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In 2010 all ECB publications feature a motif taken from the €500 banknote.

NOTE: This Working Paper should not be reported as representing the views of the European Central Bank (ECB). The views expressed are those of the authors and do not necessarily reflect those of the ECB.

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CONTENTS

Abstract

This paper studies the relative pricing of euro area sovereign CDS and the underlying government bonds. Our sample comprises weekly CDS and bond spreads of ten euro area countries for the period from January 2006 to June 2010. We first compare the determinants of CDS spreads and bond spreads and test how the crisis has affected market pricing. Then we analyse the 'basis' between CDS spreads and bond spreads and which factors drive pricing differences between the two markets. Our first main finding is that the recent repricing of sovereign credit risk in the CDS market seems mostly due to common factors. Second, since September 2008, CDS spreads have on average exceeded bond spreads, which may have been due to 'flight to liquidity' effects and limits to arbitrage. Third, since September 2008, market integration for bonds and CDS varies across countries: In half of the sample countries, price discovery takes place in the CDS market and in the other half, price discovery is observed in the bond market.

JEL classification: G00, G01;

Keywords: Credit Spread; CDS; government bond; financial crisis, limits to arbitrage;

Non-technical summary

Credit default swaps (CDS) offer trading for a wide range of instruments with exposure to credit risk. CDS provide traded insurance against credit risk. In a standard CDS contract, two parties enter into an agreement terminating either at the stated maturity or earlier when a previously specified credit event occurs and the protection component is triggered. Hence, a CDS contract serves to transfer the risk that a certain individual entity experiences a credit event from the "protection buyer" to the "protection seller" in exchange for the payment of a regular fee.

Since late September 2008, the sovereign CDS market has attracted considerable attention. Recent market developments peaked in an unprecedented 'flight to safety' episode in early May 2010 in the euro area, when investors started large scale sell-offs of a variety of risky assets.

The purpose of this paper is to provide a comprehensive analysis of the euro area sovereign CDS market. Our sample comprises weekly observations on the CDS spreads and bond yields of ten euro area countries from January 2006 to June 2010. Although market information indicates growing volumes and active trading, potentially variable liquidity is certainly a major caveat in any analysis of market prices.

Our first main contribution is a comparative analysis of the determinants of spreads on CDS and the underlying government bonds. Our approach allows us to use a comprehensive set of potential explanatory factors such as liquidity factors or proxies for risk aversion without being constrained by the specification of a particular pricing model. We find that the recent repricing of sovereign debt is strongly linked to common factors some of which proxy for changes in investor risk appetite.

Due to sizeable risk premia in CDS quotes changes in credit and non-credit-related components lead to different interpretations of market expectations. Specifically, decreasing appetite for credit-risky instruments is a different signal of market perceptions than rising expectations about future defaults in the underlying instruments. Hence, high CDS premia during the crisis may be in part due to declining risk appetite and falling market liquidity, but also to concerns about an increasing number of credit rating downgrades, rather than to principal losses on outstanding debt.

Our second main contribution is to study the 'basis', i.e. the difference between CDS spreads and the spreads on the underlying government bonds. In essence, both sovereign CDS and government bonds offer exposure to sovereign debt. Hence, the basis, which should normally be close to zero, can provide some insights into the functioning of sovereign credit markets. We find that for most countries in our sample the spread on the government bond relative to the swap rate is below the corresponding CDS spread. Our econometric analysis as well as the related literature allow us offer some potential explanations for this empirical observation. In particular, a number of authors have recently provided evidence for the existence of limits of arbitrage s and slow moving capital. They argue that deviations from the arbitrage-free parity do not seem to be easily exploitable as market frictions and structural changes throughout the crisis inhibit traders to arbitrage away these price differentials.

1. Introduction

Since August 2007, credit markets have witnessed an unprecedented repricing of credit risk. This credit market crisis has proceeded in several stages and has affected all sectors. The revaluation started in US mortgage markets; subsequently corporates, in particular banks, underwent a dramatic reassessment of their credit risk. This financial market turbulence reached a peak in the wake of the collapse of Lehman Brothers in September 2008. After this event, many major banks on both sides of the Atlantic were in major distress and massive state intervention was required in order to mitigate systemic risk and its adverse macroeconomic consequences.

Since September 2008, the sovereign debt market has attracted considerable attention. Before the crisis, trading in credit markets was concentrated on private sector instruments such as corporate credit risk or securitisation instruments. The collapse of Lehman Brothers in fall 2008 led to a fundamental reassessment of the default risk of developed country sovereigns. Widespread and large-scale state support for banks as well as other stimulus measures to the broader economy quickly increased public sector deficits to levels last seen after World War II. For example, in the UK the fiscal burden of extensive bank support measures is estimated at 44% of UK GDP (Panetta et al, 2009).

In the euro area, sovereign debt markets in several countries came under unprecedented stress in the first half of 2010. Massive sell-offs were observed for instance in Greek government bonds, with CDS spreads on Greek bonds jumping above 1,000 basis points. These tensions peaked in a 'flight to safety' episode in early May 2010, when investors started large scale sell-offs of risky assets. European public authorities then announced a number of measures to reduce distress in financial markets. In particular, EU finance ministers launched the European Financial Stability Facility (EFSF), while the ECB announced several policy measures such as interventions in bond markets under the Securities Markets Programme. The EFSF with a planned overall volume up to EUR 440 billion is intended to support euro area governments which face difficulties in accessing public debt markets (cf. Deutsche Bank, 2010). These measures all helped improving sentiment in euro area sovereign debt markets.

Traditionally, valuation of government debt issued by developed country sovereigns has treated default as a very low probability event.[3] Hence, modelling (e.g. in term structure analysis) is typically oriented towards interest rate risk or liquidity risk, rather than default risk. The absence of defaults among developed country governments has underpinned the widely used assumption that government bonds provide a good proxy for the long-horizon (default-) risk-free rate. Hence, before the crisis, the CDS market for developed country borrowers developed rather as a sideshow to the trading of emerging market debt. In addition to the perception of very low default risk in Western sovereigns, the dramatic experience of the 1997-1998 crisis in emerging market sovereigns also played a large role. Given this market focus, key papers on sovereign CDS such as Pan and Singleton (2008) or Longstaff et al. (2008)

[3] In the literature on credit risk modelling, default risk is usually defined as the narrow risk arising from an entity's failure to pay its obligations when they are due. In contrast, credit risk also covers any losses due to an entity's credit rating being downgraded (e.g. from A to BBB).

do not study euro area countries.[4] Only in the context of the worsening of the current crisis has attention turned to default risk in euro area sovereign debt. Both for trading as well as for hedging reasons, market activity in euro area sovereign CDS has grown strongly. These recent concerns about default risk in developed country government bonds have therefore also cast doubts on using government bonds for estimating risk-free rates, a core feature of asset pricing.

The purpose of this paper is to provide a comprehensive analysis of the Euro area sovereign CDS market by making use of information from the underlying bonds. Our two main contributions are first a comparative analysis of the determinants of spreads[5] and second a study of the arbitrage relationship between CDS and the underlying bonds. In the first part, we study the common factors in the first differences of bond spreads and CDS spreads and analyse the impact of the repricing of credit risk on spreads. Our approach allows us to use a comprehensive set of potential explanatory factors such as liquidity factors or proxies for risk aversion without being constrained by the specification of a particular pricing model. In the second part of our paper we analyse the '*basis*', i.e. the difference between CDS spreads and the spreads on the underlying government bonds. This variable is of particular interest because arbitrage trading should generally drive it close to zero. Hence, analysis of the determinants of the basis can help us understand market functioning as well as information transmission across the two markets which trade the same type of risk, namely sovereign credit risk. We also conduct a variety of robustness tests and discuss the economic significance of our results.

Our sample comprises weekly observations on the CDS spreads and bond yields of ten Euro area countries. The sample period is from January 2006 to June 2010. Our analysis of the 'basis' complements the existing literature on sovereign CDS of developed countries as previous research on sovereign CDS has not studied the interaction with the underlying bonds. In particular, information from the underlying bond market significantly extends the information set for explaining CDS market pricing. Dieckmann and Plank (2010) study the pricing of sovereign CDS with a focus on the 'private-public risk transfer', i.e. how sovereign CDS are related to the respective country's banking system. This question is also analysed by Ejsing and Lemke (2010) who document linkages between CDS of Euro area banks and their governments' CDS. [6]

Our first main finding is that the recent repricing of the cost of sovereign debt is strongly linked to common factors some of which proxy for changes in investor risk appetite. As regards the impact of the crisis, we find a structural break in market pricing which coincides with the sharp increase in trading of sovereign CDS. Furthermore declining risk appetite, which has characterised investor behaviour since summer 2007, has provided a sizable contribution to the observed strong increase in CDS premia.

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[4] Pan and Singleton (2008) study Korea, Turkey and Mexico. Longstaff et al. (2008) analyse 26 countries where the only EU countries are Bulgaria, Hungary, Poland, Romania and Slovakia.

[5] Following the literature on credit markets, we use the terms 'credit spread' and 'CDS premium' as synonyms because a CDS premium can be interpreted as the spreads between a corporate bond and the default- risk free-rate (Duffie, 1999).

[6] The analysis of euro area sovereign bond markets has typically focused on the role of fiscal fundamentals, market liquidity or market integration (cf. Manganelli and Wolswijk, 2009). Overall, this literature looks more at migration risk (i.e. rating downgrades) than on the risk of outright default. Euro area bond market developments in the crisis are analysed by Sgherri and Zoli (2009), Mody (2009) or Haugh et al. (2009).

Second, the nature of the relation between CDS and government bonds indicates that interdependence between the two markets differs from the patterns observed for corporate debt markets. Typically, the basis in corporate debt markets has been below zero since the start of the crisis (Fontana, 2010). In contrast, we observe a positive basis for most countries. One possible explanation for the CDS spread exceeding the bond spread are 'flight to liquidity' effects[7], which specifically lower government bond spreads in periods of market distress. The main exceptions to this pattern are Portugal, Ireland and Greece where we find a temporary negative basis in 2009 and early 2010. Since September 2008, market integration for bonds and CDS differs across countries. In half of the sample countries, price discovery takes place in the CDS market and in the other half, price discovery is observed in the bond market. In contrast, before the crisis, there was only limited trading activity in the CDS market which also affected price discovery and the linkages between the bond and the derivative market.

Overall, our results on the arbitrage relationship between bonds and CDS support the existence of 'limits of arbitrage' (Shleifer and Vishny, 1997) during the most turbulent periods of the financial crisis from late 2008 onwards and also in spring 2010. Pricing in the CDS market and the government bond market may have drifted apart because of 'flight to liquidity' effects in the latter and because of increasing hurdles for those traders who were trying to exploit what seemed to be sizable arbitrage opportunities. For instance, the number of market participants who acted as arbitrage traders declined sharply due to decreasing risk appetite and the exit of several major institutions such as Lehman. Overall, the crisis has had an adverse impact on both market and funding liquidity. Similar evidence of limits of arbitrage has been reported by Bhanot and Guo (2010) and Fontana (2010) for the basis between corporate bond spreads and the corresponding CDS during the crisis. In general, many market segments also witnessed the breakdown of what used to be stable relative pricing relationships before the crisis (cf. Mitchell and Pulvino, 2010 or Krishnamurty, 2010).

The rest of this paper is organised as follows. In section 2, we discuss the mechanism of sovereign CDS and the sample. Section 3 describes the results of the econometric analysis. Section 4 concludes the paper by summarising the main results.

2. Sample

2.1 A brief review of sovereign CDS

A CDS serves to transfer the risk that a certain individual entity or credit defaults from the "protection buyer" to the "protection seller" in exchange for the payment of a regular fee. In case of default, the buyer is fully compensated by receiving e.g. the difference between the notional amount of the loan and its recovery value from the protection seller. Hence, the protection buyer's exposure is identical to that of short-selling the underlying bond and hedging out the interest-rate risk. Commonly, CDS transactions on sovereign entities have a contractual maturity of one to ten years.

[7] Beber et al. (2009) illustrate 'flight to liquidity' effects in euro area government bonds.

The CDS spread is the insurance premium (in basis points per annum as a fraction of the underlying notional) for protection against default. As in a standard interest rate swap the premium is set such that the CDS has a value of zero at the time of origination. If a credit event occurs the protection seller compensates the protection buyer for the incurred loss by either paying the face value of the bond in exchange for the defaulted bond (physical settlement) or by paying the difference between the post-default market value of the bond and the par value (cash settlement) where the post-default value of the bond is fixed by an auction procedure. In the context of sovereign risk, the first such auction procedure was held for Ecuador in January 2009.

In a standard CDS contract on public or corporate debt, two parties enter into an agreement terminating *either* at the stated maturity *or* earlier when a previously specified "credit event" occurs and the protection component is triggered. Three important credit events defined (along with other terms of the contract) by the International Swaps and Derivatives Association (Barclays, 2010a) are:

- Failure to pay principal or coupon when they are due: Hence, already the failure to pay a coupon might represent a credit event, albeit most likely one with a high recovery (i.e. 'technical default').
- Restructuring: The range of admissible events depends on the currency and the precise terms which materialise.
- Repudiation / moratorium.

