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Essays on Credit Spreads

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Tesi di dottorato di Alessandro Fontana, [955139]

Tutore del dottorando
prof. [Loriana Pelizzon]

Coordinatore del dottorato
prof. [Agar Brugiavini]

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Signature of Author

Certified By

Loriana Pelizzon

Full Professor of Economics

University of Venice, Italy

Thesis Supervisor

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Introduction

Corporate bonds offer higher yields, then risk-free Treasury bonds because companies may default and pay only a fraction of the money borrowed. This difference, which is called credit spread, is the reward asked by investors for the potential loss in case of default, and is a market measure of creditworthiness.

The recent financial literature has highlighted that part of the credit spread on **corporate bonds** is explained by non-credit related factors [Elton, Gruber, Agrawal and Mann (2001), Collin-Dufresene, Goldstein and Martin (2001), Huang and Huang (2003), Longstaff, Mithal and Neis, (2005) Schaefer and Strabulaev (2008)]. This raises questions such as: how do financial markets value bonds? What portion of yield spreads is directly attributable to default risk? And what are the determinants of the remaining non-default component. These issues are of fundamental importance from an investment perspective since the corporate debt outstanding in the US is larger than 5 Trillion $ making it one of the larges asset classes in financial markets. These issues are also of key importance from a corporate finance perspective because the presence of a non-default component impacts the cost of capital, and might capital structure decisions as well as timing and debt and equity issue. Understanding credit spreads is also important for risk management and monetary policy.

Credit spreads: bond yield spreads and credit default swaps

There are two measures of the credit spread: the bond yield spread and the credit default swap premium (CDS). The **bond yield spread** is the differente between the yield on a bond and the yield on a risk-free benchmark with equal maturity. The corporate bond market is overwhelmingly institutional, opaque and is highly illiquid, i.e. bonds are not exchanged frequently, except for shortly after issuance. Liquidity arises from dealers' committing capital to market making, in fact, trading of corporate bonds in the secondary market differs significantly form that of stocks. Stocks trade in centralized and transparent order-driven markets in which bid and ask quotations are continuously disseminated (pre-trade transparency) and also transaction prices and quantities are reported to the investing public within few seconds of each trade (post-trade transparency). While there is limited listing on the NYSE and

AMEX, corporate bond trading, almost entirely, has taken place in a decentralized dealer oriented "over-the-counter" (OTC) market and until recently, no centralized mechanism existed to collect and disseminate post-transaction information. Quotations from dealers where available to market professionals, usually obtained by phone, and transaction prices were not made public at all. This structure has changed in July 2002, when the National Association of Security Dealers (NASD) begun a program of increased post-trade transparency for corporate bonds, known as the Trade Reporting and Compliance Engine. With the introduction of TRACE al NASD members were required for the first time to report, within one our and fifteen minutes of trade execution (after october 2003 the reporting window has been shortened to 45 minutes), prices, quantities, and other information for all secondary market transactions in corporate bonds. Data include also transaction parties identities.

Since 2003 **CDS** have become very popular and they are now considered a good benchmark for credit risk. Also CDS are traded in the decentralized dealer based OTC market. A CDS is an insurance on the default risk of a bond, therefore a bond combined with a CDS is a risk-free position. As argued by Duffie (1999), under certain conditions, CDS spreads are equal to yield spreads on bonds, with equal maturity, on the same entity. CDS are to some extent substitutes of corporate bonds, but they differ in some dimension and offer some advantages. The corporate bond repo market is illiquid, hence buying protection is an easier way for shorting credit risk. CDS have a synthetic maturity and are a flexible tool for credit risk management. Also, they are an unfunded way for taking credit risk, even though this rises the issue of counterparty risk. The CDS market is generally more reactive to new information, corporate bonds are generally illiquid being typically hold till maturity by institutional investors such as pension funds.

The main focus of the financial empirical literature on credit spreads is on measuring the non-default component and on finding its determinants.

Two main approaches to analyze credit spreads

1) The approach by Huang and Huang (2003) and Elton et.al (2001) to estimating the default component is based on a bond pricing model. First, a bond pricing model is calibrated to match historical data on corporate bond default frequencies and losses given default, then

yield spreads implied by the model are used as the estimates for the default component of observed yield spreads. The shortcoming of this approach is that estimates of the default component are sensitive to the model assumptions and it is difficult to estimate expected losses on corporate bonds with reasonable precision. Moreover, aggregate default data ignore the heterogeneity of corporate bonds and the fact that default events are rare and clustered in recession periods. Structural models, which use variables that directly affect default risk (stock, stock volatility, interest rate and leverage) predict lower credit spreads than those observed, hence they under-predict credit spreads. i.e. the default probability backed out from bond prices is higher then the historical default probabilities. The idea is that bond traders do not base their prices for bonds on historical default probabilities, instead they build an extra return for the risk they are bearing. This premium might be due to non-credit-related factors such as general bond market liquidity, systematic risk or other things.

2) The approach of Longstaff, Mithal and Neis (2004) and Blanco Brennan Marsh (2005) uses the CDS to extract the default component of the bond yield spread. The CDS-based approach relies on the idea that CDS spreads reflect both credit risk (default probability and loss given default) and the associated credit risk premium. The problem with this approach is that CDS are not a pure measure of credit risk of the underlying entity. CDS are also affected by liquidity and moreover by counterparty risk since they are unfunded instruments.

The goal of the thesis and description of the three chapters

The goal of the thesis is to measure and explain price discrepancies between CDS and bonds, i.e. the CDS-bond basis.

The basis arises because (cash) bonds and (derivative) CDS are exposed to different factors. Beyond credit risk, bond spreads are affected by funding liquidity and bond market liquidity, which are in turn connected to credit risk. While the CDS premia are affected by demand and supply imbalances (liquidity) and counterparty risk. This is equivalent of arguing that **the basis is due to risk factors and frictions that limit the arbitrage of pricing discrepancies**. There is also an issue of market segmentation, for example bonds are usually hold by pension funds which may not trade on credit derivatives. Overall, studying the basis is an effective way for identifying risk factors to which credit instruments such as CDS and bonds, on firm and governments, are exposed.

This thesis consists of three interdependent and original works on the relationship between CDS premia and bond spreads, on corporate and sovereign entities, in the period during the 2007/10 financial crisis.

The **first chapter** studies the behaviour of the CDS-bond basis, for a sample of investment-graded US firms in the period that goes from January 2006 to April 2009. In contrasts with what reported by other studies, conducted prior to the crisis, it has deviated from zero and it has become persistently negative.

The relation between bond yields and CDS is a close-to-arbitrage one that holds when markets are relatively liquid, i.e. when bid-ask spreads are narrow, market participants are able easily to find funding for purchases of bonds (leverage) and the inter-bank-lending market is well functioning. Clearly, these conditions were much better approximated by the period leading up to the crisis than the period since the onset of the crisis in the summer of 2007. If two financial variables are cointagrated (Engle and Granger (1987)) they share the same stochastic trend and are expected to drift not to far apart. The idea is that they will recover from deviations to their equilibrium relation. If this is not the case, the model describing the equilibrium relation should include the costs and risk factors that explain the deviation. To exploit the negative basis an arbitrageur must finance the purchase of the underlying bond and buy protection. I investigate the role played by economic variables that may capture cost and risk factors of implementing the negative basis trade, such as the Libor-OIS spread, the OIS-Tbill spread, the VIX and the bid-ask spread on CDS contracts, and show that, in the period during the crisis, these are the main drivers of the basis dynamics. The Libor-OIS spread captures all together (i) the funding cost and the funding liquidity risk faced by investors, (ii) counter-party risk implicit into CDS spreads and (iii) corporate bond market liquidity deterioration (Brunnermeier 2009). The OIS-Tbill spread is a measure of the "Flight to quality" phenomenon. The VIX is a measure of liquidity and risk premia in financial markets and is supposed to capture the cost of funding the negative basis trade given by the haircut and the margin requirement applied on the repo-transaction through which the bond is financed. According to Brunnermeier (2009) and Garleanu and Pedersen (2009), haircuts and margins act as market frictions that affects the implementation of price-correcting trades and give raise to price gaps between securities with identical cash-fows, but different margin requirements. Finally, the bid-ask spread on CDS contracts is a measure of liquidity conditions in credit markets.

From the beginning of August 2007, when the crisis started, all these variables experienced a dramatic shift from their historic trends, i.e. they increased suddenly and become more volatile. Bond spreads have become larger than CDS spreads, and the basis has gone into negative territory. I find that the basis dynamics is driven by the economic variables, described above, that are proxies for liquidity conditions and risk in the inter-bank lending market. The idea that during stress times asset prices depart materially farther from frictionless ideals, i.e. from their fundamentals. The deviation from parity does not imply the presence and persistence of arbitrage opportunities, in fact the basis trading is faceing liquidity and counterparty risk, hence it is not risk-free.

The **second chapter** studies the pricing of Euro area sovereign credit risk in the period 2006-2010. Two are the main contributions: first, this is a comprehensive analysis of the determinants of sovereign CDS and second it is a study of the linkages between CDS and the underlying bonds. In the first part of the work, a variety of financial market variables are related to the first differences of CDS premia; the focus is on testing how the turmoil in credit markets has affected the explanatory value of the determinants of premia. Proxies for country developments, the interest rate environment, risk aversion and market liquidity are included. This approach allows to use of 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, the focus is on the basis on government bonds. Arbitrage trading should in principle drive it close to zero. Therefore, the size and sign the basis can help to understand market functioning as well as information transmission across the two markets which trade sovereign risk.

Since late 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 aftermath of the Lehman collapse 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.

Traditionally, valuation of government debt issued by developed country sovereigns has treated default as a very low probability event. 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 1997-98 crisis in emerging market sovereigns also played a large role. Given this market focus, key papers on sovereign CDS such as Longstaff, Pan, Pedersen and Singleton (2008) do not study euro area countries. 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.

The **third chapter** proposes a methodology for measuring the CDS-bond basis which is based on the bonds' cash fows replication argument. The bond is priced according to the risk-neutral valuation paradigm using the Libor curve as the risk-free benchmark, risk-neutral default probabilities implied from the CDS curve and an assumed recovery rate. Also, a series of tests is performed to explore the sensitivity of the error between this measure and the standard measure of the basis used in the financial literature. A series of tests performed, on an hypothetical bond, illustrates how the error between this "arbitrage-free" measure and the standard measure of the basis depends on the term structure. An empirical application, on US corporate bonds, shows that the two measures exhibit a common behaviour and since the onset of the crisis, in August 2007, they have become both negative, but the "arbitrage free" basis remains smaller in absolute terms.

Measuring the basis using the bond cash-flow replication argument deals with two issues. First, by defining the corporate bond used in the arbitrage as floating-rate bond (Duffie, 1999), at par, the constant interest rate curve assumption can be avoided. Second, the Duffie (1999) CDS-bond arbitrage argument is based on the simplifying assumptions that default can happen only at coupon dates, while in practice default may happen at any time. This approximation leaves some margin of pricing errors.

In practice, the vast majority of the corporate bonds are fixed-rate and trade usually away from par, because the level of the interest rate curve is time-varying. In fact, when the bond is away from par, the shape of term structure of the risk-free rate and of the CDS affects the parity relation. Previous empirical studies such as Longstaff et al. (2005), Blanco, Brennan and Marsh (2005), Zhu (2006), Nashikkar and Subrahmanyam (2006), use only 5 year synthetic bonds, but corporate bonds do not have constant maturity in time and this may be a source of bias. Additionally, no one of these studies accounts for the shape of term structure of CDS, they assume that it is flat, this implies that the default intensities or the risk-neutral default probabilities are constant across different maturities; which is not true in practice. Compared to this methodologies, using the bonds' cash flow replication argument, we calculate the CDS-bond basis on a fixed rate corporate bond, allowing for the level of the swap rate curve and of the CDS curve to vary in time and for the curves to have different shapes. This approach avoids constructing any hypothetical bonds and allows to calculate the basis on real bonds of different maturities. In fact, it is hard address properly the coupon issue in bond price computations, because the cash flows of the hypothetical bond are not well defined. Also, there are no observable transaction data on the hypothetical bond for explaining prices with liquidity proxies in an eventual empirical analysis.

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The persistent negative CDS-bond basis during the 2007/08 financial crisis

Alessandro Fontana *

Department of Economics, University of Ca' Foscari Venice

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Abstract

I study the behavior of the CDS-bond basis - the difference between the CDS and the bond spread - for a sample of investment-graded US firms. I document that, since the onset of the 2007/08 financial crisis it has become persistently negative, and I investigate the role played by the cost of trading the basis and its underlying risks. To exploit the negative basis an arbitrageur must finance the purchase of the underlying bond and buy protection. The idea is that, during the crisis, because of the funding liquidity shortage and the increased risk in the financial sector, which exposes protection buyers to counter-party risk, the negative basis trade is risky. In fact, I find that basis dynamics is driven by economic variables that are proxies for funding liquidity (cost of capital and hair cuts), credit markets liquidity and risk in the inter-bank lending market such as the Libor-OIS spread, the VIX , bid-asks spreads and the OIS-T-Bill spread.

Results support the evidence that during stress times asset prices depart form frictionless ideals due to funding liquidity risk faced by financial intermediaries and investors; hence, deviations from parity do not imply presence of arbitrage opportunities.

Keywords: CDS; bond spread; funding rate, liquidity risk; counter-party risk; financial crisis.
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*Address: University of Ca'Foscari Department of Economics, Fondamenta San Giobbe - Cannaregio 873, 30121 Venezia, ITALY, e-mail: *fontana@unive.it*. The author is grateful to Loriana Pelizzon, Monica Billio, Domenico Sartore, Elisa Luciano, Juan Carlos Rodriguez, Stephen Schaefer and participants at the 2nd Italian Doctoral Workshop in Economics and Policy Analysis at Collegio Carlo Alberto (Turin), July 2-3 2009, the Doctoral Tutorial of the European Finance Association, Bergen (Norway), August 19 2009 and the CREDIT conference in Venice 24-25 September.

1 Introduction

The CDS-bond basis is defined as the difference between the CDS and the bond spread, with equal maturity, written on the same entity. Whenever this difference is large, it is attractive to implement a basis trade, buying (selling) credit risk in the cash market and selling (buying) it in the derivative market if the basis is negative (positive), in order to profit from price discrepancies. In early 2009, Boaz Weinstein, a trader and co-head of credit trading at Deutsche Bank was down \$1bn, Ken Griffin of Citadel was down 50% and John Thain of Merril was said to be down by more than \$10bn. The big part of these losses is due to the so called "negative basis trade".

The aim of this paper is twofold. First, study the behavior of the basis during the 2007/08 financial crisis. Second, investigate why investors have lost money, on basis trades, during that period. I document that, during the crisis, the average basis on corporate entities has become strongly and persistently negative. Such a situation has never been reported in earlier studies. For example, Blanco et. al. (2005), find that the basis is usually positive and narrow and that short-term deviations are due to CDS spreads leading bond spreads in the price discovery process. If two markets price credit risk equally then their prices should be the same in levels and should move together. Instead, I find that, during the crisis, CDS and bond spreads have deviated form the parity condition. Implications have been dramatic for negative CDS-bond basis traders who where operating on the belief that bases deviation where risk-free and short-lived arbitrage opportunities.

The followings are among the possible explanations of the deviation from parity. First, a dramatic increase of funding costs affects the CDS' pricing by no-arbitrage and reduces the basis trading return for arbitrageurs. Second, when the basis has shifted into negative territory, basis traders where reporting mark-to-market losses. Due to liquidity shortage (funding liquidity risk) basis traders have been forced to de-leverage, closing their positions, driving the basis even more negative and realizing large losses. Third, protection sellers' (dealers) counter-party risk lowers CDS spreads. Fourth, investors facing redemptions tend to cut their most liquid position which include corporate bonds, and at the same time a higher funding cost makes it more expensive, for dealers, to provide liquidity in the bond market driving bond spreads larger. All this things may play a role in explaining the negative basis and are all related to funding liquidity conditions in the financial market.

The relation between bond yields and CDS is a close-to-arbitrage one that holds when markets are relatively liquid, i.e., when bid-ask spreads are narrow, market participants are able easily to find funding for purchases of bonds (leverage or repo) and the inter-bank-lending market is well functioning. Clearly, these conditions were much better approximated by the period leading up to the crisis than the period since the onset of the crisis in the summer of 2007.

If two financial variables are cointagrated (Engle and Granger (1987)) they share the same stochastic trend and are expected to drift not to far apart. The idea is that they will recover from deviations to their equilibrium relation. If this is not the case, the model describing the equilibrium relation should include the costs and risk factors that explain the deviation. I investigate the role played by economic variables that may capture cost and risk factors of implementing the negative basis trade, such as the Libor-OIS spread, the OIS-Tbill spread, the VIX and the bid-ask spread on CDS contracts, and show that, in the period during the crisis, these are the main drivers of the basis dynamics. The Libor-OIS spread captures all together (i) the funding cost and the funding liquidity risk faced by investors, (ii) counter-party risk implicit into CDS spreads and (iii) corporate bond market liquidity deterioration (Brunnermeier 2009). The OIS-Tbill spread is a measure of the "Flight to quality" phenomenon. The VIX is a measure of liquidity and risk premia in financial markets and is supposed to capture the cost of funding the negative basis trade given by the haircut and the margin requirement applied on the repo-transaction through which the bond is financed. According to Brunnermeier (2009) and Garleanu and Pedersen (2009), haircuts and margins act as market frictions that affects the implementation of price-correcting trades and give raise to price gaps between securities with identical cash-flows but different margin requirements. Finally, the bid-ask spread on CDS contracts is a measure of liquidity conditions in credit markets.

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This paper is organized as follows. Section 2 proposes a short review of the related literature and highlights the contribution. Section 3 discusses the conceptual framework that underlines the parity relationship between the CDS and the bond spread. Section 4 describes the data. Section 5 presents the empirical analysis: methodology and results. Final remarks are offered in section 6.

2 Review of the related literature

This paper is in line with previous studies on the dynamic relation between CDS and bond spreads, such as Blanco et.al. (2005) and Norden et.al. (2004) and De Wit (2006), but it covers a different time period, which goes from 1/3/2005 to 11/19/2009[1]. The focus is on the impact of the 2007/08 financial crisis and on how common factors explain a persistent deviation from parity. Using a sample of investment-graded firms, Blanco et.al. (2005) find that the theoretical arbitrage relationship linking credit spreads over the risk-free rate to CDS prices holds reasonably well on average for most of the companies they considered (especially for US firms) when the risk-free rate is proxied by the swap rate, though they may differ significantly in the short-run. I find similar results for the period before July 2007, instead during the crisis CDS and bond spreads drift apart.

Blanco et.al. argue that CDS forms an upper bound for credit risk because of the "cheapest to delivery option",[2] while credit spread forms a lower bound because of repo costs. This implies that in normal market conditions the CDS-basis is positive on average. Differently, this paper shows that during the crisis, the bond spread is an upper bound for the price of credit risk while the CDS is a lower bound. Cash bonds are funded instrument their so spreads are adversely affected by the cost of funding that drives yields larger, while CDS spreads, which are unfunded, are affected by counter-party risk being sold at discount.

Other studies such as Zhu (2004), Norden et.al. (2004) and De Wit (2006) reach similar conclusions of Blanco et.al. (2005). Concerning relationship between CDS and bond spreads, Blanco et.al. (2005) detect cointegration for 27 of 33 firms; Zhu (2004) detects cointegration for 15 out of 24 firms; Norden et.al. (2004) detect cointegration of spreads for 36 out of 58, and De Wit (2006) detects cointegration for 88 of 144 firms. In general, for the US market there is cointergation in

[1] For example Blanco et.al. (2005) data run from 2 January 2001 through 20 June 2002. De Wit (2006) data run from January 2004 to December 2006

[2] In practice the protection buyer will deliver the cheapest-to-deliver bond from the delivery basket. This option has a positive value, for this reason protection providers will quote higher CDS premiums.

75% of the cases. Longstaff et.al. (2005) study the default and non-default component of credit spreads using CDS information and find that both specific (to the bond) liquidity and overall (market) liquidity have an impact on the non-default component. The determinants of CDS and bond spreads have been studied by Collin-Dufresene et.al. (2001), Elton et.al. (2001) and also others who find that similar factors behind changes in CDS premium and the bond spread.

This paper is also related to the empirical literature on arbitrage, cointegration (Engle and Granger (1987)) and market efficiency. Cointegration is used extensively to study the link between spot and futures markets. Brenner and Kroner (1995) used a no-arbitrage cost of carry asset pricing model to explain why some markets are expected to be cointegrated while others are not. The idea is that cointegration depends critically on the time-series dynamics of the cost of carry. They showed that spot and future prices are cointegrated, in an efficient market, if the cost of carry is stationary, if it is not, the cointegrating relation should include the stock price, the future price and the cost of carry the arbitrage too. Following this line, persistent price discrepancies are explained by the cost of carrying the arbitrage trade.

I use the same idea to show that, during the crisis, the CDS and the bond spread wonder apart because of the explosion of the cost and the risk of trading the basis.To my knowledge, no empirical study has yet investigated the issue of price discrepancies in the market for credit risk during the crisis. I provide such an examination.

3 The CDS-bond basis

3.1 The connection between CDS and bond spreads: a ”close-to-arbitrage” relation

CDS are the most liquid of the credit derivatives currently traded and form the basic building blocks for more complex structured credit products. They can be used to transfer credit risk from the investor exposed to the risk (the protection buyer) to an investor willing to assume that risk (the protection seller). A CDS is a bilateral contract where one counterparty buys default protection with respect to a reference credit event. This contract terminates at maturity or default, whichever comes first. In the event of a loss the protection buyer is compensated with the difference between the par value of the bond or loan and its market value after default. The protection seller, collects a periodic fee, and profits if the credit risk of the reference entity remains stable or improves while the swap is outstanding. CDS are almost exclusively traded over-the-counter. There are diverse participant in this market: banks, brokerage firms, insurance companies, pension funds, hedge funds and asset managers. The premium paid is quoted in basis points, per annum, of the contract's notional value; this is what we call CDS spread.

