The impact of redenomination risk in the European government bond market

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Abstract

This paper provides an empirical analysis of European sovereign yield spreads in times when these may be influenced by redenomination risk arising from the possibility that one or several countries may leave the EMU. To test for redenomination risk impact on yield spreads, I estimate one regression model with a country-specific euro break-up risk indicator and one regression model with an event-indicator assumed to display inter-European reduction in this risk through the intervention by the ECB. The results are robust to changes in liquidity, default risk, volatility and general risk-aversion and provides support for the hypothesis that yield spreads increase with redenomination risk in indebted economies and decrease with redenomination risk in competitive economies. The study however finds no significant short-term yield spread effects of ECB's intervention to reduce the risk of break-up of the EMU.

1 Introduction

Sovereign yield spreads – the difference between sovereign yields and the risk-free rate – reflect the risk premia required by investors to invest in sovereign bonds. The determinants of these risk premia have been the subject of numerous academic studies and most of these suggest that default risk, liquidity and general risk aversion are the most important causes of sovereign yield spreads.

However, the rise of the European sovereign debt crisis in 2009 has potentially introduced an additional determinant of sovereign yield spreads. As markets have started to doubt the integrity of the European Monetary Union (EMU), sovereign bond prices may have been influenced by redenomination risk. This risk refers to the probability that a sovereign issuer departs from the EMU and reintroduces its own national currency while redenominating its outstanding debt into this new currency. The existence of this probability suggests that sovereign bond prices may be influenced by hidden foreign exchange rate fluctuations.

If the theoretical future currency of a current EMU country is expected to depreciate against the euro, expected payoffs from holding bonds issued by this country will decrease with redenomination risk. By the same logic, an expected appreciation of the theoretical future currency of an economy implies that expected payoffs from holding its bonds increase with redenomination risk. The immediate implication of these effects is that yield spreads of bonds issued by the former category of countries should increase with redenomination risk, whereas an opposite relation should be evident for countries of the latter category.

In this paper, I add to the existing research on sovereign yield spreads by examining whether redenomination risk impacts European sovereign yield spreads. I do so by estimating two different panel regression models using data from 10 euro zone countries. The first regression tests for redenomination risk effects by incorporating an indicator of country-specific probability of departure from the EMU. The results from this study provide firm evidence that spreads of countries with high default risk are positively influenced by redenomination risk. The analysis also suggests that yield spreads of countries with low default risk may be negatively influenced by redenomination risk.

The second regression model serves to analyze whether yield spreads reacted to the European Central Bank's (ECB) announcement of its intervention in financial markets to reduce the risk of break-up of the EMU. If this event was unanticipated and perceived as a credible signal that the euro zone will remain in its current form, a distinct decrease in redenomination risk may have occurred around this event. The findings from my analysis however show no evidence of short-term market reactions to the announcement.

The remainder of this paper is organized as follows. Section 2 provides an overview of the main developments of the sovereign debt crisis and the origin of redenomination risk. Section 3 summarizes the main findings from previous research on sovereign yield spreads. A thorough description of the data set used in the study is given in section 4, whereas section 5 describes the econometric methodology that underpins the analysis. I report all empirical results in section 6 and provide an economic interpretation of these in section 7. Finally, I discuss potential limitations of my results in section 8, whereas section 9 concludes.

2 Overview of the European sovereign debt-crisis

2.1 Economic background

The EMU was agreed through the signing of the Maastricht Treaty in 1992 and its aim was to serve as the official currency of the European Union (EU). While the euro largely facilitated economic integration of the EU, it also prevented euro area countries from adjusting policy rates according to domestic needs. Instead, monetary policy management was centralized through its delegation to the ECB. By nature, this single monetary policy was unable to optimally influence each individual economy within the zone. As a result, European interest rates were likely set below optimal levels for some euro zone countries during the first years of the EMU (Powel, 2013).

Some of the peripheral countries of EU therefore borrowed extensively from abroad to support domestic consumption and investments. This fueled their economies and inflated their price levels. Large current account deficits and debt levels therefore arose in these countries and real exchange rates relative to the rest of the euro zone became misaligned. This implied currency overvaluation drove import growth in the peripheral countries which reduced their account balances even further. (Powel, 2013)

The global financial crisis arising from the collapse of the U.S. sub-prime market in 2007 became the trigger of the European sovereign debt crisis. The downturn in the global economy following the collapse of Lehman Brothers affected all European countries, although the highly indebted countries such as Greece, Portugal and Italy were hit particularly hard. This development gave rise to doubts regarding these countries' ability to service their debt obligations. In addition, Spain and Ireland which ran budget surpluses prior to the crisis, experienced collapsing housing markets which eliminated revenues from their construction sectors. Attempts by these countries to save their respective banking sectors damaged their sovereign credit reputations and by 2009, Greece, Ireland, Portugal, Spain and Italy suffered from severe current account deficits and capital outflows. (Whelan, 2013) While default of a European developed country was practically regarded as impossible prior to the crisis, this risk became highly evident in the late 2000's.

In early 2010, the public finances of Greece became unsustainable. Despite plenty of prior reassurances by European policy makers that Greece would neither default on its debt nor be bailed out, Greek rescue loans were provided by the International Monetary Fund (IMF) and EU in March 2010. In the following months, a fully formed bailout fund for the euro area, known as the European Financial Stability Facility (EFSF) was put in place. By late 2010 Ireland also applied for an EU-IMF bailout and Portugal followed suit in May 2011. Also, Spain and Cyprus later received external rescue loans. In 2011, a 30% haircut of Greek debt was agreed, which in effect meant the first credit event of a European sovereign issuer in the post-war era (Whelan, 2013).

2.2 Sovereign debt markets during the crisis

Through the introduction of the euro, sovereign yields in the euro area converged and the spreads between them were nearly eliminated during the first years of the euro. Despite differences in fiscal factors within the euro zone, markets appeared to price sovereign debt more or less homogeneously. Default risk premia were almost zero and were almost unaffected by sovereign debt levels (Whelan, 2013).

Markets however changed rapidly at the rise of the sovereign debt crisis in 2009. Yield spreads between countries increased dramatically, and some sovereigns saw yields on their debt rise substantially due to default risk. Portuguese and Irish CDS spreads rose well above 1000 basis points, whereas Italian and Spanish CDS spreads exceeded 600 basis points, suggesting substantial default probabilities of the indebted euro zone countries. According to Bloomberg, CDS spreads for Greek debt was observed above 6000 basis points at the time of its default.

In the stronger economies, yields eventually went in the opposite direction. Short yields in Germany, Netherlands, Finland, Belgium, Austria and France were traded close to zero in 2011, and some yields even fell substantially below zero in 2011 and 2012. These observations may partly be explained by investors' flights to quality giving rise to strong demand for assets with low risk. The probability of a break-up of the euro and an expected appreciation of these countries' theoretical future currencies may be another (a further discussion of this mechanism is given below).

Observed yield curves for 10 European countries in November 2003 and November 2011 are illustrated in figure 1 which clearly shows similar yield curves for all 10 countries in 2003 and widely dispersed yield curves in 2011.

2.3 The rise of euro break-up risk

To regain competitiveness in the global economy, an indebted country with a floating exchange rate can rely on external devaluation of its currency. In effect, this implies that the economy would lower its export costs on the global market without suffering from declining domestic demand. An alternative way out of a crisis would be internal devaluation, which involves domestic reduction in wages to reduce export costs. The

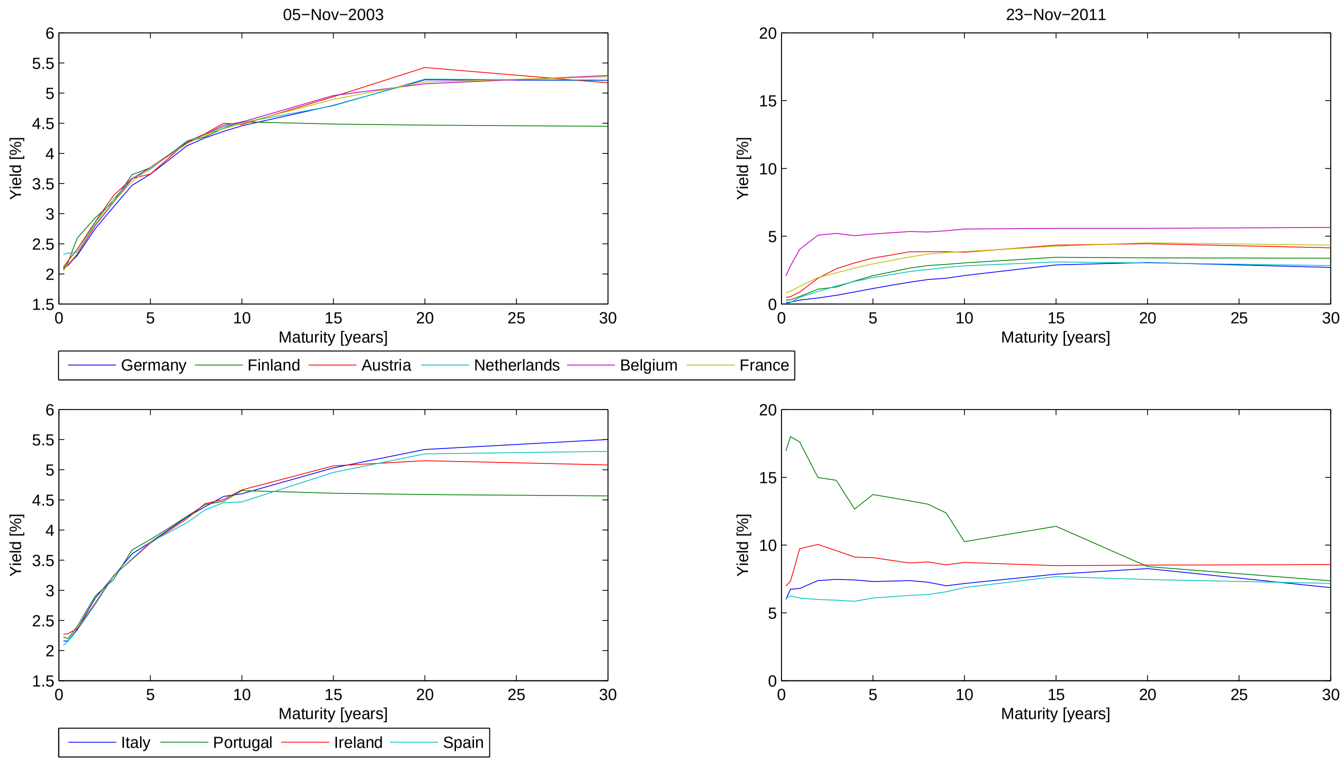

Figure 1: Observed yield curves for 10 euro zone countries. The left-most plots show yield curves in November 2003, whereas the right-most plots show observed yield curves during the crisis. The two upper plots show yield curves in Germany, Finland, Austria, Netherlands, Belgium and France, whereas the lower plots show yield curves in Italy, Ireland, Portugal and Spain.

drawback of this option is that it typically comes with a domestic recession, and is therefore an inefficient and painful way out of a crisis (Powel, 2013).

As long as the EMU prevails in its current form, external devaluation is unavailable to indebted euro countries, since these are bound to the exchange rate valuation prevailing in the whole euro area. These countries may therefore rely on internal devaluation to regain competitiveness. An alternative solution would be to simply depart from the EMU and reintroduce their own national currencies. This has given rise to speculations of a partial break-down of the euro zone, as indebted economies may simply choose or be required to leave it.

A second feasible scenario is that one or several core countries, such as Germany, would choose to abandon the euro due to the costs incurred from bailing out the indebted economies. An alternative reason for any of the vital economies to exit the EMU would be to prevent domestic inflation as price stability policy conducted by the ECB may become too relaxed. Hence, a partial disentanglement of the currency union may arise as core economies may choose to leave.

Economists have also pointed towards a possibility of a complete euro collapse. It is a common belief that this would occur if Italy, or any other core euro zone country, would default on its debt. Such an event would likely leave the banking sector insolvent and leave the ECB incapable of providing liquidity to it. Economists speculate that this scenario would lead to a complete break-down of the euro system, in which case the euro would simply seize to exist (Nordvig and Firoozye, 2012). All current EMU countries would then be required to re-introduce individual national currencies.

Although speculations regarding a complete or partial abandonment of the EMU are so far purely hypothetical, this risk has been increasingly discussed by media, investors and policy makers. For instance, at least four cover illustrations of the *Economist* in 2010 and 2011 referred to the risk of euro break-up (The Economist, 2010a,b, 2011a,b). Also, a poll among 80 central bank reserve managers conducted in 2012 suggested that these viewed a break-up of the euro as the greatest risk to the global economy (Di Cesare et al, 2012). Moreover, Nobel prize awarded Paul

Krugman has repeatedly speculated regarding the abandonment of the euro through his columns in *The New York Times* (Krugman, 2011a,b) Moreover, the president of the ECB explicitly addressed this issue during his speech on the Global Investment Conference in London in 2012, as he claimed that:

> *"the premia that are being charged on sovereign states borrowings* [...] *have to do more and more with* [...] *the risk convertibility"*

referring to markets' doubts of the survival of the euro (Draghi, 2012).

2.4 The legal and economic aspects of re-denomination risk

At foundation of the EMU, policy makers wanted the euro adoption to be irreversible. Therefore, none of the treaties defining the rules and regulation framework of the EMU contain any specific guidelines regarding a departure by one or several countries from the union (Powel, 2013). As a result, the legal consequences of a euro break-up are largely unknown and there is a great deal of uncertainty regarding the future denomination of Euro-traded assets in a hypothetical post break-up era (Nordvig and Firoozye, 2012).

However, a legal principle known as *Lex Monetae* may provide guidance in this respect. This well-established principle has a large amount of case law and specifies that sovereign nations have the internationally recognized right to determine their legal currency. Nordvig and Firoozye (2012) argue that this principle implies that debt obligations governed by local law of a euro zone country are likely to be converted into the new national currency if the country exits the EMU. As a result, the value of sovereign bonds issued by such countries may be influenced by the implied redenomination risk arising from euro break-up risk.

Due to the misalignment in real exchange rates, the indebted peripheral economies of EU are expected to see their new national currencies depreciate relative to the euro in the hypothetical scenario that these countries would leave the EMU. The value of redenominated outstanding bonds issued by such countries would therefore decline from the perspective of a foreign investor. In contrast, the hypothetical newly introduced national currencies in the wealthier European economies may appreciate relative to the euro, as a result of their stronger fiscal positions. Therefore, to a foreign investor, outstanding bonds issued by these countries may increase in value compared to if they remain euro denominated.

If these effects are present and markets perceive them, bond prices and thereby bond yields should be influenced by euro break-up risk. In particular, an increase in break-up risk should decrease (increase) prices (yields) of sovereign bonds issued by the indebted economies facing a potential depreciation. The opposite effect should be evident for bonds issued by the competitive economies. This mechanism may therefore explain the existence of negative interest rates observed in the competitive economies and may also have contributed to the increasing yields in indebted countries.

2.5 The role of the European Central Bank

Throughout the crisis, the ECB intervened in financial markets in several ways. Firstly, it provided liquidity to the banking-sector, which was severely strapped at this time. This was mainly implemented through engaging in two three-year longer-term refinancing operations (LTRO) in December 2011 and February 2012 (Powel, 2013).

Secondly, the ECB committed to purchasing sovereign bonds in secondary markets. This was first done through the Securities Markets program (SMP) announced in 2010 to supplement the EFSF before it was fully operational (Whelan, 2013). The SMP was later replaced by the Outright Monetary Transactions (OMT) program, announced in September 2012 following several statements by the ECB addressing its commitment to saving the Euro.

The first of these was provided by Draghi (2012), in a speech at the Global Investment Conference in London, where he explicitly announced that

> *"...the ECB is ready to do whatever it takes to preserve the Euro. And believe me, it will be enough".*

This speech has rendered a great deal of attention and it is commonly referred to as the *whatever-it-takes speech.*

The second statement in the summer of 2012 indicating ECB's determination to defend the euro was announced on September 2nd, 2012 during a press conference, where Draghi noted that:

> *"…exceptionally high risk premia are observed in government bond prices in several countries and financial fragmentation hinders the effective working of monetary policy. Risk premia that are related to fears of the reversibility of the euro are unacceptable, and they need to be addressed in a fundamental manner. The euro is irreversible."*

During the same press conference, the president also indicated that ECB considered undertaking non-standard monetary policy measures to repair monetary policy transmission mechanisms (The European Central Bank, 2012a).

On September 6th, the ECB finally revealed the technical details regarding the OMT program, which allowed ECB to purchase sovereign bonds in the secondary market to safeguard appropriate monetary policy transmission and the singleness of the monetary policy. The transactions were intended to focus on maturities between one and three years and the additional liquidity generated by them would be fully sterilized. In contrast to the SMP program, the OMT had no pre-set quantitative limits (The European Central Bank, 2012b).

3 Literature review

This section provides an overview of previous research on sovereign yield spreads. Studies conducted so far mainly focus on the effects of default risk, liquidity and risk aversion. In addition, the reaction of European sovereign spreads to the introduction of the EMU as well as crisis has been the topic of several recent papers. I provide an overview of each of these categories below as well as a description of my contribution to the existing literature.

3.1 Default risk impact on yield spreads

A number of studies focus explicitly on the portion of yield spreads arising from sovereign credit risk, i.e. the probability that the sovereign issuer might not be able to fully service its debt obligations. An important contribution in this respect is provided by Duffie et al (2003) who develop a model for pricing sovereign debt by considering the risks of default or restructuring events. The performance of this model is validated by estimating it on Russian dollar-denominated sovereign bonds.

A large branch of the credit default literature analyzes how sovereign risk premia are related to fiscal balance and public debt. Balassone et al (2004) estimate the impact of debt-to-GDP ratios on sovereign yield spreads relative to German government yields for EU countries in the period 1980-2003 and find a positive relation. The yield data used in the study is however derived from issues in national currencies and hence credit risk effects cannot be separated from exchange rate effects.

Lonning (2000) addresses this problem by considering observed bond issues in deutschemark for 11 EU countries. The implied elimination of exchange rate effects enables valid comparison of yields and the study finds some evidence of a positive relation between spreads and government debt and deficits. Instead, Gomez-Puig (2008) eliminates exchange rate effects in European yield spreads relative to the German government yield by using swap rate adjustments.

Several studies overcome exchange rate effects by analyzing yield spreads in common-currency areas. Bayoumi et al (1995) and Poterba and Reuben (1997) provide evidence that yield spreads of bonds issued by U.S. states relative to the New Jersey yield are positively correlated with state debt. In addition, Booth et al (2007) find that yield spreads of Canadian provinces increase with provincial debt.