For corporate as well as sovereign CDS, the premium can be interpreted as a credit spread on a bond issued by the underlying reference entity.[8] By means of a no-arbitrage argument, Duffie (1999) shows that the CDS spread should equal the spread over LIBOR on a par floating rate bond. According to this pricing analysis, the risk-reward profile of a protection seller (who is 'long' credit risk) therefore is very similar to a trading strategy which combines a bond by the same entity with a short position in a default-risk-free instrument. As will be discussed later in more detail, this theoretical equivalence allows traders to arbitrage potential price differences between an entity's bonds and its CDS.

Like most CDS contracts, sovereign CDS typically serve as trading instruments rather than pure insurance instruments. Investors commonly use sovereign CDS mainly for the following purposes:

- Taking an outright position on spreads depending on traders' expectations over a short horizon
- Hedging macro, i.e. country risk (e.g. a bank's exposure to a quasi-governmental body)
- Relative-value trading (e.g. a short position in country X and a long position in country Y)
- Arbitrage trading (e.g. government bonds vs. CDS).

In addition to country default risk, a number of additional factors may influence the information content of CDS premia. First, in relative terms, sovereign CDS volume is small. As a measure, chart 1 uses the

[8] Since May 2009, CDS trading has undergone a 'big bang' with prices now consisting of an upfront payment and a regular fixed coupon (cf. Barclays 2010a). This change in their contractual features has made trading and closing out of positions easier. Putting the two components together leads to the CDS premium which is comparable to the previous contracts. In many cases, CDS positions are collateralised with the margin providing initial protection and also a variation component.

publicly available DTCC data for two snapshots relative to the volume of total bonds outstanding. For Greece, the net open CDS amount to around 3% of their outstanding sovereign debt and for Portugal and Ireland around 7%. This magnitude is in contrast to other sovereign derivatives market, such as the Bund future, where the derivatives market exceeds the cash market. For the Bund futures market, Upper and Werner (2002) show that in periods of high volatility price discovery takes place in the derivatives market rather than the cash market. Second, liquidity in CDS markets overall is also quite heterogeneous. The most liquid instruments are index products where bid-ask spreads amount to less than one basis point and intraday pricing is available. In contrast, prices for some single-name CDS contracts with bid-ask spreads in the double-digit range are quite stale.[9] Third, sovereign CDS on e.g. euro governments are typically denominated in US$ (Barclays, 2010 a). One reason for choosing a different currency than the bond's original denomination is that this allows investors to avoid the risk of a severe depreciation of the bond's currency in case of a credit event. This currency mismatch introduces an element of exchange rate risk into the pricing of the contract. Finally, counterparty risk may matter far more for sovereign CDS than for corporate CDS. In particular, CDS on major countries may not always provide genuinely robust insurance against a large-scale default given the close linkages between sovereigns and the financial sector.

2.2 Sample details

We use weekly CDS spreads and benchmark bond yields collected from Bloomberg. Our sample period is 1 January 2006 to 28 June 2010. The series are for 10-year CDS denominated in US$ for Austria, Belgium, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. This country selection is due to data availability. We focus on the ten-year horizon as this is the common horizon for the government bond. Hence, our yield data cover benchmark bonds with a ten-year maturity.

For all countries, we calculate the bond spread relative to the ten-year swap rate because interest rate swaps are commonly seen as the market participants' preferred measure of the risk-free rate (cf. Beber et al., 2009). In addition, this approach guarantees a homogeneous benchmark across the euro area. Some papers such as Haugh et al. (2009) use the German benchmark Bund yield as a proxy for the risk-free rate. However, this approach has the disadvantage that the CDS on Germany has to be omitted from the analysis. Furthermore, the benchmark role of Bunds may lead to the existence of a significant 'convenience yield'.[10]

We start the description of our sample by taking an aggregated perspective on the repricing. Chart 2 shows the developments in European sovereign CDS (iTraxx SovX Western Europe index) and those for

[9] For the corporate market, Blanco et al (2005) show that the CDS market already in its early stage provided the benchmark for the market pricing of default risk whereas the bond market played a minor role. A key factor is that CDS contracts are standardised with a maturity of five or ten years whereas the usually high number of individual bonds shows potentially idiosyncratic components (e.g. callability, maturity or coupon). In particular, many bond investors have a hold to maturity perspective and hence do not contribute to market liquidity.

[10] For US Treasuries, Krishnamurthy and Vissing-Jorgensen (2009) estimate the 'convenience yield' at 72 BP.

European financials (iTraxx Main Investment Grade Financials index).[11] The chart illustrates the massive repricing of risk reaching its first peak in fall and winter 2008/2009 when the SovX index climbed above 150 BP (see also Ejsing and Lemke, 2010 or Dieckmann and Plank, 2010). Both financial as well as sovereign CDS rose dramatically from October 2008 to early 2009 with the more recent market developments in sovereign markets since November 2009 providing a relatively smaller repricing in the index. Before the crisis, CDS for both types of entities were trading in the range of single-digit basis points with low volatility and also low market activity.

Using a simple pricing model,[12] the implied, i.e. risk-neutral probability of default can be extracted from CDS premia. An application of this model to the most recent observations of the SovX index in chart 2 leads to an estimate of the subjective default probability of around 1.3%. This market-implied estimate by far exceeds the historical estimate as for instance the long-run default probability of an A-rated issuer is around 0.1%. Such sizable differences have been observed by a number of papers in the context of the "credit spread puzzle" (Amato and Remolona, 2003). According to this stylised fact, expected default losses frequently account for a very small fraction of credit spreads. The residual component is interpreted as a risk premium (Giesecke et al., 2010), which is frequently found to be related to market liquidity or measures of investor risk appetite.

Overall, given the definition of default events outlined above, this high level of the implied default probability for European sovereigns may be due to risk premia but also due to rising probabilities of a scenario of "technical default" rather than market concerns about principal losses on outstanding debt in a Lehman-type scenario. In addition, market concerns about migration risk (i.e. the risk of a sovereign suffering a credit rating downgrade), in particular the loss of the coveted AAA rating might also have contributed to the jumps.

From a valuation perspective, both financial and sovereign credit instruments share strong exposure to systematic risk, i.e. a major deterioration in the macroeconomic environment, which in the case of financials would cause large-scale defaults in their loan books. Such a scenario of extremely high losses resembles the market's reassessment of the risk-return relation in asset-backed securities from summer 2007 onwards. Indeed, Berndt and Obreja (2010) show that European corporate CDS are significantly related to a factor which captures what the authors call "economic catastrophe risk".

Chart 3 plots the time series of bond spreads and CDS spreads for the ten countries in our sample. The descriptive statistics are shown in tables 1 and 2. Given the pronounced changes in CDS spreads after Lehman's default we report descriptive statistics for two subsamples, 1 January 2006 to 12 September 2008 ('period I') and 15 September 2008 to 28 June 2010 ('period II'). [13]

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[11] The iTraxx Financials comprises 25 major European banks and insurance firms. The iTraxx SOVX comprises 15 Western European sovereigns (including e.g. the UK). The index started trading in September 2009, but historical data have been backfilled starting from 2004.

[12] This standard model can be written as CDS Premium = $(1- \text{LGD})*\text{PD}$, where loss given default is commonly assumed to be 60% and PD is the risk-neutral default probability (cf. Hull et al., 2005).

[13] A caveat in this analysis is that the statistics in table 1 in the first sub-period are also influenced by the low market activity in the sovereign CDS market.

The country-level plots in chart 3 confirm the massive repricing of credit risk with sample highs mostly reached in spring 2010. For example, the French CDS moved from a level below 3 basis points (BP) in June 2007 to a peak of 100 BP in June 2010. The Greek CDS spread records a first peak in late 2008 / early 2009. However, the second peak in 2010 by far exceeds the first peak as the CDS spread briefly surpassed 1000 BP, i.e. 10 percentage points. The same developments of two consecutive peaks within less than a year are also observed for Belgium, France, Ireland, Italy, Portugal, and Spain. For all other EU countries in the sample, the first peak in late 2008 and early 2009 provides the sample high. [14] In the first part of the sample, almost all sovereigns' bonds traded below the swap curve as only Greece recorded a mean positive spread. In contrast, in the second part of the sample, mean negative spreads are only observed for Germany and France.

Until the end of June 2010 euro area sovereign CDS spreads have not returned to the levels witnessed before the collapse of Lehman in September 2008. Given that our sample ends at the end of June 2010, data availability precludes us from analysing the impact of the SMP and the EFSF on CDS spreads or bond spreads. In the aftermath of Lehman's collapse, the highest average CDS spreads are observed for Greece, Ireland, Italy, Spain and Portugal, where the mean premium exceeds 100 BP. We find that volatility is also highest for these five countries. The overall lowest premium is recorded for Germany with values of below one BP (0.70 BP) in the period before Lehman and 12 BP in the period after Lehman. In addition, the table also illustrates the sharp increase in volatility in the second period.

The charts illustrate differences between the movements of bond spreads relative to the swap rate and CDS spreads (we will conduct further analysis of the difference between the two variables in the next subsection). Typically, the CDS spread is situated above the bond spread, i.e. in price terms bonds are more expensive than CDS. Before the outbreak of the financial crisis, variation in CDS spreads was low whereas bond spreads showed higher volatility. The comparatively low variability in CDS spreads also indicates that trading activity was lower. In the second part of the sample period there is also comovement between the two variables. The plots for Germany also provide evidence of the "flight to liquidity" effect. At the height of the financial crisis in late 2008, the CDS spread jumped to levels above 90 BP in part also due to fiscal concerns. At the same time, the Bund yield fell sharply to 75 basis points below the ten-year euro swap rate. Such a portfolio shift into government bonds has been observed in many episodes of market turmoil such as for example the LTCM collapse in October 1998. The typical portfolio adjustment process is that investors sell assets perceived as risky and move into liquid government bonds which are perceived to offer a 'safe-haven' status (cf. Hartmann et al, 2004). This strong demand for safe - haven assets drove bond prices up and hence yields declined. This investor strategy is also supported by the mechanics of the Basel II capital requirements where the standardised approach allocates a risk weight of zero to government debt with a rating above A+ (BCBS, 2006).

[14] At several points in time during 2010 a few countries have experienced an inversion of their credit curve (cf. Barclays, 2010 b). This means that the CDS premium for the short horizon, e.g. one or three years exceeds the premia for a maturity of five or ten years. Such a situation is very rare and has only been observed for high-yield corporates with a high perceived likelihood of imminent default.

In order to understand market pricing market liquidity is a key variable . To estimate a proxy for this variable, we make use of the approach proposed by Lesmond et al. (2007). This method has the advantage that estimation only requires a sample of daily data. In essence, low market liquidity is indicated by the fact that the price of an instrument does not change often, hence, we use the number of days per week with unchanged CDS spreads or bond prices as the basis for our proxy.

Chart 4 shows the weekly cross-country averages of the number of zero changes in CDS premia and bond prices. Two observations are notable. First, the series indicates increasing CDS market liquidity with considerable spikes at year-end. Second, liquidity in the bond market seems to be higher than in the CDS market as there are far fewer instances of unchanged prices.

2.3 The concept of the 'basis' between CDS and bonds

In general, both sovereign CDS and government bonds offer investors exposure to the risk and return of sovereign debt. The basis is defined as the CDS spread minus the credit spread on a fixed-rate bond of similar maturity. In a basis trade, investors set up a default-risk free position by combining a bond position with a CDS trade in order to directly profit from potential price differences. With unimpeded access to sufficient funding (e.g. lending from prime brokers) arbitrage should over time reduce any differentials between the two market segments. Hence, differences between the market prices of bonds and CDS can provide information on the potential existence and size of arbitrage opportunities which should typically be very small if credit markets are functioning normally (cf. JP Morgan, 2009). [15]

To exploit a negative basis an arbitrage trader has to finance the purchase of the underlying bond and buy protection in the CDS market. In this case, default risk arising from the underlying entity is fully removed from the resulting position. For a positive basis a trader short-sells the underlying bond and sells CDS protection. Hence, if the bond is cheaper than the CDS, the investor should buy the bond and buy CDS protection to "lock in" a risk-free profit and vice versa. These two cases are summarised in the following table:

	CDS > Bond Spread ('positive Basis')	*CDS < Bond Spread* ('negative Basis')
Strategy	Sell CDS protection and bond	Buy CDS protection and bond
Observed for	Most sovereigns	Corporates since crisis

Empirical analysis on the basis during the crisis so far only covers corporate bonds. Fontana (2010) and Barot and Guo (2010) show that after the outbreak of the crisis, the basis between CDS and bonds has become persistently negative. Because of the funding liquidity shortage and the increased counterparty risk in the financial sector trading on the negative basis trade is difficult to implement in practice. Hence

[15] The perspective taken by the basis measure is exactly the opposite of that taken in the calculation of the 'non-default component' in credit spreads (Longstaff et al., 2005), which subtracts the CDS from the bond spread. See also Blanco et al. (2005).

during periods of distress CDS spreads and bond spreads can depart from their arbitrage-free values due to the liquidity and CDS counterparty risk faced by financial intermediaries and investors.