How does the pricing by arbitrage of a CDS work? Let's consider the most simple situation in which: the CDS counterparties are default free, the contingent payment amount specified in the contract is the difference $100 - Y(\tau)$ between the face value and the market value $Y(\tau)$ of the underlying note issued by C at credit event time τ and the underlying note is a floating-rate note. The underlying floating-rate note is initially issued at par, it is costless to short it and there are no transaction costs. The termination payment, given a credit event, is made at the immediately following coupon date of the underlying note. The contract is settled, if terminated by the credit event by physical delivery of the underlying note in exchange for cash in the amount of its face value. Under these assumptions the CDS price may be obtained by arbitrage. A synthetic (long) CDS can be created shorting a risky floating-rate note for an initial cash receivable of 100 and buying a par default-free floating-rate note for the same amount. This portfolio has to be held till maturity or default whichever comes first. One pays coupons on the risky bond and receives the coupons on the default free one. The difference between these two quantities is the spread S of the par note issued by C over the default-free floating rate. If default happens before maturity the value of the portfolio is the difference $100 - Y(\tau)$ between the market value of the default-free floating rate note and the market value of the note issued by C. In order to have no arbitrage the net constant annuity U, which is the CDS spread, has to be fixed such that U=S. When ever U and S differ substantially arbitrageurs' trading activities arbitrage away prices discrepancies, driving prices to their no-arbitrage relation.

What described above works in a theoretical setting, in practice CDS contracts are traded in OTC markets and provided by dealers. Dealers that sell a CDS (buy credit risk) hedge their position (buying protection) short-selling the risky bond that they obtain via repo. Instead, when they buy a CDS (sell credit risk) they hedge (selling protection) buying the risky bond that they finance paying a funding rate. When a particular bond is difficult to obtain as a collateral the associated repo rate may be below the risk-free rate rising the cost of shorting. If repos are special (lower than the risk free) it becomes more costly, for the dealer, to provide a CDS short-selling the risky bond. As a consequence the CDS spread is

$$U(ask) = Spread + (RiskFree - Repo) \tag{1}$$

Differently, the financing rate is generally above the risk-free, this makes it more costly for the dealer to buy CDS from customers. So

$$U(bid) = Spread - (FinancingRate - RiskFree) \tag{2}$$

Hence, if the repos are special the basis may be persistently positive, and if the funding cost is relevant, the basis is persistently negative.

The pricing relation discussed is a first order approximation, because bonds may default at any time, not just at coupon dates; moreover bonds have generally fixed, not floating, coupons hence they might trade away from par[3]. In general, even though cash flows on a long default-free bond and a short defaultable bond are not precisely those on a CDS, it's very close. Therefore, in a situation in which market frictions are negligible, the CDS is expected to be strictly connected the bond spread irrespective of how the bond yield is related to actual default intensity.

3.2 Why is the basis negative during the crisis?

How do market frictions and various risk factors influence the basis trade which makes the parity relation, between the CDS and the bond spread, hold? The main simple reason why the basis has deviated from zero is that CDS, which are derivatives contracts, and bonds, which are cash instruments, are exposed to different risk factors.

In principle, taking credit risk purchasing a corporate bond or shorting a CDS, on a reference entity, is equivalent. The point is that corporate bonds and CDS are not substitutes. Bond prices are exposed to: interest rate risk, default risk, funding risk and market liquidity risk, while CDS

[3]The approximation depends on how much the bond is away from par, on the coupon level, on the shape of the term structure of risk-free interest rates and on the shape of CDS curve. Departures from par and from a flat shape of the interest rate term structure deteriorate the approximation. For a detailed examination of these issues see Fontana (2009).

spreads are affected, mostly, by default risk and the related risk premia and counter-party risk. Funding risk is due to the fact that bonds are cash instruments, hence the return on the investment depends on the cost of funding, while liquidity risk to the fact that deterioration of liquidity in the corporate bond market may have an adverse impact on bond prices, hence on the cost of financing the purchase of the bond itself via a reverse-repo.

Being CDS unfunded derivatives contracts instead there is an issue of counter-party risk, since the protection seller may not be able to compensate the buyer, in the event of default of the underlying name. The connection between bond yields and CDS is a "close to arbitrage" relation that is expected to hold when, markets are relatively liquid, i.e. bid-ask spreads are relatively narrow and market participants are able to easily to find funding for purchases of bonds, moreover dealers who provide protection are not risky. Clearly these conditions where much better approximated by the period leading up to the crisis than the period since the onset of the crisis in the summer of 2007.

If a bond is trading more cheaply than the CDS an arbitrageur may profit implementing a negative basis trade in two ways. A first way is with a long run focus ("arbitrage-negative-basis-trade"). He buys the bond, buys protection, swaps the libor with a swap rate of the maturity of the bond (to hedge interest rate risk) and keeps this position till maturity to gain a "risk-free" yield. This strategy is "risk-free" in the sense that the investor does not care if the underlying name defaults, since what he looses on the bond he makes back from the short risk position in the CDS. A second way is with a short run focus (speculation). A trader may speculate on the variation of the basis in a short leg of time implementing a convergence trade type strategy. When the basis is negative he buys the bond, buys protection and hedges interest rate risk, as soon as the basis narrows he closes the position selling the bond and selling the CDS. This strategy is based on the belief that the basis is going to narrow whenever it is there.

The negative basis trade is not a perfect hedge, in fact it carries risks such as funding risk, mark-to-market loss risk[4] and counter-party risk[5]. Also, there is an issue of "coupon risk" and an issue of "recovery risk" [6]. I believe there are a number of possible reasons of why the behavior of

[4]Whenever traders leverage up their position they bear the risk they maybe forced to de-levarege in case of large market losses, or in case of an exogenous reason.

[5]Among other things, CDS buyers are often buying wrong way exposure; in fact, positive correlation between bond and counter-party default implies discount to the CDS premium.

[6]As highlighted in Fontana (2009) the basis trade is not a risk-free trade because, since default may happen at

the CDS-bond basis may have deviated from zero during the 2007/08 financial crisis and they are all related to the fact that the negative basis trade, as pointed above, is not a perfect hedge.

First, a dramatic increase of cost of financing has affected dealers' CDS pricing. The lower bound on a dealers bid price for protection is provided by the net cost of financing the purchase of the underlying cash bond[7]. Under normal conditions this cost approximates the bond spread and, in turn, the CDS spread. However, when the cost of financing increases the net cost falls and with it the CDS spread below which it is worthwhile for the dealer to bid for protection while hedging in the cash market. Lowering the bid price for protection also lowers the mid-price and, therefore, standard measures of the basis. The cost of financing affects investors trading activities in a similar way. In order to exploit a negative basis an investor must finance the purchase of the bond and buy protection. During the crisis the cost of financing, if indeed financing is available, has increased substantially thus reducing or eliminating the return to arbitrageurs. The cost of funding a negative basis trade is also given by the hair cut applied on the repo-transaction through which the bond is financed. Risk in financial markets has an adverse impact on the bond s' liquidity and on the value of the bond as a collateral and contributes to and increase of haircuts, i.e. an increase of the cost of funding.

Second, bond market liquidity deterioration. Investors, facing redemption and imposed reduction of the leverage, tend to cut their most liquid position which include corporate bonds, and to cut positions on basis trades driving the basis even more into negative territory. An increase in funding costs makes it also more expensive for dealers to hold corporate bonds into inventory and therefore lowers the liquidity of the market. It is possible that this lower liquidity is reflected in higher spreads and, if so, this would also contribute to a reduction of the basis.

Third, protection sellers' counter-party risk lowers CDS spreads. Selling protection may be achieved both via the CDS market and by buying cash bonds, but an important difference between the two is that in buying a bond the protection provided is funded, i.e., in the event of default the buyer of a bond simply accepts an amount (the recovery amount) that is lower than the nominal amount. Thus the provision of protection in this case does not depend on the creditworthiness of the bondholder. On the other hand the value of protection provided by a seller of protection via CDS

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any time, the coupon is not hedged. Also when the bond is away from par there is a risk of recovery, since the amount invested in the purchase of the corporate bond is likely to be over or under-hedged.

[7]This refers to the pricing equation (2).

depends entirely on the sellers creditworthiness. Most protection sellers are financial institutions and the credit worthiness of many of these has clearly deteriorated markedly through the crisis. For example, A.I.G. and the monoline insurers, who were significant net sellers of protection, have suffered severe financial distress and, in the case of some monolines, failure. Sellers of protection are also exposed too, to some extent, to counterparty risk since they face mark-to-market losses in the event of the failure of the buyer.

4 Data

4.1 Data description

The analysis is conducted on a sample of 37 U.S. firms, that are listed on Table 1 with indication of sector and rating.

INSERT TABLE 1 HERE

Table 2 shows that 8 different sectors are well represented, but the majority of reference entities carry rating A and BBB. Data run from January 3, 2005 trough April 1, 2009, more than one semester after the "Lehman crash".

INSERT TABLE 2 HERE

CDS's are over the counter instruments traded mainly in New York and London. Indicative bid-ask quotes are provided by Thomson Financial Datastream. Prices hold at market closure at 5 p.m., are for a notional value of $10 million and are based on ISDA benchmark contracts for physical settlement. All CDS are of five years maturity, which is the most liquid one. Also corporate bonds are traded mainly over-the-counter in the US. Bond spreads over the swap rates are provided by Thomson Financial Datastream. These data are also at the close of the market at 5.50 p.m Eastern time, which is slightly later than the CDS market.

In order to match CDS's with bond spreads, I create a synthetic constant 5 years maturity bond spread. At every point in time in the sample, for each entity with suitable CDS data, I search for a bond with less than five years left to maturity, and another bond with more than five years to maturity. By linearly interpolating these spreads I approximate a five-year to maturity bond spread. When I have the choice I select the most liquid and most close to par bond. Only senior, straight bonds are used. Floating-rate notes and bonds that have embedded options, step-up coupons, or any special feature that would result in differential pricing, are not considered [8].

The bond spread is the difference between the bond yield and the risk-free rate. One possibility is to calculate the bond spread over US Treasuries yields. However, government bonds are no longer an ideal proxy for the unobservable risk-free rate. Taxation treatment, repo specials, legal constraint among others, make goverment bond yields artificially low for this purpose. As an alternative proxy for the risk-free rate is interest rate swap. Previous empirical studies on CDS, such as Houweling et.al (2003) and Blanco et.al (2005) have used swap rates as risk-free benchmarks. Swaps, being synthetic, are available in virtually unlimited quantities so that liquidity is not an issue, and they have the further advantage of being quoted on a constant maturity basis. However, swaps contain a risk premium because the floating leg is indexed to LIBOR, which is a default-risky interest rate and the presence of counter-party risk. Most importantly, investors do CDS-bond basis arbitrage using the swap rate as risk free rates.

CDS bid-ask spreads are provided by datastream. Time series data for the Libor curve and other variables used in the empirical analysis such as the T-Bill rate and the OIS (Overnight Indexed Swap) are also provided by the Federal Reserve. The VIX, i.e the implied volatility of S&P 500 index options, is downloaded from Datastream Thomson Financial.

4.2 The basis and the relevant economic variables: descriptive statistics

During the 2007/08 financial crisis the CDS-bond basis is persistently negative, i.e. bond spreads are on average larger than CDS spreads. [9] This is a signal that special factors are at work.

Figure 1 shows the time-series dynamics of then CDS, the bond spreads and the bases, for corporate entities, aggregated by rating group, separately for industrials and financials. Financials

[8] The idea is to neutralize as much as possible technical factors such as contractual specifications that affect the CDS-bond basis.

[9] Blanco et at (2005) report that the cross-sectional mean of the times series average of the CDS-bond bases, for a sample of 33 US firms, is + 6 basis points when using the swap rate as the reference rate, for AAA-AA, 0.5 bps for A and 14 bps for BBB; in general 3 bps. These result are in line with ours in the period before crisis.

entities are at the core of the crisis and default risk is much higher than for industrials, hence the CDS, the bond spread and the basis series are quite different. Spreads represent the creditworthiness and the risk of default of the underlying names and they are larger for lower ratings. Before the crisis, CDS and bond spreads where very low and the difference between them was neligeble. When the crisis started, around the beginning of August 2007, both CDS and bond spreads increased, but the basis has become negative. From September 15, 2008, when Lehman crashed, spreads exploded and the basis has become even more negative.

Table 3 shows the average and the median CDS-bond basis, across ratings, separately for the financial and the industrial sector, for three different periods: January 2005 to August 2007 is the pre-crisis period (Period 1), August 2007 to August 2008 is the pre-Lehmann crash period (Period 2) and August 2008 to March 2009 (Period 3) is the crisis period after Lehman collapsed. Before the crisis, there is evidence of the so called basis smile i.e. the average basis for the A rating category is the lowest, -4.9 bps.

INSERT TABLE 3 HERE

For AAA rating the average basis is positive, 12 bps, also because CDS are floored at zero, while bond spreads for highly rated entities are very low. For the BBB category, instead the average basis is 3.8 bps, the "Cheapest to Delivery option" increases the CDS premium with respect to the bond spread. In the second period, the basis is negative (on average -17.2 bps), except for the AAA rating. When Lehman crashed, on the 15th of September, the overall average basis went down dramatically to -147.5 bps.[10] Notice that for lower rated entities, the negative bases are larger pointing to the fact that economic and risk factors, that are at work, have different impacts across-ratings groups (collateral quality hypothesis). Also, for the financial sector spreads are generally higher, and the basis is more negative; in fact the crisis has originated from the financial sector.

Next, I discuss the variables used for explaining the CDS-bond basis and motivate their role.

Figure 2 shows the dynamics of the 3 month Libor minus the Overnight Indexed swap rate (Lib-OIS spread), and the dynamics of the difference between the OIS and the 3 month Treasury

[10] The average and the median are pretty much the same meaning the distribution is centered.

bill rate (OIS-Tbill spread). Figure 3 shows the VIX dynamics. VIX is the symbol for the Chicago Board Options Exchange Volatility Index, a popular measure of the implied volatility of S&P 500 index options. It is a measure of risk premia in financial markets. In this sense, a high value corresponds to a more volatile market. Figure 4 shows the dynamics of CDS's bid-ask spreads separately for industrial and for financials. What is the role played by the Libor-OIS spread, the OIS-Tbill spread, the VIX and the bid-ask spreads in CDS markets in our empirical analysis?

The **Libor-OIS** spread is an indicator of both the **counter-party risk** and the **funding liquidity risk** implicit in a negative basis trade[11]. The 3 month Libor is the rate at which banks declare they are willing to lend to each other unsecured. The OIS is the rate on a derivative contract on the overnight rate. In the US, the overnight rate is the effective federal funds rate and is considered risk-free. Changes in the Libor-OIS spread reflect both changes in the credit risk premium and changes in liquidity premium. The Libor-OIS spread is a measure of the risk in the inter-bank-lending-market because it reflects what banks believe is the risk of default associated with lending to other banks. When it increases, that means that lenders believe the risk of default on interbank loans is higher. As described in section 3.2, CDS providers are big banks and counter-party risk might be priced in CDS contracts.

From an economic point of view, funds are valued at the rate they could be invested in the money market; in general it is Libor plus a spread. So the funding cost to implement the negative basis arbitrage refers to the spread over the Libor rate. The problem is that during periods of financial turmoil the Libor itself dramatically increases with respect to the rate on government bonds, and often funding is even not available.

The funding cost hence refers not only to higher rates, but also to the value of the bond as a collateral. To earn an arbitrage profit an investor must use capital, and during a funding crisis capital is required to earn excess returns for constrained investors: price discrepancies between cash bonds and CDS are consistent with the margin-based asset pricing model by Garleanu and Pedersen (2009). "Typically, informed traders, such as dealers, hedge funds, or investment banks, use the purchased bonds as collateral and borrow (short term) against it, but they cannot borrow the entire price. The difference between the bond's price and collateral value, the margin, must be

[11]Counter-party risk refers to the risk that the protection buyer is not compensated, in case of default of the underlying bond, by the dealer providing the CDS contract.

financed by the traders own capital. An increase in margins or haircuts requires investors to use more of their own capital and forces traders to de-leverage their positions" Brunnermaier (2008). The idea is that the value of the bond and the margin requirements are crucial in order to determine the cost of the capital used in order to implement the negative basis trade and represent a friction that affects the implementation of price-correcting trades, i.e. margin requirements justify the price discrepancies between bonds, which are funded instruments and CDS which are unfunded instruments and can be bought without the use of capital. The **VIX** is supposed to capture, in addition to the time-dynamics of the risk premium on risky investments, the funding cost due to the deterioration of bond' s value as a collateral in the negative basis trade. In addition, risk in financial markets has an adverse impact on the bond s' liquidity, hence on the value of the bond as a collateral and contributes to increase haircuts further.

The **OIS-Tbill** spread is the spread between the Overnight Indexed Swap and the short term 3 month Treasury bill. Treasuries are the safest collateral and are particularly valuable in times of crisis. The OIS-Tbill spread dynamics captures the "flight to quality" phenomenon, and the corporate bond market liquidity deterioration. Fund managers prefer to switch to safe investments, which makes holding Treasury bonds more attractive and lowers the Treasury bond rate (Brunnermaier 2009) with respect to the OIS. Graphically these facts show up as spikes of the series. Liquidity deterioration in the corporate bond market drives yields high irrespective of the default intensity.

The **bid-ask spread** of CDS is a measure of liquidity of the CDS market. An increase of the bid-ask spread would reflect a deterioration of liquidity also in the corresponding bond market. A situation in which bonds and CDS values are uncertain because of market liquidity risk makes the basis trade more risky.

Figures 1, 2, 3 and 4 show that from the beginning of August 2007, when the crisis started, all variables experienced a dramatic shift from their historic trends. CDS, bond spreads, the Libor-OIS spread, the OIS-Tbill spread, the VIX and CDS's bid-ask spreads increased suddenly and have become more volatile, while the basis has deviated from zero and has shifted dramatically into negative territory.

INSERT FIGURES 1, 2, 3 AND 4 HERE

5 Empirical analysis

5.1 The lead-leg relationship between CDS and bond spreads

The analysis of the relationship and the adjustment process between CDS and bond spreads, in the period that goes from January 2005 to April 2009, is conducted on 4 series given by the averages of CDS and bond spreads by rating groups (AA, A and BBB Industrials and AA Financials)[12]. The focus is on averages of spreads within rating groups because the focus is on the common factors that drive the basis.[13] Data consist of weekly observations.[14]

The existence of a cointegration relationship between the levels of two I(1) variables [15] means that a linear combination of the 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 the no-arbitrage condition. A model that considers this adjustment process is the Vector Error Correction Model (VECM). Cointegration analysis is carried out in the framework proposed by Johansen (1988, 1991). This test is essentially a multivariate Dikey-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.[16] The Vector Error Correction Model is specified as follows:

$$\Delta CDS_t = \lambda_1(Z_{t-1}) + \sum_{j=1}^{q} \alpha_{1j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{1j}\Delta BS_{t-j} + \epsilon_{1t} \quad (3)$$

$$\Delta BS_t = \lambda_2(Z_{t-1}) + \sum_{j=1}^{q} \alpha_{2j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{2j}\Delta BS_{t-j} + \epsilon_{2t} \quad (4)$$

$$Z_{t-1} = CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1} \quad (5)$$

Equation (3) and (4) express the short term dynamics of CDS and bond spread changes, while Z_{t-1} is the error correction term given by the long run equation (5), that describes deviations of CDS and bond spreads from their no-arbitrage relation. The model is specified with the optimal

[12] I do not implement the analysis on the industrials AAA rating group because of the lack of data.

[13] I have conducted the analysis on single entities and results are in line with results on averages within rating groups.

[14] I have conducted the analysis on daily data and results are in line with those on weekly data.

[15] I(1) refers to non-stationarity given by the presence of a unit root.

[16] If the test does not reject the hypothesis that the number of cointerating vectors in none, the series are not cointegrated. If it can not reject the hypothesis of at most, one cointegrating vector, there is one cointegrating vector and the series are cointagrated.

number of lags for each cointegrating relation.

If the cash bond market is contributing significantly to the discovery of the price of credit risk, then λ_1 will be negative and statistically significant as the CDS market adjusts to incorporate this information. Similarly, if the CDS market is an important venue for price discovery, then λ_2 will be positive and statistically significant. If both coefficients are significant, then both markets contribute to price discovery. The existence of cointegration means that at least one market has to adjust by the Granger representation theorem (Engle and Granger 1987).

As a first step, I verify the supposed unit-root non-stationarity of the CDS and bond spread series. A stationary series follows a process which has a constant mean, variance and auto-covariance structure trough time. I apply the augmented Dickey-Fuller test to each of the 4 CDS and to each of the 4 bond spread series, independently. Results are summarized in Table 4.

INSERT TABLE 4 HERE

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).

The results of the Johansen cointagration test are shown in Table 5.

INSERT TABLE 5 HERE

The trace statistics strongly rejects the absence of cointegration, but do not reject the existence of one cointegrating relationship. Table 6, reports the estimated coefficients of the long-run regressions.

INSERT TABLE 6 HERE

The coefficients of CDS are restricted to unity, but the coefficients of bond spreads are positive, as expected, and well below unity, they are all between 0.37 and 0.49[17]. Also the constant term is significant and positive, for all rating groups. The parity relation does not hold, bond spreads

[17] A likelihood ratio (LR) test has been performed on the restriction of the coefficient of bond spreads to unity. The restrictions have been rejected. I do not report results for brevity.

are larger than CDS and the basis dynamics is affected by non-transient factors, but since CDS and bond spreads are cointegrated, i.e. they do not move in an unrelated way, the cash and the derivative market for credit risk are informationally integrated.[18] Table 7 reports results of the short-run regressions.