Perhaps the most clear-cut example of a common-currency area is the EMU, and several studies address sovereign yield spreads in Europe after the adoption of the euro. Codogno et al (2003) examine the yield differentials between EMU member states during the early years of the EMU. Their study finds that default risk, proxied by debt-to-GDP ratios, explains a small but significant portion of yield spreads. However, variations in yield spreads are to a large extent explained by movements in international risk factors measured as U.S. swap and corporate bond spreads relative to US Treasury yields. These factors are interpreted as indicators of general risk aversion in global financial markets and yield spread increases may be driven by this risk. Evidence of such effects are also reported by Dungey et al (2000), Favero et al (2005), Sgherri and Zoli (2009) and Bernoth et al (2012).

3.2 Impact of liquidity

Previous research also focuses on the impact of liquidity which is a direct measure of investors' possibility to quickly and cheaply exit positions in traded assets. It is therefore assumed to have significant impact on the price of any security. The idea is that investors should require discounts on less liquid assets in order to be compensated for the higher costs of trading them. An early piece of work in this field is provided by Amihud and Mendelson (1986) who argues that liquidity has significant impact on security prices. A similar conclusion is provided by Chordia et al (2000). While few studies argue against this conclusion, the current academic discussion is mainly focused around whether the current level of liquidity, future liquidity or both impact prices.

Longstaff (2004) studies the impact of liquidity in U.S. Treasury bond prices. In particular, this study examines the premium caused by investors' flight to more liquid securities and finds that this may amount to more than 15% of the value of some Treasury bonds. A further conclusion is provided by Goldreich et al (2005) who compare the impact of current and future liquidity on U.S. Treasury notes and find that the premium paid for more liquid bonds is mainly driven by future liquidity.

A recent paper studying the joint effects of liquidity and credit-quality on yield spreads is provided by Beber et al (2009). This analysis focuses on euro area sovereign yield spreads and finds that a majority of yield spreads are explained by default risk, although liquidity appears more important in times of market stress. Furthermore, the destination of capital flows in such episodes is almost exclusively determined by liquidity. In contrast to most papers on sovereign yield spreads which use fiscal balance or indicators of debt to proxy for default risk, Beber et al (2009) instead use the information contained in CDS spreads.

3.3 Impact of the financial crisis

The reaction of sovereign yields to financial crisis has been addressed by a number of studies. Haugh et al (2009) examine European sovereign yield spreads in the euro zone in the period 2005-2009 using German yields as benchmark and find that future deficits and debt-service ratios explain a large portion of yield spread variations. The impact of these variables is particularly evident if interacted with international risk aversion, suggesting that the financial crisis has given rise to greater impact of fiscal factors on European sovereign yield spreads.

Similarly, Barrios et al (2009) study intra-European government bond spreads in the period 2003-2009 and comment on the impact of the financial crisis on yield spreads. They suggest that sovereign yields are affected by country-specific liquidity and credit quality, in particular after the onset of the crisis. Sgherri and Zoli (2009) show that the worsening of fiscal balance in some euro zone countries has given rise to yield spread increases in the whole euro area, although particularly pronounced in the indebted economies.

Bernoth et al (2012) investigate sovereign bond yield differentials derived from the primary sovereign bond market in the period 1993-2009. The authors find that debt and deficit levels have significant impact on yield levels prior to the EMU, although these affects are almost completely eliminated after the introduction of the EMU. The rise of the sovereign debt crisis however has reversed this effect, and the study suggests a significant and positive relationship between spreads and deficits as well as debt levels respectively during the crisis years. Furthermore, it is found that the impact of international risk aversion on European spreads has become significantly positive after the onset of the crisis.

3.4 Contribution to research

In conclusion, research conducted so far provides evidence that sovereign yield spreads tend to be driven by sovereign default risk, liquidity factors and risk-aversion.

As for yield spreads in Europe, it appears that the introduction of the EMU greatly reduced these effects and nearly eliminated spreads between EMU government yields. Through the rise of the sovereign government debt crisis however, sovereign debt markets appear to have become increasingly fragmented.

I contribute to existing research by analyzing whether this fragmentation can be attributed to redenomination risk. While the existence of a single European currency should eliminate exchange rate effects in yield spread data, doubts about the persistence of the common-currency area may effectively reintroduce these to financial markets. I study these effects by incorporating country-specific indicators of EMU departure probabilities as well as an event indicator assumed to indicate inter-European reduction in euro break-up risk.

4 Data

4.1 Sovereign yields

I use daily observations of sovereign 1-year, 5-year and 10-year zero coupon bid and ask yields for 10 euro zone countries.[1] The dataset is downloaded from the Bloomberg platform and includes daily closing quotes from March 2009 through February 2014, equivalent to 1211 observation dates and 12110 observations in total for all 10 countries. As a proxy for the true market yield at each point in time, I use the mid yield equivalent to the average between ask and bid yields. The mid yield with maturity τ for country i at time t is thus calculated as

$$y_t^{i,\tau} = \frac{b_t^{i,\tau} + a_t^{i,\tau}}{2}$$

where $a_t^{i,\tau}$ and $b_t^{i,\tau}$ are the ask and bid yields with maturity τ for country i at time t. Mid yields are plotted in figure 7.

[1] The countries included in the study are Germany, Finland, Austria, Netherlands, Belgium, France, Italy, Portugal, Ireland and Spain.

4.2 Yield spreads

To construct the yield spread for each country, I use the EONIA overnight indexed swap rate (OIS) as a proxy for the risk-free benchmark rate. The index is downloaded from the Bloomberg system and displays average swap rates on the interbank market quoted by a set of representative banks with high credit-ratings and strong reputation. This choice of benchmark rate is similar to Beber et al (2009) but distinct from e.g. Haugh et al (2009) who use the German sovereign yield as proxy for the risk-free rate. While the latter alternative offers the advantage of high comparability with other sovereign yields, it nevertheless excludes the possibility to study the German sovereign yield spread explicitly. Hence, I use the EONIA swap indices to proxy for risk-free rates.

The yield spread with maturity τ for country i at time t is calculated as

$$s_t^{i,\tau} = y_t^{i,\tau} - OIS_t^\tau$$

where OIS_t^τ is the OIS rate with maturity τ observed at time t. The full data set of yield spreads is illustrated in figure 2 and summary statistics for daily first differences $\Delta s_t^{i,\tau} = s_t^{i,\tau} - s_{t-1}^{i,\tau}$ are provided in table 1.

Table 1: Sample mean, sample standard deviation as well as maximal and minimal observed values of daily first differences in sovereign yield spreads with maturities of 1 year, 5 year and 10 year for 10 euro area countries in the period March 2009-February 2014.

	Mean			Stdandard dev.			Max			Min		
	1Y	5Y	10Y	1Y	5Y	10Y	1Y	5Y	10Y	1Y	5Y	10Y
GER	0.00	0.00	0.00	0.03	0.05	0.05	0.16	0.18	0.21	-0.17	-0.19	-0.25
FIN	0.00	0.00	0.00	0.04	0.05	0.05	0.39	0.23	0.42	-0.37	-0.21	-0.45
AUS	0.00	0.00	0.00	0.04	0.05	0.05	0.31	0.32	0.27	-0.24	-0.39	-0.22
NL	0.00	0.00	0.00	0.03	0.05	0.05	0.14	0.23	0.21	-0.15	-0.18	-0.24
BEL	0.00	0.00	0.00	0.06	0.07	0.06	1.13	0.46	0.40	-0.72	-0.51	-0.35
FRA	0.00	0.00	0.00	0.03	0.05	0.05	0.20	0.29	0.22	-0.14	-0.29	-0.22
ITA	0.00	0.00	0.00	0.13	0.12	0.09	1.67	0.77	0.53	-1.34	-0.83	-0.63
POR	0.00	0.00	0.00	0.42	0.28	0.17	4.65	3.02	1.53	-2.28	-2.21	-1.59
IR	0.00	0.00	0.00	0.25	0.16	0.12	1.74	1.31	1.13	-2.90	-1.32	-1.13
SPA	0.00	0.00	0.00	0.12	0.11	0.10	0.75	0.63	0.56	-1.06	-0.84	-0.68

As shown in table 1, means of spread innovations are virtually zero for all countries

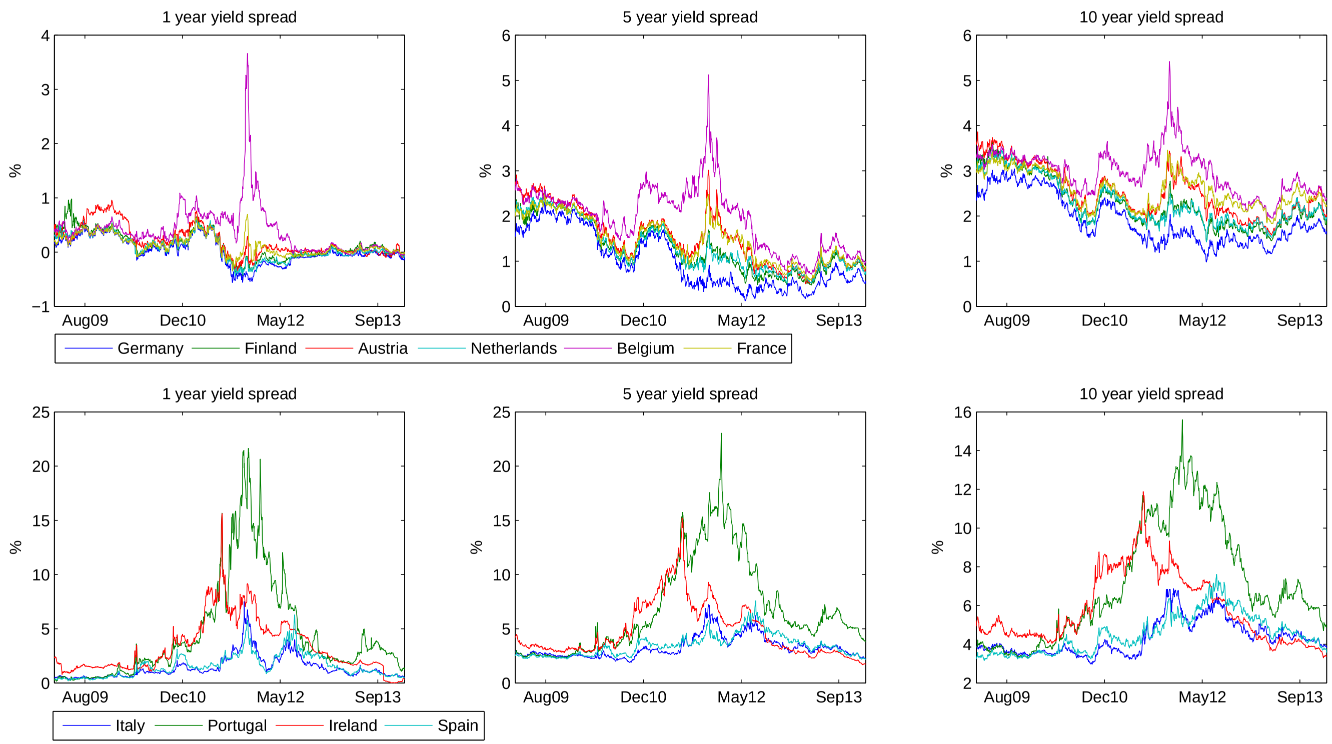

Figure 2: Observed daily sovereign 1-year, 5-year and 10-year yield spreads from March 2009 to February 2014. The upper panel displays yield spreads for Germany, Austria, Netherlands, Finland, Belgium and France and the lower panel shows corresponding observations for Italy, Spain, Portugal and Ireland.

in the sample, whereas standard deviations differ dramatically between groups. It appears that countries associated with high debt-levels demonstrate more volatility in spread innovations than the remaining sample. Portuguese, Italian, Irish and Spanish yield innovations display standard deviations in the range 0.09-0.42 percentage points, whereas corresponding values for the remaining samples are in the range 0.03-0.07 percentage points. The largest single daily drop of -2.90 percentage points is reported for the Irish 1-year spread on July 22nd, 2011. The largest daily increase amounts to 4.65 percentage points and is reported for the Portuguese 1-year spread on November 25th, 2011.

4.3 Euro break-up risk indicators

To test for evidence of redenomination risk in the data, I use two variables assumed to provide relevant information regarding this probability. As a country-specific indicator, I use the euro break-up probability index (EBI) provided by Sentix. The index is quoted separately for all euro zone countries and aims at reflecting financial markets' view on the probability that each country will leave the EMU within the next year. It is based on monthly surveys involving more than 2700 private and institutional investors, and is updated on a monthly basis. The data set used in this paper includes monthly observations from June 2012 (when the EBI was introduced) until January 2014, equivalent to 21 observations dates and 210 observations in total for all 10 countries. The index is illustrated in figure 3.

The second indicator assumed to provide useful information regarding break-up risk is the introduction of the OMT program by the ECB in the summer of 2012. As this intervention aimed at reducing the risk of reversibility of the euro, its announcement provides a natural experiment which can be used to test for break-up risk impact on yield spread data. Provided that the announcement of the program was unexpected and received as a credible signal that the ECB was willing to save the Euro at any cost, this event should have resulted in a systematic decrease in euro break-up probability for all member countries. Thus, if yields were affected by this factor prior to the announcement of the OMT, a reversal from this condition

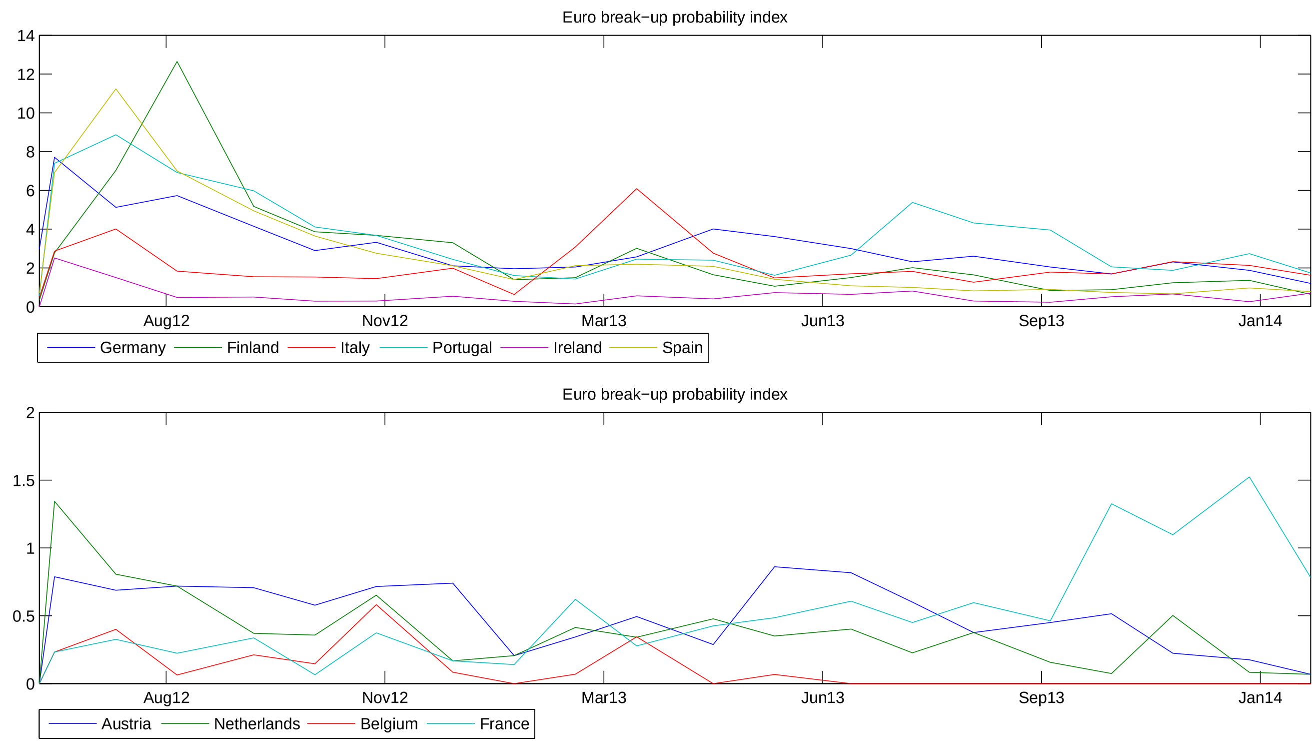

Figure 3: The Euro break-up risk index (EBI) provided by Sentix. The index is quoted separately for all euro zone countries and aims at reflecting financial markets' view on the probability that each country will leave the EMU within the next year.

should be evident in the data.

To study the effects of the OMT introduction, I define an event window which includes the three announcements by the ECB related to the OMT program described in section 2. The first is the delivery of the *whatever-it-takes-speech* by Mario Draghi on July 26th, 2012, which may be interpreted as a first indication of ECB's commitment to saving the euro. The second important development is the announcement that the ECB would undertake a bond purchasing program in some form. This information was delivered to the market on August 2nd, 2012. The third important communication around the OMT program took place on September 6th, 2012, as the ECB announced all technical details regarding the program (see section 2). Given the successive uncovering of information regarding ECB's intervention plans, markets may have perceived this information gradually between July 26th, 2012 and September 6th, 2012.

I therefore define an event window starting July 26th, 2012 and ending on September 13th, 2012, equivalent to an event window size of 35 observation dates and 350 observations in total. The ending date is set to include one week of trading days after the third communication around the OMT, to capture potential gradual absorption of this information by markets.

In order to study how variables are affected by the event through linear regressions, I define the event indicator as

$$I_t^{OMT} = \begin{cases} 1, & \text{if } t_1 \leq t \leq t_2, \\ 0, & \text{otherwise} \end{cases}$$

where t_1 denotes July 26th, 2012 and t_2 denotes September 13th, 2012. Yield spreads and the during the event window are illustrated in figure 4.