2.4 Time series of the basis measure

With the dramatic repricing of risk from September 2008 on, credit markets came under severe stress, which was reflected in both high levels and high volatility of the basis. Chart 5 plots the basis estimate. As already discussed in the context of chart 3, for seven out of ten countries the basis is positive, i.e. the CDS spread always exceeds the bond spread. Here, the mechanism of "flight to liquidity" might have played a role in driving down bond spreads. Simultaneously, however concerns about fiscal expansion drove CDS spreads up. The overall effect then was a positive spike in the basis. For such a situation, arbitrage is difficult to implement as it requires short-selling the bond and selling CDS protection. Given that liquidity in government bonds and market functioning are very heterogeneous, this positive basis therefore is rather costly to trade on (see also Barclays Capital, 2010b).

In contrast, the basis for Ireland, Greece and Portugal differs from the other seven countries as there are some negative observations. A negative basis arises when the spread on the government bond is higher than the CDS spread. Such a difference could in theory be arbitraged away by buying the bond and simultaneously buying protection in the CDS market. However, this strategy requires funding for the bond position. Hence, in periods of market turbulence, traders may be unable or unwilling to enter such a position. In particular, due to the price volatility, haircuts for the position are quite volatile and may be sizable. [16]

Chart 5 also shows the impact of the increased concerns about the fiscal situation of a number of euro area countries on the basis. Furthermore, the charts and the table show the high volatility in the basis with sharp swings materialising in particular from April 2010 on. This volatility implies that the risk-return relation of the basis arbitrage trade was also not constant. The charts provide further evidence of a structural break as the basis was relatively constant around 20 to 30 BP during the first part of the sample. Parts of this deviation could be also related to 'cheapest to deliver' options in the CDS contract (cf. JP Morgan, 2009) as well as to measurement issues for the risk-free rate and the impact of the mismatch in exchange rates between CDS in USD and euro-denominated bonds.

Comparing corporates to sovereigns indicates that the relationship between bonds and CDS to some extent depends on the type of the underlying debt. Corporate debt typically has a negative basis, which is strongly mean-reverting (cf. Fontana, 2010 or Bharot and Guo, 2010). In contrast, we have documented that Euro area sovereigns with the temporary exception of Ireland, Greece and Portugal have a positive basis.

[16] Gorton and Metrick (2009) argue that due their importance in repo market haircuts are a central mechanism of the financial crisis.

2.5 Factor analysis of the sample

We apply factor analysis to evaluate the extent of common variation across CDS, bond spreads and the basis. Table 4a shows the proportion of the total variance explained by the first factor respectively for weekly changes in CDS, weekly changes in bond spreads, and weekly changes in the basis. The sample periods are 2 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II").

Comparing the results across assets, we find that the strongest common factors are present in changes in CDS and bond spreads. In these two categories, the proportion of the total variance explained by factor 1 exceeds 80%. Overall, after September 2008, the analysis indicates the presence of significant common components for all categories of series as the weight of the first factor is always higher than 60%. The table also illustrates the structural break in both CDS and the basis where the increase in the role of the common factor grows strongly from period I to period II. In contrast, the weight of the common factor in the first differences of bond spreads declines after the collapse of Lehman in September 2008.

Overall, factor analysis shows that a common factor plays a large role in the variation in sovereign CDS spreads and credit spreads. The existence of such a strong common determinant in Euro area sovereign debt markets is a stylised fact in the empirical literature. As Sgherri and Zoli (2009, P.10) write "… *unanimous consensus in the literature that euro area government bond spreads are mostly driven by a single time-varying common factor, associated with shifts in international risk appetite*."

3. Econometric analysis

3.1 Regression Methodology

As the previous discussion has shown, fundamentals as well as changes in risk appetite with regard to sovereign risk may be among the underlying drivers of the variation of CDS spreads as well as spreads on government bonds. In the literature on credit spreads, researchers commonly use as a theoretical framework the structural model introduced by Merton (1974), which is oriented towards the analysis of corporate credit risk.[17] Gapen et al. (2005) extend this structural modelling approach towards sovereign credit risk, thereby providing a contingent-claims based valuation of default risky government bonds. Specifically, Gapen et al. (2005) argue that key drivers of the risk of sovereign default are the volatility of sovereign assets and a country's leverage. Hence, many of the theoretical results which are relevant for corporate credit risk are indeed also applicable to sovereign credit risk.

Our main aim is to investigate whether the same set of factors is priced in CDS spreads as well as in bond spreads. We start with a set of explanatory variables which comprises proxies for credit risk and for the movement of the risk-free rate. Furthermore, we include some factors, which previous research has found to be significant determinants of credit spreads (see e.g. Collin-Dufresne et al., 2001, Campbell and Taksler, 2003, Raunig and Scheicher, 2009 or Ericsson et al., 2009). In section 3.3 we then extend this set

[17] Capuano et al. (2009) discuss recent advances and challenges in credit risk modelling.

of variables. We will also build on this set of variables to study the determinants of the basis in section 3.4.

- Risk-free rate

According to the Merton (1974) model changes in the risk free rate in general are negatively related to credit spreads. A rising risk-free rate decreases the present value of the expected future cash flows, i.e. the price of the put option decreases. Furthermore, a rising risk-free rate tends to raise the expected growth rate of the firm value and hence a higher firm value becomes more likely. In turn, this implies a lower price of the put option on the firm value. Hence, these two effects should lower the credit spread. As a Euro-wide homogeneous proxy we use the Euribor three-month short rate.

- Risk appetite (RA)

As already discussed in the previous section credit spreads not only compensate investors for pure expected loss (see also Hull et al., 2005). Hence, spreads may change due to changes in investors' risk aversion even if the underlying fundamentals (i.e. the pricing under the "statistical measure") are unchanged. We use the VIX index of implied S&P 500 volatility. In order to calculate a proxy for risk appetite, we deduct a GARCH-based estimate of volatility from the VIX index. This estimate represents the risk premium which investors in equity options require in order to compensate them for equity market risk.

- Corporate CDS premium (iTraxx)

Given that credit spreads compensate investors for more than pure expected loss we include a measure of aggregate credit market developments, namely the iTraxx Main Investment Grade index. The premium on this CDS index should also contain a proxy for investors' overall appetite for credit risk.

- Proxy for a country's public debt (Debt)

In structural models of sovereign credit risk (Gapen et al., 2005) a firm's leverage defined as the ratio of debt to its assets is a major risk factor. This risk factor is also acknowledged in a fiscal policy perspective as the EU's Stability and Growth Pact aims to cap a country's total debt at 60 % of its GDP. As a proxy we use a country's total outstanding bonds relative to its GDP. This choice of variable is motivated by data availability as the amount of bonds outstanding is available in Bloomberg on a monthly frequency.[18] We expect that higher debt increases changes in CDS spreads. For bonds, in a market with elastic demand this variable also reflects bond market liquidity because a larger bond market generally contributes to lower transaction costs. However, if overall supply of new issuance exceeds existing demand, then there could also be an adverse impact on bond market liquidity. We expect the second effect to be primarily relevant for bond spreads.

- Idiosyncratic equity volatility (VOL)

In the structural credit risk model of Gapen et al. (2005) the volatility of sovereign assets is a major factor in determining a country's default risk. Campbell and Taksler (2003) find that the variation in US

[18] We use linear interpolation to obtain weekly observations.

corporate spreads is more strongly linked to idiosyncratic stock price volatility than to aggregate stock price volatility. Following this result we use the idiosyncratic volatility which we calculate as the annualised GARCH (1, 1)-volatility of idiosyncratic stock returns (defined as a country's stock returns minus Datastream euro are stock index). We expect that higher volatility raises spread changes.

- Bid–ask spread (Bid_Ask)

Tang and Yan (2007) show that the bid–ask spread is significantly positively related to CDS spreads. As there are no reliable data on issuer-specific sovereign CDS market liquidity we include the bid-ask spread of the iTraxx Main Investment Grade index. This variable should reflect common patterns in the CDS market liquidity.

As chart 3 has indicated, there is substantial heterogeneity in our sample both across time but also across countries. In order to deal with the first characteristic we estimate separate regressions for the two sub-samples which we also used for the descriptive statistics in section 2. For the second type of heterogeneity, we create a dummy ("D") for the group of countries where the market perceives public finances to be comparatively weak (cf. e.g. Buiter, 2010): Greece, Ireland, Italy, Portugal and Spain. Furthermore, we differentiate between CDS spreads and bond spreads by using separate regressions. Our baseline specification is therefore given by

$$\Delta\, Y_{it} = C + \beta_0\, VOL_{it} + \beta_1\, \Delta\, Debt_{it} + \beta_2\, \Delta\, Risk\text{-}free\ rate_t + \beta_3\, \Delta RA_{\,t} + \beta_4 \Delta\, iTraxx_{\,t} + \beta_5\, \Delta\, Bid\_Ask_{it} + \varphi_0\, D\, VOL_{it} + \varphi_1\, D\, \Delta\, Debt_{it} + \varphi_2\, \Delta\, Risk\text{-}free\ rate_t + \varphi_3\, \Delta RA_{\,t} + \varphi_4 \Delta\, iTraxx_t + \varphi_5\, \Delta\, Bid\_Ask_{it} + \varepsilon_{it} \qquad (1)$$

with Y_{it} a vector of dimension ten representing the spread of the CDS or the bond of country i at time t.

Table 5 and chart 6 summarise the explanatory variables and the corresponding signs that we expect for the respective estimates of the parameters. The effects of the factors are evaluated by means of a standard panel regression approach using the change in the CDS spreads or bond spreads as the dependent variable and also incorporating country fixed effects. The regression system is estimated with robust standard errors. We will use a similar methodology for our analysis of the basis.

3.2 Overall results for spread changes

We estimate the baseline regression as given in equation (1) for the two sample periods, 1 January 2006 to 12 September 2008 ('period I') and 15 September 2008 and 28 June 2010 ('period II'). From the panel regression analysis shown in Table 6a and Table 6b, several results are notable.

- We find some differences between the determinants of CDS spreads and bond spreads. Although both markets show a strong linkage to the iTraxx index, the relation is stronger for CDS than for bonds. Hence, credit market developments are a significant factor in the variation of Euro area sovereign spreads. In particular, the iTraxx corporate index is significant with a positive sign in both subperiods. Given that the iTraxx index is also a CDS spread, it seems plausible that this variable also picks up other CDS-market related information. More generally, a similar finding has been obtained by Haugh et al. (2009) who show that the spread on US high yield corporate bonds is an important explanatory variable for the spreads on euro government bonds.

- Since September 2008 the sovereign bond market prices country – specific factors. In the second subperiod, bond spreads are significantly positively linked to changes in a country's ratio of bonds outstanding over GDP whereas this is not the case for CDS spreads.
- The dummy D for the subgroup of countries has a significant impact. Among the interaction effects, the credit market as represented by the iTraxx index plays the largest role. In particular, the effect is positive and highly significant, indicating that CDS spreads and bond spreads of Greece, Ireland, Italy, Portugal and Spain react even stronger to market-wide developments.
- Global risk aversion is a significant determinant. The difference between US implied and historical volatility has a weakly positive effect only on the countries captured by the interaction dummy.
- Although the R squared for the second period by far exceeds the value for the first period, it nevertheless indicates a sizable unobserved component in CDS spreads which accounts for more than 75 % of the variation of CDS spreads.

Overall credit market information is a major factor in market pricing whereas equity-market volatility and debt measures do not play an important role. Furthermore, we find that CDS spreads of the dummy subgroup of countries are linked to a proxy for global risk appetite. The regressions also confirm that before the crisis, market prices were less strongly linked to fundamental determinants or global information.

Finally, we perform a factor analysis of the regression residuals. As Collin-Dufresne et al. (2001) show, residuals of corporate credit spreads still show a significant co-movement despite the fact that the regression specification has captured a wide variety of determinants. Table 4b allows us to compare the strength of the common factor across the different markets. Overall, the weight increases from period 1 to period 2. We find that the first principal component exceeds 40 % in both sub-periods for all residuals.

3.3 Further results for spread changes

In order to extend our benchmark regression described above we analyse a number of additional determinants.

- Idiosyncratic equity returns (R)

Following Collin-Dufresne et al. (2001) we use stock returns as a proxy for the overall state of a country's economy. For the purpose of a clearer identification, we use a country's idiosyncratic stock returns rather than its total returns. We define a country's idiosyncratic stock returns as the difference between its stock returns and the market-wide stock return as represented by the Datastream euro area stock index. All returns are calculated as first differences of log index values. Our hypothesis is that a positive country-specific equity return leads to a decrease in the country's spreads.

- EONIA (EONIA)

As an alternative measure of the short rate we use the EONIA rate, which is the overnight rate for unsecured interbank borrowing in the euro area.

