risk (similarly as Cihak & Mitra (2009)), so we cannot compare the effects of individual variables.

Hilscher & Nosbusch (2010) found an increasing effect of the volatility index VIX on bond spreads of a panel of 31 emerging economies. Similarly, higher debt to GDP ratio was associated with higher spreads. They also showed that trade and its volatility has a considerable impact on spreads. This is in line with our finding that current account balance as well as openness affect bond spreads.

The natural increasing effect of inflation on spreads of emerging economies holds, which was showed by Salman *et al.* (2010). Not surprisingly, they find that states which target inflation experience lower spreads.

Table 5.8: Effects of long-run spread determinants

variable	CEE group 1	CEE group 2	traditional EU members
Before the crisis (up to August 2008)			
public debt	+	+	+
budget balance			
GDP growth			
current acc. bal.			−
openness	−		
inflation	+		+
VIX	+	+	+
During/after the crisis (since September 2008)			
public debt	+		+
budget balance			
GDP growth	−	−	−
current acc. bal.		+	−
openness	−	+	
inflation	+		+
VIX	+	+	+

5.6 Robustness Checks

When we later estimated the models in 5.5, 5.6 and 5.7 with included long-term parameters VIX and VIX^2 on observations after December 2008, estimates of these two coefficient were close to estimates of coefficients of VIX and VIX^2 in 5.5, 5.6 and 5.7. Although we do not have any statistical evidence, this suggests that the population coefficients of these two variables were the same in both periods. This justifies the earlier assumption that the coefficients did not change.

5.6.1 Long-run Relationships

We test whether the speed of adjustment ϕ is equal to zero, i.e. $H_0 : \phi = 0$ against the one-sided alternative $H_a : \phi < 0$. Under the null hypothesis, there is no long-run relationship and it is not clear what do the estimators of long-run coefficients really estimate. Under the alternative, the estimators of the long-run coefficients estimate the long-run coefficients. The p-values of this test are in table 5.9. We reject the null hypothesis and we conclude that there exists a long-run relationship between spreads and other macroeconomic variables, as reported in 5.2, 5.3 and 5.4.

Table 5.9: Results of the tests of long-run relationships

model	$\hat{\phi}$	p-value
5.2 (2), CEE group 1	−0.3262	0.000
5.3 (2), CEE group 2	−0.2985	0.021
5.4 (2), traditional EU members	−0.3932	0.003

5.6.2 Consistency

There is no evidence that our PMG estimates are inconsistent. The null hypothesis of the Hausman test, under which the PMG estimates are consistent, cannot be rejected at any reasonable significance level (see table 5.10.)

5.6.3 Testing for Unit Roots

We apply the test developed by Levin *et al.* (2002). We test the null hypothesis that all panels contain unit roots against the alternative that all panels are stationary. This test requires strongly balanced panels, which is not our case, so we apply the test on the period from January 2000 to December 2010. Our dataset (26 countries and 132 periods) is large enough for this test. The

Table 5.10: Results of the Hausman test

model	statistic	value of statistic	p-value
5.2 (2), CEE group 1	χ^2_6	1.21	0.9764
5.3 (2), CEE group 2	χ^2_6	5.83	0.4413
5.4 (2), traditional EU members	χ^2_{10}	0.02	1.0000
5.5 (2), CEE group 1	χ^2_8	3.20	0.7831
5.6 (2), CEE group 2	χ^2_8	−9.34[1]	1.0000
5.7, traditional EU members	χ^2_{13}	12.04	0.5245

[1] For explanation, see 5.1.1.

Table 5.11: Results of unit-root tests

variable	p-value
public debt	0.6709
budget balance	0.0000
current account balance	0.0000
money market interest rates	0.0175
effective exchange rates	0.0090
inflation	0.0000
GDP growth	0.0809
openness	0.0000
VIX	0.0074

asymptotics of the test relies on $N/T \to 0$. When testing the unit-root of openness, we exclude Sweden, because this variables is for this country unavailable. Similarly for Latvia and debt interest payments. When testing for unit roots in market interest rates, only the period from 2002 to 2008 was used and Luxembourg was excluded. (Longer panel as well as data for Luxembourg were not available.) The p-values are in table 5.11. We conclude that the variables in question (except for possibly public debt to GDP ratio) are not unit root processes.

We also examine whether the volatility index is a sample path of a unit root process. Augmented Dickey-Fuller test (with 5 lags) on 212 observations (ranging from January 1995 to February 2013) leads to a rejection of the null hypothesis of a unit root at the 1% significance level.