In order to validate whether I_{OMT} indicates a reduction in Euro break-up risk, I consider the absolute change in the EBI index for each country over the period. The left column of table 2 summarizes the change in the EBI between July 27th, 2012 and September 28th, 2012, which closely matches the starting and ending dates of the event window. As can be seen in table 2, the EBI indicator declines for five out

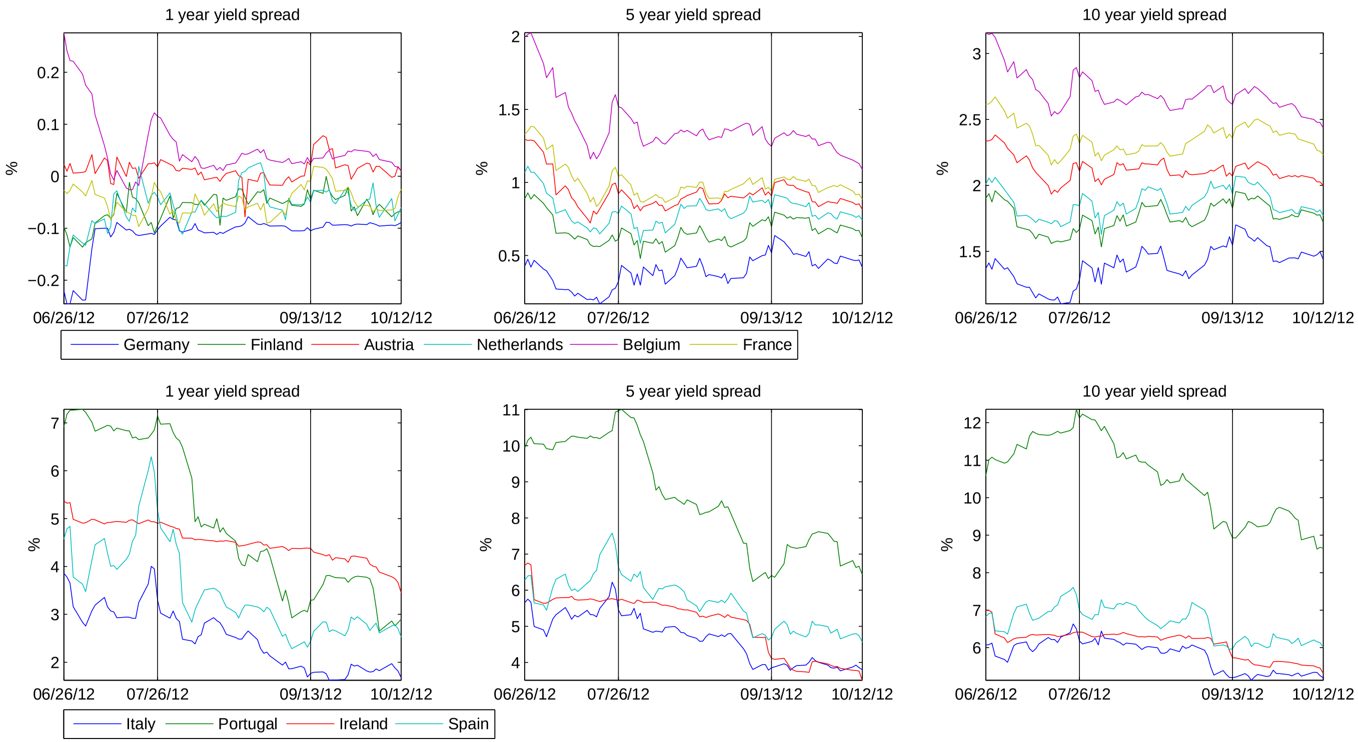

Figure 4: Observed daily sovereign 1-year, 5-year and 10-year yield spreads in 2012. The vertical lines indicate July 26th, 2012 and September 13th, 2012 respectively. In the period between these dates, the European Central Bank (ECB) announced its intention to intervene in secondary bond markets to reduce the risk of break-up of the EMU.

of 10 countries throughout the period. Whether ECB's commitment to saving the euro generated decrease in its collapse risk hence remains inconclusive.

Table 2: EBI and yield spread development between July 26th, 2012 and September 13th, 2012.

	EBI	1 year spread	5 year spread	10 year spread
Germany	-4.1613	0.038	0.324	0.3465
Finland	-3.2199	0.052	0.128	0.3875
Austria	-0.1109	0.016	0.0585	0.0255
Netherlands	-0.8851	0.05325	0.039	0.117
Belgium	0.3155	0.0025	-0.385	-0.24
France	0.2071	0.0175	-0.1835	-0.0825
Italy	0.8597	-2.0155	-2.2855	-1.4085
Portugal	0.5265	-1.632	-4.7875	-3.2915
Ireland	-0.9975	-2.1125	-1.2585	-0.38
Spain	2.2574	-2.725	-2.8825	-1.748

Table 2 also reports changes in yield spreads for 1-year maturities, 5-year maturities and 10-year maturities throughout the event window. Spreads of the indebted economies decline throughout the period, whereas yield spreads for the competitive economies increase slightly. Whether this can be related to the announcement of the OMT or caused by other factors is analyzed in section 5 and 6.

4.4 Control variables

As outlined in section 3, previous research suggests that sovereign yield spreads are affected by default risk, liquidity and risk aversion. To separate variation generated by these variables from possible variation generated by redenomination risk, I include a number of control variables in each regression.

As a control variable for country-specific and maturity-specific liquidity, I use the bid-ask spread. It is calculated separately for each maturity τ as $LIQ_t^{i,\tau} = b_t^{i,\tau} - a_t^{i,\tau}$, i.e. the difference between quoted ask yields and bid yields at each time. The data sample is illustrated in figure 5. A large spread is expected to indicate low liquidity and vice-versa. Earlier studies imply that liquidity is negatively correlated with yield spreads and hence the bid-ask spread should be positively correlated with yield spreads.

As a control variable for credit risk I use daily quoted CDS spreads for each

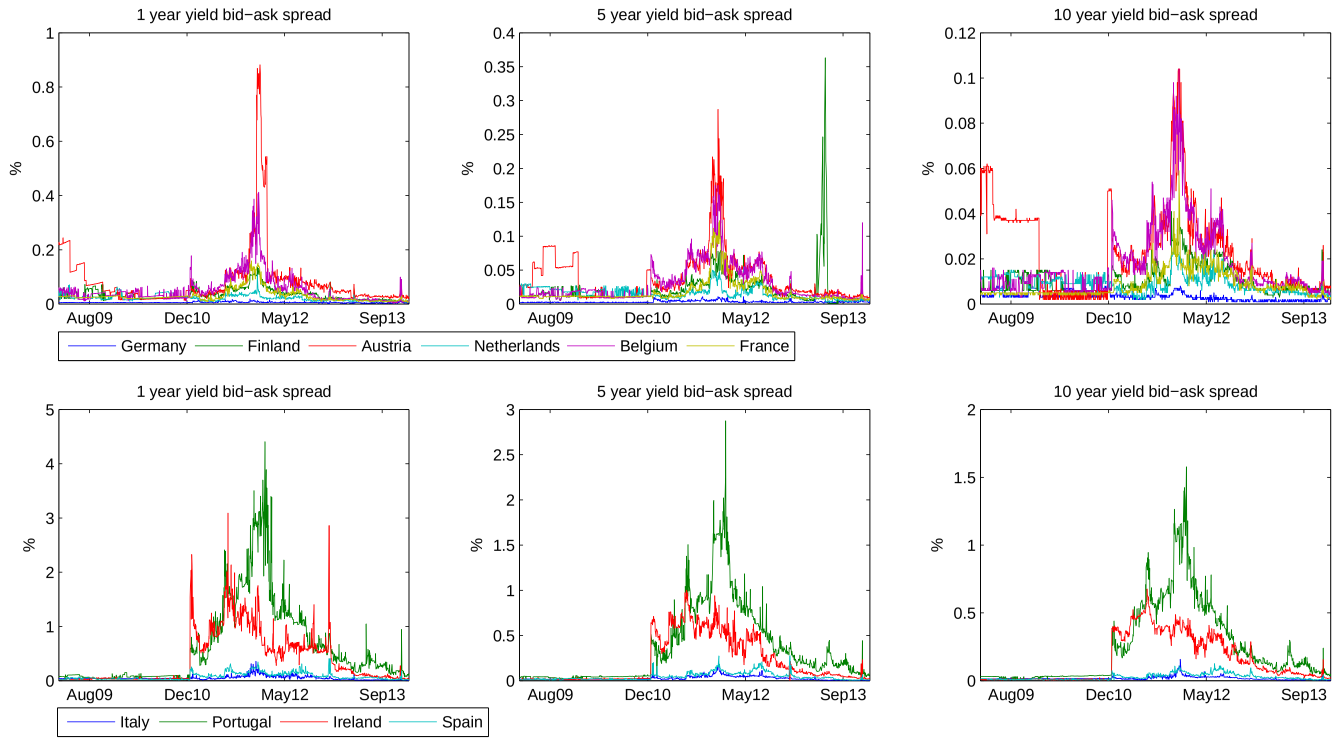

Figure 5: Daily observations of bid-ask spreads for yields with maturities of 1 year, 5 years and 10 years respectively in the period March 2009-February 2014. The upper panel displays spreads for Germany, Austria, Netherlands, Finland, Belgium and France and the lower panel shows corresponding observations for Italy, Spain, Portugal and Ireland.

sovereign issuer in the sample. This data is downloaded from the Bloomberg platform and it is assumed to provide information regarding the country-specific default risk at each point in time. Unfortunately, nearly all CDS spread series for maturities other than 5 years contain sustained periods of missing data, which makes them ill-suited for panel regressions. I therefore use the 5 year CDS spread in all regressions, even for estimations involving sovereign spreads with maturities of 1 year and 10 years. While this may reduce precision in the 1 year and 10 year maturity regressions, a large fraction of credit risk variation may likely still be captured by the 5-year CDS spread in these regressions. The full data set of observed CDS spreads is illustrated in figure 6.

As a control variable for general risk aversion, I include the spread between 10-year AAA rated U.S. Corporate bonds yields and the corresponding U.S. Treasury rate, similar to e.g. Codogno et al (2003) and Bernoth et al (2012). The spread is downloaded from the Bloomberg platform and illustrated in figure 11.

To separate country-specific Euro break-up probability from country-specific volatility, I also include the 260 day historical yield volatility for each country and maturity in the sample. This variable is quoted by Bloomberg and illustrated in figure 8. I also include the VSTOXX index which indicates the option implied volatility of the European stock market. As such, it may capture variations in yield spreads arising form expected future volatility. The VSTOXX index is illustrated in figure 10.

4.5 Unit-root tests

The regression analyses described in the next section are sensitive to the stationary properties of the variables included in the analysis. Non-stationary time series may generate spurious regression results if not correctly accounted for. In particular, a regression involving two time series that are $I(1)$ will typically generate significant regression coefficients even if the time series are independent (Wooldridge, 2009). To avoid such results, it is necessary to test if the variables included in the analysis appear to be $I(1)$ or not.

To evaluate this, I test for evidence of unit roots in the data by adopting the

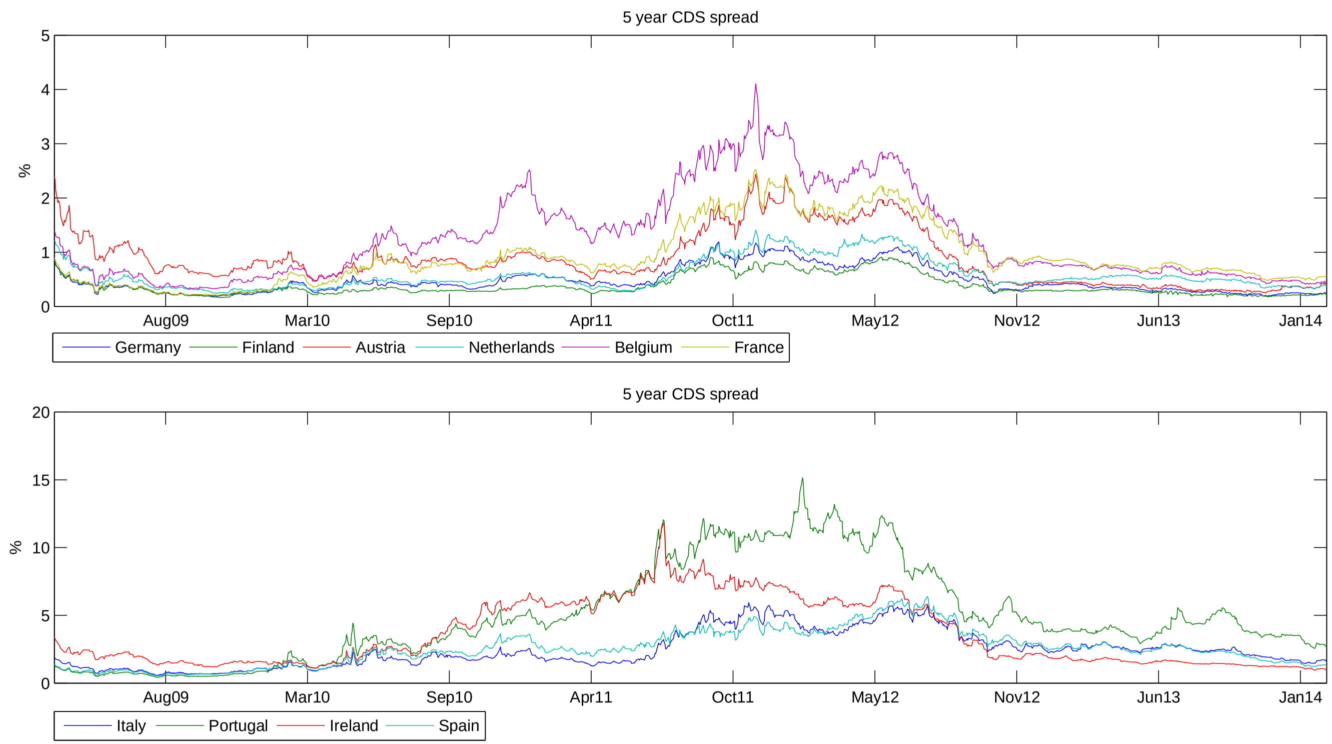

Figure 6: Observed daily 5 year CDS spreads in the period March 2009-February 2014. The upper panel displays spreads for Germany, Austria, Netherlands, Finland, Belgium and France and the lower panel shows corresponding observations for Italy, Spain, Portugal and Ireland.

augmented version of the Dickey and Fuller (1979) test. This is based on the autoregressive specification

$$x_t = \alpha + \beta t + \gamma x_{t-1} + \delta_1 \Delta x_{t-1} + \cdots + \delta_{n-1} \Delta x_{t-n+1} + \varepsilon_t,$$

where x_t represents any of the variables included in the analysis, α is the intercept of x_t and β corresponds to a possible time trend. In addition, $\delta_i \Delta x_{t-i}$, $i = 1, \ldots, n-1$ control for possible serial correlation in the error term. The γ coefficient is, however, the parameter of central interest. It provides an indication of whether there is a unit root or not in the data. To evaluate this, the Augmented Dickey-Fuller procedure simply tests the null hypothesis $H_0 : \gamma = 1$ against the alternative that $\gamma < 1$. If $\gamma = 1$, x_t appears non-stationary whereas if $\gamma < 1$ implies that x_t might need first differencing to demonstrate stationary. Table 8 summarizes results obtained from testing H_0 for all country specific variables with lag length $n = 10$ trading days. Results indicate that H_0 cannot be rejected for all leveled variable, whereas it is firmly rejected for all differenced variables. Hence, some level data appear to be $I(1)$ and first differencing is required to obtain stationary. I therefore conduct all regression analyses on differenced data.

4.6 Cross-sectional and serial dependence

To gain a further understanding of the characteristics inherent in the data set, I estimate its serial and cross-sectional correlations. Economic intuition implies that yield spreads of euro zone countries may be dependent given the economic and financial integration enabled by the EU and EMU. In addition, financial theory suggests that interest rates may obey mean-reverting processes as they partly track macroeconomic cycles. Such a mechanism would likely generate serial correlation in yield innovations.

Table 9 reports estimated Pearson correlations along with indications of whether these appear significantly different from zero or not. The results imply that yield spread correlations between most pairs are significantly non-zero. Although most of these estimates are positive, negative spread correlations are found between some pairs consisting of one indebted and one competitive country. These conclusions are valid across all three maturities.

Furthermore, serial correlations in yield spread innovations up to 20 lags along with 95% confidence bounds for each country and maturity are plotted in figures 18, 19 and 20. For most countries and maturities, several autocorrelation estimates are outside the confidence bounds, implying that serial correlation appears to be present in the data.

5 Methodology

5.1 Splitting the sample

To test for evidence of redenomination risk in yield spread data, I split the sample into one subsample containing observations with high default-risk and one subsample containing observations with low default risk. The rationale behind this division is that the economies with high default-risk suffer from poor competitiveness and may see their new currencies depreciate relative to the Euro if they were to leave the EMU. Hence, if redenomination risk is evident in the data, I am interested in detecting any difference in this impact between indebted and competitive economies.

As a proxy for the default risk, I use the 5 year CDS spread for each country and consider whether it is below or above its cross-sectional average at each point in time. I thus define the low-default risk sample dummy variable

$$I_t^{i,CDS} = \begin{cases} 1, & \text{if } CDS_t^{i,5} \leq \frac{1}{10}\sum_{j=1}^{10} CDS_t^{j,5}, \\ 0, & \text{otherwise} \end{cases}$$

as an identifier of whether an observation belongs to the low-default risk group or not. Interacting this indicator with other variables in linear regressions enables controlling for differences in impact on yield spreads between the two groups.

5.2 Benchmark regression equation

Before evaluating whether euro break-up risk data captures any of the observed variance in yield spreads, I conduct the regression analysis with control variables only. Results obtained from this estimation serve as benchmark with which other models can be compared. The benchmark equation has the form

$$\begin{aligned}\Delta s_t^{i,\tau} = \beta_0 + \beta_1 \Delta \mathrm{CDS}_t^{i,5} + \beta_2 \Delta \mathrm{LIQ}_t^{i,\tau} + \beta_3 \Delta \mathrm{VOL}_t^{i,\tau} + \beta_4 \Delta \mathrm{AAA}_t + \beta_5 \Delta \mathrm{VSTOXX}_t + \\ + \delta_0 I_{CDS} + \delta_1 I_{CDS} \Delta \mathrm{CDS}_t^{i,5} + \delta_2 I_{CDS} \Delta \mathrm{LIQ}_t^{i,\tau} + \delta_3 I_{CDS} \Delta \mathrm{VOL}_t^{i,\tau} + \delta_4 I_{CDS} \Delta \mathrm{AAA}_t + \\ + \delta_5 I_{CDS} \Delta \mathrm{VSTOXX}_t + \epsilon_t^{i,\tau}\end{aligned} \tag{1}$$

and captures potential impact of both country-specific and market-common control variables. With this specification, the coefficients $\{\beta_k\}$, $k = 1,2,...,5$ describe the relation between control variables and spreads in indebted economies, whereas the coefficients δ_k, $k = 1,2,...,5$ serve to display the difference in this impact between the samples.

In order to facilitate notation, I define

$$\begin{aligned}C_t^{i,\tau} = \beta_0 + \beta_1 \Delta \mathrm{CDS}_t^{i,5} + \beta_2 \Delta \mathrm{LIQ}_t^{i,\tau} + \beta_3 \Delta \mathrm{VOL}_t^{i,\tau} + \beta_4 \Delta \mathrm{AAA}_t + \beta_5 \Delta \mathrm{VSTOXX}_t + \\ + \delta_0 I_{CDS} + \delta_1 I_{CDS} \Delta \mathrm{CDS}_t^{i,5} + \delta_2 I_{CDS} \Delta \mathrm{LIQ}_t^{i,\tau} + \delta_3 I_{CDS} \Delta \mathrm{VOL}_t^{i,\tau} + \delta_4 I_{CDS} \Delta \mathrm{AAA}_t + \\ + \delta_5 I_{CDS} \Delta \mathrm{VSTOXX}_t\end{aligned}$$

to denote the set-up of control variables.