INSERT TABLE 7 HERE

Cross-responses of CDS and bond spreads, when significant they are generally positive, with values less than unity meaning that a movement in one market is transmitted to the other in the same direction, but with lower intensity. Also, for A and BBB industrials, the Adjusted R squared (0.38 and 0.47) is slightly higher for equation describing bond spreads changes (0.21 and 0.24), while for AA financial and industrials the Adjusted R squared (0.21 and 0.30) is slightly higher for the equation describing CDS changes.

The price discovery statistics are reported the bottom of Table 7. λ_1 is significantly positive for all rating groups, while λ_2 is significantly negative for most of the groups, indicating that both the CDS market and the bond market contribute significantly to credit risk price discovery. Following Blanco et.al., the method I use to investigate the mechanics of price discovery is a measure due to Gonzalo and Granger (1995) defined as defined as the ratio: $\frac{\lambda_2}{\lambda_2-\lambda_1}$. This approach attributes superior price discovery to the market that adjusts least to price movements in the other market. The Granger-Gonzalo measure for AA industrials, AA financials and A and BBB industrial is respectively: 0.752, 0.787, 0.599 and 0.429, meaning that for all rating groups except for BBB price discovery occurs mostly in the CDS market, eventhouh the value of GG is not much away from 0.5, meaning that new information flows into both markets, with a slight predominance of the CDS market. Price discovery occurs in the market where informed investors trade at most. CDS are unfunded instruments so they are the easiest way to trade credit risk. Because of their synthetic nature they do not suffer from the short-sales constraints seen in the cash-bond market, and buying (or selling) relatively large quantities of credit risk is possible (Blanco et. al 2005). Hence, price discovery is very much related to the market liquidity and does not give rise to systematic profitable opportunities.

[18]Concerning single relations, we find cointegration for most of the names, 20 out of 37 (with a 10% level of significance); these results are in line with those of Blanco et.al. (2005), Norden et.al (2005) and Zhu (2004), who find, for US entities, that 2/3 of the relations are cointegrated.

5.2 Explaining the negative basis during the crisis

To study the risk factors that drive the negative basis during the crisis, I apply the Engel-Granger two-step estimation approach using dummies for the crisis period. The idea is to account for the structural break that has characterized the parity relation between CDS and bond spreads and to study the different impact of the relevant economic variables, before vs. during the crisis.

I proceed as follows. First, I estimate the model using the variables in levels. The long run relationship between bond spreads, CDS and the other variables, such as the Libor-OIS spread, the OIS-TBill spread, the VIX and the bid-ask spread on CDS contracts, is the following[19]:

$$BS_t = \alpha_0 + \alpha_1 CDS_t + \alpha_2 LibOIS_t + \alpha_3 OISTbill_t + \alpha_4 VIX_t + \alpha_4 BidAsk_t + u_t \tag{6}$$

If I reject the hypothesis of a unit root in the residuals then there is a long run relationship between the variables (the variables are cointegrated). I check for stationarity of the residuals by mean of the Augmented Dickey Fuller Test:

$$\Delta \hat{u}_t = a_0 + a_1 t + \beta \hat{u}_{t-1} + \sum_{i=1}^{K} \gamma_i \Delta \hat{u}_{t-1} + \mu_t \tag{7}$$

Rejection of $\beta = 0$ means that u_t has no unit root, so that the variables in equation 6 are cointagrated. In this case the OLS estimator is super consistent and there are no spurious regression problems when I estimate the vector of parameters α in (6).

When residuals are unit-root stationary, I estimate the short run regressions, using first differences of the variables and the lagged error, obtained in the long run equation (6), by mean of the following Error Correction Model:

$$\Delta BS_t = \gamma_0 + \gamma \hat{u}_{t-1} + \sum_{i=1}^{p} \gamma_{1i} \Delta BS_{t-1} + \sum_{i=0}^{p} \gamma_{2i} \Delta CDS_{t-1} + \sum_{i=0}^{p} \gamma_{3i} \Delta LibOIS_{t-1} +$$

$$\sum_{i=0}^{p} \gamma_{4i} \Delta OISTbill_{t-1} + \sum_{i=0}^{p} \gamma_{5i} \Delta VIX_{t-1} + \sum_{i=0}^{p} \gamma_{6i} \Delta BidAsk_{t-1} + \epsilon_t (8)$$

[19] I implement the multivariate Johansen cointegration test on all the variables and I find that there is only one cointegration vector; this allows to use the more simple univariate model. I regress bond spreads on CDS because CDS slightly dominate price discovery, as shown in paragraph 5.1. and gives to the model a better fit.

Again, I apply the analysis on CDS and bond spreads averages for the four rating groups: AA, A and BBB industrials and AA financial. I use dummies for the two periods: (i) the period before the crisis that goes from January 2005 to end of July 2007, (ii) and the period during the crisis that goes from the beginning of August 2007 to April 2009.

Table 8 reports results for the long run regressions (6). In the analysis, I use interaction variables, to control for joint effects between independent variables with respect to the dependent variable. Adjusted R-squared are reported on the bottom of table.

INSERT TABLE 8 HERE

During the crisis the relation between bond spreads and CDS is generally not significant, while it becomes significant and it is positive during the crisis, as expected, given they are proxy for the risk of default of the underlying entites. Apparently CDS and bond spreads move in an unrelated way before the crisis; this is due to the fact that the basis is small, i.e. the parity approximately holds, but there is little variation, hence arbitrage forces do not enter into play to bring the credit spreads back to their equilibrium relation: they move within the arbitrage bounds determined for example by bid-ask spreads and transaction costs.[20] Moreover, the relevant economic variables, namely the Libor-OIS spread, the OIS-Tbill spread, the VIX and the bid-ask spread on CDS are all significant, only in the period during the crisis, with the expected sign.

The Libor-OIS spread, the CDS bid-ask and the VIX spread drive the bond spread larger, hence the basis more negative as expected. The bid-ask spread on CDS is a proxy for liquidity. Liquidity in the bond and in the CDS market are generally positively cross-correlated. The VIX captures the deterioration of the value of the bond as a collateral. The cost of funding a negative basis trade depends on the hair cut applied on the repo-transaction through which the bond is financed. Excessive volatility in financial markets has an adverse impact on the value of the bond as a collateral and contributes to and increase of haircuts. Along this lines the VIX has the highest impact (coeff 2.4) on the basis for the AA financials which is the most risky group and it has

[20]Also the structural break is modeled accounting for the change of the mean of the variables, not for the change of the variance. High variance, of the variables, in the crisis period lowers the significance of the cointegrating vector in the period before the crisis where the variance is low. The focus of the study is on the behavior of the spreads during the crisis.

the lowest impact (coeff 0.6) on the basis AA industrials which is the most creditworthy group. The OIS-Tbill spread makes an exception. In two cases, for AA financials and BBB industrials, which are the more risky rating groups in the analysis, it has an unexpected negative sign, for A industrial it is not significant while for AA industrials it has a positive sign. This variable is expected to capture the "flight to quality" effect driving bond spreads larger, but it turns out not to be the case for all rating groups. The economic impact of these variables is the highest for bond spreads of the financial sector, which has been the one at the core of the crisis. Also the constants are generally significant during the crisis, meaning that non-transient unobservable factors influencing the relation between bond spread and CDS have come into play .

Notice that interaction variables are significant, relevant and has homogeneous signs across rating groups. The Libor-OIS*VIX variable has a negative sign meaning that when the Libor-OIS spread and the VIX increase jointly their total effect on spreads is slightly lower than the sum of the two respective parameters. Differently the OIS-Tbill*VIX variable has a positive sign meaning that when the OIS-Tbill spread and the VIX increase jointly their total effect on spreads is slightly higher than the sum of the two respective parameters. Most importantly these interaction variables act as controls for our relevant economic variables. All the other interaction variables have been tried, but they turned out to be irrelevant.

The ADF test statistic, reported on the bottom of Table 8, rejects the null hypothesis of a unit root in the residuals of the long run regression, therefore I estimate the short run regressions using the Error Correction Model Specification. Results are reported in table 9. For brevity of exposition, in the table, I show only those variables that are significant[21]. Adjusted R-squared are reported on the bottom of table.

INSERT TABLE 9 HERE

As for the long run regression, also in the short run regression, the relevant economic variables tend to be significant, with expected signs, during the crisis period, moreover the signs of the estimated parameters are generally consistent across the long and short run regressions. The error

[21] Having 8 variable with 2 dummies and approximately 4 lags each, in the ECM estimation, the table would be to big.

correction terms are significant with a negative sign, meaning that whenever bond spreads are larger than CDS spreads they tend to revert to the long run equilibrium. This result is in line with the results of paragraph 5. Further, as expected bond spread changes are positively related to CDS changes to lagged bond spread changes, to Libor-OIS spread changes, to VIX changes and to bid-ask spread changes. For AA financial and BBB industrials, for which the OIS-Tbill variable has a negative impact in the long run regression, but also for AA industrials it has again a negative impact in the short run regression.

Graphs 5 and 6, report the actual-fitted and residuals and show that the estimated model fits the data quite well. The adjusted R-squared is on average 0.98 for the long run regression and around 0.65 for the short run regression.

INSERT FIGURES 5 AND 6 HERE

5.3 Interpretation of the results

Since the beginning of the crisis, in July 2007, the perceived credit risk in the economy has increased al well as the risk of default on interbank loans.

First, because of the general increase of default risk in the economy, CDS dealers (which are financial institutions such as banks, insurance companies or hedge funds) are paying higher funding rates. This effect is captured by the evolution of the Libor-OIS spread. A dramatic increase of cost of financing has affected dealers' CDS pricing as explained in section 3.2.[22] The cost of financing affects investors trading activities in a similar way. In order to exploit a negative basis an investor must finance the purchase of the bond and buy protection. During the crisis the cost of financing, if indeed financing is available, has increased substantially thus reducing or eliminating the return to arbitrageurs. Also, because of the high market volatility, measured by mean of the VIX, margin requirements (i.e. haircuts) for purchasing risky bonds (via repo transactions) have dramatically increased (deterioration of funding liquidity); this has reduced the profitability and the possibility,

[22]The lower bound on a dealers bid price for protection is provided by the net cost of financing the purchase of the underlying cash bond. In normal conditions this cost approximates the bond spread and, in turn, the CDS spread. However, when the cost of financing increases the net cost falls and with it the CDS spread below which it is worthwhile for the dealer to bid for protection while hedging in the cash market. Lowering the bid price for protection also lowers the mid-price and, therefore, standard measures of the basis.

for investors, to implement basis trade, and explains the cross-sectional difference in the basis across ratings, i.e. lower rated bonds and financials exhibit the most negative basis. It turns out that funding liquidity constraints provide a source of commonality (Acharya and Pedersen 2005) in explaining bond prices and returns, hence also the basis dynamics.

Second, liquidity has migrated from corporate bond market to the Treasury bond market, driving risky bond yields larger. This "flight to quality" effect is captured jointly by the evolution of the OIS-Tbill spread and by the sharp increase of the VIX and CDS's bid-asks spread.

Third, being CDS contracts an unfunded way of selling protection[23], counterparty risk has contributed driving bond spreads larger than CDS spreads. In fact, during the crisis protection sellers (dealers which are mostly big banks) have higher default correlation to the assets being protected. Default risk in the inter-bank lending market is captured, not only by the dynamics of the CDS on banks, but also by the evolution of the Libor-OIS spread. This risk is priced into CDS contracts of both financials and industrials driving their spreads lower irrespective of the actual default intensity (discount).

Overall, results support the evidence that during the crisis the negative basis trade is largely exposed to risk factors such as funding liquidity risk and counter-party risk, i.e. it is not risk-free. The size of the basis is the return asked by investors on negative basis trades, hence it is a premium due to exposure to systematic risk factors not an idiosyncratic arbitrage opportunity.

5.4 Robustness checks

The analysis reported above has been implemented also on single entities and results are similar to those obtained on averages of credit spreads within rating groups. Investors carry out basis trades on single entities, but common risk factors affects bases with similar underlying risks in the a similar way. Also, results using daily data are similar to those obtained on weekly data. Bond and CDS prices refers to mid-quotes not to real transactions. The focus of the paper is on the systematic factors which drive discrepancies between CDS and bond spreads. Quotes are well-behaved averages of transaction prices and are cleaned from the noise due to idiosyncratic factors.

[23]While, bond being cash instruments, buying a corporate bond is a funded way of selling protection, hence counterparty risk is not an issue. But the issue is the cost of financing the purchase of the bond itself.

Univariate analysis of the credit spreads time-series shows the presence of conditional heteorskedasticity (ARCH and GARCH Engle (1982)). For this reason I implement a cointegration test that is robust to GARCH effects. I study the dynamic relationship between CDS and bond spreads by the mean of a Vector Auto Regression, with the introduction of a tractable multivariate GARCH formulation, such as the "BEKK", proposed by Engel and Kroner (1995). Results show that the incorporation of the GARCH part allows to conclude more clearly that cointegration exists. The presence of heteroskedasticity makes it more difficult to reject the null of no cointegration, but since cointegration between CDS and bond spreads is found anyway, even without controlling for GARCH effects, I do not implement this methodology in the analysis proposed in the paper.

The choice of the specification of the model in (section 5.2), has been for the univariate ECM, which allows to easily account for the structural break by mean of period dummy variables. I run the multivariate Johansen cointegration test on all the economic variables variables of equation (6) jointly and I find that there is only one cointegration vector; this allows to use the univariate model. The reason why I regress bond spreads on CDS is because CDS slightly dominate price discovery, as shown in paragraph 5.1. and gives to the model a better fit. The analysis has also been carried out estimating separately, for the pre-crisis and the crisis period with, the multivariate VECM and gives results that are in line with those obtained using the univariate framework.

The structural break of August 2007 is modeled exogenously, because there is a general consensus on the timing of the start of the 2007/08 financial crisis. One could think of modeling the structural break by mean of a switching regime model, but in the sample period under study (2006-2009), there is clear evidence of two states and there is no evidence of a switch between good and bad states of the credit market conditions; it would be interesting to apply switching regime models on credit spreads on longer samples which contain more crisis periods.

6 Conclusion

This paper documents that during the crisis, from July 2007 on, there are relevant price discrepancies in the markets for credit risk: the basis is persistently negative, meaning that it would be cheaper to take credit risk in the cash market, which has been quite infrequent in the past. In principle, in such a situation, arbitrageurs could buy risky bonds hedge against default risk and earn more that the risk free rate. Results show that during the crisis the negative basis trade is largely exposed to risk factors such as funding liquidity risk and counter-party risk, i.e. it is not risk-free. The size of the basis is the return asked by investors on negative basis trades, hence it is a premium due to exposure to systematic risk factors not an idiosyncratic arbitrage opportunity.

Variables that capture the cost and risk factors of implementing the negative basis trade, such as the Libor-OIS spread, the OIS-Tbill spread, the VIX and the bid-ask spread on CDS contracts, are the main drivers of the basis dynamics in the period during the crisis. The Libor-OIS spread captures all together (i) the funding cost and the funding liquidity risk faced by investors, (ii) counter-party risk implicit into CDS spreads and (iii) corporate bond market liquidity deterioration (Brunnermeier 2009). The OIS-Tbill spread is a measure of the ”Flight to quality” phenomenon. The VIX is a measure of liquidity and risk premia in financial markets, but most importantly it explains the bond value deterioration as a collateral. Finally, the bid-ask spread on CDS contracts is a measure of general liquidity conditions in credit markets.

Results support the evidence that during stress times asset prices depart form frictionless ideals due to funding liquidity risk faced by financial intermediaries and investors; hence, deviations from parity do not imply presence of arbitrage opportunities. Funding liquidity constraints provide a source of commonality (Acharya and Pedersen 2005) in explaining bond prices and returns, hence also the basis dynamics.

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Table 1: **List of the 37 reference entities**. The ratings are from S&P at 8/1/2008.

Entity	Code	Sector	S&P Ratings
JpMorgan Chase	JPM	Financial	AAA
Citigroup Inc	CIT	Financial	AA
Morgan Stanley	MST	Financial	AA
Wachovia Corp	WAC	Financial	AA
Merrill Lynch	MLY	Financial	A
Textron	TXT	Manifacturing	A
Caterpillar	CAT	Manifacturing	A
Deere	DEE	Manifacturing	A
Emerson Electric	EMR	Manifacturing	A
United Technologies	UNT	Manifacturing	A
Tyco International	TYC	Manifacturing	BBB
Procter&Gamble	PRG	Consumer	AA
Colgate Palmolive	CLG	Consumer	AA
Avon protucts	AVN	Consumer	A
Whirlpool Corp	WRP	Consumer	BBB
Mattel Inc	MTT	Consumer	BBB
Newell Rubbermaid	NLL	Consumer	BBB
Waste Mgmt Inc	WST	Consumer	BBB
PPG Industries	PPG	Chemicals	A
Air Products	AIR	Chemicals	A
Dow Chemical	DOW	Chemicals	BBB
Lubrizol	LBZ	Chemicals	BBB
Hess	HSS	Petr&Gas	BBB
Sunoco	SUN	Petr&Gas	BBB
Valero	VAL	Petr&Gas	BBB
Archer-Daniels	ARC	Food&Beverage	A
Kraft	KFT	Food&Beverage	A
Coca Cola Co	CCL	Food&Beverage	A
General Mills	GML	Food&Beverage	BBB
ConAgra	CAG	Food&Beverage	BBB
Anheuser-Bush Cos	ANH	Food&Beverage	BBB
AT&T/SBC	SBC	Telecomunications	A
BellSouth	BEL	Telecomunications	A
Johnson&Johnson	J&J	Pharma	AAA
Pfizer	PFZ	Pharma	AAA
Abbott	ABB	Pharma	AA
Hospira	HOS	Pharma	BBB

Table 2: **Number of reference entities by rating and by sector**.

Sector / Rating	AAA	AA	A	BBB	Total
Financial	-	4	1	-	5
Manifacturing	-	-	5	1	6
Consumer	-	2	1	4	7
Chemicals	-	-	2	2	4
Petr&Gas	-	-	-	4	4
Food&Beverage	-	-	3	3	6
Telecomunication			2	-	2
Pharmaceutical	2	1	-	1	4
Total	2	7	14	14	37

Table 3: **Average and median basis before and during crisis**. This table provides the average and the median of the CDS-bond basis, defined to be the difference between the CDS spread and the bond spread. For each reference entity and expressed in basis points. The bond spread is calculated as the difference between the 5-year interpolated yield on the risky bond and the 5-year swap rate. Sample period is divided into three parts: 1/3/2005 to 7/31/2007 is the period before crisis (Period 1), 8/1/2007 to 7/31/2008 is the crisis period (Period 2) Lehman and 8/1/2008 to 4/1/2009 (Period 3) is the crisis period after Lehman collapsed. Crossectional mean and median are provided, for groups of entities according to rating, separately for the financial and industrial sector

Average Basis (Median)	1st Period	2nd Period	3rd Period
Industrials			
AAA	12.0	0.5	-60.0
	(11.1)	(0.9)	(-77)
AA	7.3	-9.2	-77.1
	(8.9)	(-8.8)	(-88.5)
A	-4.9	-25.9	-126.1
	(-5.2)	(-24.4)	(-143)
BBB	3.8	-32.8	-165.8
	-4.2	(-32.1)	(-206.4)
Financials			
AA	-7.3	-18.7	-308.4
	(-5.5)	(-21.2)	(-394.4)
Average all	2.2	-17.2	-147.5

Table 4: **ADF unit root tests**. Sample period 1/3/2005 - 4/1/2009. Automatic selection of lags based on SIC: 0 to 14. * Means 1% level rejection based on MacKinnon (1996) one-sided p-values.

Statistics	CDS	Bond Spread
ADF - Level		
AA Industrials	0.971	0.936
AA Financials	0.977	0.997
A Industrials	0.999	0.982
BBB Industrials	0.996	0.999
ADF - First difference		
AA Industrials	0.000*	0.000*
AA Financials	0.000*	0.000*
A Industrials	0.000*	0.000*
BBB Industrials	0.000*	0.000*

Table 5: **Cointegration tests**. Sample period 1/3/2005 - 4/1/2009. Unrestricted Cointegration Rank Test (Trace test). Trace test indicates 1 cointegrating eqn(s) at the 0.05 level. Automatic selection of lags based on SIC: 0 to 17. * denotes rejection of the hypothesis at the 0.05 level. **MacKinnon-Haug-Michelis (1999) p-values.