Chapter 6

Conclusion

The crucial factor behind bond spreads is the expected probability of default. The probability of default is in turn a function of macroeconomic fundamentals. The widely used (standard) bond spread model which relates probability of sovereign default with bond spreads is very simple. It considers bonds with one-year maturity and without coupon payments only, it ignores the possibility of debt realignment and relies on the assumption that during the life span of a bond there is at most one default. Moreover, it does not take into account that the loss suffered by a bond holder depends on the time remaining to maturity.

We develop a bond spread model which relaxes the assumptions of the standard bond spread model, so it is more realistic. This alternative model can be, under certain conditions, reduced to the standard bond spread model. Consequently, when there is no need to estimate the probabilities of default, the standard bond spread model can be used to estimate the relationships between macroeconomic fundamentals and bond spreads, while relying on the less strict assumptions of the new model. But this new model could in principle also be used to obtain simple estimates of probabilities of default directly from observed spreads.

We identified two subgroups of CEE countries which can be characterized by similar bond spread determinants. The first group is formed by Lithuania, Poland, Slovakia and Slovenia. The countries in the second group are Bulgaria, Hungary, Latvia and Romania. For the Czech Republic, no long-run relationship between bond spreads and fundamentals has been found.

Higher level of public debt increased bond spreads of countries in the first group both before and during the crisis. The effect of public debt on spreads in the second group of countries was significant only before the crisis. Bond markets in CEE seem to put more weight on total level of public debt rather than on the budget deficits. Before the crisis, there was no evidence of a relationship between the growth of real output and spreads for any of the groups. During the crisis, higher growth of real output decreased bond spreads in both groups. Global factors, represented by global volatility index, had considerable impact on CEE bond spreads. Higher uncertainty on global financial markets increases bond spreads in CEE as well as in western Europe. Apart from that, we found significant effect of openness (defined as the sum of exports and imports over GDP), current account balance, and inflation. Finally, bond spread determinants of the two groups differ from those of a group of selected western European countries.

Nevertheless, some questions remain open, especially in the theory of bond spreads. The assumptions of the proposed bond spread model could be further relaxed, e.g. by allowing the a priori probability of default of a given bond to change in time. With regard to empirical research of bond spreads in the CEE region, the effect of the financial and debt crisis on non-EU members has not yet been studied; however, since bond yield data of non-EU members are in general not freely available, this would require access to private databases. In terms of the methodological approaches to modeling of bond spreads, a possible approach might be to let all or some coefficients be country-specific random variables, and estimate their densities. Non-parametric estimation of the effect of fundamentals on spreads would be innovative, since the fundamentals may have non-linear impact on spreads. The common assumption of linearity between fundamentals and logarithms of spreads should be tested.

Bibliography

11. Protocol on the convergence criteria: C 310/339 of Official Journal of the European Union, 16.12.2004.

Akitoby, B. & T. Stratmann (2008): "Fiscal policy and financial markets." *The Economic Journal* **118(533)**: pp. 1971–1985.

Alexopoulou, I., I. Bunda, & A. Ferrando (2010): "Determinants of government bond spreads in new eu countries." *Eastern European Economics* **48(5)**: pp. 5–37.

Bunda, I., A. J. Hamann, & S. Lall (2009): "Correlations in emerging market bonds: The role of local and global factors." *Emerging Markets Review* **10(2)**: pp. 67–96.

Cameron, A. & P. Trivedi (2009): *Microeconometrics using Stata.* College Station, Tex.: Stata Press.

Cihak, M. & S. Mitra (2009): "The financial crisis and european emerging economies." *Czech Journal of Economics and Finance (Finance a uver)* **59(6)**: pp. 541–553.

Codogno, L., C. Favero, & A. Missale (2003): "Yield spreads on emu government bonds." *Economic Policy* **18(37)**: pp. 503–532.

Comelli, F. (2012): "Emerging market sovereign bond spreads: Estimation and back-testing." *Emerging Markets Review* **13(4)**: pp. 598–625.

Danninger, S., I. Tytell, R. Balakrishnan, & S. Elekdag (2009): "The transmission of financial stress from advanced to emerging economies." *IMF Working Papers 09/133*, International Monetary Fund.

Ebner, A. (2009): "An empirical analysis on the determinants of cee government bond spreads." *Emerging Markets Review* **10(2)**: pp. 97–121.