- Implied volatility index (VIX)

In the extended specification we use the VIX rather than the iTraxx and the risk aversion estimate extracted from the VIX, as the VIX itself was shown to be a significant determinant of sovereign credit risk by Pan and Singleton (2007)

- Slope of the term structure (SLOPE)

In the Longstaff and Schwarz (1995) structural credit risk model with stochastic interest rates, a rising slope of the term structure lowers credit spreads. In this model, in the long run, the short rate converges to the long rate. Hence an increasing slope of the term structure should lead to an increase in the expected future spot rate. This in turn, will decrease credit spreads through its effect on the drift of the asset value process, assuming that there are no significant term premia. We assume that a similar effect may hold for sovereign spreads and define the slope of the term structure as the difference between the ten-year euro swap rate and the three-month Euribor rate.

- Exchange rate uncertainty (USDVOL)

Given that we use US$-denominated contracts, variation in the Euro-US$ rate may also influence the variation in CDS spreads. In particular, higher uncertainty about future variation of the Euro-US$ rate may also have an impact on CDS spreads. For this purpose, we use the implied exchange rate volatility as a control variable. Our data source is the EVZ volatility index provided by CBOE. This index follows the approach for the VIX index. We expect the implied exchange rate volatility to have a positive effect on CDS spreads as higher uncertainty about the future path of the exchange rate should make protection more costly.

Our extended panel specification is therefore given by

$$\Delta Y_{it} = C + \beta_0 R_{it} + \beta_1 \Delta VOLA_{it} + \beta_2 \Delta DEBT_{it} + \beta_3 \Delta VIX_t + \beta_4 \Delta Eonia_t + \beta_5 \Delta Slope_t + \beta_6 \Delta USDVOL_t + \varphi_0 D R_{it} + \varphi_1 D \Delta VOLA_{it} + \varphi_2 D \Delta LEVERAGE_{it} + \varphi_3 D \Delta VIX_t + \varphi_4 D \Delta Eonia_t + \varphi_5 D \Delta Slope_t + \varphi_6 D \Delta USDVOL_t + \varepsilon_{it} \qquad (2)$$

Results for this specification are given in table 7. We concentrate on the second subperiod as the previous analysis has shown that in the first period, market pricing was less strongly related to fundamentals.

Overall, replacing iTraxx and risk aversion by the VIX leads to more or less unchanged estimates compared to the base-case model. Among the three additional variables, the EONIA rate and the idiosyncratic returns are not significant, but the slope has a significantly negative impact on CDS and bond spread changes with the size of the coefficient being almost identical. The implied exchange rate volatility has an effect only when interacted with the country subgroup representing Greece, Ireland, Italy, Portugal and Spain. Hence, only the CDS spreads of the subgroup of countries are significantly linked to exchange rate variation.

As an alternative measure for market liquidity we evaluate the explanatory value of the proxies based on the number of unchanged price quotations (see also section 2.2 and chart 4). The results (omitted for reasons of space) show that both sets of variables do not have a significant effect in the regression analysis.

3.4 Lead-lag analysis of bond spreads and CDS

We focus on the lead-lag relationship in order to measure the adjustment process between CDS and bond spreads. Hence, we can analyse whether the derivative market or the cash market leads in the pricing process. Given the shift in the behaviour of CDS spreads and bond spreads after Lehman's default we split the sample again into two periods. In order to obtain a better overview of pricing dynamics we analyse daily rather than weekly CDS and bond spreads.

As a first step, we verify the unit-root non-stationarity of the CDS and bond spread series[19]. The existence of a cointegration relationship between the levels of two I(1) variables means that a linear combination of these variables is stationary. Cointegrated variables move together in the long run, but may deviate from each other in the short run, which means they follow an adjustment process towards equilibrium. A model that considers this adjustment process is the Vector Error Correction Model (VECM)[20].

The Vector Error Correction Model is specified as follows:

$$\Delta CDS_t = \lambda_1 (Z_{t-1}) + \sum_{j=1}^{p} \alpha_{1j} \Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{1j} \Delta BondSpread_{t-j} + \varepsilon_{1t} \tag{3a}$$

$$\Delta BondSpread_t = \lambda_2 (Z_{t-1}) + \sum_{j=1}^{p} \alpha_{2j} \Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{2j} \Delta BondSpread_{t-j} + \varepsilon_{2t} \tag{3b}$$

$$Z_{t-1} = CDS_{t-1} - \alpha_0 - \alpha_1 BondSpread_{t-1} \tag{3c}$$

Equation (3a) and (3b) express the short term dynamics of CDS and bond spread changes. [21] Z_{t-1} is the error correction term given by the long run equation (3c) that describes deviations of CDS and bond spreads from their approximate no-arbitrage relation.

If the cash bond market is contributing significantly to price discovery, then λ_1 will be negative and statistically significant as the CDS market adjusts to incorporate this information. Similarly, if the CDS market has an important role in price discovery, then λ_2 will be positive and statistically significant[22]. If both coefficients are significant, then both markets contribute to price discovery. The existence of cointegration between CDS and bond spreads implies that at least one market has to contribute to price discovery and the other has to adjust[23].

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[19] We apply the augmented Dickey-Fuller test to each of the 10 Sovereign CDS and bond spread series, independently. We do not report results for brevity. As expected, the test does not reject the null hypothesis of a unit root for all series in their levels, but it does for all series in their first differences, i.e. all series are integrated once, I(1).

[20] Cointegration analysis is carried out in the framework proposed by Johansen (1988, 1991). This test is essentially a multivariate Dickey-Fuller test that determines the number of cointegrating equations, or cointagrating rank, by calculating the likelihood ratio statistics for each added cointegration equation in a sequence of nested models.

[21] We specify the model with the optimal number of lags for each cointegrating relation.

[22] The idea is that if the error term of the equilibrium long-run regression is predicting changes in CDS, in the short run regression, it means that bond prices move generally first; if the error is positive the CDS is above its value implied by the equilibrium relation and it has to adjust downward, i.e λ_1 is negative. Instead, if the error term of the equilibrium long-run regression is predicting changes in bond spreads it means that CDS move generally first; if the error is positive the bond spread is below its value implied by the equilibrium relation and it has to adjust upward, i.e. λ_2 is negative.

[23] This relation is an implication of the Granger representation theorem (Engle and Granger 1987).

We proceed as follows. We test for cointegration between the CDS and spread bond for each single country. Where we find cointegration we study the lead-lag dynamics by means of the bivariate VECM and we analyse the statistical and economic significance of the coefficients λ_1 and λ_2. This approach attributes superior price discovery to the market that adjusts least to price movements in the other market. Results are shown in table 8. [24]

- Before the crisis

From the cointegration analysis performed on each country, we find that CDS and bond spreads are not cointegrated. We apply the Granger causality test on CDS and bond spread changes, but again no lead-lag relation is detected. Finally, correlation analysis does not indicate econometric evidence of a relationship for most of the countries.

For this result, one potential explanation is that the parity between CDS and bond spreads approximately holds in the sense that the size of the basis is similar for the two groups of countries. However, probably in part due to low trading activity in the CDS market before the crisis CDS spreads are relatively constant (cf. table 1 and chart 3). Arbitrage forces do not come into play, i.e. CDS and bond spreads move in an unrelated manner because they do not move outside the arbitrage bounds determined by transaction costs.

- Since September 2008

As shown by the trace test statistics for CDS and bond spreads, all country pairs are cointegrated in the second part of our sample. For Germany, France, the Netherlands, Austria and Belgium λ_1 is statistically significant and has a negative sign, while λ_2 is not significant, meaning price discovery takes place into the cash market. The λ_1 coefficient for Germany, the Netherlands and Austria is quite substantial and is approximately - 0.2; for France and Belgium it is smaller, namely - 0.005. For Italy, Ireland, Spain, Portugal and Greece λ_1 is not significant and λ_2 is significant and positive, implying that the derivatives market is leading in price discovery and the cash market adjusts. The λ_2 coefficients for Italy and Ireland are approximately 0.02, while for Spain, Portugal and Greece they are slightly larger, on average 0.5.

Overall our results illustrate that the market for sovereign CDS was very quiet before the peak of the crisis in fall 2008. Since the start of the crisis, with a dramatic re-pricing of risk, for Germany, France, the Netherlands, Austria and Belgium the cash market has a predominant role in price discovery. In the case of Italy, Ireland, Spain, Greece and Portugal CDS markets are playing a major role in terms of price discovery. Price discovery occurs in the market where informed investors trade at most. CDS are unfunded instruments so they are the cheapest way to trade credit risk. Because of their synthetic nature they do not suffer from the short-sales constraints in the cash market, and buying (or selling) relatively large quantities of credit risk is less difficult (Blanco et. al 2005). However, this price discovery process

[24] When both λ_1 and λ_2 are significant we use the measure of Gonzalo and Granger (1995) defined as the ratio $\frac{\lambda_2}{\lambda_2 - \lambda_1}$. If the CDS market dominates the Granger-Gonzalo measure will be close to 1 while if the bond market dominates price discovery then the measure will be closer to zero.

does not necessarily give rise to systematically profitable opportunities. We evaluate the size of these potential arbitrage opportunities in the next section.

3.5 Regression analysis of the basis

As shown in chart 5, the basis has deviated from the long run average of about 30 bps since the onset of the crisis in August 2007 and it has increased dramatically after the Lehman collapse in September 2008. This raises the question to what extent market frictions and risk factors influence basis trading which ought to make the no-arbitrage relation between CDS and bonds hold. One explanation for the persistent non-zero basis is that CDS, which are derivatives contracts, and bonds, which are cash instruments, are exposed to different risk factors. In principle, taking credit risk by purchasing a corporate bond or by shorting a CDS on the reference entity is equivalent. However, from a trader's perspective bonds and CDS are not perfect substitutes: Bond prices are affected by interest rate risk, default risk, funding risk and market liquidity risk, whereas CDS spreads are affected, mostly, by default risk and counterparty risk.

When the basis is positive government bonds are more expensive than CDS (i.e. bond spreads are lower than CDS). Arbitrageurs may profit from this situation by implementing a positive basis trade, short-selling the bond, and writing CDS protection. However, in practice it might be costly to obtain the bond via a repo transaction in order to short-sell it. At the same time, a situation in which repo rates are very low and highly rated bonds might be difficult to obtain in order to short-sell makes it costly for protection writers to hedge their positions.

During stress periods for government bonds, which are usually perceived as safe assets, liquidity might play a major role in driving prices up, hence yield spreads would decline through 'flight to liquidity' effects. In contrast, deteriorating market liquidity might contribute to increasing the yields of those government bonds which are perceived to face non-negligible default risk. Hence, the dynamics of the sovereign CDS-bond basis may have shifted during the crisis due to 'flight to liquidity' effects which have had a heterogeneous impact on euro area countries. Counterparty risk might also affect the basis dynamics as the CDS spread is affected by the creditworthiness of protection providers, i.e. major banks. Once risk in the inter-bank sector increases default protection is perceived as less valuable.

Given that we use US$-denominated CDS contracts, variation in the Euro-US$ rate may also influence the variation in CDS spreads. It seems plausible that the implied exchange rate volatility has a positive effect on CDS spreads as higher uncertainty about the future path of the exchange rate should make protection more costly. Since the protection buyer, in case of the default of the underlying, is compensated in US$, the value of protection in US$ would have a higher value if the Euro is expected to depreciate.

Overall, we adapt the set of variables from the previous subsections to the analysis of the basis. These variables and their expected signs are summarised in Table 9. The **Euribor-Eurepo** three-month spread is expected to have a positive impact on the basis. When the repo rate is lower that the Euribor, it is costly to implement a positive basis trade which implies short-selling the underlying bond obtained via repurchase agreement[25] and selling protection. The risk aversion estimate extracted from the VIX (**RA**) is expected to have a positive impact on the basis, since CDS are more volatile and sensitive to shifts in risk appetite.

The uncertainty in the Euro-US$ exchange rate may influence the basis, since it is an additional source of risk for the dealer providing protection on a European entity in US$. For this purpose, we again use the implied exchange rate volatility **USD_VOL** as a control variable. We expect the implied exchange rate volatility to have a positive effect on CDS spreads as higher uncertainty about the future path of the exchange rate should make protection more costly.

The **iTraxx Financials** CDS index is expected to have a negative impact on the basis. This variable captures the CDS market's assessment of major European financial institutions. Since major banks are protection providers the index premium at least partly represents counterparty risk implicit in sovereign CDS contracts. In this sense CDS are expected to have a discount with respect to the bond spread when the likelihood of the protection seller's default is non-negligible.

As discussed before, the ratio of the amount of bonds outstanding to GDP (**Debt**) represents a measure of leverage, hence it captures the fiscal fundamentals, but it also potentially captures bond market liquidity effects. Depending on the market environment, this variable can play different roles in the explanation of the basis. On the one hand, in a market with elastic demand this variable generally reflects bond market liquidity as a larger bond market generally contributes to lower transaction acts. On the other hand, if the overall supply of newly issued bonds exceeds existing demand, then there could also be an adverse impact on market liquidity, leading to an increase in the liquidity premium of bond spreads. We again use the idiosyncratic equity volatility (**Vol**) as a second measure of country fundamentals. An increase in idiosyncratic equity volatility captures a deterioration of country specific credit risk and is expected to have a positive impact both on CDS and bond spreads, so the impact on the basis is ambiguous.