Group	Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
Industrials AA	None *	0.086	19.504	15.892	0.012*
N. lags (4)	At most 1	0.005	1.296	9.164	0.908
Financials AA	None *	0.134	33.490	20.261	0.000*
N. lags (4)	At most 1	0.010	2.209	9.164	0.735
Industrials A	None *	0.124	30.717	20.261	0.001*
N. lags (6)	At most 1	0.010	2.209	9.164	0.735
Industrials BBB	None *	0.122	30.006	20.261	0.001*
N. lags (6)	At most 1	0.009	1.975	9.164	0.782

Table 6: **Long-run regressions.** Sample period 1/3/2005 - 4/1/2009. This table reports the estimates of the equation that describes the long run relationship between CDS and bond spreads, given by $CDS_t = \alpha_0 + \alpha_1 BS_t$, for each of the four rating groups. T-statistics in ( )

	Industrials AA	Financials AA	Industrials A	Industrials BBB
CDS	1	1	1	1
Bond spread	0.372	0.448	0.498	0.467
	(16.407)***	(19.055)***	(28.269)***	(30.479)***
Constant	11.031	16.127	8.292	-23.452
	(8.513)***	(2.602)*	(4.349)**	(11.421)***

Table 7: **Short-run regressions** This table reports the estimates of the short run dynamics of CDS and bond spread changes. Sample period 1/3/2005- 4/1/2009. The measure is based on the following Vector Error Correction Model regressions:

$$\Delta CDS_t = \lambda_1(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1}) + \sum_{j=1}^{q} \alpha_{1j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{1j}\Delta BS_{t-j} + \epsilon_{1t}$$

$$\Delta BS_t = \lambda_2(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1}) + \sum_{j=1}^{q} \alpha_{2j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{2j}\Delta BS_{t-j} + \epsilon_{2t}$$

The final lines report the "Adjusted R Squared" of each regression and the Granger-Gonzalo measure, which is a measure of the contribution of the two markets to price discovery and is defined as: $\frac{\lambda_2}{\lambda_2 - \lambda_1}$ and is bounded between 0 and 1. T-statistics in ( )

	Industrials AA		Financials AA	
	CDS	Bond spread	CDS	Bond spread
CointEq1	-0.076	0.233	-0.084	0.314
	(-3.318)**	(2.697)*	(-1.013)	(3.481)**
D(CDS(-1))	0.258	1.146	0.174	0.002
	(3.813)**	(4.536)***	(2.087)*	(0.024)
D(CDS(-2))	0.061	-0.068	-0.058	0.109
	(0.855)	(-0.253)	(-0.693)	(1.207)
D(CDS(-3))	0.104	-0.735	-0.034	-0.008
	(1.461)	(-2.747)*	(-0.437)	(-0.106)
D(CDS(-4))	0.026	0.527	-0.171	-0.003
	(0.387)	(2.046)*	(-2.226)*	(-0.047)
D(Bond spread(-1))	0.045	0.262	-0.240	-0.468
	(2.415)*	(3.750)**	(-3.213)*	(-5.810)***
D(Bond spread(-2))	0.009	0.053	0.232	-0.098
	(0.491)	(0.737)	(2.898)*	(-1.133)
D(Bond spread(-3))	-0.050	0.048	0.280	0.023
	(-2.638)*	(0.676)	(3.396)**	(0.263)
D(Bond spread(-4))	0.012	0.048	-0.308	-0.127
	(0.688)	(0.692)	(-3.709)**	(-1.424)
Adj. R-squared	0.210	0.189	0.306	0.212
GG Measure	0.752		0.787	

	Industrials A		Industrials BBB	
	CDS	Bond spread	CDS	Bond spread
CointEq1	-0.182	0.272	-0.201	0.151
	(-2.642)**	(4.024)**	(-3.648)**	2.539*
D(CDS(-1))	-0.056	0.071	0.141	0.198
	(-0.664)	(0.847)	(1.804)	(2.329)**
D(CDS(-2))	0.125	0.054	0.180	0.118
	(1.563)	(0.698)	(2.332*)	(1.417)
D(CDS(-3))	0.167	0.032	-0.052	0.341
	(2.135)*	(0.418)	(-0.675)	(4.082)**
D(CDS(-4))	0.181	0.191	-0.124	-0.091
	(2.324)*	(2.509)*	(-1.520)	(-1.031)
D(CDS(-5))	0.017	0.036	0.145	-0.499
	(0.220)	(0.477)	(1.788)	(-5.659)***
D(CDS(-5))	0.114	-0.207	0.338	-0.079
	(1.504)	(-2.777)*	(3.881)**	(-0.846)
D(Bond spread(-1))	0.096	0.263	0.091	0.251
	(1.355)	(3.748)**	(1.359)	(3.452)**
D(Bond spread(-2))	-0.098	0.204	0.072	0.221129
	(-1.386)	(2.920)*	(1.07785)	(3.049)**
D(Bond spread(-3))	-0.375	0.024	-0.197	-0.058
	(-5.412)***	(0.354)	(-2.930)**	(-0.800)
D(Bond spread(-4))	-0.032	-0.001	-0.081	0.144
	(-0.439)	(-0.017)	(-1.361)	(2.244)*
D(Bond spread(-5))	0.131	0.149	0.117	0.200
	(1.814)	(2.094)*	(1.927)*	(3.050)**
D(Bond spread(-6))	0.242	0.133	0.105	-0.015
	(3.455)**	(1.929)*	(1.852)	(-0.257)
Adj. R-squared	0.215	0.386	0.241	0.476
GG Measure	0.599		0.429	

Table 8: **Long-run regression.** Sample period 1/3/2005 - 4/1/2009. P-value in ( )

Bond Spread	AA Industrial	AA Financials	A Industrial	BBB Industrial
Dum1	19.339	19.552	57.344	26.103
	(0.1253)	(0.795)	(0.029)**	(0.380)
Dum2	-58.506	-251.917	-124.763	-94.378
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dum1*(CDS)	-1.002	-0.436	-0.117	0.264
	(0.035)**	(0.642)	(0.828)	0.383
Dum2*(CDS)	1.000	0.473	0.413	0.969335
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dum1*Lib-OIS	-0.418	-0.333	-3.131	0.760
	(0.208)	(0.970)	(0.294)	(0.786)
Dum2*Lib-OIS	0.186	1.280	0.525	0.492
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dum1*OIS-Tbill	-0.075	0.508	-0.212	0.082
	(0.838)	(0.750)	(0.151)	(0.913)
Dum2*OIS-Tbill	0.273	-1.336	-0.009	-0.606
	(0.000)***	(0.000)***	(0.947)	(0.000)***
Dum1*VIX	-0.140	0.808	-1.395	-0.054
	(0.871)	(0.867)	(0.380)	(0.979)
Dum2*VIX	0.688	2.417	1.557	1.052
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dum1*Bid-Ask	0.850	4.972	1.225	1.043
	(0.414)	(0.054)*	(0.446)	(0.486)
Dum2*Bid-Ask	7.284	44.854	23.806	19.891
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dum1*Lib-OIS*VIX	0.047	0.036	0.134	-0.035
	(-0.667)	(0.956)	(0.538)	(0.863)
Dum2*Lib-OIS*VIX	0.000	-0.012	-0.007	-0.009
	(-0.813)	(0.001)***	(0.000)***	(0.000)***
Dum1*OIS-TBill*VIX	0.007	-0.042	0.013	-0.009
	(0.786)	(0.706)	(-0.801)	(0.856)
Dum2*OIS-TBill*VIX	-0.013	0.031	-0.006	0.012
	(0.000)***	(0.003)***	(0.1370)	(0.005)***
Adj. R-Squared	0.97	0.98	0.97	0.98
ADF Test on resid	(0.00)	(0.00)	(0.00)	(0.00)

Table 9: **Short-run regression.** Sample period 1/3/2005 - 4/1/2009. P-value in ( )

	AA Industrial	AA Financials	A Industrial	BBB Industrial
ECM1(-1)	-0.673	-	-0.231	-0.259
	(0.042)**	-	(0.044)**	(0.058)*
ECM2(-1)	-0.368	-0.131	-0.122	/
	(0.0003)***	(0.021)**	(0.091)**	/
Dum2*D(CDS)	-	2.243	-	0.260
	-	(0.017)**	-	(0.007)***
Dum2*D(CDS(-1))	0.727	0.282	0.254	0.176
	(0.013)**	(0.000)***	(0.001)***	(0.058)*
Dum2*D(CDS(-2))	-	0.395	-	-
	-	(0.000)***	-	-
Dum2*D(CDS(-3))	-	0.167	-	0.283
	-	(0.041)**	-	(0.005)***
Dum2*D(CDS(-4))	0.822	-	0.248	-
	(0.021)**	-	(0.007)***	-
Dum2*D(Bond spread(-1))	0.277	-0.152	0.235	-
	(0.009)**	(0.077)*	(0.018)**	-
Dum2*D(Bond spread(-3))	-	0.304	-	-
	-	(0.009)**	-	-
Dum2*D(Bond spread(-4))	-	-0.202	-	-
	-	(0.025)**	-	-
Dum2*D(Lib-OIS(-2))	-	0.655	-	-
	-	(0.009)***	-	-
Dum2*D(Lib-OIS(-3))	-	-	-	0.158
	-	-	-	(0.052)*
Dum2*D(Lib-OIS(-4))	-	-	-	0.161
	-	-	-	(0.037)**
Dum2*D(OIS-TBill)	-	-1.625	-	-0.375
	-	(0.000)***	-	(0.000)***
Dum2*D(OIS-TBill(-2))	-	-	-	-0.193
	-	-	-	(0.092)*
Dum2*D(OIS-TBill(-3))	-0.180	-	-	-
	(0.0133)**	-	-	-
Dum2*D(OIS-TBill(-4))	-	-0.561	-	-
	-	(0.025)**	-	-
Dum2*D(VIX)	-	-5.646	-	-
	-	(0.000)***	-	-
Dum2*D(VIX(-2))	-	3.288	-	-
	-	(0.000)***	-	-

	AA Industrial	AA Financials	A Industrial	BBB Industrial
Dum2*D(Bid-Ask)	2.917	-	-	-
	(0.041)**	-	-	-
Dum2*D(Bid-Ask(-1))	-	-	4.255	4.097
	-	-	(0.080)*	(0.055)*
Dum2*D(Bid-Ask(-2))	-	-	-4.674	4.977
	-	-	(0.032)**	(0.031)**
Dum2*D(Bid-Ask(-4))	-	14.394	-	-
	-	(0.000)***	-	-
Dum2*D(Lib-OIS*VIX)	-	0.013	-	-0.004
	-	(0.056)*	-	(0.038)**
Dum2*D(Lib-OIS(-1)*VIX(-2))	-	-0.022	-	-
	-	(0)***	-	-
Dum2*D(Lib-OIS(-1)*VIX(-3))	0.006	0.010	-	-
	(0.006)***	(0.018)**	-	-
Dum2*D(Lib-OIS(-1)*VIX(-4))	-	-	-	-0.004
	-	-	-	(0.005)***
Dum1*D(VIX(-1)*OIS-TBill)	-	0.066	-	0.011
	-	(0)***	-	(0.007)***
Dum2*D(VIX(-2)*OIS-TBill(-2))	-	-	-0.010	-
	-	-	(0.0337)**	-
Dum2*D(VIX(-4)*OIS-TBill(-4))	-	0.026	-	-
	-	(0.003)***	-	-
Adj. R-Squared	0.43	0.89	0.51	0.76

Figure 1: **CDS, bond I-spread and basis.** This figure shows the time series of the cross-sectional averages of the CDS, the bond I spreads (5y YTM - 5y swap rate) and the basis (CDS - I spread) by rating, separately for industrials and financials. The series are expressed in basis points. Sample period 1/3/2005 - 4/1/2009.

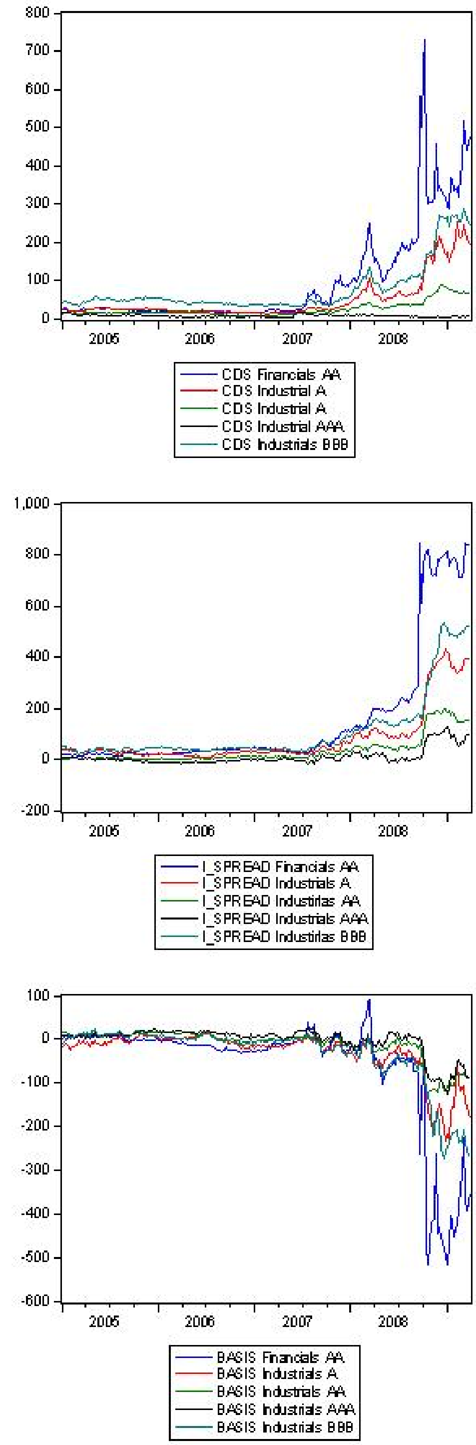


Figure 2: **Libor-OIS spread and OIS-TBill spread**. The Libor-OIS spread is the difference between the interest rate on interbank loans (Libor) with a maturity of 3 months and the Overnight Indexed Swap. The OIS-TBill spread is the difference between the Overnight Indexed Swap and short-term U.S. government debt (”T-bills”) with a maturity of 3 months.

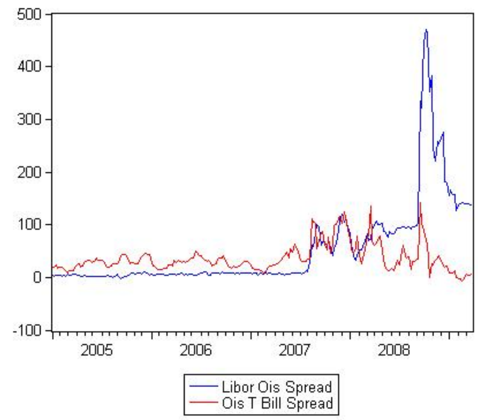


Figure 3: **Time series of the VIX**. The VIX is the Chicago Board Options Exchange Volatility Index. The volatility is implied from options written on the SP500 Stock Index.

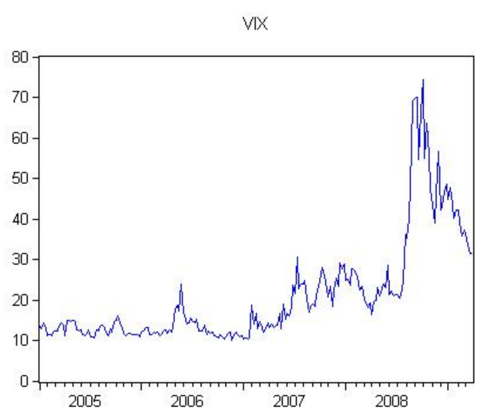


Figure 4: **Time series of the bid-ask spread on CDS contracts**. The series cross-sectional time-series for indutrials and financials and are expressed in basis points.

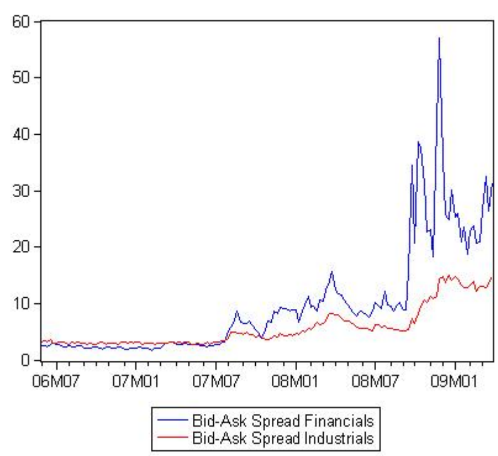


Figure 5: **Long run regressions estimation.**

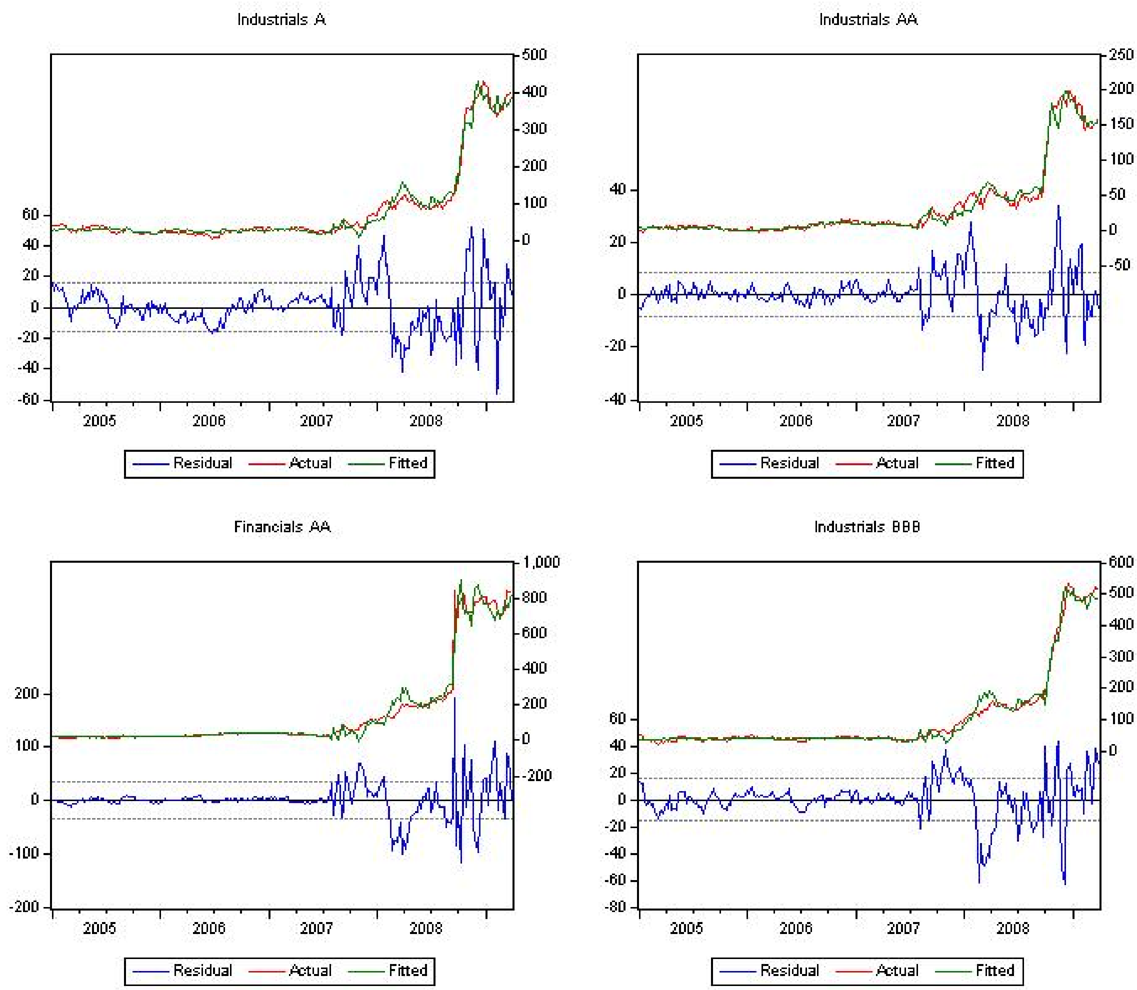
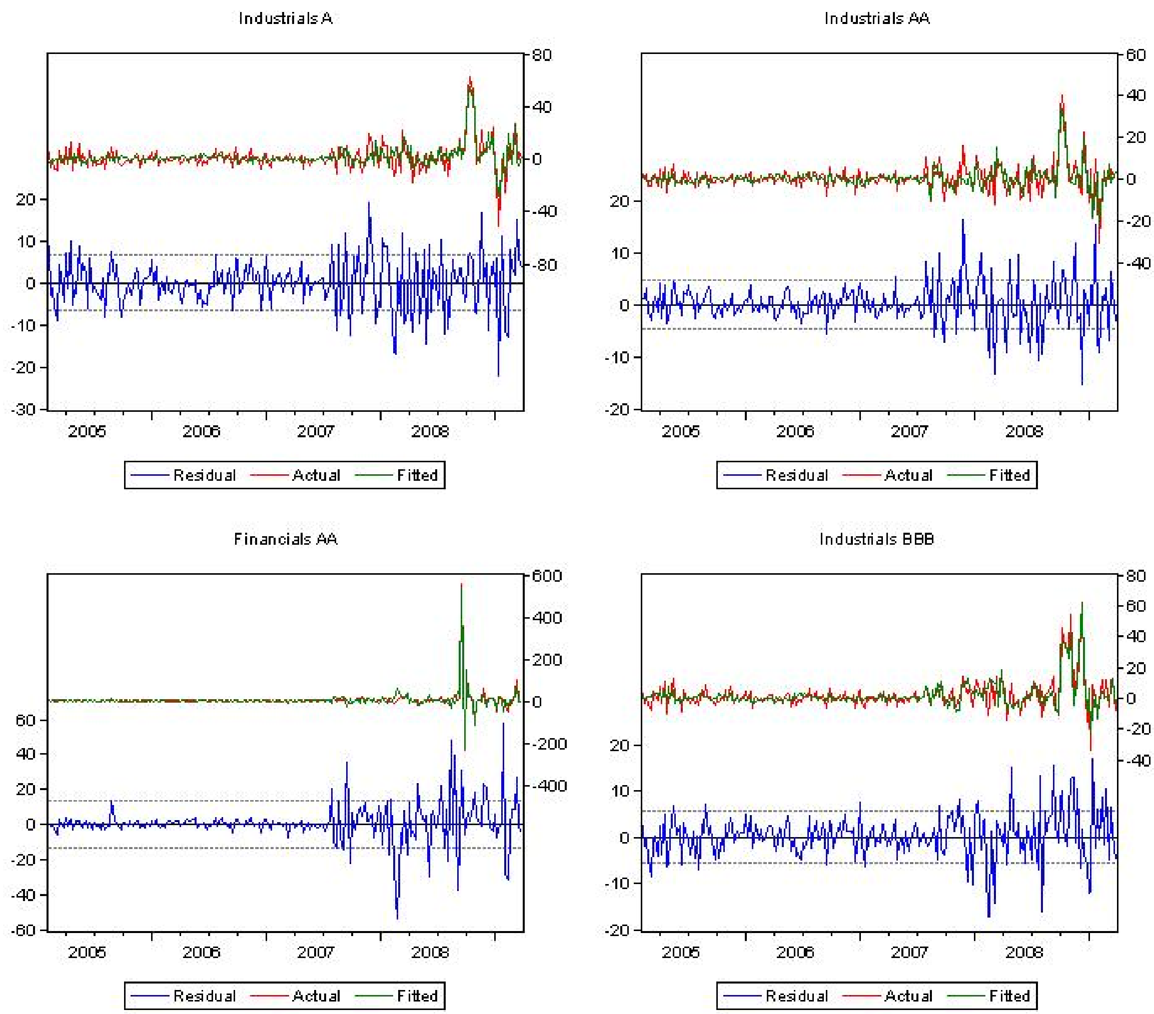


Figure 6: **Short run regressions estimation.**



Market pricing of Euro Area CDS

Alessandro Fontana*

Martin Scheicher †

May 1, 2010

Preliminary and incomplete please do not quote

Abstract

This paper studies the determinants of market prices of Euro area sovereign CDS and the linkages between CDS and the underlying bonds, i.e. the basis. Our main focus is on the Euro area CDS market overall rather than on country-specific developments. The sample comprises daily CDS premia of ten Euro area countries for the period of January 2006 to March 2010. We relate a variety of financial market variables to first differences of CDS premia and test how the crisis has affected market pricing and the interaction between CDS and bonds. Our first main finding is the recent repricing of sovereign credit risk seems due to common factors as well as to country-specific determinants. 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. We find that since September 2008, the bond and CDS markets are integrated for some countries while for other countries price discovery mostly takes place in the CDS market.