Edwards, S. (1984): "Ldc foreign borrowing and default risk: An empirical investigation, 1976-80." *American Economic Review* **74(4)**: pp. 726–34.

Edwards, S. (1986): "The pricing of bonds and bank loans in international markets: An empirical analysis of developing countries' foreign borrowing." *European Economic Review* **30(3)**: pp. 565 – 589.

Eichengreen, B., A. K. Rose, C. Wyplosz, B. Dumas, & A. Weber (1995): "Exchange market mayhem: The antecedents and aftermath of speculative attacks." *Economic Policy* **10(21)**: pp. 249–312.

Everitt, B. S., S. Landau, M. Leese, & D. Stahl (2011): *Cluster Analysis*. London; New York: John Wiley and Sons Ltd, fifth edition.

Feder, G. & R. E. Just (1977): "A study of debt servicing capacity applying logit analysis." *Journal of Development Economics* **4(1)**: pp. 25–38.

Greene, W. H. (2003): *Econometric Analysis*. Upper Saddle River, NJ: Prentice Hall, 5. edition.

von Hagen, J., L. Schuknecht, & G. Wolswijk (2011): "Government bond risk premiums in the eu revisited: The impact of the financial crisis." *European Journal of Political Economy* **27(1)**: pp. 36 – 43.

Härdle, W. & L. Simar (2003): *Applied multivariate statistical analysis*. Springer Verlag.

Hausman, J. A. (1978): "Specification tests in econometrics." *Econometrica* **46(6)**: pp. 1251–71.

Hilscher, J. & Y. Nosbusch (2010): "Determinants of sovereign risk: Macroeconomic fundamentals and the pricing of sovereign debt." *Review of Finance* **14(2)**: pp. 235–262.

International Monetary Fund (2003): "Global financial stability report, september 2003: Market developments and issues." pp. 58–59.

JP Morgan (2000): "Introducing the J.P. Morgan Implied Default Probability Model: A Powerful Tool for Bond Valuation." pp. 1–11.

Laubach, T. (2009): "New evidence on the interest rate effects of budget deficits and debt." *Journal of the European Economic Association* **7(4)**: pp. 858–885.

Levin, A., C.-F. Lin, & C.-S. James Chu (2002): "Unit root tests in panel data: asymptotic and finite-sample properties." *Journal of Econometrics* **108(1)**: pp. 1–24.

Maltritz, D. (2012): "Determinants of sovereign yield spreads in the eurozone: a bayesian approach." *Journal of International Money and Finance* **31(3)**: pp. 657–672.

Nickel, C., P. C. Rother, & J. C. Rulke (2009): "Fiscal variables and bond spreads evidence from eastern european countries and turkey." *Working Paper Series 1101*, European Central Bank.

Nickell, S. J. (1981): "Biases in dynamic models with fixed effects." *Econometrica* **49(6)**: pp. 1417–26.

Pesaran, M. H., Y. Shin, & R. P. Smith (1999): "Pooled mean group estimation of dynamic heterogeneous panels." *Journal of the American Statistical Association* **94(446)**: pp. 621–634.

Pesaran, M. H. & R. Smith (1995): "Estimating long-run relationships from dynamic heterogeneous panels." *Journal of Econometrics* **68(1)**: pp. 79–113.

Petrova, I., M. Papaioannou, & D. Bellas (2010): "Determinants of emerging market sovereign bond spreads: Fundamentals vs financial stress." *IMF Working Papers 10/281*, International Monetary Fund.

Poghosyan, T. (2012): "Long-run and short-run determinants of sovereign bond yields in advanced economies." *IMF Working Papers 12/271*, International Monetary Fund.

Rudebusch, G. D. & E. T. Swanson (2012): "The bond premium in a dsge model with long-run real and nominal risks." *American Economic Journal: Macroeconomics* **4(1)**: pp. 105–43.

Salman, F., M. Chivakul, & R. Llaudes (2010): "The impact of the great recession on emerging markets." *IMF Working Papers 10/237*, International Monetary Fund.

Schreiber, S. (2008): "The hausman test statistic can be negative even asymptotically." *Journal of Economics and Statistics (Jahrbuecher fuer Nationaloekonomie und Statistik)* **228(4)**: pp. 394–405.

Treaty on the Functioning of the European Union: Consolidated version 2012, OJ C 326 of Official Journal of the European Union, 26.10.2012.

Appendix A

Content of Enclosed DVD

An enclosed DVD contains data in Stata and MS Excel formats and Stata commands.