5.3 Testing for country-specific euro break-up risk impact

To test for the impact of country-specific euro break-up risk, I complement the benchmark model in Eq. (1) with the Sentix index EBI_t^i as well as its interaction with the low-default risk group dummy variable $I_t^{i,CDS}$. This model has the form

$$\Delta s_t^{i,\tau} = C_t^{i,\tau} + \gamma_1 \Delta \mathrm{EBI}_t^i + \gamma_2 I_t^{i,CDS} \Delta \mathrm{EBI}_t^i + \epsilon_t^{i,\tau}, \tag{2}$$

where γ_1 and γ_2 are regression coefficients to be estimated.

Using this specification enables separate detection of euro break-up risk impact on the two groups. The γ_1 coefficient serves to detect the relation between spreads and redenomination risk for the high-default risk sample, whereas γ_2 captures the difference in this effect between the low-default risk sample and the high-default risk sample. In particular, $\gamma_1 + \gamma_2$ indicates the relation between ΔEBI_t^i and $\Delta s_t^{i,\tau}$ for the low-default risk sample. If euro break-up risk exerts a downward pressure on yields in countries with low default risk, $\gamma_1 + \gamma_2$ should be significantly negative.

5.4 Testing for OMT event impact

To analyze how sovereign yield spreads reacted to the OMT announcement event, I use the regression equation

$$\Delta s_t^{i,\tau} = C_t^{i,\tau} + \theta_1 I_t^{OMT} + \theta_2 I_t^{i,CDS} I_t^{OMT} + \epsilon_t^{i,\tau}, \tag{3}$$

where θ_1 and θ_2 are regression coefficients to be estimated. Similar to the model specified by Eq. (2), the coefficients θ_1 and θ_2 allow for isolation of the separate effects of euro break-up impact on the two sub-groups. In particular, the coefficient θ_1 serves to detect OMT event impact on sovereign yields in high-default risk countries, whereas the coefficient θ_2 should indicate the difference in this impact between the two groups. Again, the quantity $\theta_1 + \theta_2$ provides information regarding the reaction of yield spreads in low-default risk countries specifically.

If low-default risk countries were negatively influenced by break-up risk and the OMT event was perceived as a credible signal to reduce this risk, a reversal of this effect should be visible during the event window. Hence, yield spreads should increase in low-default risk countries and the quantity $\theta_1 + \theta_2$ should be significantly positive.

5.5 Estimation periods and first differing

Each of the models (1), (2) and (3) require different estimation periods and frequencies. While the estimation of the benchmark Eq. (1) can be done using the full data set of daily observations between March 2009 and February 2014, estimations of Eqs. (2) and (3) are constrained to smaller data sets.

Eq. (2) can only be estimated using monthly data between June 2012 and January 2014, as these are the only available observation dates of the EBI index. In total, the number of observation dates sums to 21 which in effect translates into 20 observation dates after first differencing the data.

As for model (3) I am interested in detecting a distinct decrease of euro break-up risk implied by the introduction of the OMT. Hence, the pre-event period used for estimating this model must contain observations which can be credibly assumed to be influenced by consistently high levels of euro break-up risk. Ideally, the pre-event period should be chosen such that break-up risk remains at a constant level in this period, gradually decrease throughout the event window and remain at a constant lower level in the post-event period. As the euro crisis emerged in 2009, break-up risk may have gradually increased between 2009 and 2012. Therefore, the starting date of the estimation period for model (3) is set to January 2012 at which perceived Euro break-up risk may have been substantial given the restructuring process of Greek's debt going on at the time. The estimation period for model (3) is hence limited to daily data between January 2012 and February 2014.

To facilitate comparison between model (2) and the baseline model, I also estimate Eq. (1) on monthly data between June 2012 and January 2014. This allows for a direct quantification of the increased explainability arising from introducing euro break-up risk in the model.

In conclusion, I estimate model (1) on daily as well as monthly data, whereas model (2) and (3) are estimated using only monthly and daily data respectively. The first differences in variables in each regression equation hence refer to either daily or monthly changes in variables, depending on whether daily or monthly data is used in each particular case. Table 3 summarizes the frequencies and estimation periods for each regression. In addition, the table reports the number of observations in each group, sorted by country. As expected, the subsample with high default risk observations mainly consists of Spanish, Italian, Irish and Portuguese data, whereas German, Finnish, Austrian, Belgian, Dutch and French observations dominate the low default risk sample.

Table 3: Summary of frequencies, estimation periods and number of observations per group for each regression model.

	Baseline model (1)				Model (2)		Model (3)	
	Mar 2009 - Feb 2014		Jul 2012 - Jan 2014		Jul 2012 - Jan 2014		Jan 2012 - Feb 2014	
	Daily		Monthly		Monthly		Daily	
	$I_{CDS}=1$	$I_{CDS}=0$	$I_{CDS}=1$	$I_{CDS}=0$	$I_{CDS}=1$	$I_{CDS}=0$	$I_{CDS}=1$	$I_{CDS}=0$
GER	1210	0	20	0	20	0	505	0
FIN	1210	0	20	0	20	0	505	0
AUS	986	224	20	0	20	0	505	0
NL	1210	0	20	0	20	0	505	0
BEL	1206	4	20	0	20	0	505	0
FRA	1210	0	20	0	20	0	505	0
ITA	144	1066	0	20	0	20	0	505
POR	143	1067	0	20	0	20	0	505
IR	0	1210	0	20	0	20	0	505
SPA	45	1165	0	20	0	20	0	505
Total	7364	4736	120	80	120	80	3030	2020

5.6 Econometric technique

To estimate the panel regression models implied by Eqs. (1), (2) and (3), I use ordinary least squares (OLS) estimation techniques. While standard estimation procedures assume that the data is cross-sectionally and serially independent, this assumption is evidently unrealistic in the current case. As shown in table 9 and figures 18, 19 and 20, spread innovations in the sample display firm evidence of cross-sectional as well as serial correlation. I therefore adopt an estimation procedure suggested by Driscoll and Kraay (1998), which is robust to both of these types of dependence.

For each of the regression models, let the scalar s_{it} denote the yield spread of country i at time t, $\mathbf{z}_{it}$ the corresponding $(K+1)\times 1$ vector of regressor variables and ψ the representative $(K+1)\times 1$ vector of regression coefficients. Here T denotes the number of observation dates, $i = 1,2,...,10$ indicates country and $t = 1,2,...,T$ refers to observation dates. In addition, K denotes the number of explanatory variables in each model. The regression equations can then be expressed compactly as

$$s_{it} = \mathbf{z}_{it}'\psi + \epsilon_{it}.$$

Stacking all observations yields the $10T \times 1$ vector

$$\mathbf{s} = \begin{pmatrix} s_{11} & \ldots & s_{1T} & s_{21} & \ldots & s_{10,T} \end{pmatrix}'$$

and the $10T \times (K+1)$ matrix

$$\mathbf{Z} = \begin{pmatrix} \mathbf{z}_{11} & \ldots & \mathbf{z}_{1T} & \mathbf{z}_{21} & \ldots & \mathbf{z}_{10,T} \end{pmatrix}'.$$

A consistent estimator of the vector ψ is then given by the standard OLS estimator

$$\hat{\psi} = \left(\mathbf{Z}'\mathbf{Z}\right)^{-1}\mathbf{Z}'\mathbf{s}$$

provided that each regressor in $\mathbf{z}_{it}$ is uncorrelated with the error terms ϵ_{is} for all s and t. Error terms are however allowed to be heteroscedastic, autocorrelated and correlated across countries, as such effects are accounted for by Driscoll and Kraay (1998) standard errors. These are obtained as the square roots of the diagonal entries of the $(K+1) \times (K+1)$ matrix

$$V(\hat{\psi}) = \left(\mathbf{Z}'\mathbf{Z}\right)^{-1}\hat{\mathbf{M}}_T\left(\mathbf{Z}'\mathbf{Z}\right)^{-1}$$

where

$$\hat{\mathbf{M}}_T = \hat{\mathbf{\Omega}}_0 + \sum_{j=1}^{m} w\left(j,m\right)\left[\hat{\mathbf{\Omega}}_j + \hat{\mathbf{\Omega}}_j^T\right]$$

is a $(K+1) \times (K+1)$ matrix originally proposed by Newey and West (1987) to ensure robustness to autocorrelation and heteroskedasticity. The scalar m denotes the maximum lag-length up to which the error terms may be serially correlated and the weight function is chosen as

$$w\,(j{,}m) = 1 - \frac{j}{m+1}$$

to guarantee positive semi-definiteness of $\hat{\mathbf{M}}_T$. Furthermore,

$$\mathbf{\Omega}_j = \sum_{t=j+1}^{T} \mathbf{h}_t(\hat{\psi})\mathbf{h}_{t-j}(\hat{\psi})^T$$

is a $(K+1) \times (K+1)$ matrix, where

$$\mathbf{h}_t(\hat{\psi}) = \sum_{i=1}^{N(t)} \mathbf{z}_{it} \left(s_{it} - \mathbf{z}_{it}^T \hat{\psi} \right)$$

are the $(K+1) \times 1$ vectors of moment conditions of the OLS model.

6 Empirical results

6.1 Baseline regression results using daily data

Table 4 displays estimated regression coefficients along with Driscoll and Kraay (1998) standard errors for Eq. (1) from using daily data in the period March 2009-February 2014. In addition, I report corresponding estimated coefficients of all control variables in the low default-risk sample in table 10.

As expected, CDS spreads demonstrate a positive and significant relationship with yield spreads for all maturities. The result is evident among indebted as well as competitive countries although with different magnitudes. While the indebted sample displays coefficients in the range 0.42-0.84, the effect of low default risk reduces this impact by 0.26-0.60. Hence, yield spreads in countries with high levels of credit risk appear more sensitive to variations in this risk, compared to spreads of the competitive economies. There is, however, no significant difference between default risk impact between the two groups for 10-year maturity data.

The detection of a positive relationship between CDS spreads and European sovereign yield spreads is directly comparable with the findings of Beber et al (2009) who report positive coefficients across all maturities included in their study. It however does not differentiate between CDS spread impact between indebted and competitive economies.

As for international risk aversion, results shown in tables 4 and 10 imply that 1-year and 5-year spreads in both samples are positively influenced by this factor. Again, the effect is significantly less important in the low default risk sample compared to the high default-risk sample. Coefficients in the former group range between 0.03 and 0.06 whereas coefficients in the latter group attain values between 0.10 and 0.20.

Hence, higher default risk appears to increase the impact of international risk-aversion on yield spreads. This hypothesis is consistent with Bernoth et al (2012) who report evidence that international risk-aversion impact on European yield spreads is significant and positive after the onset of the financial crisis, although no such effect is evident in the pre-crisis years. Given the increase in default risk that has taken place in European sovereign markets since then, impact of international risk-aversion may have increased as a result.

Results also confirm a positive relation between the bid-ask spread and sovereign yield spreads with maturities of 1 year and 5 years respectively in the high-default risk sample. The relation is, however, not significant in the competitive sample suggesting that liquidity mainly drives spread variation in sovereign markets with high default risk. Yet, the coefficient is not significant for the 10-year maturity in neither of the samples, implying that liquidity may have less impact on spreads with longer maturities in the sample period. Liquidity impact appears most evident in the 5-year maturity segment, as implied by the higher significance and greater magnitude of the corresponding coefficient.

Again, this partially confirms results reported by Beber et al (2009), although their study finds significant relationships across a number of maturities, including the 10-year segment. Nevertheless, the implied higher importance of liquidity of indebted countries may explain the findings by e.g. Barrios et al (2009) who reports evidence that liquidity has become more important since the emergence of the crisis.

If higher default risk increases the importance of liquidity, the increase in importance of this factor during the crisis may have been driven by the increase in credit risk.

Moreover, variations in implied stock market volatility has no significant relationship with yield spreads of indebted economies, yet its impact is significant and negative in competitive economies across all three maturities. I interpret this result as evidence of a flight-to-quality effect. This is consistent with Beber et al (2009) who report that both liquidity and credit quality determine destinations for capital flights, although liquidity appears more important in times of distressed markets. Given the higher liquidity as well as lower credit risk prevailing in the low-default risk sample, capital is expected to mainly flow into these markets as uncertainty in stock markets increase.

Country-specific volatility has no significant relationship with yield spreads. This may be an effect of the fact that future volatility – not historical – is the important risk factor taken into consideration by investors.

6.2 Baseline regression results using monthly data

I next estimate the baseline model on monthly data between June 2012 and January 2014. Regression results are reported in table 5 and estimated coefficients of the low-credit risk sample are reported in table 11.

While default risk effects are more or less preserved in the high-default risk sample, its impact on the competitive countries seems to have weakened somewhat in this data set.

Moreover, VSTOXX appears to have lost its impact on spreads of competitive economies, whereas international risk-aversion effects have changed sign. It is significant and negative for the 1-year maturity in the low default risk sample and the 5-year maturity in the high-default risk sample. In addition, country-specific historical volatility has a significant and negative relationship on 1 year maturities in the high-credit risk sample.

Table 4: The table reports estimated regression coefficients of the benchmark model using the full data set of daily data between March 2009 and February 2014. Driscoll and Kraay (1998) standard errors are provided in parenthesis and are robust to cross sectional correlation as well as serial correlation up to 30 lags.

	(1) 1 year spread	(2) 5 year spread	(3) 10 year spread
CDS	0.842***	0.711***	0.428***
	(8.51)	(10.54)	(9.86)
LIQ	0.0895**	0.380***	0.200
	(3.14)	(4.11)	(1.46)
VOL	-0.551	0.168	0.00350
	(-1.12)	(0.23)	(0.01)
AAA	0.190***	0.107**	0.00405
	(3.42)	(2.97)	(0.18)
VSTOXX	0.00124	-0.0921	0.0349
	(0.01)	(-1.47)	(0.75)
I^{CDS}	-0.000909	-0.000910	-0.00108
	(-0.23)	(-0.34)	(-0.63)
Low CDS spread effects			
I^{CDS}CDS	-0.602***	-0.257**	-0.0593
	(-5.73)	(-2.71)	(-0.72)
I^{CDS} LIQ	0.000475	-0.177	0.230
	(0.01)	(-0.90)	(0.72)
I^{CDS} VOL	0.667	0.0896	0.305
	(1.29)	(0.12)	(0.67)
I^{CDS}AAA	-0.157**	-0.0377	0.0326
	(-2.84)	(-1.20)	(1.25)
I^{CDS}VSTOXX	-0.110	-0.124*	-0.205***
	(-1.30)	(-2.10)	(-4.97)
Observations	12100	12100	12100
Groups	10	10	10
R^2	0.2595	0.3677	0.2771
Time fixed effects	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: The table reports estimated regression coefficients of the benchmark model using monthly data from June 2012 to January 2014. Driscoll and Kraay (1998) standard errors are provided in parenthesis and are robust to cross sectional correlation as well as serial correlation up to 1 lag.

	(1)	(2)	(3)
	1 year spread	5 year spread	10 year spread
CDS	0.611**	0.850***	0.699***
	(3.73)	(4.89)	(5.22)
LIQ	-0.00923	0.138	-2.631
	(-0.05)	(0.18)	(-1.62)
VOL	-0.798***	0.292	-0.481
	(-4.38)	(0.63)	(-0.63)
AAA	-0.478	-0.740*	-0.802
	(-1.80)	(-2.38)	(-1.99)
VSTOXX	0.309	-0.0512	0.405
	(1.33)	(-0.19)	(1.19)
I^{CDS}	0.0748	0.0287	0.0594
	(1.44)	(0.80)	(1.49)
Low CDS spread effects			
I^{CDS}CDS	-0.485**	-0.296	-0.288
	(-3.73)	(-1.12)	(-1.50)
I^{CDS} LIQ	0.836	1.015	0.507
	(1.62)	(1.21)	(0.12)
I^{CDS}VOL	0.856***	0.242	0.537
	(4.65)	(0.35)	(1.22)
I^{CDS}AAA	0.301	0.418	0.351
	(1.04)	(1.01)	(0.73)
I^{CDS}VSTOXX	-0.465	-0.166	-0.445
	(-1.93)	(-0.60)	(-1.71)
Observations	200	200	200
Groups	10	10	10
R^2	0.2557	0.6034	0.4849
Time fixed effects	No	No	No

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6.3 Regression results with country-specific euro break-up risk

Table 6 provides coefficient estimates and standard errors for Eq. (2) using monthly observations between June 2012 and January 2014 for all 10 countries. In addition, table 12 reports estimated coefficients for the low-default risk sample.

A first indication of whether redenomination risk may explain yield spread variation can be obtained by comparing R^2 values of model estimates for Eqs. (1) and (2). Estimation results reported in tables 5 and 6 show that R^2 increases from 0.26 to 0.53 for 1-year spread estimations when country-specific euro break-up risk is added to the equation, suggesting a twofold increase of explained spread variance. The corresponding effect for 5-year and 10-year spreads are however considerably smaller. R^2 merely increases by 0.02-0.03 for these maturities when the EBI indicator is included in these equations.

Further insights regarding redenomination risk effects can be reached by considering the coefficient estimates of the EBI indicator. As shown in table 6, the EBI has a positive and significant relation with yield spreads across all three maturities in the high default risk sample. This result is consistent with the hypothesis that indebted economies are expected to see their newly introduced currencies depreciate if they would leave the Euro zone. The positive relation impact of break-up risk in indebted economies is particularly evident in the shorter end of the yield curve.

Moreover, coefficients of the interaction between I_{CDS} and EBI are significant and negative for all three spread maturities, suggesting that the effect is substantially lower than for the indebted countries. In fact, the estimated coefficients imply that the effect may slightly negative for the low-default risk sample. Such a relation would be consistent with the hypothesis that competitive economies may see their new currencies appreciate if they would abandon the Euro and reintroduce national currencies.

As shown in table 12, the impact of Euro break-up risk is significant and negative for the 5 year maturity segment among the competitive economies, whereas no significance is obtained for the remaining two maturities. Estimated coefficients in these segments are however negative.

Table 6: The table reports estimated regression coefficients of the regression-model with country-specific euro break-up risk using monthly data between June 2012 and January 2014. Driscoll and Kraay (1998) standard errors are provided in parenthesis and are robust to cross sectional correlation as well as serial correlation up to 1 lag.