Keywords: Credit Spread; CDS; government bond; financial crisis

JEL Classification Numbers: G00, G01;

*Address: University of Ca'Foscari Department of Economics, Fondamenta San Giobbe - Cannaregio 873, 30121 Venezia, ITALY, e-mail: *fontana@unive.it*

†Financial Research Division, European Central Bank; Kaiserstrasse 29, D 60311, Frankfurt am Main, Germany. Tel: +49+69 1344 8337; Fax: +49+69 1344 8922; Email: martin.scheicher@ecb.int. The opinions in this paper do not necessarily reflect those of the ECB or the Eurosystem.

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, were undergoing 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 late 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 aftermath of the Lehman collapse 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, the fiscal burden of extensive bank support measures in the UK is estimated at 44% of UK GDP (Panetta et al, 2009).

Traditionally, valuation of government debt issued by developed country sovereigns has treated default as a very low probability event[1]. 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 1997-98 crisis in emerging market sovereigns also played a large role. Given this market focus, key papers on sovereign CDS such as Pan and

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

Singleton (2008) or Longstaff et al. (2008) do not study euro area countries. 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 a core feature of asset pricing.

The purpose of this paper is to provide a comprehensive analysis of Euro area sovereign CDS. The paper aims to help understand the functioning of the sovereign CDS market. Our two main contributions are first a comprehensive analysis of the determinants of CDS and second a study of the linkages between CDS and the underlying bonds. In the first part, we relate a variety of financial market variables to the first differences of CDS premia and test how the turmoil in credit markets has affected the explanatory value of the determinants of premia. We include proxies for country developments, the interest rate environment, risk aversion and market liquidity. Our approach allows us to use of 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 also conduct a variety of robustness tests and also examine the economic significance of our results. In the second part we analyse the basis, i.e. the difference between CDS premia and the spreads on the underlying government bonds. This variable is of specific interest because arbitrage trading should generally drive it close to zero. Hence, the size and sign 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.

Our sample comprises daily data on the CDS premia and bond yields of ten Euro area countries and their corresponding bond yields. The sample period is from January 2006 to March 2010. Our paper complements the small number of studies on sovereign CDS. Dieckmann and Plank (2010) also study the pricing of sovereign CDS but with a focus on the private-public risk transfer, i.e. how sovereign CDS are related to developments in the respective countrys 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. Other key papers focus on emerging markets: Pan and Singleton (2008) study Korea, Turkey and Mexico and Longstaff et al. (2008) analyse 26 countries where the only EU countries are Bulgaria, Hungary, Poland, Romania and Slovakia. More generally, research on CDS premia mostly analyses corporate debt markets (see Ericsson et al., 2009 for a recent paper).

In the context of euro area sovereign bond markets, the analysis 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. The focus on macro determinants of bond spreads leads the literature to study e.g. the extent to which the bond market prices fiscal fundamentals. Euro area bond market developments in the crisis are analysed by Sgherri and Zoli (2009), Mody (2009) or Haugh et al. (2009).

Our first main finding is the recent repricing of sovereign credit risk is linked due to common factors such as investor risk appetite as well as to country-specific determinants. 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 and heightened concerns about market liquidity, both of which have characterised investor behaviour since summer 2007, have provided a sizable contribution to the observed strong increase in premia.

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. The main exception is Portugal and Greece where we find a temporary negative basis in 2009. One possible explanation here is the flight to quality effect which specifically lowers government bond spreads. Since September 2008, the bond and CDS markets are integrated for some countries while for other countries price discovery mostly takes place in the CDS 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. In this context, a caveat is that at the time of writing, the period of repricing had not yet come to an end.

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 empirical analysis on CDS. In section 4 we study the linkages between CDS and bonds. Section 5 concludes the paper by summarising the main results.

2 Sample

2.1 Some background on 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 buyers exposure is identical to that of short-selling the underlying bond and hedging out the interest-rate risk. Commonly, CDS transactions have a maturity of one to ten years.

The CDS premium is the annual insurance premium (in basis points as a fraction of the underlying notional) for protection against default. As in a standard swap the premium is set such that the CDS has zero value at the time of origination. No-arbitrage conditions suggest that this CDS can be replicated synthetically by shorting a par floating rate coupon bond with the same maturity date, and buying a default-risk-free note.

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 auction procedure was held for Ecuador in January 2009.

In general, corporate and sovereign CDS provide traded insurance against credit risk. 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 credit events defined (along with other terms of the contract) by the International Swaps and Derivatives Association (ISDA) (Barclays, 2010a) are:

- Failure to pay principal or coupon when they are due;
- Restructuring;
- Repudiation / moratorium.

In the current situation, the first two credit events are of major importance. As regards failure to pay, this criterion indicates that already the failure to pay a coupon on an outstanding bond might represent a credit event, albeit one with high recovery. As regards restructuring, the range of admissible events depends on the currency and the precise terms which materialise.

Like most CDS contracts, sovereign CDS typically serve as trading instruments rather than pure insurance instruments. Investors 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 banks 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).

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. This intuition has been formalised by Duffie (1999). Using a no-arbitrage argument he shows that a CDS premium 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 position which comprises a bond by the same entity[2]. As will be discussed later, this theoretical equivalence allows traders to arbitrage potential price differences between an entitys bonds and its CDS.

A number of factors may influence the information content of market prices. In relative terms, sovereign CDS volume is small: e.g. for Greece, the net open CDS amount to less than five percent of their outstanding sovereign debt (see chart 1 which uses the publicly available DTCC data). This 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. Another caveat is that counterparty risk may matter far more for sovereign CDS than for corporate CDS. In particular, CDS on major countries seem unlikely to provide genuinely robust default insurance given the close linkages between sovereigns and the financial sector. Finally, liquidity in CDS markets 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[3].

2.2 Sample construction

We use daily CDS premia and bond yields collected from Datastream. The series are for 10-year CDS denominated in Euro for Austria, Belgium, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal and Spain. This 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 constant ten-year maturity.

[2]Since May last year, 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.

[3]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.

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. Longstaff et al., 2005). In addition, this approach guarantees a homogeneous benchmark across the euro area. Some papers (e.g. Haugh et al., 2009) have used the German benchmark Bund yield as a proxy for the risk-free rate. This choice has two disadvantages: First, the CDS on Germany can not be included in the analysis. Second, there is evidence that US Treasuries contain a sizable convenience yield. For instance, Krishnamurthy and Vissing-Jorgensen (2009) estimate this component at 72 BP. Given the benchmark role of the Bund, a similar component seems likely to exist also in their prices.

2.3 Sample details

We start by illustrating recent developments from an aggregate perspective. For this purpose, chart 2 compares the developments in sovereign CDS (iTraxx SovX Western Europe index) with those for European financial firms (iTraxx Main Investment Grade Financials index).[4] The chart illustrates the massive repricing of risk reaching its peak in fall and winter 2008/2009 (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. 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. Underpricing in corporate credit markets before the crisis is documented by Raunig and Scheicher (2009) who show that up to July 2007 bank CDS were conditionally lower than industrial CDS even after controlling for firm-level credit risk.

Using a simple pricing model[5], the implied, i.e. subjective probability of default can be extracted from the CDS premia on Western European sovereign debt shown in chart 2. Applying this model to the recent observations of the SovX index leads to a subjective

[4]The iTraxx Financials comprises 25 major European banks and insurance firms. The iTraxx SOVX comprises 15 Western European sovereigns (including e.g. the UK).

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

default probability of 1.3%. This market-implied estimate by far exceeds the historical estimate as for instance the long-run PD of an A-rated issuer is around 0.1%. This confirms the stylised fact of the credit spread puzzle (Amato and Remolona, 2003), which describes the empirical observation that expected default losses account for a very small fraction of credit spreads. These residual components are usually interpreted as risk premia. Overall, given the definition of default events outlined above, this high PD level 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, migration risk (the risk of a sovereign suffering a credit rating downgrade in particular from the gold-plated AAA rating) might also have contributed to the jumps. We will take these factors into account in our analysis of determinants of CDS premia.

From a valuation perspective, both financial and sovereign 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. Such a scenario of extremely high losses resembles the markets reassessment of asset-backed securities from summer 2007 on. For senior tranches, which were typically given the same AAA-rating as major sovereigns, the main risk is a tail event which has a low probability but is also very severe. Hence, these tranches are also seen as economic catastrophe bonds (cf. Coval et al, 2009).

Chart 3 plots the time series of the ten Euro area countries in our sample. The descriptive statistics are shown in table 1. Given the pronounced changes in CDS premia after Lehmans default we report descriptive statistics for two subsamples, January, 1 2006 to September, 12, 2008 (period I) and September, 15, 2008 and March, 1 2010 (period II).

Country-specific developments show considerable heterogeneity. The country-level plots in chart 3 confirm the massive repricing of credit risk. For example, the German CDS moved from a level below 3 basis points (BP) in June 2007 to a peak of 90 BP in late February 2009. The Greek CDS achieves a first peak in late 2008 and early 2009. However, here the second peak in late 2009 exceeds the first peak. The same developments of two consecutive peaks are also observed for Portugal and to a lesser extent for Spain. For all other EU countries in the sample, the first peak in late 2008 and early 2009 provides the sample high. In this context, at several points in time a few countries have experienced an inversion of their credit curve (cf. Barclays, 2010). 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 likelihood of imminent default.

Overall, at the time of writing euro area sovereign CDS premia have not returned to the levels witnessed before the collapse of Lehman in September 2008. In the aftermath of Lehmans collapse, the highest average CDS premia are observed for Greece, Ireland, Italy and Austria. For each of these countries the mean premium exceeds 100 B (cf. table 1). We find that volatility is also highest for Greece, Ireland and Austria. Notable sample highs in the second subperiod are observed for Greece and Ireland where the CDS exceeded 300 BP with a level of 379 and 365 BP respectively. In contrast, in the first half of the sample, the overall maximum is a value of 74 BP for Greece. The overall lowest premia are 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 price volatility after September 2008.

2.4 Principal component analysis of the CDS premia

Factor analysis shows that a common factor plays a large role in the variation in sovereign CDS premia. This econometric approach estimates the extent of common variation from the CDS premia shown in chart 3. The estimation uses daily changes in CDS premia over the second subperiod, i.e. September 15 of 2008 to March, 1 2010. Due to the short sample period after November 2009 testing for more recent structural breaks is not possible.

Results in table 2 show evidence for a strong common component in the CDS premia. The existence of such a strong common determinant in Euro area debt prices is a stylised fact in the literature[6]. This primary common factor allocates similar weights across indi-

[6] 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-varyng common factor, associated with shift in international risk appetite. "

vidual countries, indicating that it has a similar impact across countries. The explanatory value of this factor varies between 32% for Spain and 82% for Italy. The residual variation in CDS premia can be interpreted as an indication for country-specific factors which are not captured buy the principal common component.

This factor can be analysed in more detail by regressing it on a broad list of financial market variables (cf. lower half of table 2). Here the strongest effects are observed between the factor and the change in the iTraxx CDS corporate index. Furthermore, a high correlation is also observed with German bond yields and the US stock market as represented by the SP 500. These findings support the existence of significant risk premia in sovereign CDS premia.

3 Determinants of CDS premia

3.1 Regression methodology

As the discussion above has shown, fundamentals as well as changes in risk appetite with regard to sovereign risk may be one of the underlying drivers of the variation of CDS premia. We start with a set of variables which comprises proxies for credit risk and for the movement of the risk-free rate. In addition, 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) or Ericsson et al. (2009)). In the robustness analysis in section 3.3 we extend this set of variables. We will also build on this set of variables to study the determinants of the linkages between bonds and CDS.

- Idiosyncratic equity returns

Following Collin-Dufresne et al. (2001) we use stock returns as a proxy for the overall state of a countrys economy. For the purpose of a clearer identification, we use a countrys idiosyncratic stock returns rather than its total returns. We define 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 return on the equity index leads to a decrease in the countrys CDS.

- Leverage proxy

In structural credit risk models the other major determinant besides equity volatility is an entitys leverage. In corporate credit risk analysis, leverage is usually defined as a firms total debt over its total assets. Given that sovereign credit risk is of a different nature, we define our leverage measure as total outstanding bonds over GDP. This variable is also motivated by the Stability and Growth Pact which aims to cap a countrys total debt at 60 % of its GDP[7]. We expect that higher leverage increases changes in CDS. Another interpretation of this variable is that in a market with elastic demand this variable also reflects bond market liquidity as a larger bond market generally contributes to lower transaction acts. However, if overall supply of new issuance exceeds existing demand, then there could also be an adverse impact on market liquidity.

- Risk free rate

According to the Merton (1974) framework 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, in the Merton (1974) model these two effects should lead to a lower credit spread. As a Euro-wide proxy we use the ten-year Euro swap rate.

- Global risk aversion

As already discussed in the previous section credit spreads not only compensate investors for pure expected loss (see also Hull et al., 2005). Hence, CDS premia may change due to changes in investors risk aversion even if the underlying fundamentals

[7]Bonds outstanding are measured at a monthly frequency and the GDP is at a quarterly frequency. We use linear interpolation to obtain weekly observations.

(i.e. the pricing under the statistical measure) are unchanged. We use the VIX index of implied SP 500 volatility. 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. Our baseline specification is therefore given by

$$\Delta Y_{it} = C + \beta_0 R_{it} + \beta_1 \Delta LEVERAGE_{it} + \beta_2 \Delta Swaprate_t + \beta_3 \Delta VIX_t + \phi_0 D * \Delta R_{it} + \phi_1 D * \Delta LEVERAGE_{it} + \phi_2 \Delta Swaprate_t + \phi_3 \Delta VIX_t + \epsilon_{it} \quad (1)$$

with Y_{it} representing the CDS premium on country i at time t. In order to extend our benchmark regression described above we use a number of additional CDS determinants.

- Idiosyncratic equity volatility

Structural credit risk models as introduced by Merton (1974) argue that equity volatility is a major factor in determining an entitys default risk. Campbell and Taksler (2003) find that the variation in the spreads on US corporate bonds is more strongly linked to idiosyncratic stock price volatility than to aggregate stock price volatility. Following these authors the idiosyncratic volatility is then calculated as the annualised GARCH(1,1)-volatility of idiosyncratic stock returns. We expect that higher volatility has a positive impact on changes in CDS.

- Slope of the term structure

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. We assume that a similar effect may hold for CDS premia and define the slope of the term structure as the difference between the ten-year swap rate and the three-month Euribor rate.

- Bid-ask spread

Tang and Yan (2007) show that the bidask spread is significantly positively related to CDS premia. As there are no reliable data on 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 credit market liquidity.

- Corporate CDS premium

Given that credit spreads compensate investors for more than pure expected loss we include an alternative measure of credit market developments, namely the iTraxx Main Investment Grade index. Similar to the VIX index, the premium on this CDS index can also be interpreted as a proxy for investor appetite for credit risk. Hence, as a robustness test we replace the VIX with the iTraxx index. This choice is also motivated by our findings in the principal components analysis. As already discussed in section 2.4, the primary common factor in CDS changes shows a strong link to the changes in iTraxx CDS index (cf. table 2).

Table 3 and chart 4 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 premia as the dependent variable and also incorporating country fixed effects. All regressions are estimated with White standard errors to account for the crossectional heteroscedasticity in the changes of premia. We will use a similar methodology for our analysis of the basis in the next section.

3.2 Overall results

We estimate the baseline regression as given in equation (1) for the two sample periods, January, 1 2006 to September, 12, 2008 (period I) and September, 15, 2008 and March, 1 2010 (period II). From the panel regression analysis shown in Table 4, several results are notable.

- First, we find that the explanatory power of our set of determinants is much larger in the second period than in the first period. More factors are significant in the second period than in the first period and the R-squared is also higher.

- Second, since September 2008 the sovereign CDS market prices country specific factors. In the second subperiod, idiosyncratic equity market developments have a significant impact on changes in CDS premia. As expected, this linkage is positive with positive returns lowering a countrys CDS premium.

- Third, international market developments are a significant factor in the variation of Euro area sovereign CDS premia. In particular, the VIX index is significant with a positive sign in both subperiods. Hence, increases in US equity implied volatility lead to rising Euro area CDS premia.

- Fourth, CDS premia are significantly linked to changes in the proxy for the risk-free rate. This relationship is negative as the Merton (1974) model predicts. Hence, this prediction of the corporate credit risk model also holds true for sovereign credit risk.

- Fifth, in addition to the role of idiosyncratic equity market information also the dummy D for the subgroup of countries has a significant impact. Among the interaction effects, global information plays the largest role. In particular, the VIX is positive and highly significant, indicating that the CDS premia of Greece, Ireland, Italy, Portugal and Spain react even stronger to US implied volatility. The same finding, albeit with a negative sign, holds true for the change in ten-year swap rate: A change in the rate has a comparatively stronger effect on the countries captured by the interaction dummy.

- Finally, although the R squared for the second period by far exceeds the value for the first period, it nevertheless indicates a sizable unobserved component which accounts for far more than 50 % of the variation of CDS premia.

Hence, overall we find that country-specific information is priced with the role of equity-market specific returns also being important. Furthermore, sovereign CDS premia are significantly linked to proxies for global risk appetite. The regressions also confirm that in the period before the crisis, market prices were only weakly linked to fundamental determinants, in particular country-level information such as the stock returns.

The economic significance of our findings is also notable. For example, in period II, a 1% extra return in a countrys stock market would lower the countrys CDS premium by more than 100 BP. As the country interaction dummy is not significant, this effect does not differ between the two groups of countries in our sample.

3.3 Further results and robustness tests

Our first extended panel regression is defined as follows:

$$\Delta Y_{it} = C + \beta_0 R_{it} + \beta_1 \Delta VOLA_{it} + \beta_2 \Delta LEVERAGE_{it} + \beta_3 \Delta VIX_t + \beta_4 \Delta Eonia_t + \beta_5 \Delta Slope_t + \beta_6 \Delta BidAsk_t + \phi_0 D * R_{it} + \phi_1 D * \Delta VOLA_{it} + \phi_2 D * \Delta LEVERAGE_{it} + \phi_3 D * \Delta VIX_t + \phi_4 D * \Delta Eonia_t + \phi_5 D * \Delta Slope_t + \phi_6 D * \Delta BidAsk_t + \epsilon_i t (2)$$

Results for this specification are given in table 5. 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, we find that coefficients for the idiosyncratic country returns and the VIX are more or less unchanged to the estimates obtained from the base-case model. Among the three additional variables, the EONIA and the idiosyncratic volatility are not significant but the slope has a negative impact. Given that we also found a negative effect of similar size for the swap rate it seems that that variable is the main determinant among the proxies for the interest rate environment.

We also find that the changes in the iTraxx bid-ask spread have a significantly negative effect on the first differences of the CDS premia. This means that rising bid ask spreads (i.e. lower liquidity in the corporate CDS market) coincide with lower sovereign CDS premia. One of the reasons for this counterintuitive finding could be that rising sovereign CDS premia lead to more demand for more protection which makes the overall market more liquid. Our second extended panel regression replaces the VIX index with the iTraxx CDS index:

$$\Delta Y_{it} = C + \beta_0 R_{it} + \beta_1 \Delta LEVERAGE_{it} + \beta_2 \Delta Swaprate_t + \beta_3 \Delta iTraxx_t + \phi_0 D \Delta R_{it} + phi_1 D \Delta LEVERAGE_{it} + \phi_2 \Delta Swaprate_t + \phi_3 \Delta iTraxx_t + \epsilon_{it} \quad (3)$$

Results for this specification are shown in table 6. We find that the iTraxx index has similar but more significant effects than the VIX index. Given that the iTraxx index is also a CDS premium, it seems plausible that this variable also picks up other CDS-market related information. A similar finding has also been documented for the Euro area government bond market. For instance, Haugh et al. (2009) find that the spread on US high yield corporate bonds is an important explanatory variable for the spreads on government bonds.