- Folder 1: Data
- Folder 2: Stata commands

Appendix B

Additional Graphs

Graphs B.2 to B.9 contain monthly observations from January, quarterly observations from the first quarter, and yearly observations.

Figure B.1: Boxplots of spreads in CEE, by countries and years

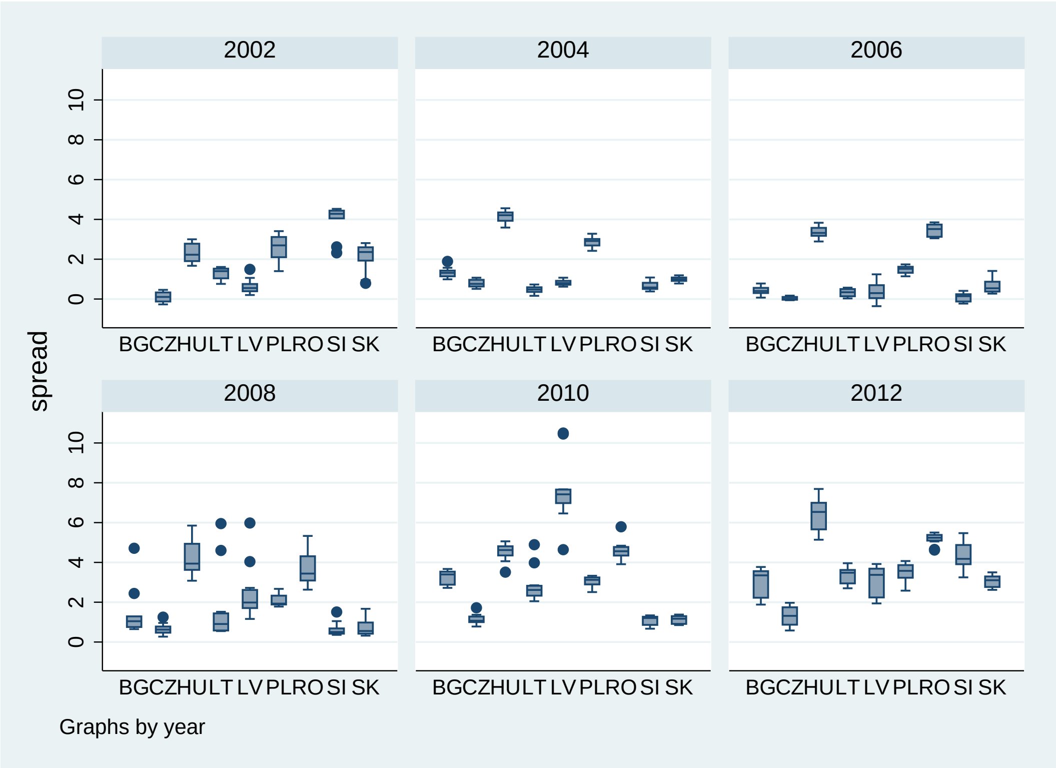


Figure B.2: Public debt and spreads in CEE

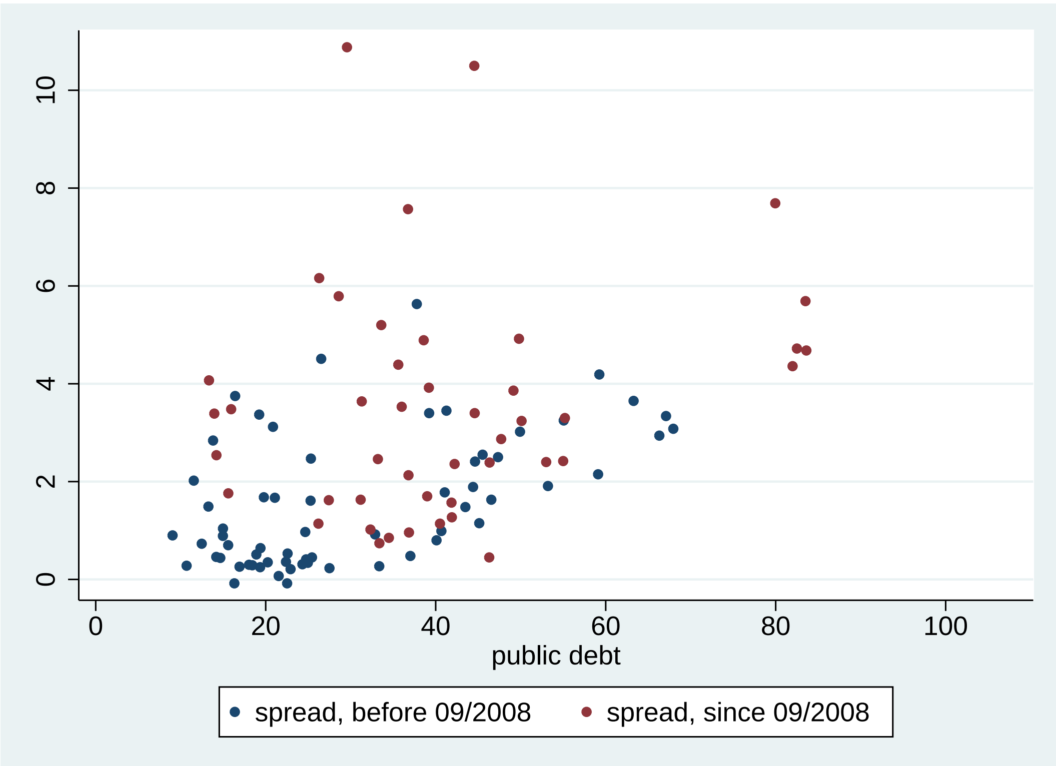