	(1) 1 year spread	(2) 5 year spread	(3) 10 year spread
CDS	0.509**	0.800***	0.604***
	(3.85)	(4.77)	(4.33)
LIQ	0.0256	0.0433	-1.861
	(0.14)	(0.06)	(-1.18)
VOL	-0.814***	0.0870	-0.778
	(-4.50)	(0.18)	(-0.93)
AAA	-0.397	-0.707*	-0.709
	(-1.40)	(-2.35)	(-1.86)
VSTOXX	0.241	-0.0607	0.368
	(1.14)	(-0.24)	(1.17)
I^{CDS}	0.0998	0.0484	0.0785
	(1.88)	(1.74)	(2.22)
EBI	0.0912**	0.0483*	0.0613*
	(3.32)	(2.75)	(2.99)
Low CDS spread effects			
I^{CDS} LIQ	0.799	1.111	-0.186
	(1.48)	(1.42)	(-0.04)
I^{CDS}VOL	0.872***	0.452	0.846
	(4.79)	(0.73)	(1.69)
I^{CDS}CDS	-0.383**	-0.237	-0.191
	(-3.92)	(-0.92)	(-1.03)
I^{CDS}AAA	0.220	0.386	0.259
	(0.75)	(0.99)	(0.58)
I^{CDS}VSTOXX	-0.397	-0.155	-0.409
	(-1.92)	(-0.63)	(-1.81)
I^{CDS}EBI	-0.0915**	-0.0638**	-0.0654**
	(-3.35)	(-3.32)	(-3.25)
Observations	200	200	200
Groups	200	200	200
R^2	0.5362	0.6203	0.5158
Time fixed effects	No	No	No

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

6.4 Regression results from OMT event study

Table 7 reports regression results of the OMT event study model given by Eq. (3) using daily data between January 2012 and February 2014. In addition, table 13 displays coefficient estimates for each variable in the low-default risk sample.

As shown, CDS spread variations remain important determinants of spread changes in both subsamples. Even in this sample period, the effect is greater for the indebted economies compared to the competitive ones. In addition, changes in liquidity remains important for explaining spread movements in the high-default risk sample.

Similar to the baseline regression on the full estimation period, this regression provide support for positive impact of international risk-aversion on spreads of competitive economies. The corresponding effect on the high-default-risk sample has however vanished.

The coefficient estimate for the OMT event dummy is the variable of central interest. As shown in tables 7 and 13, the analysis shows no significant impact of the OMT event indicator on yield spread innovations. This verdict appears consistent across subsamples and maturities. It either suggests that that there is lack of support for the hypothesis that euro break-up risk impacts sovereign yield spreads or that markets simply did not react to ECB announcements throughout the course of the event window.

7 Economic implications

7.1 Implications of country-specific break up risk

The empirical results reported in section 6 provide firm evidence in favor of the hypothesis that sovereign yield spreads increase with country-specific redenomination risk in indebted economies. This idea is economically justified by an expected depreciation of theoretical future currencies of such countries. Moreover, the study shows weak evidence that an opposite effect is present in yield spread data of competitive economies. This mechanism would be supported by the idea of expected appreciation of theoretical future currencies in such countries.

Table 7: The table reports estimated regression coefficients of the model with an OMT event indicator using daily data between January 2012 and February 2014. Driscoll and Kraay (1998) standard errors are provided in parenthesis and are robust to cross sectional correlation as well as serial correlation up to 30 lags.

	(1) 1 year spread	(2) 5 year spread	(3) 10 year spread
CDS	0.759***	0.874***	0.552***
	(5.05)	(8.10)	(18.88)
LIQ	0.0728*	0.230*	0.172
	(2.16)	(2.60)	(1.23)
VOL	-0.943***	0.254	-0.319
	(-4.45)	(0.49)	(-0.67)
AAA	0.0685	0.0619	-0.000760
	(0.73)	(1.18)	(-0.02)
VSTOXX	0.0560	0.0323	0.155**
	(0.54)	(0.46)	(2.67)
I^{CDS}	0.00410	0.000881	0.00167
	(1.05)	(0.37)	(0.68)
I^{OMT}	0.0166	0.00785	-0.00296
	(0.48)	(0.47)	(-0.36)
	Low CDS spread effects		
I^{CDS} LIQ	-0.102	0.0637	0.170
	(-1.68)	(0.24)	(0.28)
I^{CDS} VOL	0.883***	0.103	0.707
	(4.00)	(0.15)	(1.34)
I^{CDS}CDS	-0.620***	-0.513***	-0.317***
	(-5.64)	(-5.26)	(-4.08)
I^{CDS}AAA	-0.0529	0.0677	0.160**
	(-0.55)	(1.11)	(3.26)
I^{CDS}VSTOXX	-0.0697	-0.0929	-0.216**
	(-0.69)	(-1.46)	(-3.31)
$I^{CDS}I^{OMT}$	0.00544	0.00661	0.00477
	(0.21)	(0.68)	(0.73)
Observations	5050	5050	5050
Groups	10	10	10
R^2	0.2592	0.4435	0.3937
Time fixed effects	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The presence of redenomination risks effect has tremendous implications for sovereign debt markets not to mention sovereign borrowers. As an example, I consider the estimated coefficients of euro break-up risk impact and multiply by observed values of EBI indices for Spain, Portugal and Finland. This exercise suggests that 1 year spreads of Spanish and Portuguese yields may have been 70-90 basis points above levels justified by traditional determinants in the summer of 2012 when EBI indices for these countries reached all-time high levels of approximately 8% -11%. Equivalently, regression estimates imply that the Finnish 5 year yield might have been almost 20 basis points below justified levels as a result of redenomination risk in the same time period.

The impact of these effects has important consequences for the indebted economies in particular. As debt-to GDP ratios in Greece, Italy, Portugal and Ireland exceed 100%, increases of sovereign yields by 70-90 basis points suggest increases in government outlays of more than 0.7% of GDP. Clearly, such an adjustment would imply a substantial increase in debt service burden of these countries. This effect alone would likely increase default risk which in turn would increase borrowing costs even further. Also, it would imply a welfare loss to residents as interest payments to non-residents increase.

Furthermore, redenomination risk giving rise to increasing or decreasing sovereign yields may hamper monetary policy transmission mechanisms. The effectiveness of these tools is likely a crucial determinant of the outcome of the sovereign debt crisis. Hence, understanding the impact of redenomination risk in fixed income markets is of fundamental importance.

Finally, redenomination risk has important portfolio management implications. Failure to account for yield variations arising from the implied FX risk inherent in break-up risk, may give rise to large unexpected portfolio losses within the banking sector. This may generate further financial instability in European and global markets.

7.2 Implications of failure to detect OMT impact

The failure to detect spread reactions to ECB's announcement of the OMT program either suggests that there are no redenomination risk effects in spreads, or that financial markets did not react to the new information throughout the course of the event window. The latter alternative is supported by the lack of consistent decreases in all EBI indicators in the event window, as shown in table 2 and illustrated in figure 14. This scenario may have arisen if the new information provided by ECB was anticipated by financial markets and already incorporated in asset prices prior to the event. If this was the case, spread changes arising from the implied reduction in break-up risk had likely already taken place in the pre-event period.

Alternatively, markets may have reacted slower or quicker to the OMT announcement than admitted by the size of the event window. The former would be consistent with the efficient market hypothesis which suggests that new information should be incorporated instantly upon arrival to the market. All spread adjustments arising from the systematic decrease in perceived break-up risk may simply have taken place in one single trading day, possibly on 26th of July, 2012 upon delivery of the *whatever-it-takes speech*. Unfortunately, the size of the cross-sectional dimension in the sample would not admit such a small event window size. Hence, an instant adjustment in spreads would be difficult to detect by statistical methods.

Another possible explanation for lack of detection of market reactions to the OMT announcement may simply be poor confidence in ECB's ability to defend the euro. The new information may not have been perceived as a credible signal of a reduction in redenomination risk, and hence spread adjustments may not have occurred. Whether ECB's announcement of the OMT contributed to saving the euro or not remains a question for future research.

8 Limitations

The empirical study of this paper relies on the econometric technique outlined in section 5. As such, its conclusions are constrained by the limitations of statistical inference. One of the main concerns in this respect is the sample size of the data set used for the study. Fortunately, the standard error estimator of Driscoll and Kraay (1998) is insensitive to the number of countries included in the study. In fact, the estimator is consistent independently of the cross-sectional sample size. It however relies on large T asymptotics and its validity may therefore be reduced if the time dimensional size is too small.

The estimation of the baseline model on the full data set contains 1210 observation dates, whereas the event study regression relies on 505 observation dates. These sample sizes are likely large enough to generate confident regression results.

However, the estimation of Eq. (2) only relies on 20 observation dates. From a statistical point of view, this size may be too small to be considered reliable. Clearly, this imposes a limitation of the confidence in the detected impact of euro break-up risk on yield spreads and larger sample period would have enabled more robust inference. Yet, EBI index data is only available since June 2012 and a larger sample size was therefore unavailable at the time of this study. Analyzing the impact of country-specific break-up risk when more observation dates are available therefore remains a task for future research.

The findings of this paper are also limited to the interpretation of its statistical results. Clearly, the analysis indicates positive and negative relations between the EBI and spreads of indebted and competitive economies respectively. While this finding is consistent with the interpretation of a causal relationship between redenomination risk and spreads, there may in fact be other mechanisms giving rise to these findings.

An alternative interpretation of the results is that the EBI in fact serves as a proxy for future volatility. It is likely that the departure of one or several countries from the euro zone may give rise to unstable financial markets due to increased uncertainty regarding the European economy. Therefore, movements in country-specific euro break-up risk may reflect variations in expected future volatility. Hence, even in absence of causal redenomination risk effects on yield spreads, a positive relationship may be still have been generated by investors' expectation of future volatility.

This problem is reduced by the inclusion of historical volatility as a control variable in all regressions. Yet, investors likely consider future volatility over historical volatility when pricing assets. Hence, future research may be devoted to studying the impact of euro break-up risk on debt markets with improved indicators of country-specific volatility.

9 Conclusion

In this paper, I have examined determinants of sovereign yield spreads in light of the European sovereign debt crisis. While earlier studies provide evidence that yield spreads are mainly driven by default risk, liquidity and risk aversion, I contribute to existing research by studying the effects of redenomination risk.

The results of this study has two main parts. Firstly, the analysis finds significant relations between country-specific euro break-up risk and sovereign yield spreads. In particular, I find that sovereign yield spreads of indebted countries are positively correlated with country-specific euro break-up risk. This result is consistent with the hypothesis that indebted economies would see their theoretical future currencies depreciate relative to the euro if they would depart from the EMU. The study also provides some evidence of a moderately negative relation between sovereign yield spreads of competitive economies and euro break-up risk. This is consistent with expected appreciations of theoretical future currencies of such economies.

Secondly, the study finds that yield spreads did not react to ECB's announcement of its intentions to intervene in secondary bond markets to reduce the risk of break-up of the EMU. This either suggests that this information might not have been perceived as a credible signal to reduce the risk of break-up of the EMU or that spread adjustments took place quicker or slower than admitted by the econometric specification used.

The detection of significant relations between sovereign yield spreads and country-specific break-up risk has important implications for monetary policy making as well portfolio risk management.

References

Amihud, Yakov; Mendelson, Haim 1986, *Asset Pricing with Liquidity Risk*, Journal of Financial Economics 77, 375-410

Balassone, Fabrizio ;Franco, Daniele;Giodano, Raffaela; 2004, *Market-Induced Fiscal Discipline: Is There a Fall-Back Solution for Rule Failure?*, Bank of Italy

Barrios,Salvador; Iversen, Per; Lewandowska, Magdalena; Setzer, Ralph 2009, *Determinants of intra-euro area government bond spreads during the financial crisis*, Economic and Financial Affairs, European Comission, Economic Papers 388

Bayoumi, Tamim; Goldstein, Morris; Woglom, Geoffrey 1995, *Do Credit Markets Discipline Sovereign Borrowers? Evidence from U.S. States*, Journal of Money, Credit and Banking 27, 1046-1059

Beber, Alsessandro; Brandt, Michael W.; Kavajecz, Kenneth A. 2009, *Flight-to-Quality or Flight-to-Liquidity? Evidence from the Euro-Area Bond Market*, The Review of Financial Studies 22, 925-957

Bernoth, Kerstin; von Hagen, Jürgen; Schuknecht, Ludger 2012, *Sovereign risk premiums in the European government bond market*, Journal of International Money and Finance 31, 975-995

Booth, Laurence; Georgopoulos, George; Hejazi, Walid 2007, *What drives provincial-Canada yield spreads?*, Canadian Journal of Economics 40, 1008-1032

Chordia, Tarun; Roll, Richard; Subrahmanyam, Avanidhar 2000, *Commonality in liquidity*, Journal of Financial Economics 56, 3-28

Codogno, Lorenzo; Favero, Carlo; Missale, Alessandro 2003, *Yield spreads on EMU government bonds*, Review of Finance 8, 171-197

Dickey, David; Fuller, Wayne; 1979, *Distribution of the Estimators for Autoregressive Time Series With a Unit Root*, Journal of the American Statistical Association 74, 427-431

Di Cesare, Antonio; Grande, Giuseppe; Manna, Michele; Taboga, Marco 2012, *Recent Estimates of sovereign risk premia for sovereign euro-area countries*, Occasional Papers 128, Banca D'Italia

Driscoll, John C; Kraay, Aart C. 1998, *Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data*, Review of Economics and Statistics 80, 549-560

Duffie, Darrell; Pedersen, Lasse Heje; Singleton, Kenneth J. 2003, *Modeling Sovereign Yield Spreads: A case Study of Russian Debt*, The Journal of Finance 58, 119-159

Dungey, Mardi; Martin, Vance L.; Pagan, Adrian R. 2000, *A Multivariate Latent Factor Decomposition of International Bond Yield Spreads*, Journal of Applied Econometrics 15, 697-715

Draghi,Mario; 2012, Speech at the Global Investment Conference, 2012, online `http://www.youtube.com/watch?v=hMBI5OFXDps`, accessed on April 2nd, 2014

Favero, Carlo; Pagano, Marco; von Thadden, Ernst-Ludwig 2005, *Valuation, Liquidity and Risk in Government Bond Markets*, Working Paper 281, IGIER

Geyer, Alois; Kossmeier, Stephan; Pichler Stefan 2004, *Measuring Systemic Risk in the EMU Government Yield Spreads*, Review of Finance 8, 171-197

Goldreich, David; Hanke, Bernd; Nath, Purnendu 2005, *The Price of Future Liquidity: Time Varying Liquidity in the U.S. Treasury Market*, Review of Finance 9, 1-32

Gómez-Puig, Marta 2008, *Monetary integration and the cost of borrowing*, Journal of International Money and Finance, 27, 455-479

Haugh, David; Ollivaud, Patrice; Turner, David 2009, *What Drives Sovereign Risk Premiums?: An Analysis of Recent Evidence from the Euro Area*, OECD Economics Department Working Papers 718

Krugman,Paul; 2011, *Legends of the Fail*, The New York Times, online `http://www.nytimes.com/2011/11/11/opinion/legends-of-the-fail.html?_r=0`, accessed on April 2nd, 2014

Krugman,Paul; 2011, *Euro Zone Death Trip*, The New York Times, online `http://www.nytimes.com/2011/09/26/opinion/euro-zone-death-trip.html`, accessed on April 2nd, 2014

Longstaff, Francis A. 2004, *The Flight-to-Liquidity Premium in U.S. Treasury Bond Prices*, Journal of Business 77, 511-526

Lonning, Ingunn 2000, *title*, Weltwirtschaftliches Archiv, 136, 259-283

Newey,-; West, - 1987, *A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix*, Econometrica 55, 703-708

Nordvig, Jens; Firoozye, Nick 2012, *Planning for an orderly break-up of the European Monetary Union*, Submission to Wolfson Economics Prize 2012

Poterba, James M.; Rueben, Kim S.1997, *State Fiscal Institutions and the U.S. Municipal Bond Market*, Fiscal Institutions and Fiscal Performance. University of Chicago Press, 1999. 181-208.

Powel, David J. 2013, *The Trader's Guide to the Euro Area: Economic Indicators, the ECB and the Euro Crisis*, (John Wiley and Sons Ltd.)

Sgherri, Silvia; Zoli, Edda; 2009, *Euro area sovereign risk during the crisis*, International Monetary Fund, IMF Working Papers 09/222

The Economist; 2010, online `http://www.economist.com/printedition/2010-11-20` accesed on April 2nd, 2014

The Economist; 2010, online `http://www.economist.com/printedition/2010-12-04` accesed on April 2nd, 2014

The Economist; 2011, online `http://www.economist.com/printedition/2011-07-16` accesed on April 2nd, 2014

The Economist; 2011, online `http://www.economist.com/printedition/2011-09-17` accesed on April 2nd, 2014

The European Central Bank; 2012, *Introductory statement to the press conference* , online `http://www.ecb.europa.eu/press/pressconf/2012/html/is120802.en.html` accessed on April 2nd, 2014

The European Central Bank; 2012, Press release: *Technical features of Outright Monetary Transactions*, online `http://www.ecb.europa.eu/press/pr/date/2012/html/pr120906_1.en.html` accessed on April 2nd, 2014

Whelan, Karl 2013, *Sovereign default and the euro*, Oxford Review of Economic Policy 29, 478-501

Wooldridge, Jeffrey M. 2009, *Introductory Econometrics – a modern approach*, 4th ed (South-Western Cengage Learning)

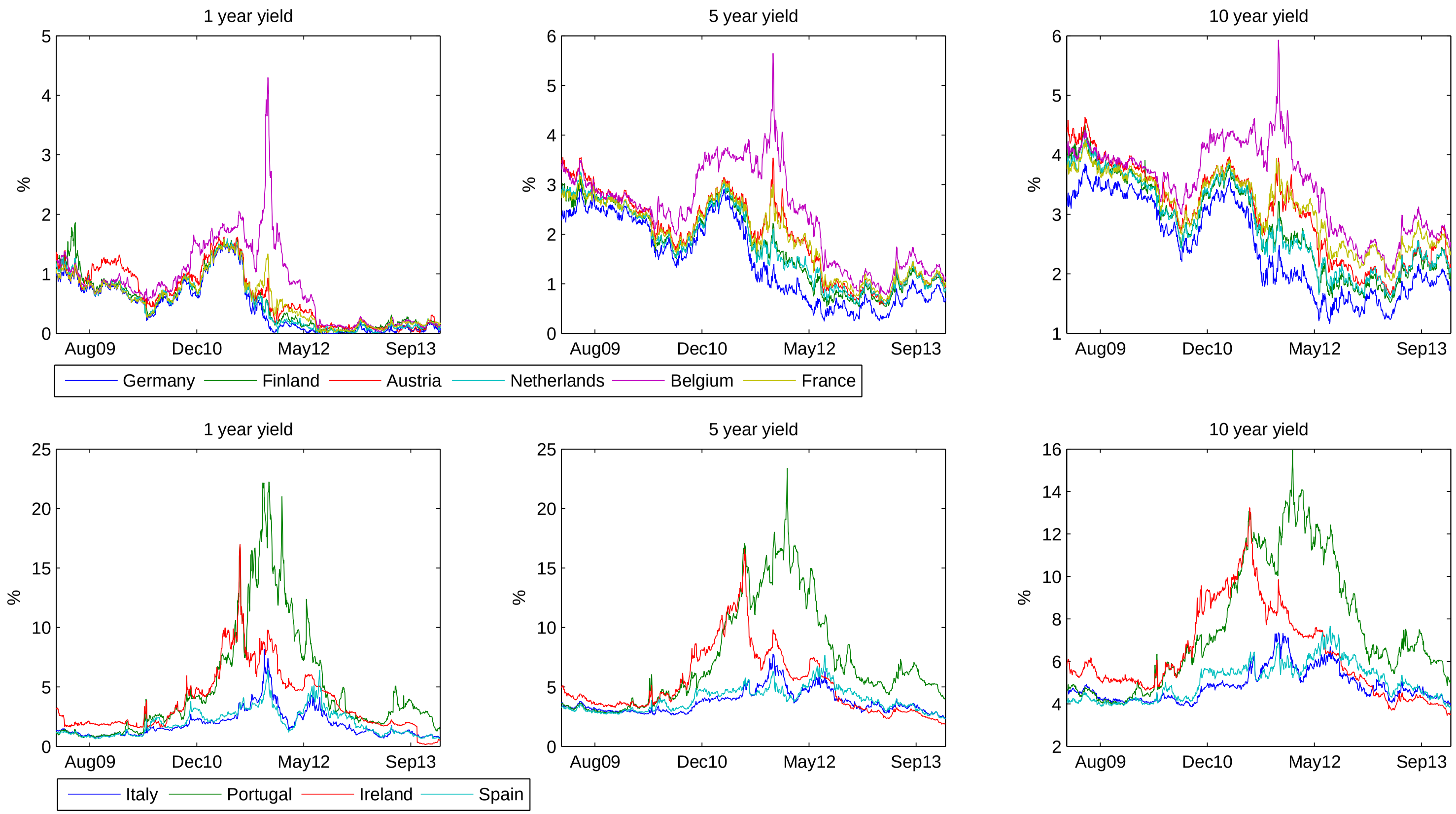

Figure 7: Observed daily sovereign 1-year, 5-year and 10-year mid yields from March 2009 to February 2014. The upper panel displays yields for Germany, Austria, Netherlands, Finland, Belgium and France and the lower panel shows corresponding observations for Italy, Spain, Portugal and Ireland.