We estimate the regression as given below again for the two sample subperiods:

$$Basis_{it} = C + \beta_0 \ Basis_{it-1} + \beta_1 \ (Euribor\text{-}Eurepo)_t + \beta_2 \ RA_t + \beta_3 \ log(USD\_VOL)_t + \beta_4 log(\ iTraxx\ Financials)_t + \beta_5 \ log(Debt)_{it} + \beta_6 \ log(Vol)_{it} + \varphi_1 \ D^*(Euribor\text{-}Eurepo)_t + \varphi_2 \ D^* \ RA_t + \varphi_3 \ D * log(USD\_VOL)_t + \varphi_4 D^* \ log(Itraxx\ Financials)_t + \varphi_5 \ D *log(Debt)_{it} + \varphi_6 D *log(Vol)_{it} + \varepsilon_{it} \qquad (4)$$

From the results in Table 10, two main points emerge. First, more factors are significant in the second period than in the first period as it has also been the case to some extent for the CDS and bond spread changes. Second, the dummy D for the subgroup of countries has a significant impact in the case of an aggregate proxy (iTraxx Financials) and a country specific variable (total debt).

In addition we note the following results.

- The basis is mean reverting. Deviations between CDS and bond spreads tend to decline. The coefficient on the lagged basis is approximately 0.85 before and 0.73 during the crisis.

[25] The cost of a positive basis trade is the difference between the repo rate gained on the repo transaction and the Libor rate which has to be paid on the shorted bond.

- In the crisis sub-period, the Euribor-Eurepo spread rate has a positive (14.65) and significant impact on the basis. This spread measures the cost of shorting a bond in a positive basis arbitrage trade; this effect is homogeneous across all countries.
- Proxies for aggregate risk appetite are a significant factor in the variation of the basis. In particular, the S&P 500 risk aversion is significant with a positive (0.23) coefficient during the crisis. Hence, an increase in US equity risk aversion raises the basis which is at least partly related to the significant effect of the S&P 500 risk aversion on CDS spreads observed in section 3.2. This finding is in contrast to results for the corporate basis (Fontana, 2010).
- In contrast to our hypothesis, the uncertainty in the Euro-US$ exchange rate does not have a significant impact on the basis dynamics.
- Idiosyncratic equity volatility is significantly negatively related (-6.87) to the dynamic of the basis. This might be due the fact that the positive impact on bond spreads is stronger than on CDS spreads, as the analysis of spreads in section 3.2 has shown.
- The group of countries' bases without the dummy is not sensitive to the iTraxx Financials level dynamics while for countries captured by the dummy this linkage is negative (-16.81). This highlights the heterogeneity among countries in terms of CDS counterparty risk effects. Protection on countries in the first group is perceived to be less risky while for the countries in the dummy group the CDS premium is linked to creditworthiness of protection providers. Hence, an increasing risk assessment of major financial institutions makes CDS protection less valuable. A decrease of the CDS premium relative to the bond spread then implies a reduction of the basis.
- Before the crisis the impact of debt is negative and small (-7.17) for all countries, while during the crisis there is a crossectional difference in the impact of total debt. The basis of Germany, France, Netherlands, Belgium and Austria is positively related to the amount outstanding of bonds divided by GDP (coefficient of 51.93). Our analysis cannot explain the direction of the causality, since it seems plausible that bond issuance patterns are related to the level of the interest rates in order to optimise sovereign debt costs and to raise funds for state aid measures. In contrast, for Greece, Ireland, Italy, Portugal and Spain which on average have lower bases, the interaction dummy indicates an overall negative impact of the amount of bonds outstanding (total coefficient of -12.48 = 51.93 – 64.41). As shown in the time series of the debt variable in chart 6, governments have issued substantial amounts of debt in the period following the Lehman collapse and the subsequent recovery in March 2009. Larger amounts of outstanding bonds may have deteriorated bond liquidity, driving bond spreads up beyond CDS spreads, hence the basis has become smaller and in some cases negative.
- The adjusted R squared for the first and second period are respectively 0.95 and 0.75.

In sum, we find that during the crisis period the sovereign bases are mean reverting and significantly linked to the cost of short-selling bonds, to proxies for global risk appetite and to country-specific factors. We also find crossectional differences in the effect of counterparty risk and debt outstanding.

3.6 Further results for the regression analysis of the basis

In order to extend our benchmark regression described above we use a number of additional determinants.

- Stock market trading volume (**equity volume**)

This variable captures country specific stock market liquidity conditions, which are expected to be correlated with country specific bond market liquidity and hence also with the basis. One reason for using this indirect proxy is that the segmentation of trading across a number of fixed income platforms means that there is no reliable information on market turnover. For each country we use data for trading volumes on a major stock index (e.g. for Germany we use the DAX or for Italy the FTSE MIB). A decrease in equity trading volume captures the deterioration of country specific market liquidity and is expected to drive bond spreads larger than CDS spreads. As the mean of the basis is positive, the relation between the basis and stock market volume is expected to be negative.

- Outstanding stock of U.S. dollar financial commercial paper (**CP fin outstd**)

Given that financial institutions use a substantial amount of short-term borrowing to fund their trading operations, this variable measures the availability of market-based funding for trading operations, (see also Adrian, Etula and Shin, 2010). Due to the lack of comparable data for Europe we use data from the Federal Reserve Bank of New York. If the volume of CP increases, we would expect the basis to decline towards zero as the funding allows for increased arbitrage operations.

- Volume of term repurchase agreements (**Term Repo Outst**)

The volume of term repos is an alternative measure of potential leverage constraints for major financial institutions. This variable represents repo transactions for the New York Federal Reserve's primary dealers. The typical horizon of these operations is overnight, but the Fed can also conduct these operations with terms out to 65 business days. Term-repo volume is not only a measure of market based funding availability, but it might also reflect the difficulty for arbitrageurs to find government bonds to short-sell in order to profit from the positive basis.

We estimate the regression as given below again for the two sample subperiods:

$$Basis_{it} = C + \beta_0\ Basis_{it-1} + \beta_1\ (Euribor\text{-}Eurepo)_t + \beta_2\ RA_t + \beta_3\ log(USD\_VOL)_t + \beta_4 log(\ iTraxx\ Financials)_t + \beta_5\ log(Debt)_{it} + \beta_6\ log(Vol)_t + \beta_7\ log(Cp\ Fin\ Outst)_t + \beta_8\ log(Term\ Repo\ Outst)_t + \beta_9\ log(Equity\ Volume)_t + \varphi_1\ D^*(Euribor\text{-}Eurepo)_t + \varphi_2\ D^*\ RA_t + \varphi_3\ D * log(USD\_VOL)_t + \varphi_4\ D^*\ log(Itraxx\ Financials)_t + \varphi_5\ D * log(Debt)_{it} + \varphi_6 D * log(Vol)_{it} + \varphi_7 D * log(Cp\ Fin\ Outst)_t + \varphi_8 D * log(Term\ Repo\ Outst)_t + \varphi_9 D * log(Equity\ Volume)_t + \varepsilon_{it} \quad (5)$$

The introduction of these new variables does not materially affect the coefficients and the significance of the variables from the baseline model. Results of the regression analysis are shown in Table 11. Before the crisis the basis is significantly and positively related to the commercial paper outstanding (13.36). When U.S. dollar funding liquidity is high, the risk appetite of dollar-funded intermediaries is high and their required compensation for holding risky assets is low. In such a situation bond spreads are narrow and the basis is positive. During the crisis, for the dummy group country, the basis is negatively related to the commercial paper outstanding (-21.81). This indicates that when funding liquidity started to deteriorate the basis in general has not been affected, but for the dummy country group it widened. Furthermore, during the crisis, for the dummy group of countries, the basis is positively related to term-repo (15.52).[26] Finally, the stock market volume does not affect the basis. Hence, it might be the case that stock market liquidity conditions are already captured by other variables in the regressions, such as the country specific idiosyncratic equity volatility.

Overall, our analysis in this subsection shows that variables which provide a measure of the availability of market-based funding affect the sovereign basis dynamics. Results are in line with the idea that financial institutions use a substantial amount of short-term borrowing to fund their trading operations and that this structural feature then directly affects market pricing (see also Adrian, Etula and Shin, 2010).

4. Conclusions

The crisis has led to a wide-ranging discussion on the costs and benefits of CDS. As robust and significant evidence on many of the questions is not yet available, it seems too early to draw definite research-based conclusions. Furthermore, a review of these general issues many of which are related to US subprime assets is beyond the scope of this paper (Stulz, 2010 offers a comprehensive review of the risks and benefits of the CDS market).

Our first main finding is that the recent repricing of sovereign credit risk seems mostly due to common factors. Our regressions for CDS and bond spreads separately and the regression analysis of the basis in some respects lead to similar findings, in particular as regards the driving factors of CDS and bond spreads and the dynamics of the basis and the evidence for structural breaks since the outbreak of the crisis.

Second we observe that for most countries the CDS spread exceeds the spread on the corresponding government bond relative to the swap rate. The exceptions here are Portugal, Ireland and Greece where we find a temporary negative basis. Since September 2008, market integration for bonds and CDS differs across countries. In half of the sample countries, price discovery takes place in the CDS market and in the other half, price discovery is observed in the bond market. In contrast, before the crisis, limited trading activity in the sovereign CDS market affected price discovery and the linkages between the bond and the derivative market. Since the start of the crisis period the sovereign bases are mean reverting and significantly linked to the cost of short-selling bonds, to proxies for global risk appetite and to country-specific factors. We also find a crossectional difference in the impact of counterparty risk and debt issuance.

Overall, our results provide further supportive evidence for the existence of arbitrage crashes and slow moving capital. Deviations from the arbitrage-free parity do not seem to be easily exploitable as market frictions and structural changes throughout the crisis inhibit traders to arbitrage away these price differentials. Duffie (2010) discusses how asset prices can differ from the arbitrage-free and friction-less

[26] We have also tested the overnight repo (short term funding liquidity) variable, but there is no significant effect on the basis.

case when there are significant institutional impediments (i.e. '*slow moving capital*') such that market participants can not immediately profit from apparent mispricing. According to Mitchell and Pulvino (2010) during the crisis traders could not exploit arbitrage opportunities such as the large negative basis in US corporate debt due to restrictions in the availability of capital. Another paper which is closely related to our analysis is Fleckenstein et al. (2010) who document that a persistent arbitrage opportunity between US Treasuries and TIPS is partly related to supply factors.[27]

The results in this paper support the evidence that there are major commonalities as well as differences between corporate and sovereign CDS. On the one hand, both markets have witnessed a substantial repricing with a reassessment of the likelihood of tail events. The repricing of public debt seems to be driven by strong common factors as well as by country-specific effects. Risk premia play an important role in the spike in both types of CDS spreads. On the other hand, there are sizable differences. Besides the potential importance of technical default, the mechanism of 'flight to liquidity' is a major factor in public debt markets. This mechanism is supported e.g. by the mechanics of the Basel II capital requirements where the standardised approach treats government debt with a rating above A+ as risk-free. Together with the impact of limits to arbitrage, this "flight to liquidity effect" seems to drive a wedge between CDS spreads and the prices of the underlying government bonds. Comparing our results for sovereigns to those for corporates, we find a significant difference as private-sector debt typically had a negative basis (Fontana, 2010) whereas we showed that sovereign debt has a positive basis. This essentially implies a liquidity premium in corporates and a liquidity discount in sovereigns.

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[27] See also Mercurio (2009). Duarte et al. (2007) provide a general discussion of arbitrage in fixed income markets.