Figure B.3: Public debt and spreads in CEE, by countries

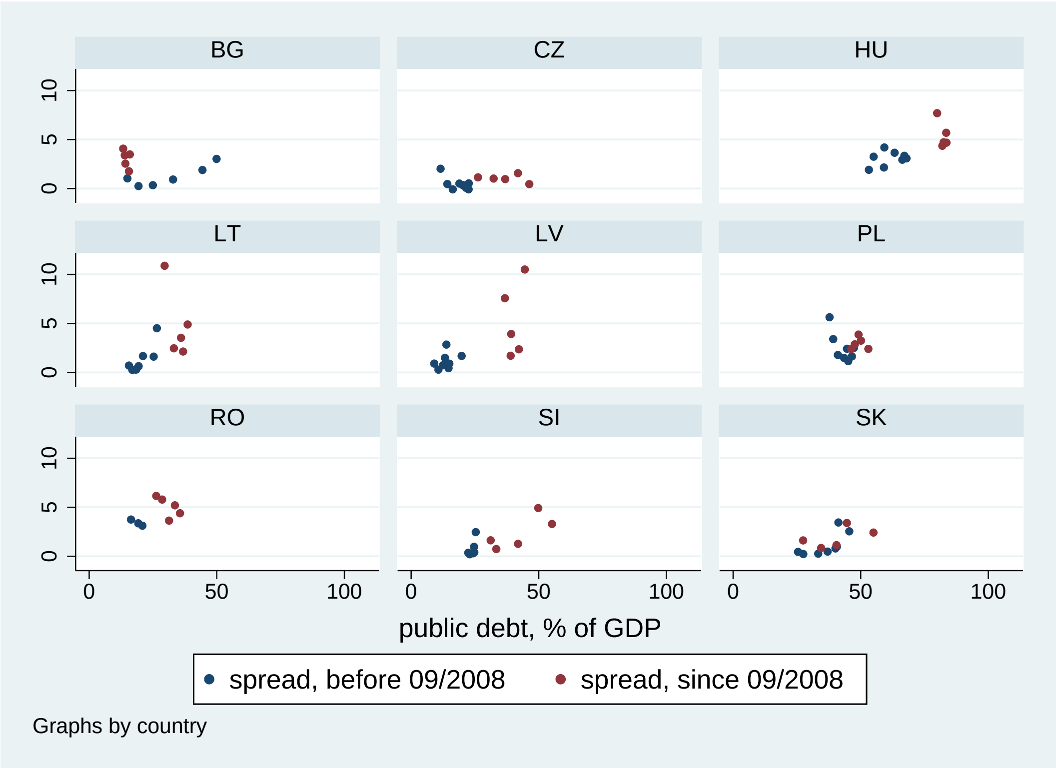


Figure B.4: Budget balance and spreads in CEE

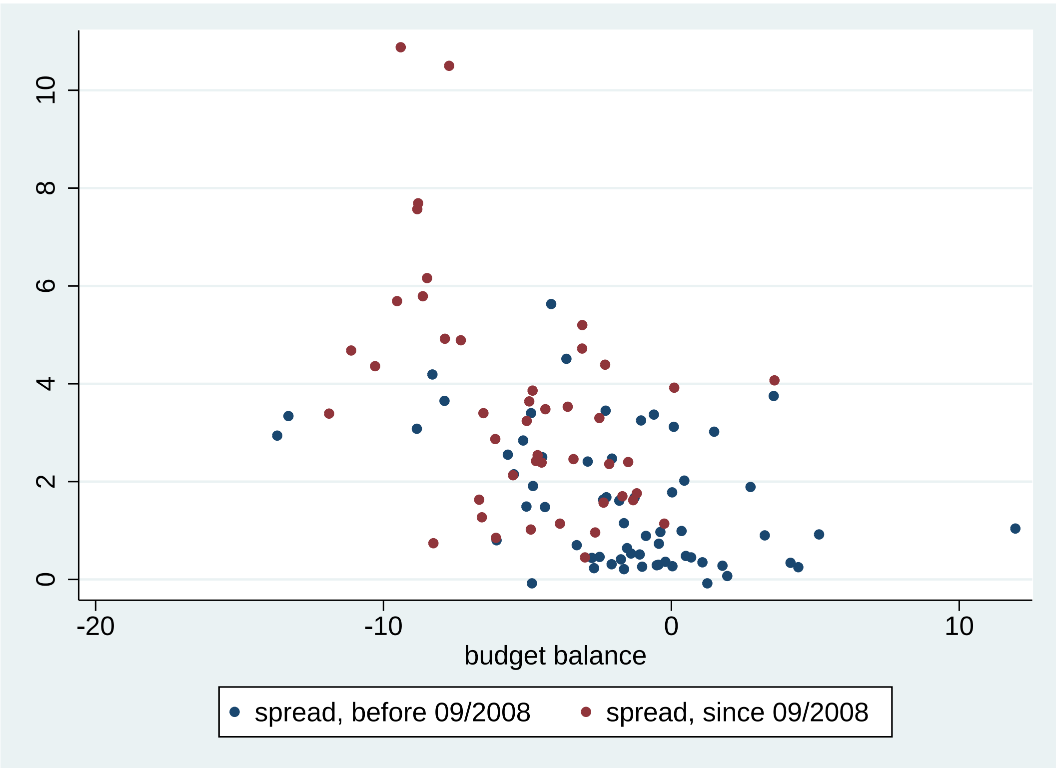