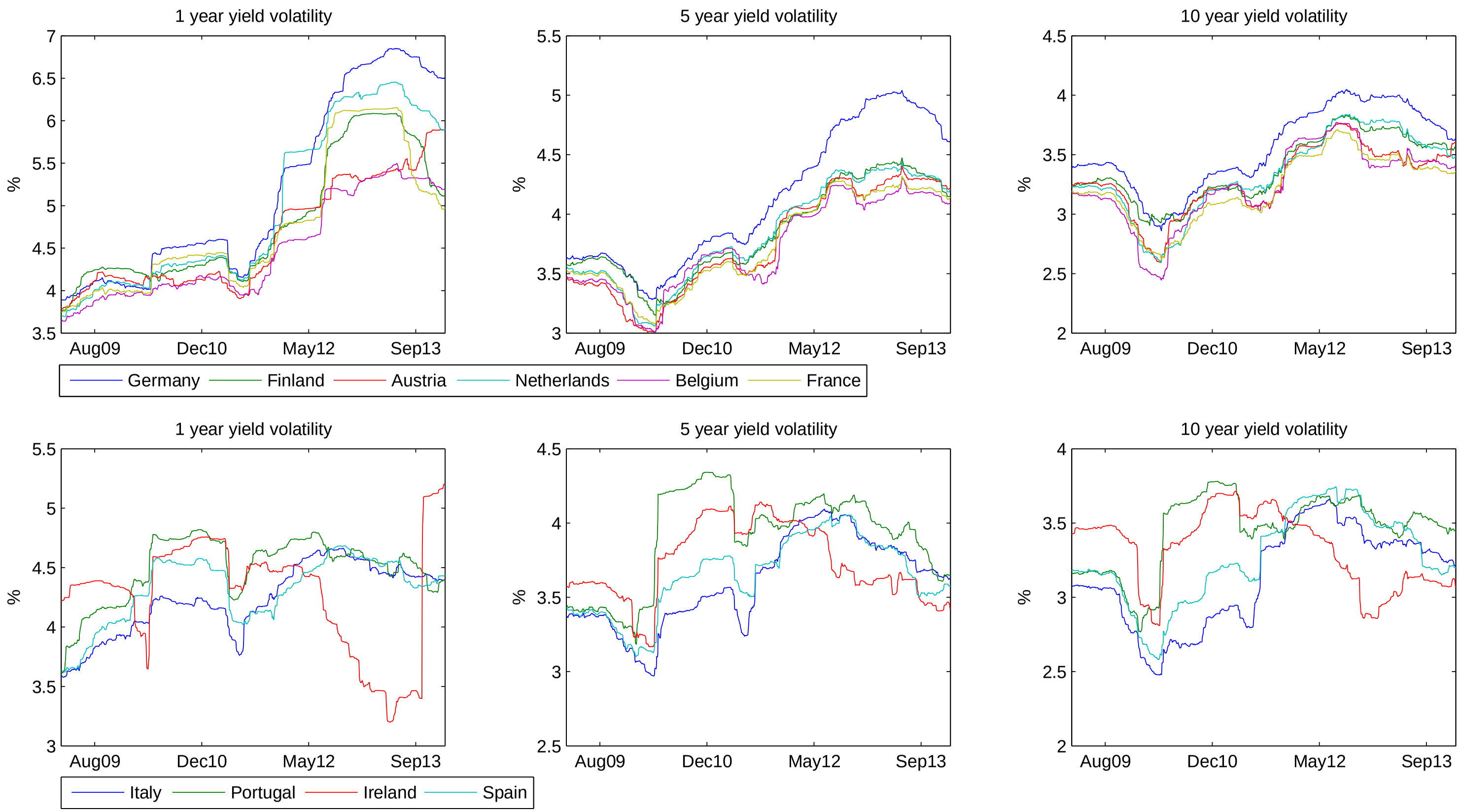

Figure 8: Observed 260 day historical volatilities of sovereign yields with maturities of 1 year, 5 year and 10 years for 10 european countries in the period March 2009 - February 2014.

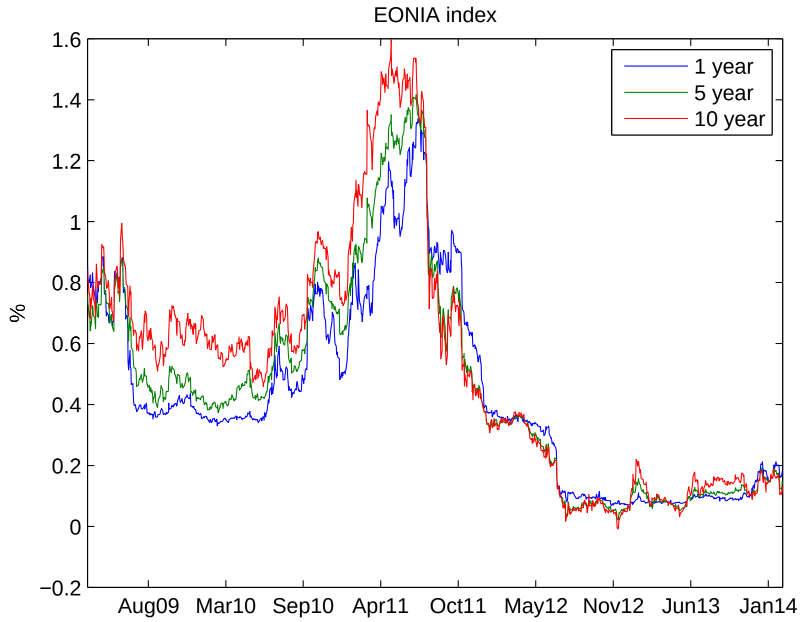

Figure 9: Observed 1-year, 5-year and 10-year overnight indexed swap (OIS) rates in the European market between March 2009 and February 2014. The indices display average swap rates on the interbank market quoted by a set of representative banks with high credit-ratings and strong reputation.

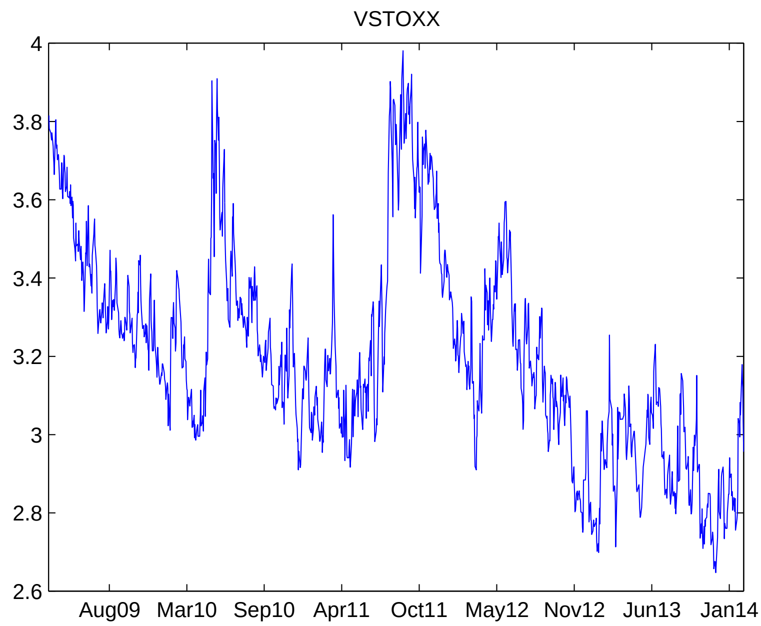

Figure 10: VSTOXX implied volatility index between March 2009 and February 2014.

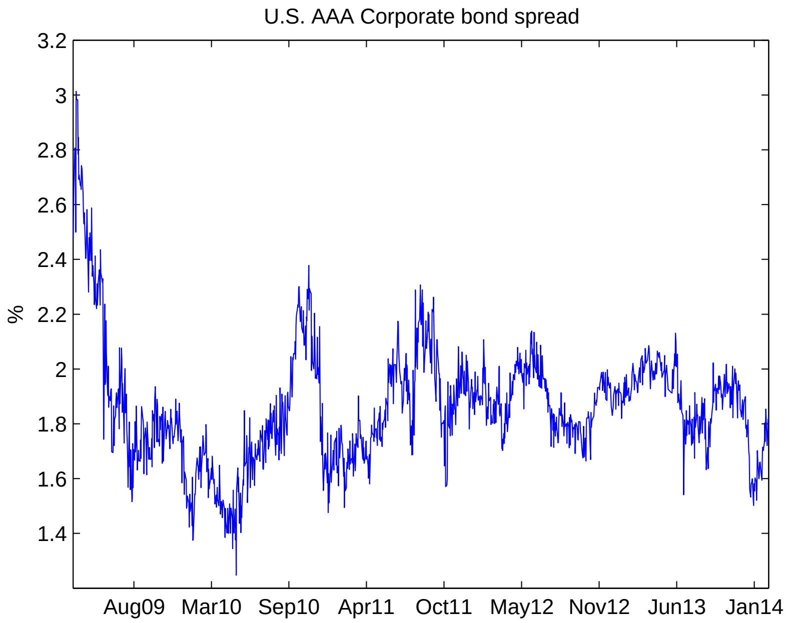

Figure 11: The spread between 10-year U.S. AAA rated corporate bond yields and the corresponding U.S. Treasury rate in the period March 2009-February 2014.

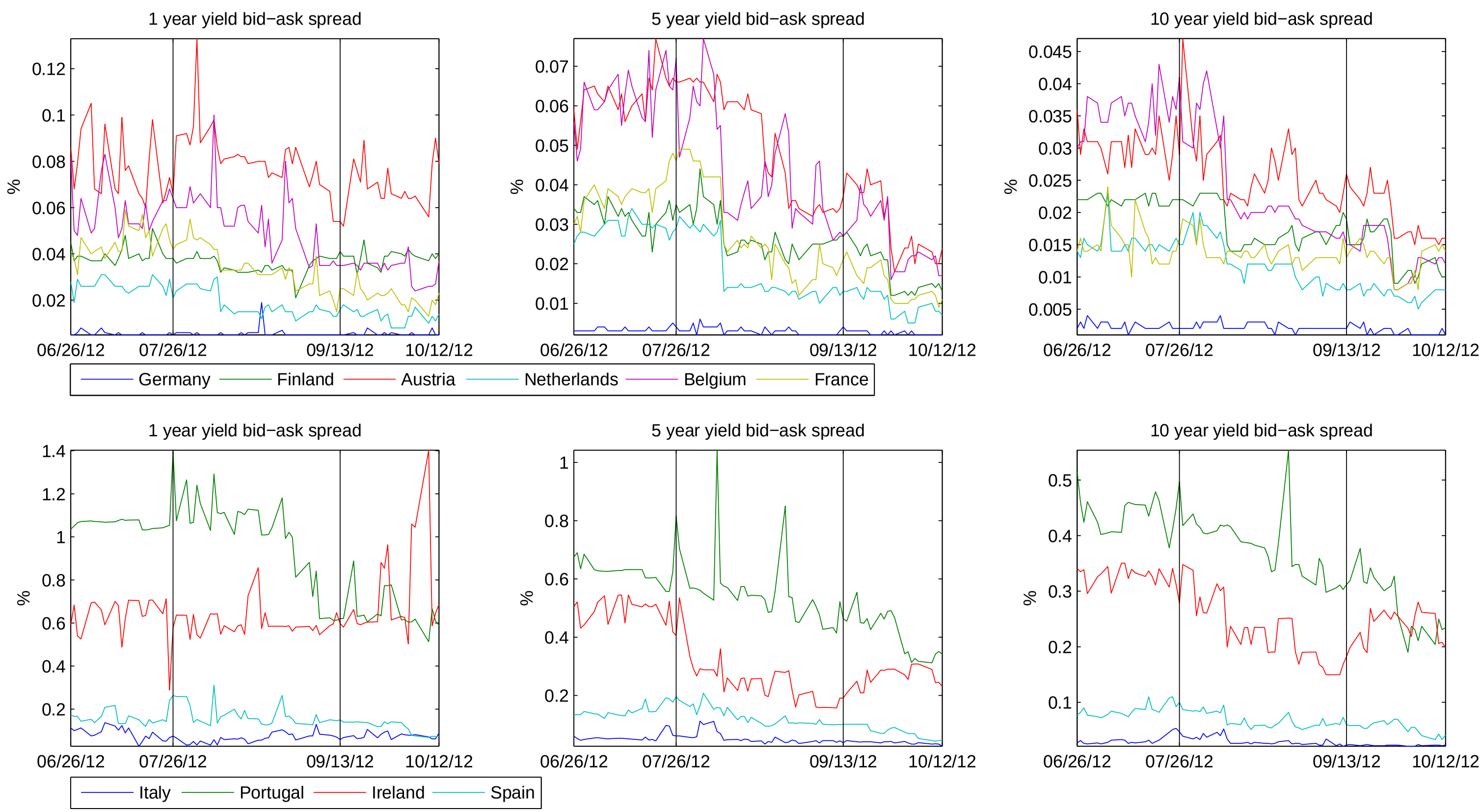

Figure 12: Observed bid-ask spreads for 1-year, 5-year and 10-year sovereign yields for 10 European countries. The vertical lines indicate July 26th, 2012 and September 13th, 2012 respectively. In the period between these dates, the European Central Bank (ECB) announced its intention to intervene in secondary bond markets to reduce the risk of break-up of the EMU.

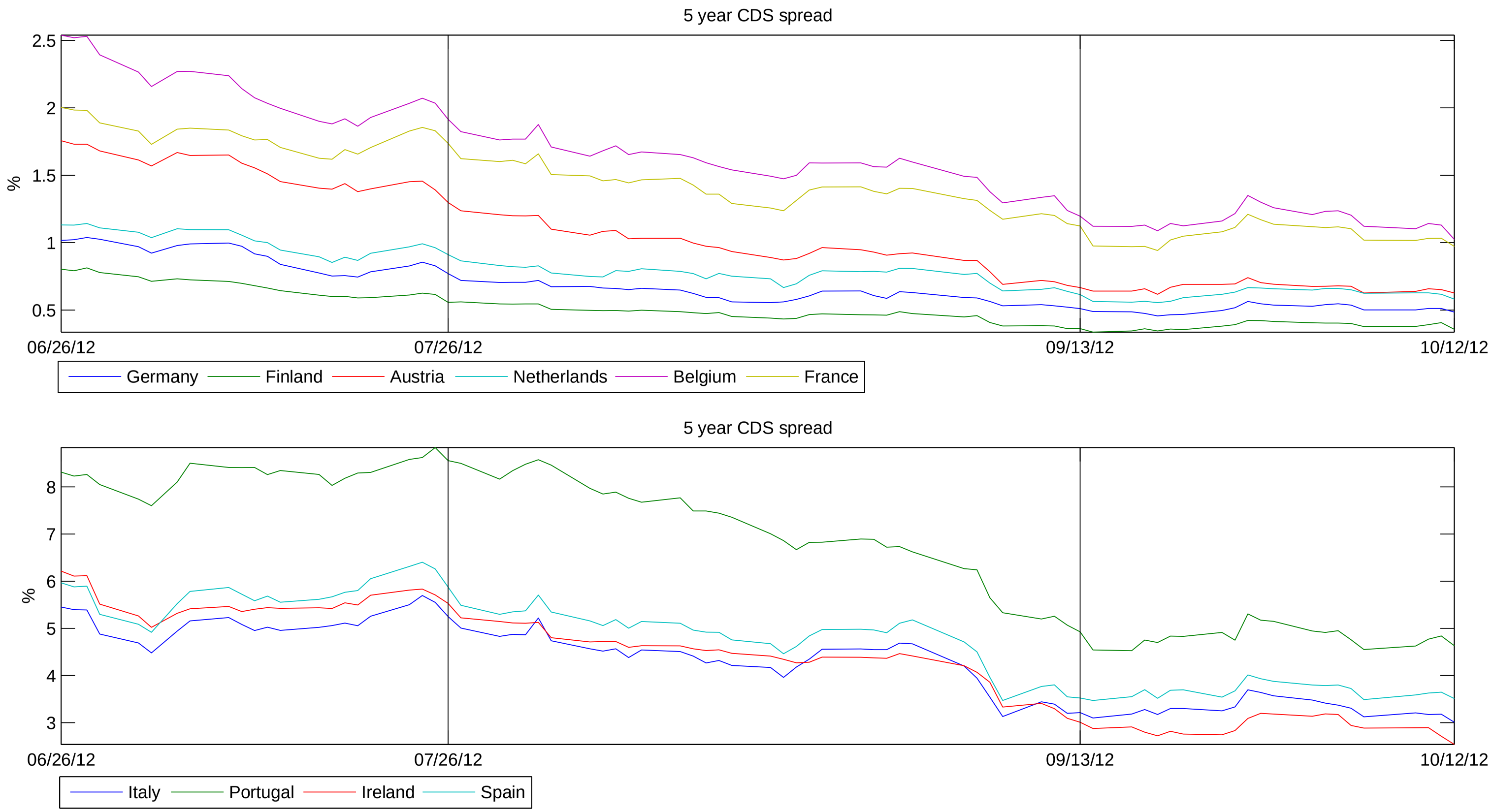

Figure 13: Observed 5 year CDS spreads for 10 European countries. The vertical lines indicate July 26th, 2012 and September 13th, 2012 respectively. In the period between these dates, the European Central Bank (ECB) announced its intention to intervene in secondary bond markets to reduce the risk of break-up of the EMU.