Chart 1: DTCC Net notional for Euro area sovereigns relative to volume of bonds outstanding

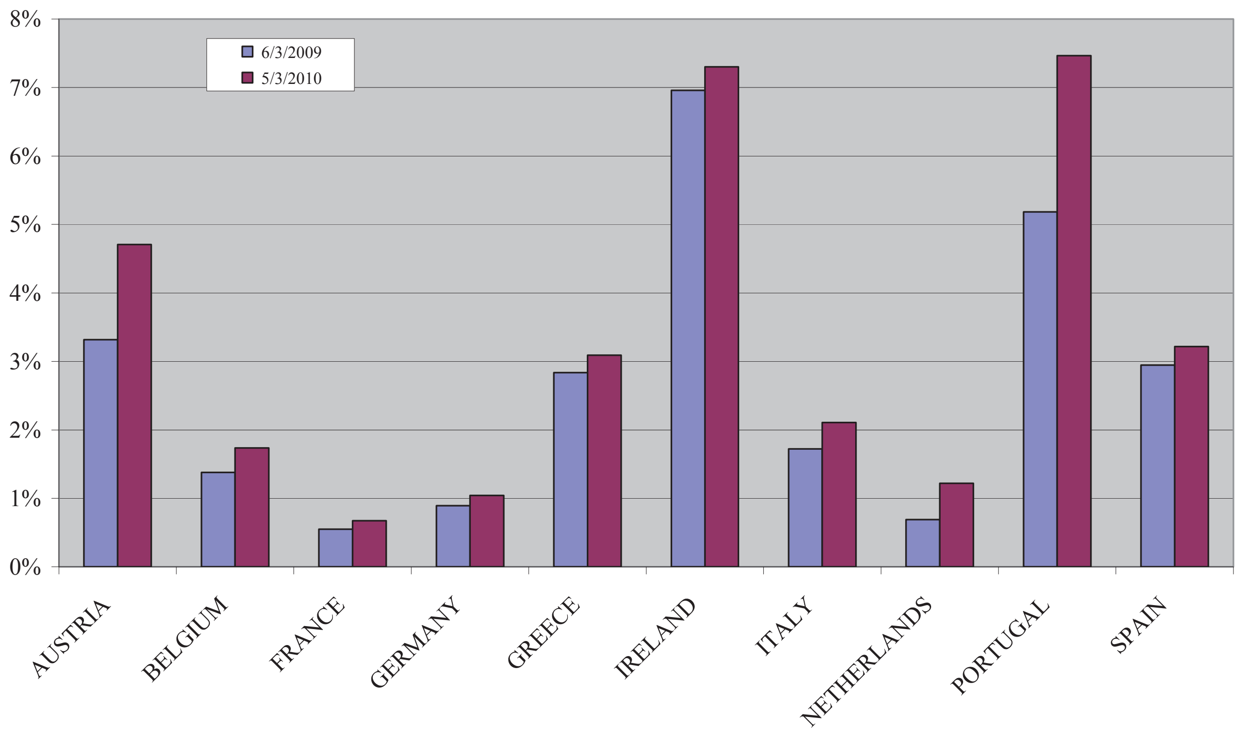


Chart 2: iTraxx CDS index for European financials vs. West European sovereigns

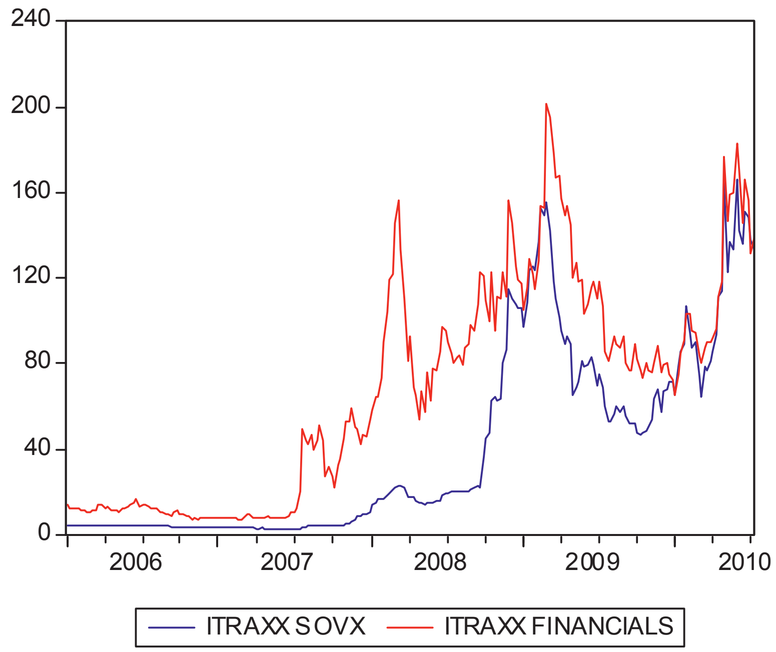


Chart 3: CDS spreads and bond spreads for Euro area sovereigns

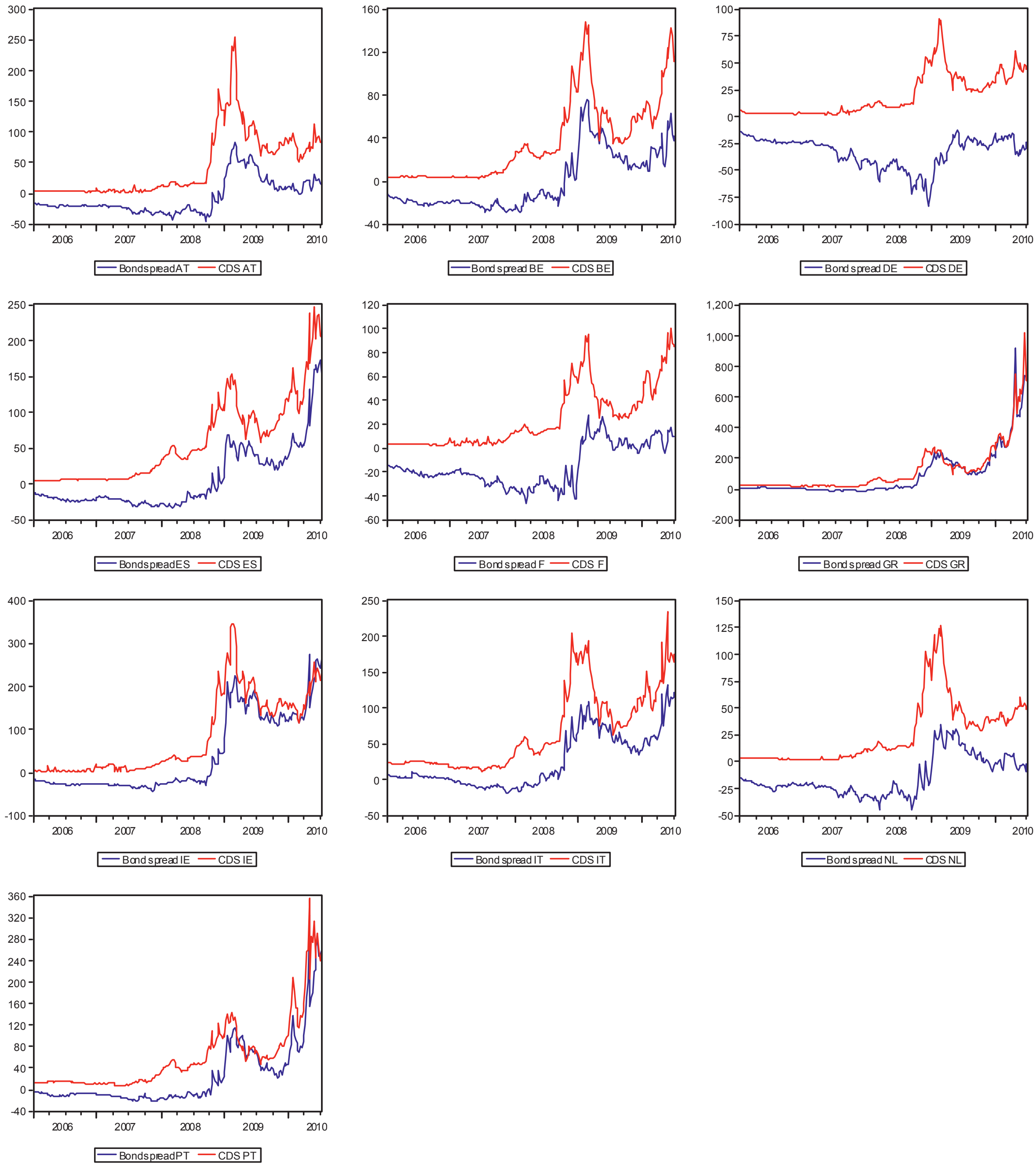
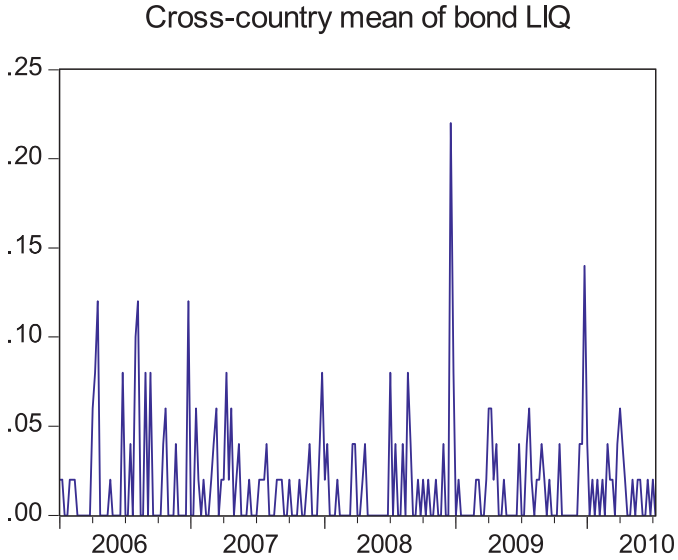


Chart 4: Liquidity proxies

The sample period is 1 January 2006 to 28 June 2010. The variable is constructed as the total number of zero price changes per week. The chart shows the cross country means per week.