Figure B.5: Effective exchange rate and spreads in CEE

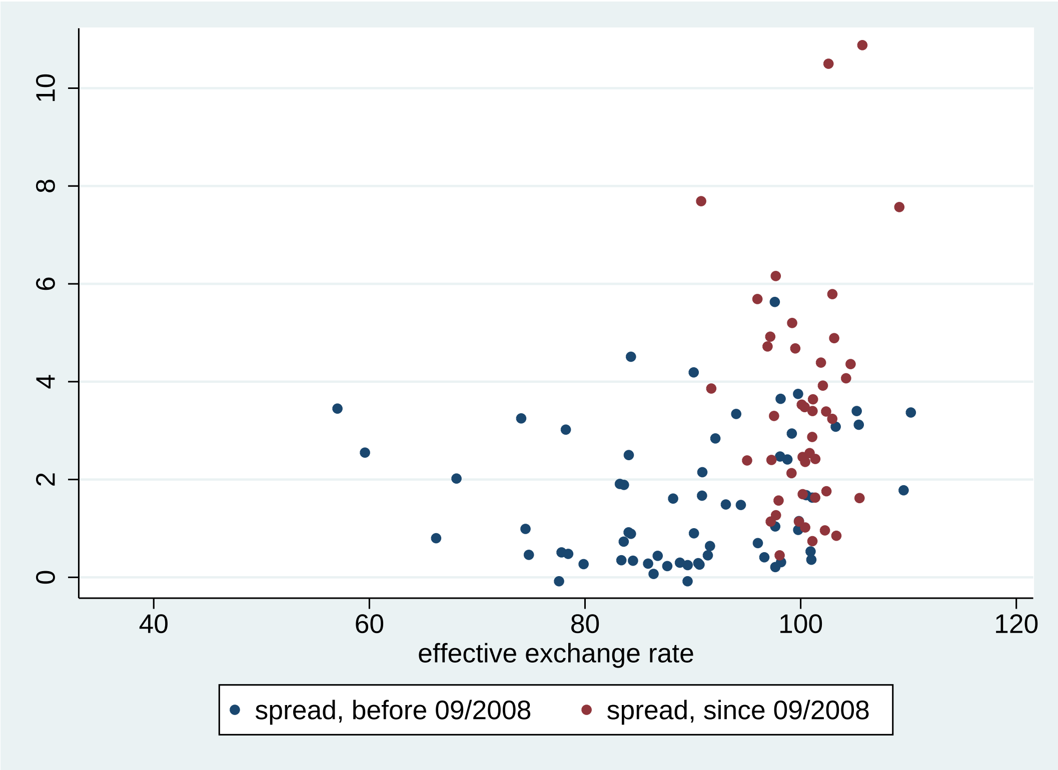


Figure B.6: Current account balance and spreads in CEE

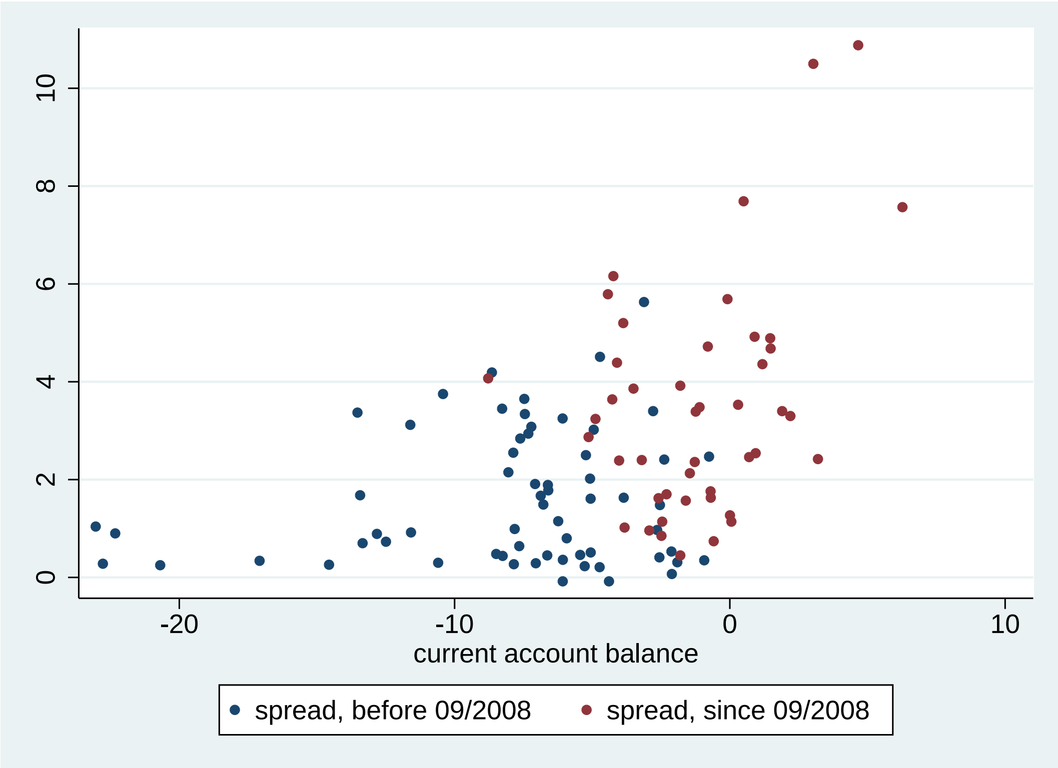