4 What are the links between government bonds and sovereign CDS?

4.1 The concept of the "basis"

In essence, both sovereign CDS and government bonds offer exposure to sovereign debt. Combining these two market prices can provide insights into potential dysfunctions in credit markets. The variety of different but related products allows investors to combine instruments so that the resulting arbitrage positions would allow them to directly profit from potential price differences. Hence, market prices of bonds and CDS can be used to analyse the potential existence and size of arbitrage opportunities which should typically be very small if credit markets are functioning normally.

In the context of CDS markets, the difference between the CDS premium and the credit spread of an entitys bonds is a key indicator. With unimpeded access to sufficient funding (e.g. lending from prime brokers) arbitrage should over time reduce any differentials between the two markets segments which trade the same type of credit risk. Given these preconditions, the basis is defined as the CDS premium minus the credit spread on a bond of similar maturity.

If the basis deviates from zero such that transaction costs are covered, arbitrage traders can set up positions without default risk. To exploit a negative basis an arbitrageur must finance the purchase of the underlying bond and buy protection. In this case, the default risk is fully removed from the 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.

Empirical analysis on the basis so far only covers corporate bonds. Fontana (2010) shows 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 risky. Hence, these results illustrate that during periods of distress CDS premia and bond prices may depart from arbitrage-free values due to liquidity and counterparty risk faced by financial intermediaries and investors.

These two cases are summarised in the following table:

	CDS larger than Bond Spread (positive Basis)	CDS smaller than Bond Spread (negative Basis)
Strategy	Sell CDS protection and bond	Buy CDS protection and bond
Observed for	Most sovereigns	Corporates since crisis

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. Based on the approach taken in chart 2, chart 5 again compares aggregate developments for the basis for euro area sovereigns and for Financials. The estimate for the corporate basis is derived from JP Morgans investment grade bond index for Financials and the iTraxx Financials CDS premium (the CDS premia are plotted in chart 2). Until summer

2008, the basis was oscillating around zero. Then, it first moved to large positive peaks for sovereigns and unusually large negative levels for corporates. Hence, for firms, the bond spread temporarily exceeded the CDS premium. More recently, the corporate as well as the sovereign basis have continued their trend of normalisation[8].

As regards country specific effects, the basis for Greece and Portugal shows developments which differ from those observed for the other countries (cf. chart 6 and table 7). In particular, for those two countries we observe a negative basis in March 2009 whereas for all other countries the basis is predominantly positive. A negative basis arises when the spread on the government bond exceeds the CDS premium. Such a difference could be arbitraged away by buying the bond and simultaneously buying protection. 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.

Interaction between CDS and bonds can have beneficial effects for bond yields. Specifically, the very low level of CDS premia before the crisis led some traders to buy protection in order to profit from what they saw as a sizable underpricing[9]. After the outbreak of the crisis, jumps in the CDS premia caused these traders to experience large mark-to-market losses which they then neutralised by buying the underlying bonds. The resulting position is default-risk free and profits from the difference between the CDS and the bond spreads.

The high positive basis observed for many countries can be interpreted in terms of the flight to quality phenomenon, which has been observed in most episodes of market turmoil, e.g. the LTCM collapse in October 1998. Investors start to sell assets perceived as risky and move into liquid and default-risk free government bonds (cf. Hartmann et al, 2004). This strong demand for safe haven assets drove bond prices up and hence yields declined.

Besides the potential importance of technical default, the mechanism of flight to quality is a major factor in public debt markets. This mechanism is supported e.g. by the

[8] A caveat is that the basis depends on which proxy is chosen as a risk-free rate. This issue is particularly relevant for government bonds. Hence, an alternative would be to use the German government bond yield, which due its large liquidity might also significantly affect the pricing relationships.

[9] This is similar to the nickels in front of a steam roller effects discussed by Longstaff et al (2007). This term describes a strategy which generates small returns most of the time, but occasionally threatens to experience dramatic losses

mechanics of the Basel II capital requirements where the standardised approach treats government debt with a rating above A+ as risk-free (i.e. risk weight is zero). Simultaneously, concerns about fiscal overexpansion drove CDS premia shot up. The overall effect then was a positive spike in the basis. For such a situation, arbitrage is more difficult to implement as it requires short-selling the bond. Given that liquidity in government bonds and market functioning are very heterogeneous, this positive basis therefore is rather difficult to trade on (see also Barclays Capital, 2010b).

4.2 Principal components analysis of the basis

We again apply factor analysis to analyse the extent of common variation across CDS, bonds and the difference between CDS and credit spreads. Chart 7 shows the cumulative weight of the first, first two and first three factors respectively for changes in CDS, changes in bond yields, changes in bond spreads, the basis and the changes in the basis. The sample periods are again January 2006 to September 12, 2008 (I) and to September 12, 2008 to March 2010 (II).

Comparing the results across assets, we find that the strongest common factors are present in changes in bond yields and in the level of the basis. In these two categories, the cumulative weight of the first three factors exceeds 90%. Overall, after September 2008, the analysis indicates the presence of significant common components for all categories of series as the cumulative weight of the first three factors is close to or higher than 80%. The chart again illustrates the structural break in CDS where the increase in the role of the common factor grows strongly from period 1 to period 2. In contrast, the behaviour of the first differences of the basis does not change markedly after the collapse of Lehman in September 2008. Similar developments are also observed for the first differences of the spread.

4.3 Lead-lag analysis of bond spreads and CDS

We focus on the lead lag relationship, i.e. the adjustment process between CDS and bond spreads. Hence we can analyse see whether sovereign credit risk price discovery takes place in the derivative or in the cash market. Given the shift in the behaviour of CDS premia and bond spreads after July 2007 we carry out the analysis for two sub-samples, January, 1 2006 to July, 30, 2007 (pre-crisis period) and August, 1, 2007 and March, 1 2010 (Crisis period). Data consist of daily observations.

As a first step, we verify the supposed unit-root non-stationarity of the CDS and bond spread series[10] .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)[11] .

The Vector Error Correction Model is specified as follows:

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

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

$$Z_{t-1} = CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1}$$

Equation (4a) and (4b) express the short term dynamics of CDS and bond spread changes[12], while Z_{t-1} is the error correction term given by the long run equation (4c) that describes deviations of CDS and bond spreads from their approximate no-arbitrage relation.

If the cash bond market is contributing significantly to the discovery of the price of credit risk, 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 $_2$ will be positive and statistically significant . If both coefficients are

[10]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).

[11]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.

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

significant, then both markets contribute to price discovery. The existence of cointegration means that at least one market has to adjust by 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 countty. Where we find cointegration we study the lead-lag dynamics by means of the bivariate VECM and we look at the coefficients λ_1 and λ_2. When both λ_1 and λ_2 are significant the method we use to investigate the mechanics of price discovery is the measure due to Gonzalo and Granger (1995) (CG) defined as the ratio: $\frac{\lambda_2}{\lambda_2 - \lambda_1}$.

This approach attributes superior price discovery to the market that adjusts least to price movements in the other market. If CDS dominates GG will be close to 1 while if the bond market dominates price discovery then GG will be closer to zero. When CDS and bond spreads are not cointegrated we estimate a VAR on the variables in their first differences and implement the Granger causality test. Results are shown in Table 8 A for the pre crisis period and in table 8 B for the crisis period.

- Before the crisis

As shown by the trace test statistics CDS and bond spreads of countries such as Germany, France, Austria and Belgium are generally cointegrated. Also λ_1 are statistically significant and have a negative sign, while λ_2 are not significant, meaning price discovery take place into the bond market. In contrast, CDS and bond spreads of countries such as Italy, Ireland, Spain, Portugal or Greece are generally not cointegrated, i.e. there is no econometric evidence of a relationship. Hence, to study price discovery we apply the Granger causality test, but again no lead-lag relation is detected.

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, but probably due to low trading activity in the CDS market before the crisis and low price volatility CDS premia are relatively constant (cf. table 1). Arbitrage forces do not come into play, i.e. CDS and bond spreads move in an unrelated way because they do not move outside the arbitrage bounds determined by transaction costs.

- During the crisis

As shown by the trace test statistics CDS and bond spreads, all countries are cointegrated. For countries like Germany, λ_1 are statistically significant and have a negative sign, while λ_2 are generally significant and have a positive sign: discovery take place into both the cash and the derivative markets. More specifically, the Granger-Gonzalo measure for Germany is 0.5, for the Netherlands 0.6 and for Belgium 0.52. While for France it is 0.75 and for Austria λ_2 is not significant meaning the derivative market is dominating. For the other countries, price discovery take place mostly into the derivative market. The Granger-Gonzalo measure for Italy is 0.6 and for Spain 0.64. While for Ireland, Portugal and Greece λ_1 is not significant and λ_2 is significant and positive, meaning the derivative market is leading.

Overall our results support the evidence that the market for Sovereign credit risk was very quiet before the onset of the crisis in August 2007. During the crisis, with a dramatic re-pricing of risk, for countries such as Germany, France or the Netherlands, cash and derivatives markets seem well integrated.

Instead in the case of other countries such as Greece or 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 easiest way to trade credit risk. Because of their synthetic nature they do not suffer from the short-sales constraints seen in the cash-bond market, and buying (or selling) relatively large quantities of credit risk is possible (Blanco et. al 2005). But, this price discovery does not necessarily give rise to systematically profitable opportunities.

4.4 Explaining the Sovereign CDS-bond basis: Methodology and results

As shown in chart 6 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 how market frictions and various risk factors influence the basis trade which makes the parity relation, between the CDS and the bond spread, hold. One simple but important reason why the basis has deviated from zero 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 traders perspective bonds and CDS are not substitutes. Bond prices are affected by interest rate risk, default risk, funding risk and market liquidity risk, whereas CDS premia are affected, mostly, by default risk and counter-party risk.

A situation in which the basis is positive means that government bonds are more expensive than the CDS (bond spreads lower than CDS). Arbitrageurs may profit by implementing a positive basis trade, short selling the bond, and writing protection. The key point is that it is not easy and it might be costly to obtain the bond via repo transaction, in such a way to short it.

During stress periods for government bonds, which are usually perceived as safe, liquidity might play a major role in driving prices up, hence yield spreads decline through flight to quality effects. In contrast, deterioration of liquidity might be relevant in increasing yields for those government bonds which are perceived to face non-negligible default risk. Hence one key reason why the behaviour of the sovereign CDS-bond basis may have shifted during the crisis could be captured by the flight to quality phenomenon which has a heterogeneous impact on Euro area countries.

For this purpose we investigate the role played by proxies for aggregate risk, such as the Eonia and the VIX which might have an impact on all sovereign entities and, at the same time we analyse country specific variables such as stock index dynamics and bond market liquidity which might explain heterogeneity. These variables and their expected signs are clarified in Table 9. Overall, we adapt the set of variables we used in the previous section to the specific analysis of the basis. Eonia is the risk free overnight inter-bank rate and is expected to have a positive impact on the basis. Whenever Eonia increases, capturing the increase in the risk in the inter-bank market, we might expect funds to flow into government securities driving bond spreads lower. VIX as a measure of global risk appetite is expected to act similarly. The country specific stock index dynamics, which capture the fundamentals underlying the government bonds, is expected to have a positive impact on the basis.

Finally, the ratio between the amount of bonds outstanding and the GDP is a measure of leverage, hence it captures the fiscal fundamentals, but in this framework it captures also the bond market liquidity. Depending on the situation, this variable can therefore 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 component of the bond spreads. We estimate the regression as given in equation (5) again for the two sample periods, January, 1 2006 to September, 12, 2008 (period I) and September, 15, 2008 and March, 1 2010 (period II).

$$Basis_{it} = C + \beta_0 Basis_{it-1} + \beta_1 Eonia_t + \beta_2 StockIndex_{it} + \beta_3 VIX_t + \beta_4 Bondsoutstanding_{it} + \phi_1 DEonia_t + \phi_2 DStockIndex_{it} + \phi_3 D * VIX_t + \phi_4 D * Bondsamoutst_{it} + \epsilon_{it} \quad (5)$$

From the regression analysis shown in Table 10, two main points emerge. First, we find that the role of determinants is much larger in the second period than in the first period as it has also been the case for the CDS analysis in section 3. Far more factors are significant in the second period than in the first period. Second, the dummy D for the subgroup of countries has a significant impact in the case of two country specific variables such the dynamics of the stock index and the amount of bonds outstanding.

In addition we note the following results.

- First, the basis is mean reverting. Deviations between CDS and bond spreads tend to diminish. The coefficient on the lagged basis is slightly lower during the crisis meaning the variables revert slower to their equilibrium, but this effect is still very strong.
- Second, in the second sub-period, the Eonia rate has a positive and significant impact on the basis. The Eonia rate which is also driven by counterparty risk in the inter-bank lending market impacts on the CDS more intensely than on the bond spread driving the basis temporary positive; this effect is homogeneous across all countries.

- Third, proxies for aggregate risk appetite are a significant factor in the variation of the basis. In particular, the VIX index is significant with a positive sign in both sub-periods, but with a larger coefficient during the crisis. Hence, increases in US equity implied volatility lead to rising bases which is related to the significant effect of the VIX on CDS premia observed in section 3. This finding is in contrast to results for the corporate basis (Fontana, 2010).

- Fourth, in the second sub-period, country specific equity market developments have a significant impact on the basis. The first group of countries are not sensitive to the stock index level dynamics while for countries captured by the dummy, this linkage is positive with a higher stock market index associated with larger bases and a lower stock market index associated with lower bases. This variable captures the heterogeneity between countries in terms of flight to quality. The bonds of countries in the first group are perceived to be safe in any case while for the countries in the dummy group bond creditworthiness (hence bond spreads) is linked to the dynamics of the stock index. For example as the stock index increases, bonds are perceived safer and the basis increases.

- Finally, we find a crossectional difference in the impact of bond volume. The basis of Germany, France, Netherlands, Belgium and Austria is positively related to the amount outstanding of bonds (coefficient of 141). It is not clear from our analysis which is the direction of 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 the state aid measures. In contrast, for countries such as Greece, Ireland, Italy, Portugal and Spain which have lower bases, the interaction dummy indicates an overall much smaller impact of the amount of bonds outstanding (total coefficient of 21). As shown in chart 4 governments have issued debt in the period following the Lehman collapse and the subsequent recovery in March 2009. For some countries larger amount outstanding have deteriorated bond liquidity driving bond spreads larger irrespective to the default risk.

- The adjusted R squared for the first and second are both very high: 0.96 and 0.87.

In sum, we find that the sovereign bases are significantly linked both to proxies for global risk appetite such as the VIX index and to country-specific factors. Overall, the basis is mean reverting. In the second sub-period, country specific equity and bond market developments have a significant impact on the basis.

5 Conclusions

Results support the evidence that there are major commonalities as well as differences between the corporate and sovereign CDS. On the one hand, both markets have witnessed a substantial repricing with a reassessment of the likelihood of tail events. This repricing of public debt seems to be driven by strong common factors as well as by country-specific effects. Hence, risk premia play an important role in the spike in CDS premia. On the other hand, there are sizable differences. Besides the potential importance of technical default, the mechanism of flight to quality is a major factor in public debt markets. This mechanism is supported e.g. by the mechanics of the Basel II capital requirements: The standardised approach treats government debt with a rating above A+ as risk-free (i.e. risk weight is zero). The flight from risk - effect in particular may drive a wedge between the prices of bonds and CDS premia. However, such deviations from the arbitrage-free parity may not necessarily imply arbitrage opportunities as market frictions may inhibit traders to arbitrage away these price differentials.

As regards the linkages between CDS and government bonds a key factor is the flight to quality effect which is absent in corporate bond markets and which specifically lowers government bond spreads during periods of market distress. Overall, we observe that for most countries the CDS premium exceeds the spread on the corresponding government bond. The main exception here is Portugal and Greece where we find a temporary negative basis in March 2009. Since September 2008, our analysis indicates that the bond and CDS markets are integrated for some countries while for other countries price discovery mostly takes place in the CDS 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.

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Chart 1: Net notional for selected Euro area sovereigns (DTCC)