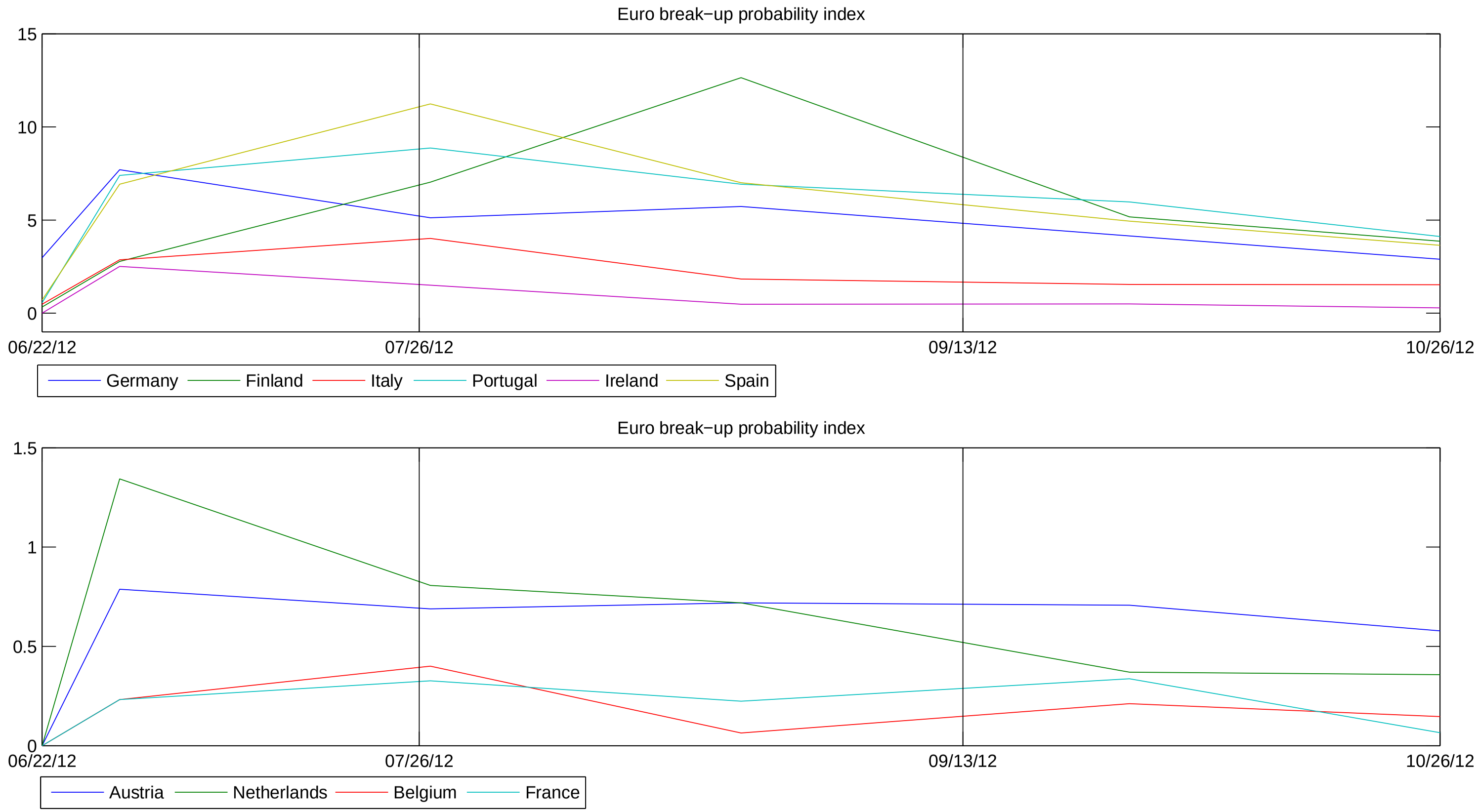

Figure 14: The Euro break-up risk index (EBI) provided by Sentix. The index is quoted separately for all euro zone countries and aims at reflecting financial markets' view on the probability that each country will leave the EMU within the next year. The vertical lines indicate July 26th, 2012 and September 13th, 2012 respectively. In the period between these dates, the European Central Bank (ECB) announced its intention to intervene in secondary bond markets to reduce the risk of break-up of the EMU.

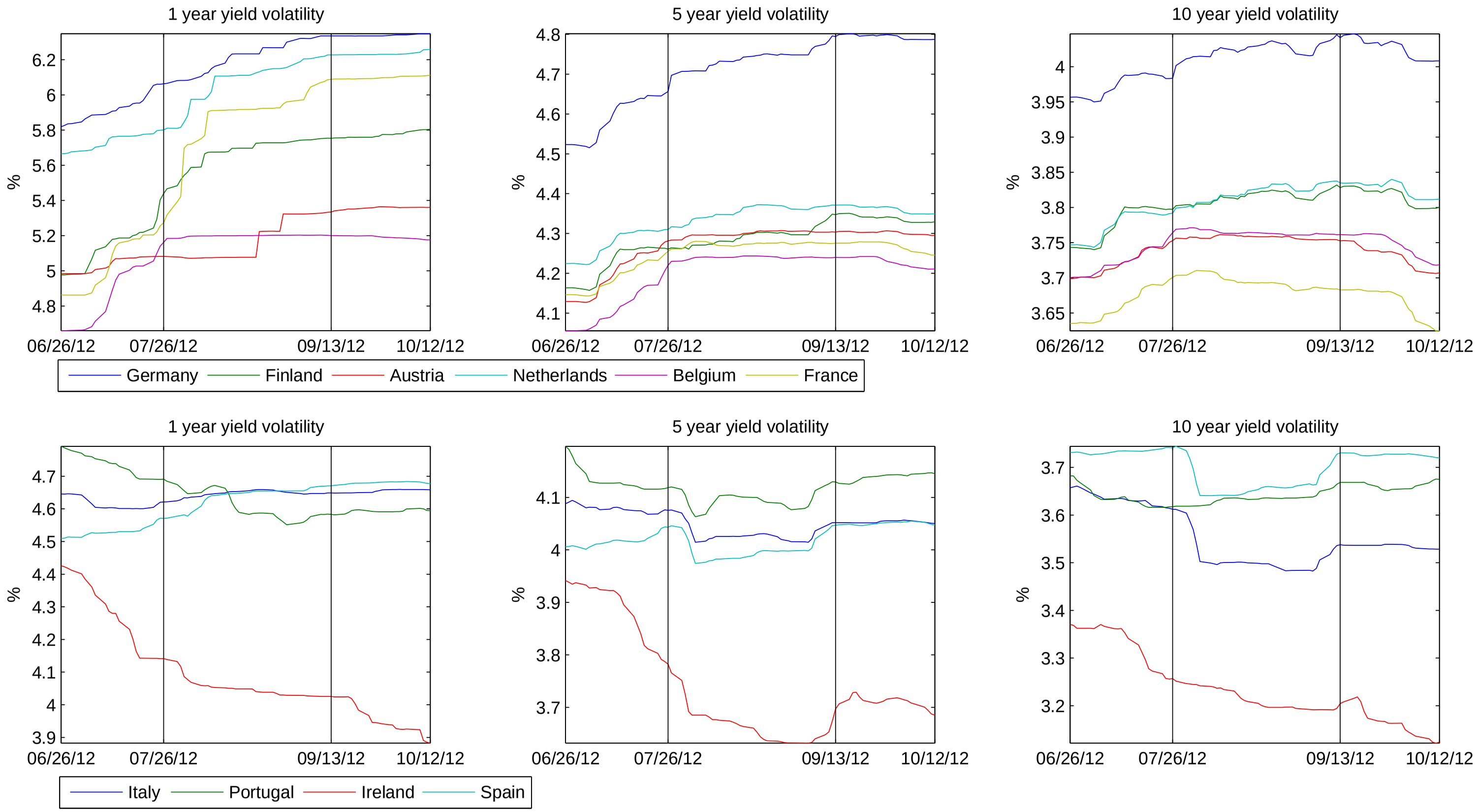

Figure 15: Observed 260 day historical volatilities of sovereign yields with maturities of 1 year, 5 year and 10 years for 10 european countries. The vertical lines indicate July 26th, 2012 and September 13th, 2012 respectively. In the period between these dates, the European Central Bank (ECB) announced its intention to intervene in secondary bond markets to reduce the risk of break-up of the EMU.

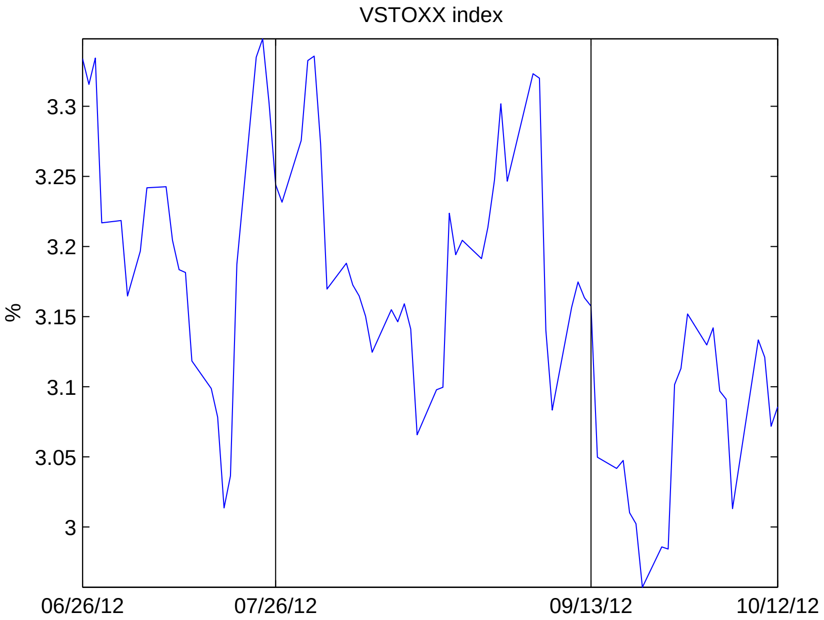

Figure 16: VSTOXX implied volatility index. The vertical lines indicate July 26th, 2012 and September 13th, 2012 respectively. In the period between these dates, the European Central Bank (ECB) announced its intention to intervene in secondary bond markets to reduce the risk of break-up of the EMU.

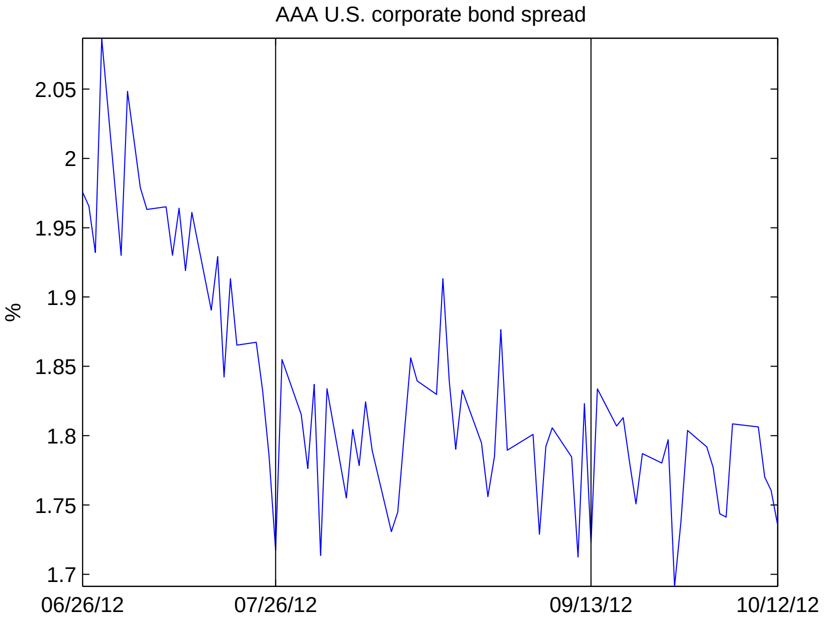

Figure 17: The spread between 10-year U.S. AAA rated corporate bond yields and the corresponding U.S. Treasury rate. The vertical lines indicate July 26th, 2012 and September 13th, 2012 respectively. In the period between these dates, the European Central Bank (ECB) announced its intention to intervene in secondary bond markets to reduce the risk of break-up of the EMU.

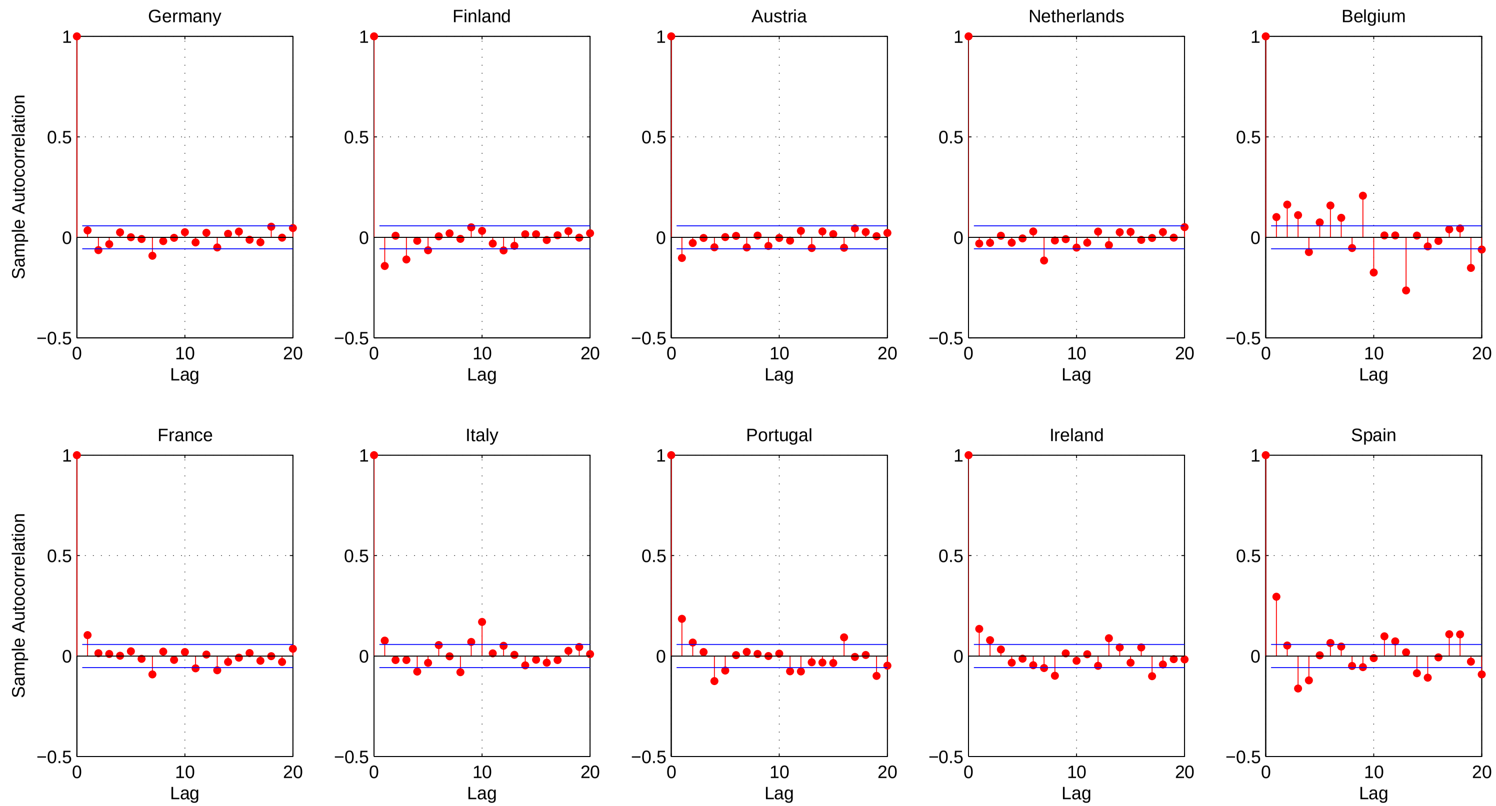

Figure 18: Estimated autocorrelations for daily 1 year sovereign spread innovations of 10 European countries in the period March 2009-February 2014. The horizontal lines indicate confidence bounds. If several autocorrelations are outside these bounds, significant autocorrelations appear present in the data.