Figure B.7: GDP growth and spreads in CEE

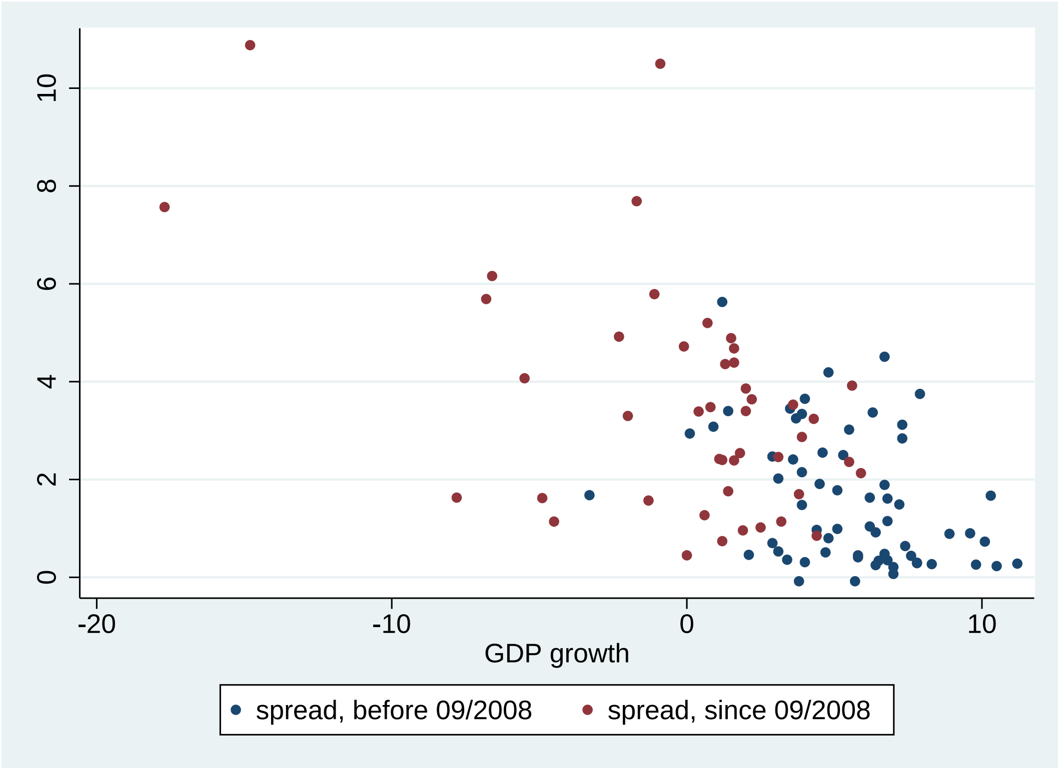


Figure B.8: Volatility index and spreads in CEE

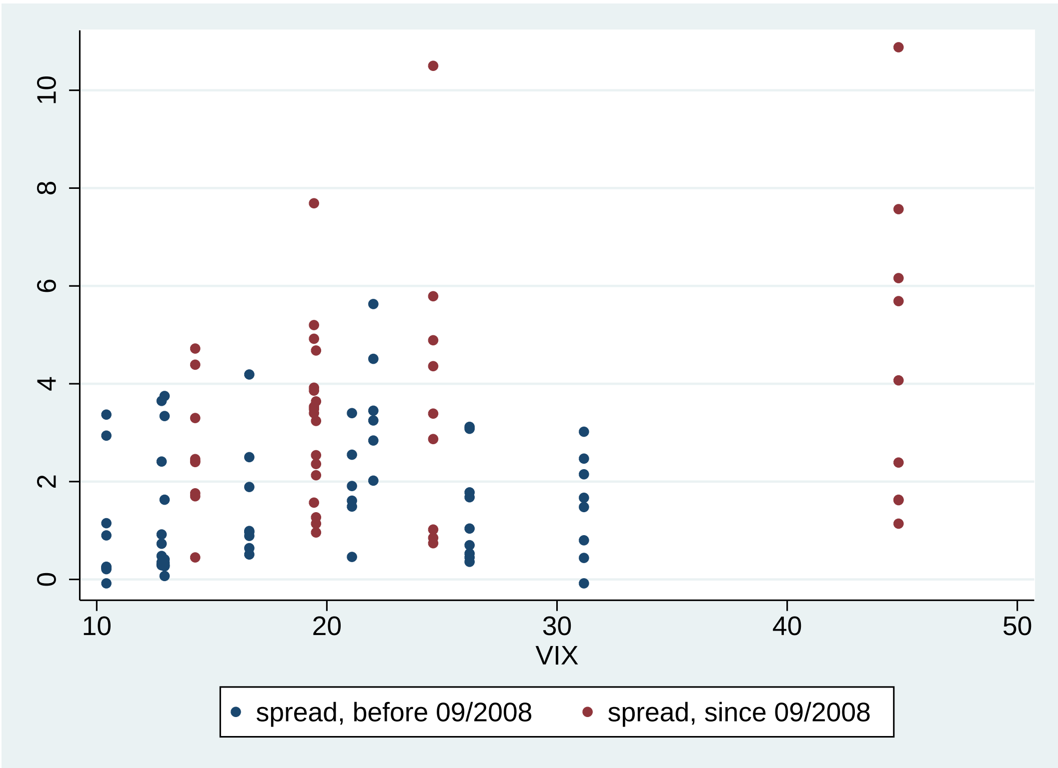


Figure B.9: Openness and spreads in CEE