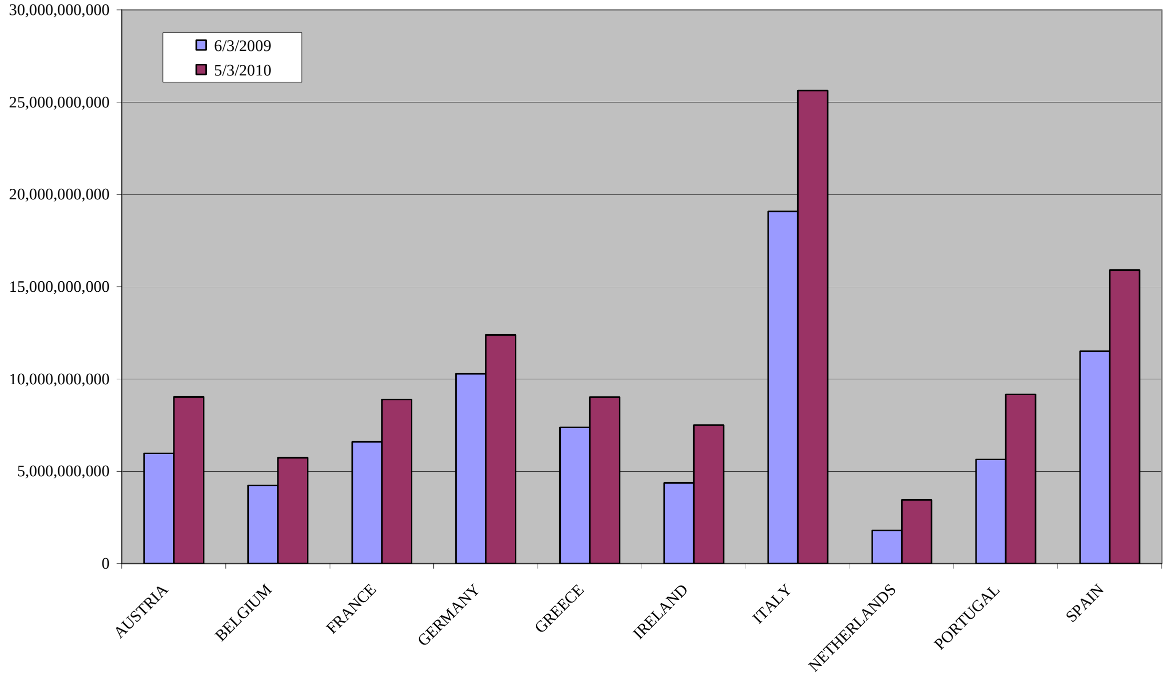

Chart 2: iTraxx CDS index for European financials vs. European sovereigns

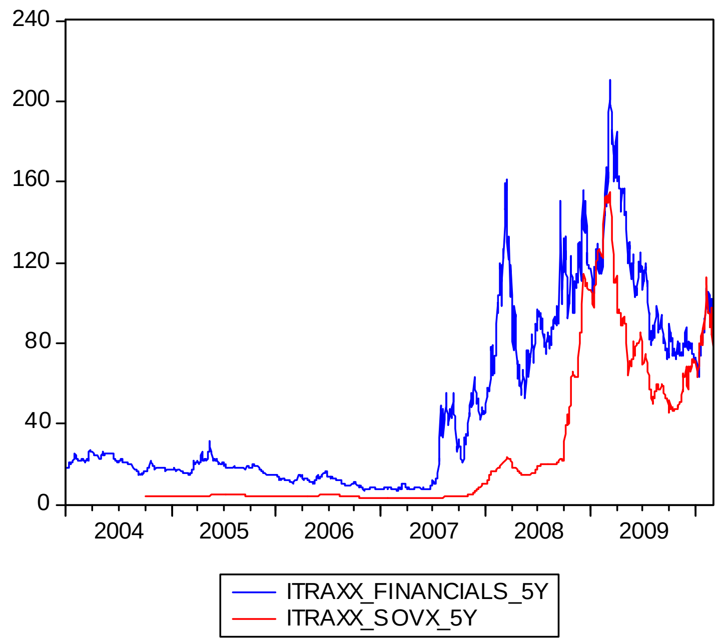

Chart 3: CDS premia for Euro area sovereigns

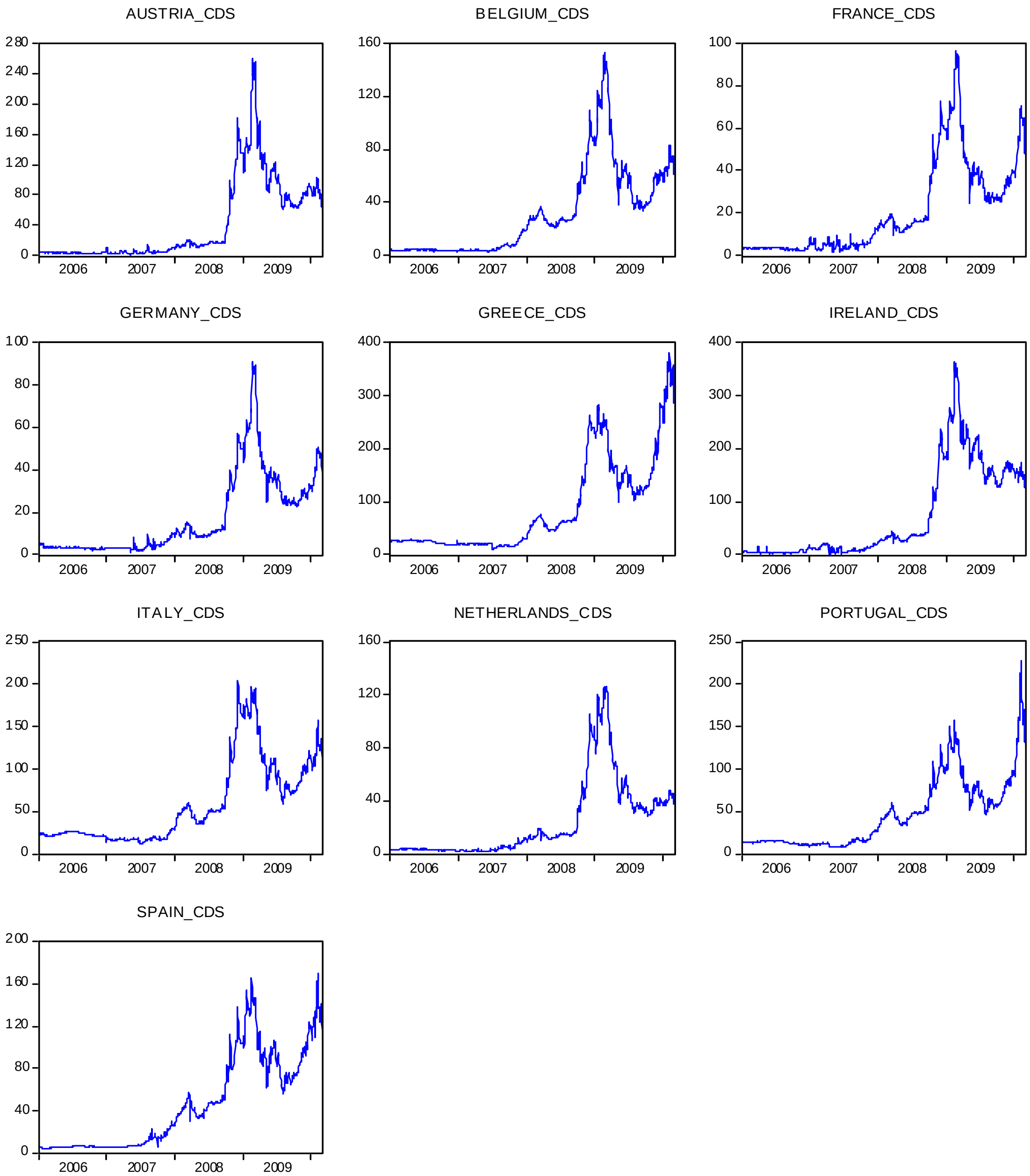

Chart 4: Time series of explanatory variables

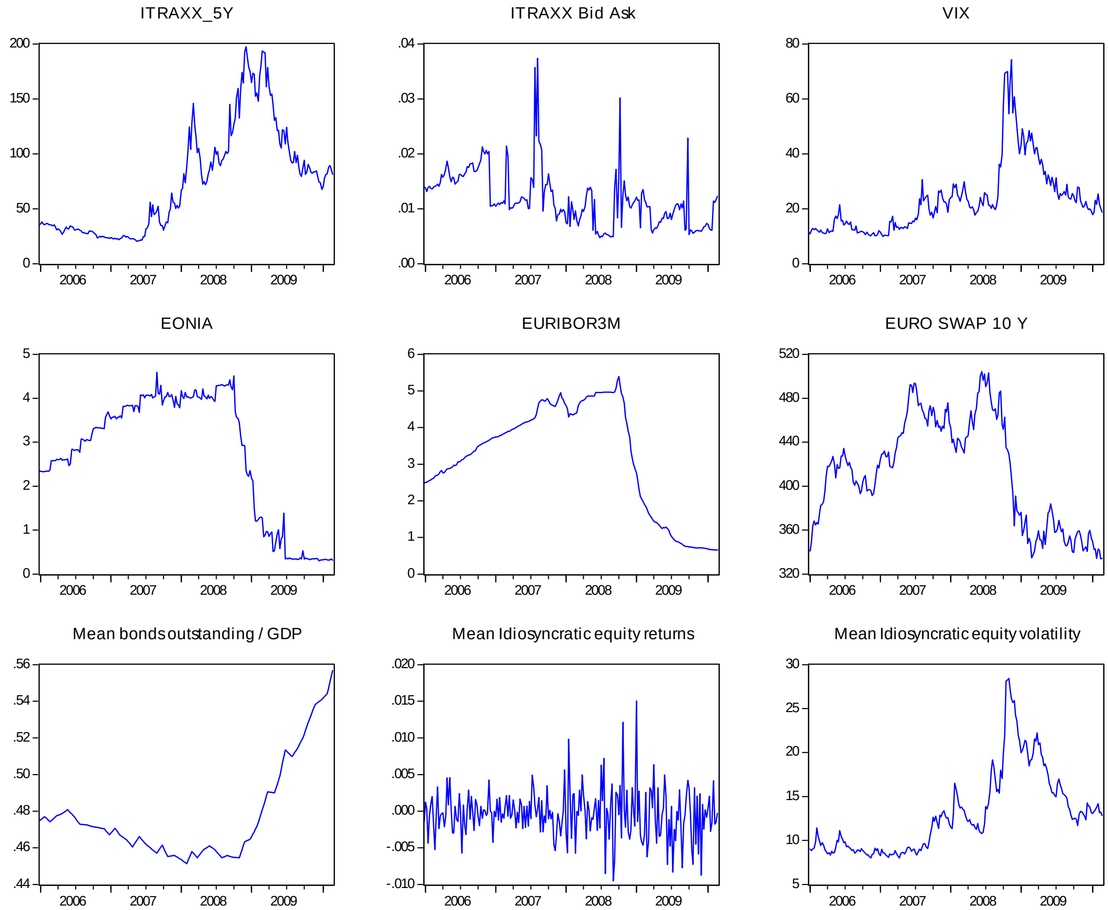

Chart 5: Basis (=CDS - bond spreads) for Euro area sovereigns and Financials

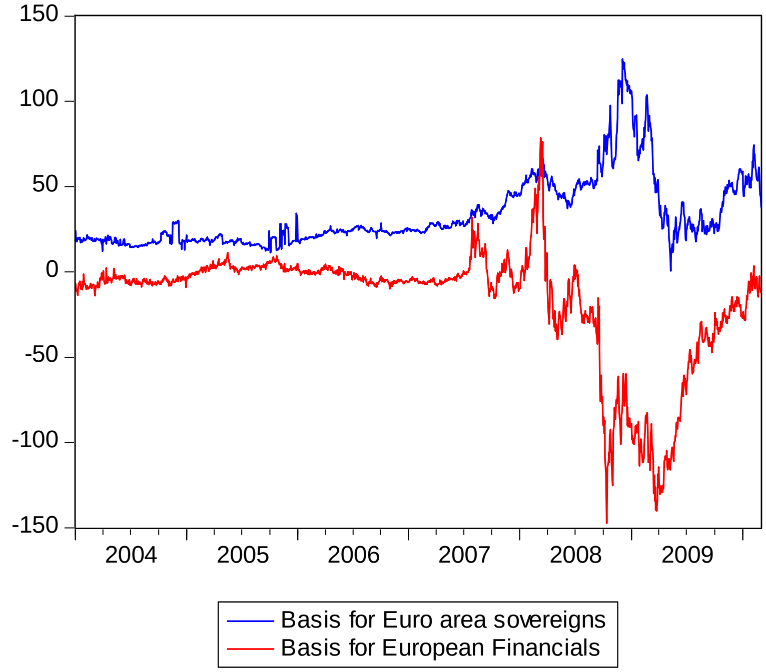

Chart 6: Basis (=CDS - bond spreads) for Euro area sovereigns

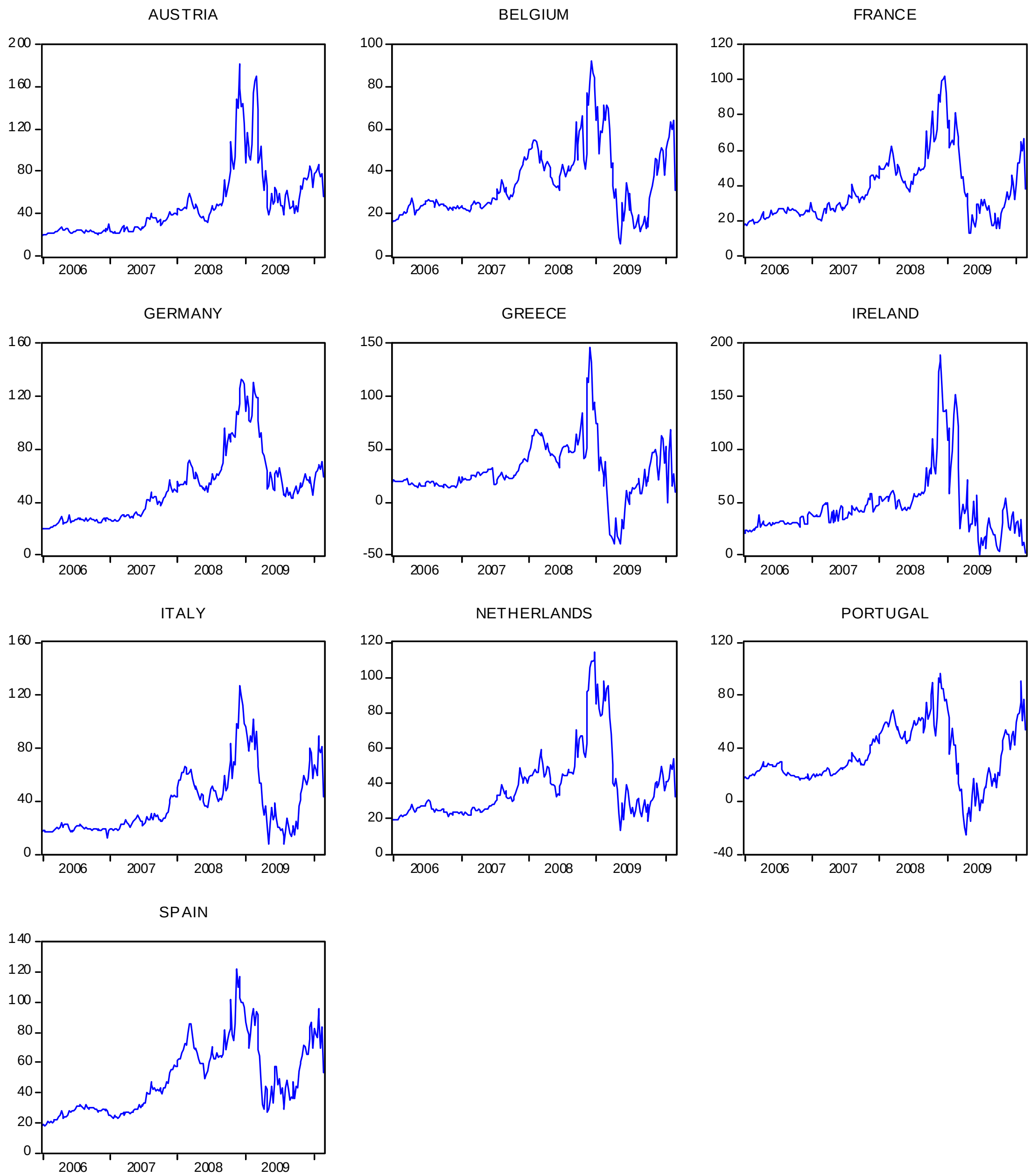

Chart 7: Factor analysis of CDS, bonds and basis

This graph plots the cumulative weight of the first, first two and first three factors respectively for changes in CDS, changes in bond yields, changes in bond spreads, the basis and the changes in the basis. The sample periods are January 2006 to September 12, 2008 ("I) and to September 12, 2008 to March 2010 ("II").

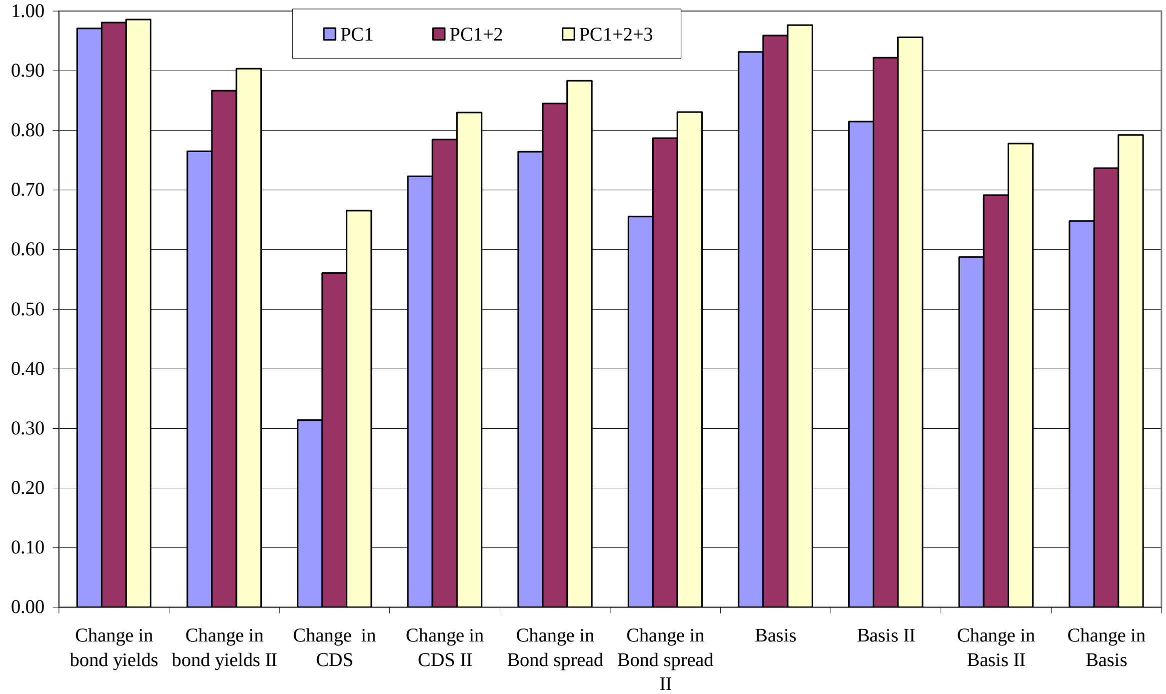

Table 1: Descriptive statistics of levels of CDS premia

Period I

	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	6.70	3.80	21.10	0.80	5.21	705
BELGIUM	10.77	4.30	37.00	2.40	10.02	705
FRANCE	6.94	4.40	19.80	1.40	5.05	705
GERMANY	5.57	3.50	15.10	0.70	3.36	705
GREECE	30.89	25.00	74.50	10.80	16.86	705
IRELAND	14.23	10.40	43.40	2.30	12.10	705
ITALY	27.36	22.70	59.80	11.40	12.46	705
NETHERLANDS	6.20	3.50	19.30	1.80	4.84	705
PORTUGAL	21.47	14.80	59.80	7.20	14.18	705
SPAIN	17.28	6.90	57.50	4.20	15.90	705

Period II

	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	102.12	88.60	260.10	16.80	45.77	383
BELGIUM	67.59	60.82	152.86	29.50	28.34	383
FRANCE	45.08	39.90	96.60	16.50	17.71	383
GERMANY	38.93	35.50	90.70	12.00	16.01	383
GREECE	186.81	163.60	379.90	64.50	71.24	383
IRELAND	177.95	165.20	365.00	40.20	60.84	383
ITALY	114.40	107.00	205.30	52.50	37.54	383
NETHERLANDS	55.46	42.80	126.30	15.30	28.18	383
PORTUGAL	91.33	82.00	227.10	45.60	33.54	383
SPAIN	98.53	95.80	169.00	50.50	26.03	383

Table 2: Factor analysis for CDS changes (9/2008-3/2010)

	AUSTRIA	BELGIUM	FRANCE	GERMANY	GREECE
Weight of F1	0.83	0.84	0.81	0.78	0.78
Explan. V	73%	73%	63%	59%	60%

	IRELAND	ITALY	NETHERLANDS	PORTUGAL	SPAIN
Weight of F1	0.78	0.92	0.79	0.85	0.93
Explan. V	58%	82%	65%	67%	32%

Dependent Variable: Factor 1

Variable	Coefficient	t-Statistic
Constant	-0.01	-0.19
VIX	-0.03	-1.33
ITRAXX Corporates	0.05	4.87
10Y Swap rate	0.02	1.20
German Bund Yield	-0.05	-4.01
EONIA	0.04	0.15
EURIBOR3M	1.04	0.65
Euro area stock index	-1.22	-0.43
S& P 500	-11.25	-3.26
Adjusted R-squared	0.13	

Table 3: 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 premium. The data sources are Bloomberg, Datastream and JP Morgan.

Notation	***Definition***	***Sign***
R	Idiosyncratic equity return	(-)
Leverage	Bonds outstanding / GDP	(+)
Swap rate	Euro 10 Y swap rate	(-)
VIX	VIX index of implied volatility	(+)
VOL	Idiosyncratic equity volatility	(+)
EONIA	Euro overnight rate	(-)
Slope	Euro 10 Y swap rate - Euribor	(-)
ITRAXX	ITRAXX 5 Y index	(+)
ITRAXX Bid-Ask	ITRAXX 5 Y Bid-Ask spread	(+)

Table 4: Results of baseline regression model

This table reports the results from panel regressions of weekly changes in premia including fixed effects:

$\Delta Y_{it} = C + \beta_0 \; R_{it} + \beta_1 \, \Delta \, LEVERAGE_{it} + \; \beta_2 \, \Delta \, Swap\ rate_t + \beta_3 \; \Delta \, VIX_{\,t} \; + \varphi_0 \, D \, \Delta \, R_{it} + \varphi_1 \, D \, \Delta \, LEVERAGE_{it} + \varphi_2 \, \Delta \, Swap\ rate_t + \varphi_3 \, \Delta \, VIX_t \; + \varepsilon_{it}$

The t-statistics based on White standard errors are given adjacent to the coefficient estimates. Coefficients marked in bold are significant at 5 %. The two periods are January, 1 2006 to September, 12, 2008 ('period I') and September, 15, 2008 and March, 1 2010 ('period II').

Period I

	Coeff	t-stat
Intercept	0.09	0.63
R	-3.31	-0.35
Leverage	32.85	1.19
Swap rate	0.08	3.01
VIX	-0.01	-1.52
Dummy R	-6.82	-0.38
Dummy Leverage	30.33	0.61
Dummy Swap rate	0.15	2.98
Dummy VIX	0.03	0.90
R-squared	2%	

Period II

	Coeff	t-stat
Intercept	0.11	0.10
R	-123.03	-2.69
Leverage	373.19	1.52
VIX	0.58	3.60
Swap rate	-0.39	-4.53
Dummy R	26.06	0.29
Dummy Leverage	-748.79	-1.47
Dummy Swap rate	0.31	2.29
Dummy Swap rate	-0.31	-4.21
R-squared	26%	

Table 5: Results of extended regression model

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

$\Delta Y_{it} = C + \beta_0 R_{it} + \beta_1 \Delta VOLA_{it} + \beta_2 \Delta LEVERAGE_{it} + \beta_3 \Delta VIX_t + \beta_4 \Delta Eonia_t + \beta_5 \Delta Slope_t + \beta_6 \Delta Bid Ask_t + \varphi_0 D R_{it} + \varphi_1 D \Delta VOLA_{it} + \varphi_2 D \Delta LEVERAGE_{it} + \varphi_3 D \Delta VIX_t + \varphi_4 D \Delta Eonia_t + \varphi_5 D \Delta Slope_t + \varphi_6 D \Delta Bid Ask_t + \varepsilon_t$

The t-statistics based White standard errors are given adjacent to the coefficient estimates. Coefficients marked in bold are significant at 5 %. The two periods are January, 1 2006 to September, 12, 2008 ('period I') and September, 15, 2008 and March, 1 2010 ('period II').

	Period I		Period II	
	Coeff	t-stat	Coeff	t-stat
Intercept	-0.07	-0.50	-0.67	-0.37
R	-3.98	-0.44	-125.19	-2.72
VOL	0.04	2.46	0.06	0.59
Leverage	28.39	1.02	392.09	1.64
VIX	0.11	3.55	0.62	3.54
EONIA	-0.72	-0.99	1.33	0.32
Slope	-0.01	-0.92	-0.34	-3.73
ITRAXX Bid-Ask	-42.32	-1.91	-265.83	-2.14
Dummy*R	-13.16	-0.87	41.33	0.48
Dummy*VOL	-0.03	-1.34	0.01	0.06
Dummy*Leverage	43.63	0.91	-776.59	-1.43
Dummy*VIX	0.15	2.60	0.32	2.24
Dummy*EONIA	1.48	1.22	3.03	0.85
Dummy*Slope	0.00	0.08	-0.29	-3.67
Dummy*ITRAXX Bid-Ask	-37.65	-1.07	-137.28	-1.22
R-squared	6%		25%	

Table 6: Results of regression model using the iTraxx index

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

$$\Delta Y_{it} = C + \beta_0 \ R_{it} + \beta_1 \ \Delta \ LEVERAGE_{it} + \beta_2 \ \Delta \ Swap\ rate_t + \beta_3 \ \Delta \ ITRAXX_t + \varphi_0 \ D \ \Delta \ R_{it} + \varphi_1 \ D \ \Delta \ LEVERAGE_{it} + \varphi_2 \ \Delta \ Swap\ rate_t + \varphi_3 \ \Delta \ ITRAXX_t + \varepsilon_{it}$$

The t-statistics based on White standard errors are given adjacent to the coefficient estimates. Coefficients marked in bold are significant at 5 %. The two periods are January, 1 2006 to September, 12, 2008 ('period I') and September, 15, 2008 and March, 1 2010 ('period II').