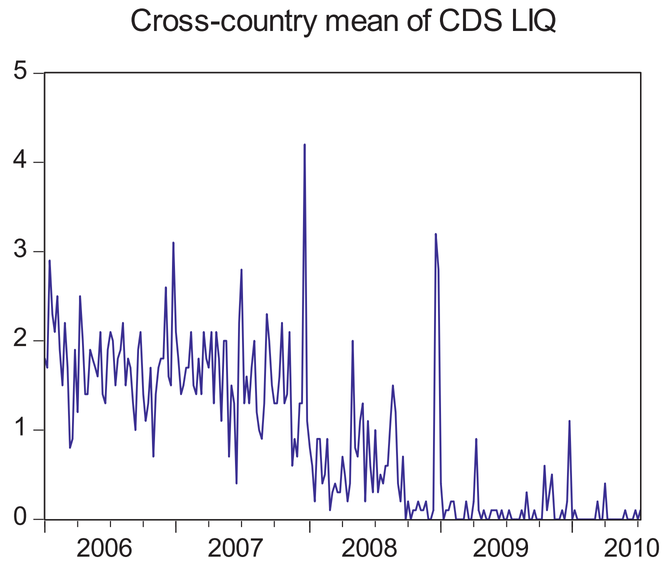


Chart 5: Basis (=CDS - bond spread) for Euro area sovereigns

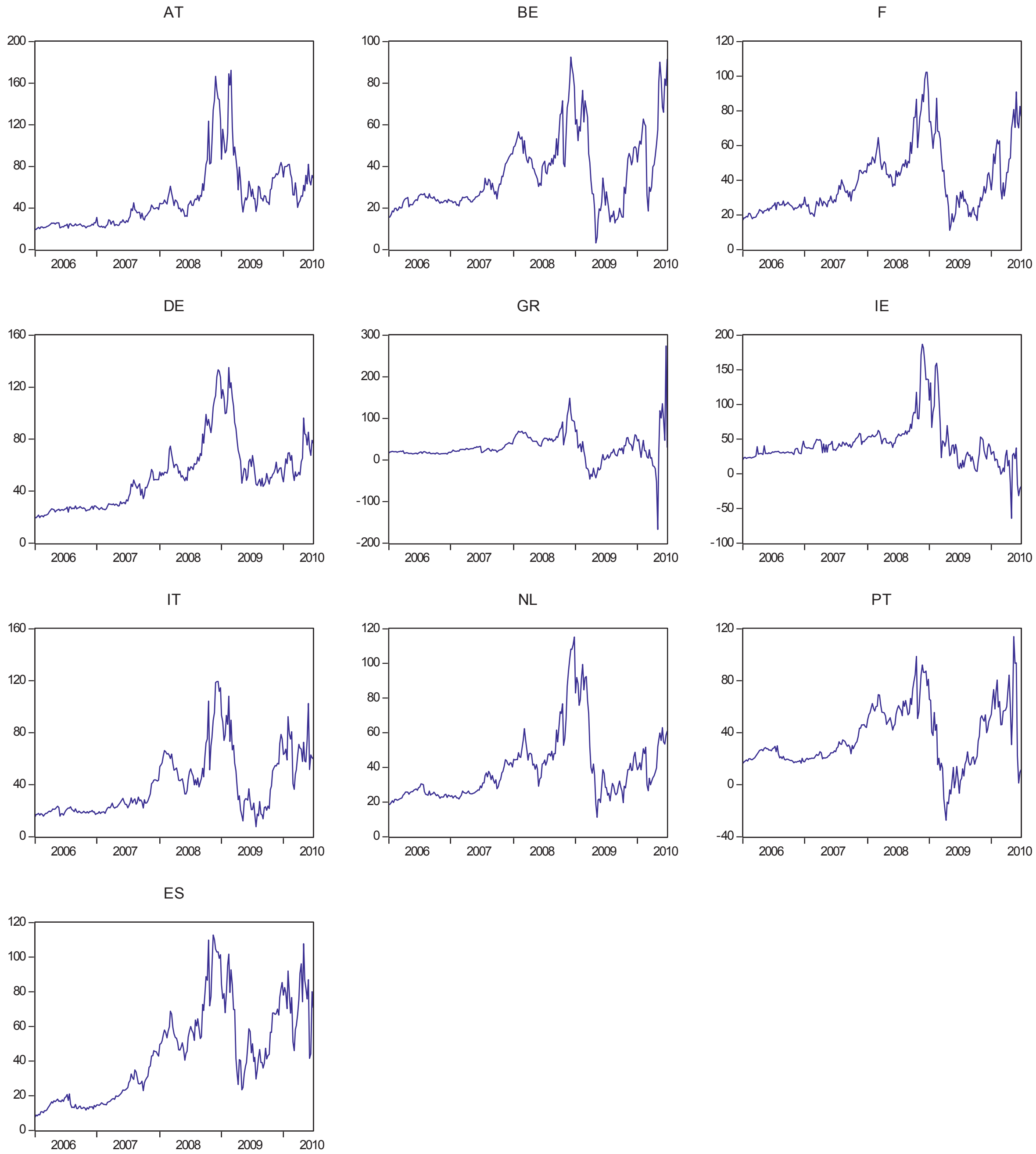


Chart 6: Set of explanatory variables for base case regression

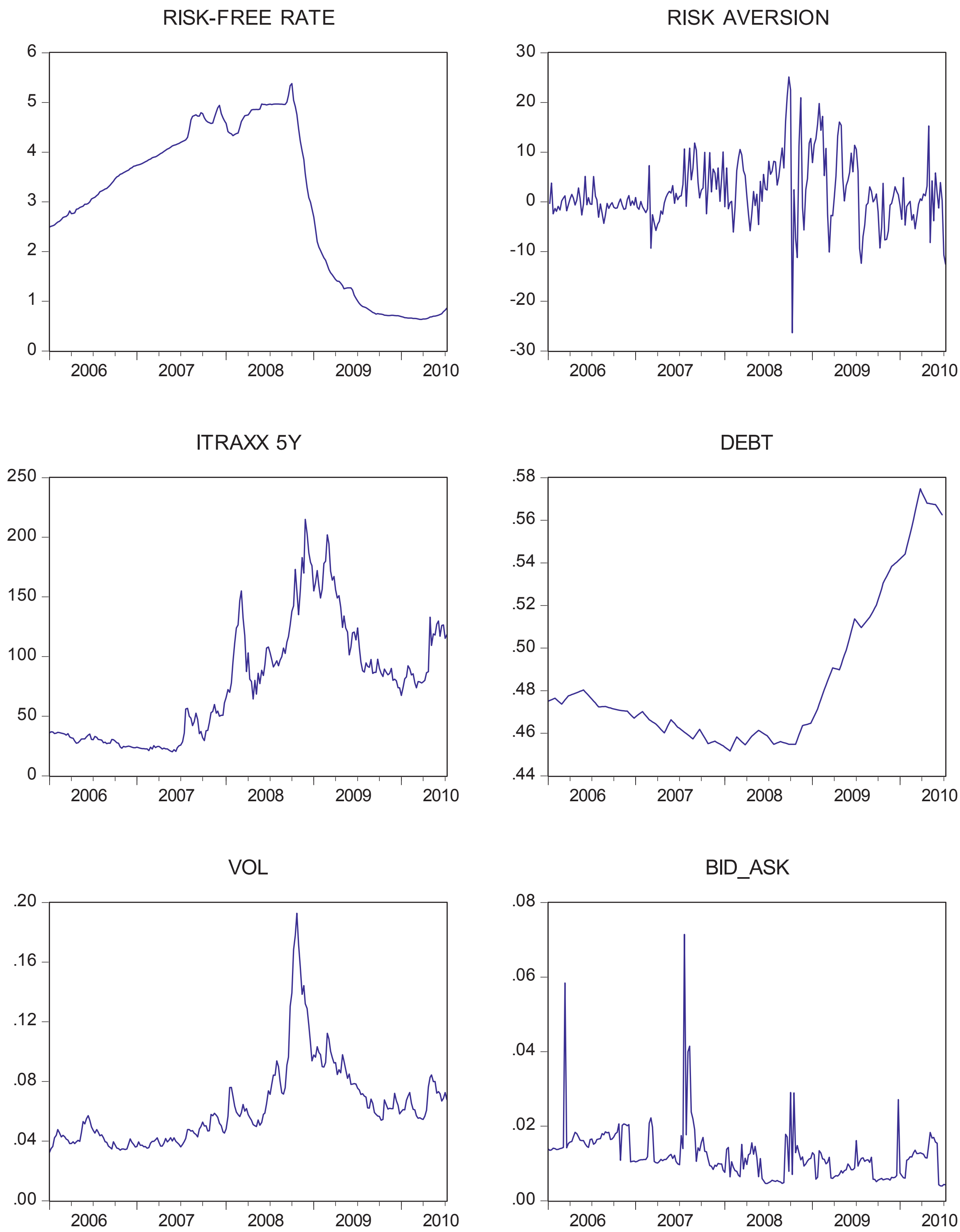


Table 1: Descriptive statistics of levels of CDS spreads

The sample periods are 1 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II"). All statistics are in basis points.

	Period I					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	6.75	3.80	19.70	1.90	5.25	141
BELGIUM	10.80	4.40	34.90	2.90	10.02	141
FRANCE	6.99	4.40	19.80	1.90	5.05	141
GERMANY	5.61	3.50	15.00	1.80	3.38	141
GREECE	30.98	25.00	73.20	11.00	16.94	141
IRELAND	14.43	10.79	39.80	2.50	12.05	141
ITALY	27.43	22.70	59.00	11.70	12.49	141
NETHERLANDS	6.21	3.56	19.30	1.80	4.83	141
PORTUGAL	21.51	14.60	56.00	7.50	14.19	141
SPAIN	17.37	7.07	54.20	4.20	16.01	141

	Period II					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	97.15	86.73	255.26	16.90	42.13	94
BELGIUM	72.08	63.57	148.10	29.50	30.05	94
FRANCE	49.78	44.60	100.28	16.50	20.10	94
GERMANY	39.85	36.68	90.70	12.40	14.94	94
GREECE	251.35	200.89	1018.50	65.80	172.42	94
IRELAND	180.32	170.07	347.30	40.50	57.91	94
ITALY	121.39	113.41	234.18	53.20	39.79	94
NETHERLANDS	53.85	44.93	126.26	15.50	25.65	94
PORTUGAL	116.76	92.65	355.06	47.05	67.97	94
SPAIN	112.88	102.60	247.30	50.90	43.21	94

Table 2: Descriptive statistics of government bond spreads

The sample periods are 1 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II"). All statistics are in basis points. The reference rate is the 10-year swap rate.

	Period I					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	-24.64	-22.06	-15.57	-42.14	5.84	141
BELGIUM	-19.61	-19.89	-7.38	-29.10	4.58	141
FRANCE	-25.64	-23.56	-13.35	-46.79	6.87	141
GERMANY	-32.33	-26.73	-13.99	-60.47	11.57	141
GREECE	1.33	2.20	20.16	-13.79	8.25	141
IRELAND	-26.02	-26.53	-11.55	-43.27	5.91	141
ITALY	-2.42	-1.90	12.11	-17.97	7.65	141
NETHERLANDS	-25.72	-23.96	-15.31	-44.32	5.77	141
PORTUGAL	-11.45	-11.61	-2.65	-21.67	4.49	141
SPAIN	28.82	20.07	-11.38	-34.22	5.24	141

	Period II					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	22.18	17.85	90.44	-54.60	30.13	94
BELGIUM	24.98	21.15	82.61	-32.72	21.29	94
FRANCE	-1.51	3.21	28.22	-52.28	18.12	94
GERMANY	-35.61	-27.07	-9.74	-83.41	18.88	94
GREECE	156.86	148.36	362.92	4.12	71.84	94
IRELAND	120.79	129.03	227.83	-39.76	61.27	94
ITALY	59.48	57.04	115.44	-2.05	22.44	94
NETHERLANDS	4.23	4.40	36.40	-53.46	18.82	94
PORTUGAL	53.99	46.28	139.12	-20.12	33.56	94
SPAIN	33.06	34.85	70.29	-27.21	21.89	94

Table 3: Descriptive statistics of the basis

The sample periods are 1 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II"). The basis is defined as CDS spread minus bond spread (relative to the 10-year swap rate). All statistics are in basis points.

	Period I					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	31.39	26.50	61.04	19.37	10.11	141
BELGIUM	30.41	25.71	56.61	15.60	9.87	141
FRANCE	32.63	27.97	64.59	17.05	11.18	141
GERMANY	37.94	30.15	74.67	19.49	14.53	141
GREECE	29.65	23.58	68.96	13.74	15.16	141
IRELAND	40.45	40.24	62.66	20.34	10.78	141
ITALY	29.86	23.51	66.27	15.46	13.78	141
NETHERLANDS	31.93	27.21	62.32	18.56	9.82	141
PORTUGAL	32.96	26.76	69.38	16.45	15.19	141
SPAIN	28.82	20.73	68.88	7.65	17.38	141

	Period II					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	76.58	69.01	172.46	35.93	32.16	94
BELGIUM	45.49	45.24	92.57	3.20	23.09	94
FRANCE	49.34	44.51	102.31	11.10	24.09	94
GERMANY	73.65	64.70	135.16	43.62	25.53	94
GREECE	30.58	25.32	273.69	-167.03	53.43	94
IRELAND	47.78	30.96	187.08	-64.24	50.31	94
ITALY	56.99	57.66	119.46	7.71	28.65	94
NETHERLANDS	50.53	42.12	115.23	11.13	25.40	94
PORTUGAL	40.79	46.18	114.03	-27.22	31.99	94
SPAIN	67.1	69.7	112.8	23.4	23.1	94

Table 4a: Factor analysis

The sample periods are 1 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II").

	Proportion explained by factor 1 (%)
CDS – period I	72.6
CDS – period II	84.5
Bond spreads – period I	80
Bond spreads – period II	62.4
Basis – period I	64.8
Basis – period II	77.9

Table 4b: Factor analysis

This table reports the results of a factor analysis on the residuals of the baseline regressions (1) of CDS and bond spread changes on the explanatory variables. The sample periods are 1 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II").

	Proportion explained by factor 1 (%)
Bond residuals – period I	63.2
Bond residuals – period II	43.4
CDS residuals – period I	49.5
CDS residuals – period II	50.1

Table 5: Description of explanatory variables and expected signs for parameter estimates

This table reports the variables used in the regressions where the dependent variable is the change in the CDS spread. The data sources are Bloomberg, Datastream and JP Morgan.

Notation	Definition	Sign
Risk-free rate	Euribor 3 M	(-)
Risk Aversion	VIX index - GARCH volatility	(+)
iTraxx	ITRAXX 5 Y CDS index	(+)
Debt	Bonds outstanding / GDP	(+)
Vol	Idiosyncratic equity volatility	(+)
Bid_Ask	Bid-Ask spread of iTraxx	(+)

Table 6a: Results of baseline regression model

This table reports the results from regressions of weekly CDS spread changes including country fixed effects: $\Delta\, CDS_{it} = C + \beta_0\, \Delta\, Risk\text{-}free\ rate_t + \beta_1\, \Delta Risk\ Aversion_t + \beta_2 \Delta\, iTraxx_t + \beta_3\, \Delta\, Debt_{it} + \beta_4\, VOL_{it} + \beta_5\, \Delta\, Bid\_Ask_{it} + \varphi_0\, D\, Risk\text{-}free\ rate_t + \varphi_1\, D\, \Delta Risk\ Aversion_t + \varphi_2\, \Delta\, iTraxx_t + \varphi_3\, \Delta\, Debt_{it} + \varphi_4 \Delta\, VOL_{it} + \varphi_5\, \Delta\, Bid\_Ask_{it} + \varepsilon_{it}$ *The t-statistics are given adjacent to the coefficient estimates The sample periods are 1 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II").*

Period I

Variable	Coefficient	t-Statistic
Intercept	0.12	(1.30)
Risk-free rate	-0.61	(-0.16)
Risk aversion	-0.01	(-0.59)
Itraxx 5y	0.05	(3.31)***
Debt	8.01	(0.26)
Vol	0.31	(0.06)
Bid_ask	7.58	(0.84)
Dummy Risk-free rate	2.31	(0.46)
Dummy Risk Aversion	-0.03	(-1.06)
Dummy Itraxx 5y	0.09	(4.78)***
Dummy Debt	17.16	(0.45)
Dummy Vol	9.42	(1.46)
Dummy bid-ask	5.38	(0.48)
Adjusted R-squared	0.13	

Period II

Variable	Coefficient	t-Statistic
Intercept	1.94	(1.39)
Risk-free rate	-2.69	(-0.33)
Risk aversion	0.03	(0.46)
Itraxx 5y	0.54	(9.00)***
Debt	180.70	(0.92)
Vol	4.26	(0.36)
Bid_ask	-78.00	(-0.85)
Dummy Risk-free rate	8.51	(0.39)
Dummy Risk Aversion	0.55	(1.60)*
Dummy Itraxx 5y	0.64	(3.07)***
Dummy Debt	-541.76	(-0.94)
Dummy Vol	-22.63	(-0.75)
Dummy bid-ask	-407.47	(-1.26)
Adjusted R-squared	0.25	

Table 6b: Results of baseline regression model

This table reports the results from regressions of weekly bond spread changes including country fixed effects: Δ *Bond spread*$_{it}$ = $C + \beta_0 \Delta$ *Risk-free rate*$_t$ + β_1 Δ*Risk Aversion* $_t$ + $\beta_2 \Delta$ *iTraxx* $_t$ + β_3 Δ *Debt*$_{it}$ +β_4 *VOL*$_{it}$ + β_5 Δ *Bid_Ask*$_{it}$ +φ_0 *D Risk-free rate*$_t$ +φ_1 *D* Δ*Risk Aversion* $_t$ + φ_2 Δ *iTraxx*$_t$ + φ_3 Δ *Debt*$_{it}$ + $\varphi_4 \Delta$ *VOL*$_{it}$ + φ_5 Δ *Bid_Ask*$_{it}$ + ε_{it}

The t-statistics are given adjacent to the coefficient estimates. The sample periods are 2 January 2006 to 8 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II").