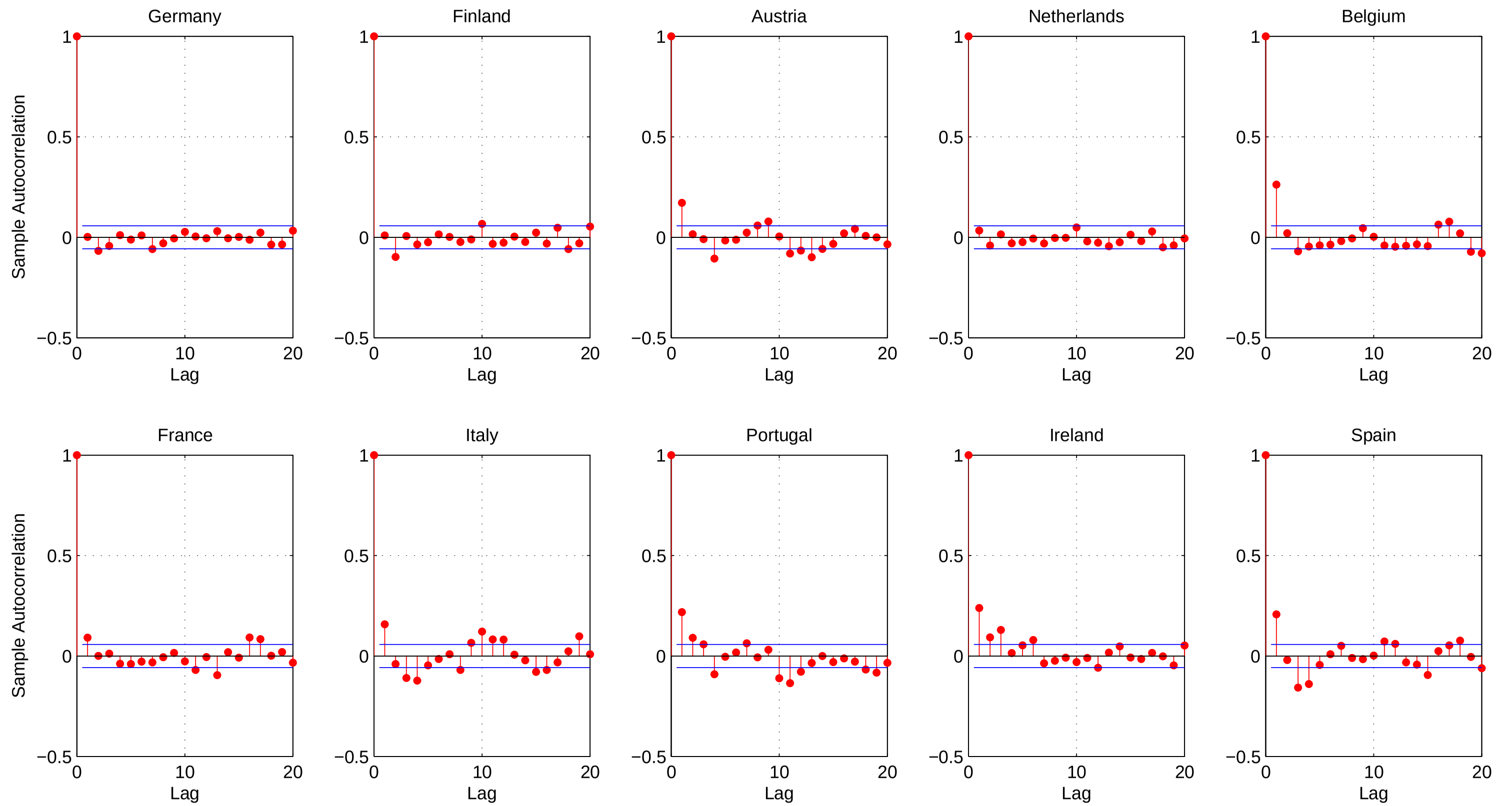

Figure 19: Estimated autocorrelations for daily 5 year sovereign spread innovations of 10 European countries in the period March 2009-February 2014. The horizontal lines indicate confidence bounds. If several autocorrelations are outside these bounds, significant autocorrelations appear present in the data.

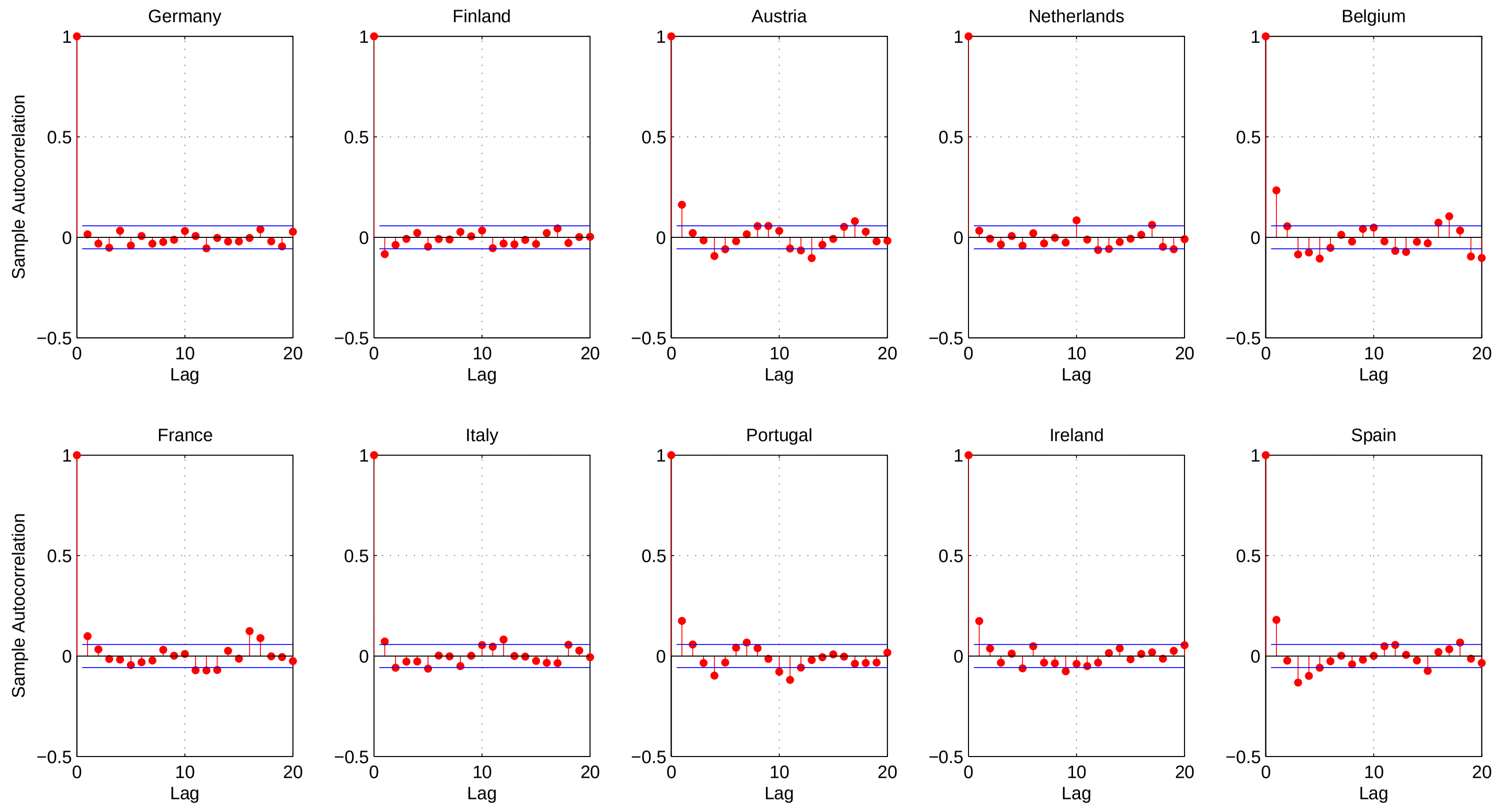

Figure 20: Estimated autocorrelations for daily 10 year sovereign spread innovations of 10 European countries in the period March 2009-February 2014. The horizontal lines indicate confidence bounds. If several autocorrelations are outside these bounds, significant autocorrelations appear present in the data.

Table 8: Test statistics obtained from the augmented Dickey and Fuller (1979) test with lag $n = 10$ days on yield spreads, bid-ask spreads, historical volatilities and CDS spreads for 10 euro area countries. Significant test statistics suggest rejection of the null hypothesis of unit roots in the data.

	Yield spreads			Bid-ask spreads			Volatilities			CDS spreads
	1Y	5Y	10Y	1Y	5Y	10Y	1Y	5Y	10Y	5Y
Level data										
Germany	-1.99***	-1.35	-1	-1.24	-1.56	-1.7	2.3	2.03	0.516	-1.03
Finland	-1.85	-1.34	-1.42	-1.27	-3.53***	-1.55	0.94	1.32	0.789	-1.2
Austria	-1.63	-1.51	-1.3	-3.19***	-1.72	-2.17***	3.1	1.27	0.439	-1.61
Netherlands	-2.02***	-1.59	-1.13	-2.06***	-1.78	-1.5	1.8	1.35	0.427	-1.41
Belgium	-2.16***	-1.01	-0.666	-1.73	-1.69	-1.3	1.7	0.855	0.203	-0.817
France	-1.94	-1.23	-0.721	-1.32	-1.73	-1.26	0.8	1.29	0.296	-0.651
Italy	-1.28	-0.646	-0.351	-1.38	-1.84	-2.06***	1.2	0.217	0.0702	-0.631
Portugal	-0.825	-0.492	-0.351	-0.94	-1.32	-1.1	0.6	0.0184	0.134	-0.627
Ireland	-0.855	-0.801	-0.545	-1.82	-1.46	-1.19	0.3	-0.325	-0.595	-0.685
Spain	-1.41	-0.578	-0.261	-1.79	-1.64	-1.31	0.86	0.167	-0.0589	-0.522
Differenced data										
Germany	-6.07***	-5.58***	-6.2***	-14.2***	-15.4***	-11.5***	-7.5***	-7.52***	-7.32***	-10.4***
Finland	-6.89***	-6.16***	-6.39***	-12***	-13.7***	-12.7***	-5.7***	-8.31***	-8.12***	-10.4***
Austria	-5.53***	-6.1***	-6.6***	-10.5***	-11.4***	-12.1***	-7.8***	-6.21***	-6.6***	-12.1***
Netherlands	-6.19***	-6.29***	-6.4***	-11.8***	-12.5***	-13.1***	-8.7***	-7.77***	-6.75***	-10.9***
Belgium	-6.9***	-5.48***	-5.97***	-14.7***	-13.6***	-11.5***	-6.3***	-7.72***	-7.69***	-11.1***
France	-7.73***	-5.9***	-6.31***	-11.1***	-11.2***	-14.3***	-7.4***	-6.85***	-6.68***	-11.5***
Italy	-6.4***	-5.72***	-5.61***	-15.1***	-12.2***	-12.1***	-8.1***	-7.02***	-7.78***	-11.5***
Portugal	-7.77***	-6.72***	-5.44***	-13.3***	-10.7***	-11.2***	-6.7***	-6.21***	-6.06***	-11***
Ireland	-8.35***	-6.41***	-5.67***	-14.5***	-12.2***	-11.5***	-9.4***	-6.92***	-7.68***	-11.9***
Spain	-5.98***	-5.77***	-6.06***	-13.1***	-13.3***	-13.6***	-6.3***	-7.53***	-7.63***	-12.6***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Estimated cross correlations of daily changes in 1-year, 5-year and 10-year sovereign yield spreads for 10 euro zone countries.

	Germany	Finland	Austria	Netherlands	Belgium	France	Italy	Portugal	Ireland	Spain
				1 year yield spreads						
Germany	1	0.6***	0.6***	0.7***	0.2***	0.7***	-0.03	-0.1***	-0.04	0.01
Finland	0.6***	1	0.5***	0.6***	0.2***	0.5***	0.006	-0.06*	-0.001	0.02
Austria	0.6***	0.5***	1	0.6***	0.3***	0.6***	0.1***	-0.02	0.008	0.1***
Netherlands	0.7***	0.6***	0.6***	1	0.3***	0.7***	0.04	-0.07*	0.001	0.06*
Belgium	0.2***	0.2***	0.3***	0.3***	1	0.4***	0.4***	0.2***	0.1***	0.3***
France	0.7***	0.5***	0.6***	0.7***	0.4***	1	0.1***	-0.007	-0.007	0.2***
Italy	-0.03	0.006	0.1***	0.04	0.4***	0.1***	1	0.3***	0.2***	0.6***
Portugal	-0.1***	-0.06*	-0.02	-0.07*	0.2***	-0.007	0.3***	1	0.4***	0.2***
Ireland	-0.04	-0.001	0.008	0.001	0.1***	-0.007	0.2***	0.4***	1	0.2***
Spain	0.01	0.02	0.1***	0.06*	0.3***	0.2***	0.6***	0.2***	0.2***	1
				5 year yield spreads						
Germany	1	0.8***	0.6***	0.9***	0.3***	0.6***	-0.1***	-0.09**	-0.09**	-0.1***
Finland	0.8***	1	0.7***	0.8***	0.4***	0.7***	-0.01	-0.04	-0.007	-0.008
Austria	0.6***	0.7***	1	0.7***	0.6***	0.8***	0.2***	-0.005	0.06*	0.2***
Netherlands	0.9***	0.8***	0.7***	1	0.5***	0.8***	0.04	-0.03	-0.003	0.06*
Belgium	0.3***	0.4***	0.6***	0.5***	1	0.7***	0.5***	0.2***	0.2***	0.5***
France	0.6***	0.7***	0.8***	0.8***	0.7***	1	0.2***	-0.05	0.04	0.2***
Italy	-0.1***	-0.01	0.2***	0.04	0.5***	0.2***	1	0.3***	0.3***	0.8***
Portugal	-0.09**	-0.04	-0.005	-0.03	0.2***	-0.05	0.3***	1	0.4***	0.3***
Ireland	-0.09**	-0.007	0.06*	-0.003	0.2***	0.04	0.3***	0.4***	1	0.3***
Spain	-0.1***	-0.008	0.2***	0.06*	0.5***	0.2***	0.8***	0.3***	0.3***	1
				10 year yield spreads						
Germany	1	0.7***	0.6***	0.9***	0.4***	0.6***	-0.1***	-0.03	0.02	-0.07*
Finland	0.7***	1	0.6***	0.8***	0.4***	0.6***	-0.008	0.004	0.1***	0.03
Austria	0.6***	0.6***	1	0.7***	0.7***	0.8***	0.2***	0.08**	0.2***	0.2***
Netherlands	0.9***	0.8***	0.7***	1	0.5***	0.7***	0.03	0.02	0.1***	0.07*
Belgium	0.4***	0.4***	0.7***	0.5***	1	0.7***	0.5***	0.2***	0.3***	0.5***
France	0.6***	0.6***	0.8***	0.7***	0.7***	1	0.3***	0.05	0.1***	0.3***
Italy	-0.1***	-0.008	0.2***	0.03	0.5***	0.3***	1	0.3***	0.3***	0.8***
Portugal	-0.03	0.004	0.08**	0.02	0.2***	0.05	0.3***	1	0.4***	0.3***
Ireland	0.02	0.1***	0.2***	0.1***	0.3***	0.1***	0.3***	0.4***	1	0.3***
Spain	-0.07*	0.03	0.2***	0.07*	0.5***	0.3***	0.8***	0.3***	0.3***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: The table reports estimated regression coefficients for the benchmark model using only observations of countries with CDS spreads below the cross-sectional average at each date. The sample consists of daily data between March 2009 and February 2014. Driscoll and Kraay (1998) standard errors are provided in parenthesis and are robust to cross sectional correlation as well as serial correlation up to 30 lags.

	(1) 1 year spread	(2) 5 year spread	(3) 10 year spread
CDS	0.239**	0.451***	0.370***
	(2.94)	(5.05)	(5.36)
LIQ	0.0769	0.226	0.442
	(1.09)	(1.35)	(1.50)
VOL	0.0319	0.320	0.437
	(0.27)	(1.36)	(1.92)
AAA	0.0330***	0.0682***	0.0373
	(3.88)	(3.42)	(1.45)
VSTOXX	-0.106***	-0.215***	-0.169***
	(-3.42)	(-6.09)	(-5.18)
Constant	-0.00200	-0.00291	-0.00205
	(-0.94)	(-0.94)	(-0.93)
Observations	7364	7364	7364
Groups	10	10	10
R^2	0.0816	0.1739	0.1346
Time fixed effects	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: The table reports estimated regression coefficients for the benchmark model using only observations of countries with CDS spreads below the cross-sectional average at each date. The sample consists of monthly data between June 2012 and January 2014. Driscoll and Kraay (1998) standard errors are provided in parenthesis and are robust to cross sectional correlation as well as serial correlation up to 1 lags.

	(1) 1 year spread	(2) 5 year spread	(3) 10 year spread
CDS	0.125	0.554	0.411
	(1.72)	(1.48)	(1.49)
LIQ	0.827	1.153**	-2.124
	(1.42)	(3.58)	(-0.55)
VOL	0.0576	0.534	0.0567
	(1.19)	(0.73)	(0.08)
AAA	-0.177*	-0.322	-0.451
	(-2.31)	(-1.10)	(-1.54)
VSTOXX	-0.157	-0.217	-0.0402
	(-1.93)	(-1.03)	(-0.17)
Constant	0.00114	0.00705	0.00450
	(0.14)	(0.18)	(0.10)
Observations	120	120	120
Groups	10	10	10
R^2	0.0609	0.1857	0.1122
Time fixed effects	No	No	No

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12: The table reports estimated regression coefficients for the regression model with country-specific euro break-up risk using only observations of countries with CDS spreads below the cross-sectional average at each date. The sample consists of monthly data between June 2012 and January 2014. Driscoll and Kraay (1998) standard errors are provided in parenthesis and are robust to cross sectional correlation as well as serial correlation up to 1 lags.

	(1) 1 year spread	(2) 5 year spread	(3) 10 year spread
CDS	0.126	0.563	0.414
	(1.67)	(1.50)	(1.50)
LIQ	0.825	1.154**	-2.047
	(1.39)	(3.52)	(-0.52)
VOL	0.0579	0.539	0.0681
	(1.17)	(0.74)	(0.10)
AAA	-0.177*	-0.321	-0.450
	(-2.31)	(-1.09)	(-1.53)
VSTOXX	-0.157	-0.215	-0.0407
	(-1.93)	(-1.03)	(-0.17)
EBI	-0.000261	-0.0155*	-0.00404
	(-0.08)	(-2.63)	(-0.58)
Constant	0.00115	0.00749	0.00483
	(0.14)	(0.20)	(0.11)
Observations	120	120	120
Groups	10	10	10
R^2	0.2304	0.1958	0.1129
Time fixed effects	No	No	No

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13: The table reports estimated regression coefficients for the model with an OMT event indicator using only observations of countries with CDS spreads below the cross-sectional average at each date. The sample consists of daily data between January 2012 and February 2014. Driscoll and Kraay (1998) standard errors are provided in parenthesis and are robust to cross sectional correlation as well as serial correlation up to 30 lags.

	(1) 1 year spread	(2) 5 year spread	(3) 10 year spread
CDS	0.130^{*}	0.345^{**}	0.227^{**}
	(2.41)	(3.17)	(2.92)
LIQ	0.00742	0.292	0.341
	(0.19)	(1.14)	(0.52)
VOL	-0.0878^{**}	0.560	0.567
	(-3.23)	(1.29)	(1.60)
AAA	0.0161	0.128^{***}	0.160^{***}
	(1.04)	(4.70)	(5.79)
VSTOXX	-0.00700	-0.0546	-0.0553
	(-0.46)	(-1.17)	(-1.22)
I^{OMT}	0.00427	0.0115	0.0117
	(1.42)	(1.20)	(1.13)
Constant	-0.00310	-0.00880	-0.00818
	(-0.87)	(-0.80)	(-0.66)
Observations	3034	3034	3034
Groups	10	10	10
R^2	0.0549	0.1355	0.1263
Time fixed effects	Yes	Yes	Yes

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$