Period I

Variable	Coefficient	t-Statistic
Intercept	-0.04	(-0.32)
Risk-free rate	-1.20	(-0.24)
Risk aversion	0.01	(0.40)
Itraxx	-0.12	(-3.35)***
Debt	9.84	(0.14)
Vol	-4.99	(-0.72)
bid_ask	-0.69	(-0.73)
Dummy Risk-free rate	3.92	(1.98)**
Dummy Risk Aversion	-0.02	(-1.18)
Dummy Itraxx	0.12	(5.64)***
Dummy Debt	-2.38	(-0.03)
Dummy Vol	5.80	(0.65)
Dummy bid-ask	1.45	(1.09)
Adjusted R-squared	0.57	

Period II

Variable	Coefficient	t-Statistic
Intercept	1.65	(1.32)
Risk-free rate	-7.28	(-0.64)
Risk aversion	-0.06	(-0.73)
Itraxx	0.15	(2.12)**
Debt	280.88	(1.64)*
Vol	1.47	(0.14)
bid_ask	-3.54	(-1.00)
Dummy Risk-free rate	-5.66	(-0.20)
Dummy Risk Aversion	0.42	(0.97)
Dummy Itraxx	0.80	(2.49)**
Dummy Debt	-860.05	(-1.22)
Dummy Vol	89.44	(1.59)
Dummy bid-ask	0.63	(0.05)
Adjusted R-squared	0.16	

Table 7: Results of extended regression model

This table reports the results from panel regressions with country fixed effects specified as follows:

$\Delta Y_{it} = C + \beta_0 R_{it} + \beta_1 \Delta VOL_{it} + \beta_2 \Delta DEBT_{it} + \beta_3 \Delta VIX_t + \beta_4 \Delta Eonia_t + \beta_5 \Delta Slope_t + \beta_6 \Delta USD\_VOL_t + \varphi_0 D R_{it} + \varphi_1 D \Delta VOL_{it} + \varphi_2 D \Delta LEVERAGE_{it} + \varphi_3 D \Delta VIX_t + \varphi_4 D \Delta Eonia_t + \varphi_5 D \Delta Slope_t + \varphi_6 D \Delta USD\_VOL_t + \varepsilon_{it}$

The t-statistics based White standard errors are given adjacent to the coefficient estimates. The sample period is 15 September 2008 to 28 June 2010.

	ΔCDS		Δ Bond Spread	
	Coeff	**t-stat**	**Coeff**	**t-stat**
Intercept	2.38	(1.67)*	1.99	-1.7
R	34.28	-0.67	32.15	-0.88
VOL	2.88	-0.22	2.39	-0.27
DEBT	169.99	-0.73	302.55	(1.88)**
VIX	0.63	(2.95)***	-0.12	(-0.76)
EONIA	-2.74	(-0.37)	-7.37	(-1.03)
SLOPE	-14.84	(-2.18)**	-14.01	(-2.54)**
USD_VOL	0.26	-0.68	0.2	-0.39
Dummy*R	-60.82	(-0.67)	70.69	-0.94
Dummy*VOL	-47.97	(-1.53)	63.81	-1.28
Dummy*DEBT	-444.21	(-0.69)	-775.24	(-1.06)
Dummy*VIX	1.11	(2.11)**	1.09	-1.46
Dummy*EONIA	-5.66	(-0.76)	-11.98	(-1.41)
Dummy*SLOPE	-17.77	(-1.63)*	-10.49	(-0.80)
Dummy*USD_VOL	1.83	(1.93)**	2.18	-1.49
R-squared	0.13		0.07	

Table 8: Lead-lag relationship between CDS and bond spreads

The lead-lag analysis reported in the tables below is implemented for each single sovereign entity. Johansen cointegration test results (p. values of the trace test statistics) are reported in the first line of table. Where we find cointegration we study the lead-lag dynamics by mean of the bivariate VECM specified as below and we look at the adjustment coefficients λ1 and λ2.

$$\Delta CDS_t = \lambda_1 (Z_{t-1}) + \sum_{j=1}^{p} \alpha_{1j} \Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{1j} \Delta BondSpread_{t-j} + \varepsilon_{1t}$$

$$\Delta BondSpread_t = \lambda_2 (Z_{t-1}) + \sum_{j=1}^{p} \alpha_{2j} \Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{2j} \Delta BondSpread_{t-j} + \varepsilon_{2t}$$

When both λ1 and λ2 are significant the method we use, to investigate the mechanics of price discovery, is the measure due to Gonzalo and Granger (1995) defined as the ratio: $\frac{\lambda_2}{\lambda_2 - \lambda_1}$ *. The t- statistics are given adjacent to the coefficient estimates. When we do not find cointegration we run the Granger causality test on the series in their levels. The sample period is 15 September 2008 to 28 June 2010.*

Country	Germany	France	Netherlands	Austria	Belgium	Italy	Ireland	Spain	Portugal	Greece
Trace test										
p-v	0.037**	0.082*	0.000***	0.000***	0.1000*	0.065*	0.098*	0.074*	0.100*	0.069*
lambda 1	-0.019	-0.005	-0.028	-0.022	-0.004	0.014	-0.009	0.008	0.024	0.026
t-stat	[-3.405]**	[-2.682]*	[-4.166]***	[-4.696]***	[-2.856]*	[1.794]	[-0.868]	[0.599]	[1.540]	[1.337]
lambda2	-0.004	-0.004	0.001	0.002	-0.003	0.018	0.019	0.039	0.044	0.066
t-stat	[-0.483]	[-1.682]	[0.211]	[0.308]	[-1.934]	[3.430]**	[2.176]*	[3.773]**	[3.361]**	[3.477]**
P. discov	Bond	Bond	Bond	Bond	Bond	Cds	Cds	Cds	Cds	Cds

Table 9: Explaining the basis: description of explanatory variables and expected signs for parameter estimates

This table reports the variables used in the regressions with country fixed effects where the dependent variable is the basis defined as CDS 10y – (Yield of 10y benchmark bond – 10y swap rate). The first group of countries is Germany, France, Netherlands, Austria and Belgium. The dummy variable defines the second group of countries given by Italy, Ireland, Spain, Portugal and Greece. The data sources are Bloomberg, Federal Reserve Bank of New York and Datastream.

Notation	*Definition*	*Sign*
Basis (-1)	Lagged basis	(+)
Euribor-Eurepo	3m Euribor vs. eurepo spread	(+)
Risk Aversion	S&P 500 risk aversion	(+)
USD_VOL	Implied volatility of USD/EUR	(+)
Itraxx Financials	Itraxx Financials 5y CDS index	(+/-)
Debt	Bond outst/GDP	(+/-)
Vol	Idiosyncratic equity vol	(+/-)
Equity Volume	Country specific stock index volume	(-)
Cp Fin Outst	US$ Financial commercial paper outstanding	(-)
Term-Repo Outst	Term repurchase agreements outstanding of the Federal Reserve’s primary dealers	(-)
Dummy	Dummy for group II	(+/-)

Table 10: Results of the basis regression: baseline model

This table reports the results from panel regressions of weekly observations of the basis including country fixed effects:

$$Basis_{it} = C + \beta_0 \; Basis_{it-1} + \beta_1 \; (Euribor\text{-}Eurepo)_t + \beta_2 \; Risk\ Aversion_t + \beta_3 \; log(USD\_VOL)_t + \beta_4 log(iTraxx\ Financials)_t + \beta_5 \; log(Debt)_{it} + \beta_6 \; log(Vol)_{it} + \varphi_1 \; D^*(Euribor\text{-}Eurepo)_t + \varphi_2 \; D^* \; Risk\ Aversion_t + \varphi_3 \; D * log(USD\_VOL)_t + \varphi_4 D^* \; log(Itraxx\ Financials)_t + \varphi_5 \; D * log(Debt)_{it} + \varphi_6 D * log(Vol)_{it} + \varepsilon_{it}$$

*The t-statistics is based on White cross-section standard errors are given adjacent to the coefficient estimates. Coefficients marked *** are significant at 1 %, ** are significant at 5 % and * are significant at 10 %. The sample periods are 2 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II").*

Period I

Variable	Coefficient	t-Statistic
Intercept	-6.81	(-1.12)
Basis (t-1)	0.85	(30.45)***
Euribor-Eurepo	-3.74	(-2.49)**
Risk Aversion	0.06	(1.10)
USD_VOL	-2.43	(-0.71)
Itraxx Financials	2.53	(4.32)***
Debt	-7.17	(2.15)**
Vol	-0.05	(-0.10)
Dummy Euribor-Eurepo	0.91	(0.82)
Dummy Risk Aversion	-0.03	(-0.70)
Dummy USD_VOL	4.02	(1.26)
Dummy Itraxx Financials	-0.21	(-0.49)
Dummy Debt	-0.38	(-0.08)
Dummy Vol	0.34	(0.49)
Adjusted R-squared	0.95	

Period II

Variable	Coefficient	t-Statistic
Intercept	-1.42	(-0.04)
Basis (t-1)	0.73	(7.80)***
Euribor-Eurepo	14.65	(3.63)***
Risk Aversion	0.23	(2.25)**
USD_VOL	7.36	(0.76)
Itraxx Financials	5.70	(1.04)
Debt	51.93	(2.84)***
Vol	-6.87	(-2.53)***
Dummy Euribor-Eurepo	-10.22	(-1.41)
Dummy Risk Aversion	-0.08	(-0.60)
Dummy USD_VOL	5.30	(0.51)
Dummy Itraxx Financials	-16.81	(-1.67)*
Dummy Debt	-64.41	(-3.67)***
Dummy Vol	4.91	(1.09)
Adjusted R-squared	0.75	

Table 11: Results of the basis regression: extended model

This table reports the results from panel regressions of weekly observations of the basis including country fixed effects:

$Basis_{it} = C + \beta_0 \ Basis_{it-1} + \beta_1 \ (Euribor\text{-}Eurepo)_t + \beta_2 \ RA_t + \beta_3 \ log(USD\_VOL)_t + \beta_4 log(iTraxx \ Financials)_t + \beta_5 \ log(Debt)_{it} + \beta_6 \ log(Vol)_t + \beta_7 \ log(Cp \ Fin \ Outst)_t + \beta_8 \ log(Term \ Repo \ Outst)_t + \beta_9 \ log(Equity \ Volume)_t + \varphi_1 \ D^*(Euribor\text{-}Eurepo)_t + \varphi_2 \ D^* \ RA_t + \varphi_3 \ D * log(USD\_VOL)_t + \varphi_4 \ D^* \ log(Itraxx \ Financials)_t + \varphi_5 \ D * log(Debt)_{it} + \varphi_6 D * log(Vol)_{it} + \varphi_7 D * log(Cp \ Fin \ Outst)_t + \varphi_8 D * log(Term \ Repo \ Outst)_t + \varphi_9 D * log(Equity \ Volume)_t + \varepsilon_{it}$

*The t-statistics is based on White cross-section standard errors are given adjacent to the coefficient estimates. Coefficients marked *** are significant at 1 %, ** are significant at 5 % and * are significant at 10 %. The sample periods are 2 January 2006 to 12 September 2008 ("period I) and 15 September 2008 to 28 June 2010 ("period II").*

	Period I		Period II	
Variable	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Intercept	-181.09	(-4.95)***	24.29	(0.17)
Basis (t-1)	0.80	(27.90)***	0.71	(7.42)***
Euribor-Eurepo	-1.81	(-1.41)	14.10	(3.31)***
RA	0.05	(0.83)	0.25	(2.40)**
USD_VOL	-2.87	(-0.75)	11.43	(1.18)
Itraxx Financials	0.06	(4.32)***	0.05	(1.18)
Debt	3.73	(1.05)	24.34	(1.28)
Vol	0.49	(0.95)	-7.89	(-3.07)***
Cp Fin Outst	13.36	(3.65)***	-9.00	(-1.08)
Term Repo Outst	0.29	(0.16)	6.35	(1.11)
Equity Volume	-0.55	(-1.24)	0.65	(0.52)
Dummy Euribor-Eurepo	0.04	(0.04)	-9.72	(-1.46)
Dummy RA	-0.06	(-1.07)	-0.06	(-0.43)
Dummy USD_VOL	3.62	(1.07)	11.95	(1.01)
Dummy Itraxx Financials	0.00	(-0.14)	-0.13	(-1.47)
Dummy Debt	-7.38	(-1.40)	-60.73	(-2.80)**
Dummy Vol	0.35	(0.51)	0.34	(0.09)
Dummy Cp Fin Outst	0.78	(0.22)	-21.81	(-1.73)*
Dummy Term Repo Outst	1.50	(0.97)	15.52	(1.73)*
Dummy Equity Volume	0.32	(0.68)	-2.85	(-0.99)
Adjusted R-squared	0.95		0.75	

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