Period I

	Coeff	t-stat
Intercept	0.05	0.40
R	-1.97	-0.21
Leverage	31.00	1.27
Swap rate	-0.02	-1.95
iTraxx	0.05	4.43
Dummy R	-6.33	-0.39
Dummy Leverage	22.43	0.46
Dummy Swap rate	0.02	0.72
Dummy iTraxx	0.07	3.41
R-Squared	3%	

Period II

	Coeff	t-stat
Intercept	0.52	0.50
R	-93.59	-2.34
Leverage	234.77	1.10
Swap rate	-0.33	-4.11
iTraxx	0.35	4.83
Dummy R	18.33	0.21
Dummy Leverage	-767.76	-1.67
Dummy Swap rate	-0.29	-3.75
Dummy iTraxx	0.15	2.59
R-Squared	31%	

Table 7: Descriptive statistics of spreads and basis

A) Levels of bond spreads relative to 10-year swap rate

	Period I					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	-24.57	-22.03	-14.12	-50.09	5.80	705
BELGIUM	-19.50	-19.87	-7.17	-31.38	4.61	705
FRANCE	-25.57	-23.44	-11.41	-48.02	6.82	705
GERMANY	-32.22	-26.66	-12.47	-72.89	11.49	705
GREECE	1.37	2.71	20.33	-15.27	8.22	705
IRELAND	-25.89	-26.56	-10.55	-43.97	5.88	705
ITALY	-2.45	-2.07	12.60	-19.36	7.60	705
NETHERLANDS	-25.63	-23.77	-13.66	-48.17	5.75	705
PORTUGAL	-11.42	-11.46	-1.95	-22.56	4.49	705
SPAIN	-22.71	-22.82	-9.86	-34.22	5.16	705
	Period II					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	22.18	17.85	90.44	-54.60	30.13	383
BELGIUM	24.98	21.15	82.61	-32.72	21.29	383
FRANCE	-1.51	3.21	28.22	-52.28	18.12	383
GERMANY	-35.61	-27.07	-9.74	-83.41	18.88	383
GREECE	156.86	148.36	362.92	4.12	71.84	383
IRELAND	120.79	129.03	227.83	-39.76	61.27	383
ITALY	59.48	57.04	115.44	-2.05	22.44	383
NETHERLANDS	4.23	4.40	36.40	-53.46	18.82	383
PORTUGAL	53.99	46.28	139.12	-20.12	33.56	383
SPAIN	33.06	34.85	70.29	-27.21	21.89	383

B) Basis levels

	Period I					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	31.27	26.45	68.59	17.92	10.00	705
BELGIUM	30.27	25.68	62.68	14.17	9.85	705
FRANCE	32.52	27.56	66.82	14.81	11.12	705
GERMANY	37.79	30.04	86.69	17.37	14.43	705
GREECE	29.52	23.68	70.51	9.90	15.08	705
IRELAND	40.12	40.26	79.34	18.77	10.85	705
ITALY	29.81	23.65	68.65	12.04	13.78	705
NETHERLANDS	31.83	27.26	65.37	16.96	9.82	705
PORTUGAL	32.89	26.70	75.17	14.06	15.25	705
SPAIN	40.00	30.85	90.60	16.28	17.68	705
	Period II					
	Mean	Median	Maximum	Minimum	Std. Dev.	N
AUSTRIA	79.94	73.19	185.36	27.03	34.03	383
BELGIUM	42.61	42.96	92.57	-6.59	22.32	383
FRANCE	46.59	40.23	102.31	0.48	24.19	383
GERMANY	74.54	63.78	135.16	35.14	27.16	383
GREECE	29.95	26.02	152.80	-50.51	40.35	383
IRELAND	57.16	39.84	189.07	-9.92	47.70	383
ITALY	54.92	55.31	130.18	-3.37	30.90	383
NETHERLANDS	51.23	41.48	115.23	4.70	27.18	383
PORTUGAL	37.34	41.32	98.62	-27.24	31.42	383
SPAIN	65.47	68.93	121.65	10.43	23.84	383

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

The lead-leg 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 A and B). 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 λ_1 *and* λ_2*.*

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

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

When both λ_1 *and* λ_2 *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:* $\dfrac{\lambda_2}{\lambda_2 - \lambda_1}$*. 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 two periods are January, 1 2006 to July, 12, 2007 ('pre-crisis') and August, 1, 2007 and March, 1 2010 ('crisis period').

A: Pre-crisis period 1/1/2006-7/30/2007

Country	Germany	France	Netherlands	Austria	Belgium	Italy	Ireland	Spain	Portugal	Greece
Trace Test p-v.	0.004	0.012	0.987	0.001	0.036	0.312	0.233	0.998	0.371	0.292
Lambda 1	-0.146	-0.154	-0.013	-0.223	-0.082	No VAR	No VAR	No VAR	No VAR	No VAR
t-stat	[-4.436]	[-4.670]	[-1.292]	[-5.424]	[-3.422]	Granger	Granger	Granger	Granger	Granger
Lambda2	0.059	0.016	-0.05	0.045	-0.056	Causality	Causality	Causality	Causality	Causality
t-stat	[0.839]	[0.406]	[-1.409]	[0.972]	[-0.837]					
Price discovery	Bond mkt	Bond mkt	No	Bond mkt	Bond mkt	No	No	No	No	No

B: Crisis period 8/1/2007-2/25/2010

Country	Germany	France	Netherlands	Austria	Belgium	Italy	Ireland	Spain	Portugal	Greece
Trace Test p-v.	0.017	0.012	0.002	0	0.008	0.01	0.005	0.001	0.062	0.023
Lambda 1	-0.011	-0.008	-0.015	0.004	-0.021	-0.017	0.015	-0.019	0.004	-0.014
t-stat	[-3.236]	[-1.542]	[-2.702]	[0.49963]	[-2.755]	[-2.041]	[1.554]	[-1.838]	[0.441]	[-1.008]
Lambda2	0.012	0.024	0.023	0.027	0.023	0.026	0.029	0.033	0.03	0.042
t-stat	[1.930]	[3.360]	[3.340]	[4.663]	[2.727]	[3.487]	[3.971]	[3.967]	[3.085]	[2.926]
GG	0.501	0.747	0.603	no	0.527	0.606	1	0.64	no	no
Price discovery	Both mkts	Mostly Cds	Both mkts	Cds mkt	Both mkts	Both mkts	Cds	Mostly Cds	Cds mkt	Cds mkt

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 - YTM 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, Datastream

Notation	***Definition***	***Sign***
Basis (-1)	Lagged basis	(+)
Eonia	Overnight Inter-bank rate	(+)
Stock Index $_i$	Country Stock Index	(+)
VIX	VIX index of implied volatility	(+)
Bonds amt out $_i$	Bonds outstanding / GDP	(+/-)
Dummy	Dummy for group II	(+/-)

Table 10: Results of the basis regression

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

$$Basis_{it} = C + \beta_0\ Basis_{it-1} + \beta_1\ Eonia_t + \beta_2\ Stock\ Index_{it} + \beta_3\ VIX_t + \beta_4\ Bonds\ outstanding_{it} + \varphi_1\ D\ Eonia_t + \varphi_2\ D\ Stock\ Index_{it} + \varphi_3\ D\ VIX_t + +\varphi_4\ D\ Bonds\ am\ outst_{it} + \varepsilon_{it}$$

The t-statistics is based on White cross-section standard errors are given adjacent to the coefficient estimates. Coefficients marked in bold are significant at 5 %. The two periods are January, 1 2006 to September, 12, 2008 ('period I') and September, 15, 2008 and March, 1 2010 ('period II').

Period I

Variable	Coefficient	t-Statistic
Intercept	-0.29	-0.10
Basis (-1)	**0.88**	**35.83**
Eonia	0.53	1.48
Stock Index $_i$	0.00	-0.62
Vix	**0.20**	**3.44**
Bond amt out $_i$	3.71	0.65
Dummy Eonia	-0.16	-0.59
Dummy C. Stock Index $_i$	0.00	0.22
Dummy Vix	**0.08**	**1.95**
Dummy Bond amt out $_i$	-9.05	-0.84
Adjusted R-squared	0.96	

Period II

Variable	Coefficient	t-Statistic
Intercept	**-54.87**	**-2.06**
Basis (-1)	**0.84**	**24.11**
Eonia	1.47	1.24
Country Stock Index	0.01	0.65
Vix	**0.37**	**2.21**
Bond amount outstanding	**141.50**	**2.31**
Dummy Eonia	-0.60	-0.53
Dummy C. Stock Index	**0.02**	**2.02**
Dummy Vix	-0.02	-0.27
Dummy Bond amt outst	**-119.62**	**-2.25**
Adjusted R-squared	0.87	

Measuring the CDS-bond basis on fixed-rate bonds

Alessandro Fontana *

Department of Economics, University of Ca' Foscari Venice

May 1, 2010

Abstract

This paper proposes a methodology for measuring the CDS-bond basis, i.e the pricing differential between the CDS and the underlying fixed rate bond. The bond is priced according to the risk-neutral valuation paradigm, by mean of the cash-flows replication argument, using the Libor curve as the risk-free benchmark, risk-neutral default probabilities implied from the CDS curve and an assumed recovery rate. The basis is calculated by shifting the entire Libor curve, in the bond pricing model up or down, until the present value of the cash flows of the bond equal the market price; the basis is defined as the shift of the Libor curve.

A series of tests, performed on an hypothetical bond, illustrates how the error between this "arbitrage-free" and the standard measure of the basis, used in the financial literature, depends on the risk-free and CDS term structures.

An empirical application, on US corporate bonds, shows that the two measures exhibit a common behavior, i.e. they are approximately zero, in normal market conditions and they become negative since the onset of the crisis in August 2007, but the "arbitrage free" basis remains smaller in absolute terms.

Keywords: CDS; bond spread; basis; risk-neutral default probabilities; recovery rate; risk-neutral valuation.

JEL Classification Numbers: (G10, G12)

*Address: University of Ca'Foscari Department of Economics, Fondamenta San Giobbe - Cannaregio 873, 30121 Venezia, ITALY, e-mail: *fontana@unive.it*. The author is grateful to Loriana Pelizzon (University Ca' Foscari of Venice) and Stephen Schaefer (LBS) for supervision, advice and suggestions.

1 Introduction

The no-arbitrage argument that supports the equivalence relation between the CDS and the yield spread on a floating rate bond, by Duffie (1999) and Hull and White (2000) is only approximate for fixed-rate bonds. By defining the bond used in the arbitrage trade as a floating-rate one, which by construction stays always at par, the constant interest rate curve assumption can be avoided. In practice, the vast majority of bonds have fixed-rates and trade usually away from par, since the level of the interest rate curve is time-varying. When the bond is away from par, the shape of term structure of the risk-free rate and of the CDS affects the parity relation.

The objective of this paper is threefold. **First**, to provide a methodology for measuring the CDS-bond basis, i.e the pricing differential between a CDS and the underlying fixed-rate bond using the "no-arbitrage argument". The bond is priced according to the risk-neutral valuation paradigm, by mean of the cash-flows replication argument, using the Libor curve as the risk-free benchmark, risk-neutral default probabilities implied from the CDS curve and an assumed recovery rate. The basis is calculated by shifting the entire Libor curve, in the bond pricing model up or down, until the present value of the cash flows of the bond equal the market price; the basis is defined as the shift of the Libor curve.

The **second** objective is to investigate the error measurement that derives from different approximations that have been done in the empirical literature that focuses on explaining the behavior of the CDS-bond basis. A series of tests has been performed, on an hypothetical bond, to illustrated the size of basis-error under different assumptions on the level, the change in the level and the shape of the swap rate and of the CDS curves. In the numerical application, the "basis error" is defined as the difference between the basis calculated with the Duffie (1999) argument (I-basis) and the basis calculated with the bonds' cash flow replication argument proposed in this paper. The analysis highlights five peculiarities of the basis error, that derive from the approximations described above. First, the basis-error is larger for a bond with a higher coupon. This is due to the so called "coupon risk". This means that, in the cross-section, for lower rated bonds, which generally have higher coupons and higher default probabilities, the basis-error is larger. Second, the shift of the swap rate curve has a different impact on the basis error depending on the shape of the CDS curve, meaning the impact on the basis-errors for bonds with different rating is different. In fact, generally low rating categories have inverted[1] CDS curves. Third, the shift of the CDS curve level has a convex impact on the basis-errors. The convexity is the result of the interaction between the "coupon risk" and the "recovery risk": as the CDS curve increases and the risk-neutral probabilities of default become higher the "coupon risk" increases, with a negative effect on the basis-error, but at the same time the bond goes far below par and the recovery rate comes into play with a positive effect on the basis error. The impact is the greatest for bonds that are significantly away from par. Fourth, when the swap curve is upward sloping the basis error is negative, but slightly smaller than in the case of a flat swap curve. When the swap curve is downward sloping the basis error is negative and it slightly larger than in the case of a flat swap curve. Fifth, when the CDS curve is steep risk neutral default probabilities are more reactive to changes in the level of the CDS curve, than when the curve is flat. When it is inverted they are less reactive. The effect on the basis-error goes trough the impact of risk neutral default probabilities on "coupon risk".

The **third** objective is to illustrate the empirical behavior of the I-basis (classical measure used in the literature) and the "arbitrage-free basis" calculated using corporate bonds' transaction prices (US) from the TRACE and CDS premia provided by Markit in the period between 2006 and 2008. Results support the evidence that the two measures of the basis co-move and are approximately zero before the crisis, while during the crisis the "arbitrage free" basis is less negative than the I-basis.

Previous empirical studies such as Longstaff et al. (2005), Blanco, Brennan and Marsh (2005), Zhu (2006), Nashikkar and Subrahmanyam (2006), use only 5 year synthetic bonds, because corporate bonds do not have constant maturity as the corresponding CDS, but this may be a source of bias. Additionally, no one of these studies accounts for the shape of term structure of CDS, they assume that it is flat, which implies that the risk-neutral default probabilities are constant across different maturities; this is not true in practice.

[1] An inverted interest rate curve is a curve which is downward sloping.

Compared to these methodologies, using the bonds' cash flow replication argument, the CDS-bond basis is calculated on a fixed rate corporate bond, allowing for the level of the swap rate curve and of the CDS curve to vary in time and for the curves to have different shapes. This approach avoids constructing any hypothetical bond and allows to calculate the basis on real bonds with different maturities. In fact, it is hard address properly the coupon issue in bond price computations, because the cash flows of the hypothetical bond are not well defined. Also, there are no observable transaction data on the hypothetical bond for explaining prices with liquidity proxies in an eventual empirical analysis.

This paper is organized as follows. Section 2 discusses the parity relationship between the CDS and the bond spread by Duffie (1999). Section 3 describes the methodology proposed for calculating the CDS-bond basis. Section 4 reports the numerical application. Section 5 illustrates the empirical behavior of the basis. Final remarks are presented in section 6.

2 The equivalence relation between CDS and bond yields

As discussed by Duffie (1999) and Hull and White (2000), theoretically, CDS spreads are closely related to bond yield spreads. The cash flows from a portfolio consisting of a short n-year risky bond at par (Y) and the cash flows on a long n-year risk-free bond at par (L) are very close to those from a long n-year CDS contract, in all states of the world. The relationship $(Y - L) = S$ approximately holds, meaning the CDS-bond basis has to be zero. Whenever S is greater than Y- L, arbitrageurs will find profitable to buy a risk-free bond, short a corporate bond and sell a CDS contract. Similarly, whenever S is less than Y - L, arbitrageurs will find profitable to buy a corporate bond, buy a CDS and short a risk-free bond.

Note that from a technical point of view, in case of default, the synthetic CDS package is worth the face value of the risk-free bond plus accrued interest minus the market value of the risky bond. While in practice a long CDS is worth just face value minus the market value of the risky defaulted bond, hence the synthetic CDS is worth more, so the arbitrage relation is only approximate. In fact, an arbitrageur that buys a n-year risky bond and buys protection is not compensated for the accrued coupon in case of default. As discussed by Duffie (1999) and Hull and White (2000) it is possible to adjust for this fact correcting downward the synthetic CDS spread. Let define AI* as the expected accrued interest, of the coupon C, on the bond at the time of the default. Let assume roughly half of the coupon to be accrued when default happens and suppose the risk-neutral default probabilities between two coupon times are given by RN, then the adjustment is:

$$AI* = RN \times \frac{C}{2} \tag{1}$$

Since default can happen at any time there is the "accrued coupon risk" issue, hence this approximation leaves some margin of pricing errors. Distortions are larger the larger the coupon on underlying note and the larger the risk neutral default probabilities of the risky bond.

Moreover, in practice, the vast majority of bonds are fixed-rate and trade usually away from par. The Duffie (1999) arbitrage argument applied to fixed-rate bonds assumes that the interest rate curve level does not change so that a bond stays always at par. When this is not the case, the term structure of the risk-free rate and of CDS are relevant for determining the no-arbitrage relation. By defining the corporate bond used in the arbitrage as floating-rate bond at par and the risk-free bond as a floating risk-free bond at par the constant interest rate assumption can be avoided.

3 The CDS-bond basis: replication argument

For the "no-arbitrage" condition to hold, if two instruments have identical cash-flows in all states of the world they must have the same price.[2] Cash-flows of fixed rate corporate bonds are distributed over time. Hence, if there is no-arbitrage then coupon bonds prices must be consistent with the entire risk-free rate curve and the entire CDS curve[3].

The next paragraphs describe the risk-neutral bond pricing methodology, and the steps

[2] An arbitrage transaction has to require no invested capital and offer a positive probability of a positive profit and a zero probability of a negative profit.

[3] In practice, bond prices based on information extracted from CDS, will not be exactly equal market prices, because of transaction costs, counter-party risk in CDS contracts, liquidity, bond specialness and so on.

to get the risk-free zero curve from the Libor curve, and the term structure of risk-neutral default probabilities from the CDS curve. Then, the methodology for measuring the basis, which is based on the replication of the bonds' cash flows, is presented.

3.1 The pricing of the bond

For illustrating the pricing of a n-year corporate bond, which has coupons at a yearly frequency, let Q_t denote risk-free survival probabilities in the 1-year period that goes from t-1 to t, conditional on survival till $t-1$. F_t denote the 1-year forward rates in the period that goes from t-1 to t, implied from the Libor risk-free curve[4]. R is the recovery rate on the par value of the bond, which is 100, an P_t is the price of the bond at time t.[5]

According to the risk-neutral default valuation paradigm, the price is the present value of the risk-neutral expected payoffs. The price, in period $n-1$, is obtained considering that the bond may not or may default at the maturity n:

$$P_{n-1} = \frac{1}{1+f_n}[Q_n * (100+c) + (1-Q_n) * R)] \quad (2)$$

hence, in period t:

$$P_t = \frac{1}{1+f_{t+1}}[Q_{t+1} * P_{t+1} + (1-Q_{t+1}) * R)] \quad (3)$$

finally, in period 0:

$$P_0 = \frac{1}{1+f_1}[Q_1 * P_1 + (1-Q_1) * R)] \quad (4)$$

The expected value of each cash-flow of the bond is obtained using risk-neutral default probabilities, of the corresponding maturity, and is discounted with the risk-free interest rate of the corresponding maturity. This bond price calculation methodology accounts

[4]Libor rates for maturities beyond 9 month, hence for maturities such as 1, 2, 3, 4, 5, 7, 10 and 15, are denominated swap rates. These are the fixed par rates correspondent to the short term floating Libor rate.

[5]This model assumes that the risk-free interest rate and default events are independent. Also counterparty risk in CDS is ignored.

for the shape of the risk-free zero curve and for the shape of the CDS curve, in fact it defines a consistency relation between the bond price and both the entire risk-free rate curve and the entire CDS curve. Hence, this "CDS based" bonds' no-arbitrage price is directly comparable to the market price of the corporate bond.

3.2 Estimation of the risk-free forward rates using the Libor curve

Following Grinblatt (2001), Longstaff et.al (2005) and Hull et.al (2004), and also the standard market practice, the USD Libor curve is used as the measure of the risk-free rate for calculating the basis. Although Treasuries are almost truly default free, they may be affected by other factors, such as the specialness or taxation benefits. The Libor curve is a par curve, hence it has to be transformed into a zero curve as follows. Starting with the 1-period Libor-rate the discount factor d_1 is worked out. With the 2-period Libor-rate, knowing d_1, d_2 is worked out; in the same way d_3 and d_4 are obtained. From the discount factors the 1-year implied forward rates, f_1, f_2, f_3 and f_4 are calculated, which are the used for pricing the bond.

3.3 Estimation of risk-neutral default probabilities from CDS spreads

If the risk-neutral probability of state s at time T is p_s then the value of a contract that pays \$1 in that state is:

$$V = e^{-rT}\hat{E}(CF) = e^{-rT}(p_s \times 1) = e^{-rT}p_s \tag{5}$$

Therefore, if the risk-neutral survival probability for time t is q_t then the value of \$1 paid only if the credit has survived to time t is: $e^{-rt}q_t$.

The cash-flows for the premium leg of a CDS contract are the followings. In a CDS contract that matures after N periods of length Δ (i.e., at time NΔ), the premium of $\$S_N$ per year is paid either until the end of the contract or until default, whichever comes first. If the credit has survived to period t then the payment at period t is $S_N\Delta$ and the PV of the payment is: $e^{-rT}q_tS\Delta = D_tq_tS\Delta$ where D_t is the risk-free discount factor for time t.

The RN-probability that default occurs between t-1 and t is $(q_{t-1} - q_t)$ and, in this case the premium is paid, on average, for half the time between t-1 and t (i.e., $\Delta/2$) and so the PV of this component is: $\Delta_t(q_{t-1} - q_t)S\frac{\Delta}{2}$. The total PV of the premium leg for a contract that matures in N is:

$$\sum_{t=1}^{N} D_t q_t S_N \Delta + D_t(q_{t-1} - q_t)S\frac{\Delta}{2} = \frac{\Delta S_n}{2}\sum_{t=1}^{N} D_t(q_{t-1} + q_t) \tag{6}$$

The cash-flows for the protection leg are the followings. In the event of default the CDS pays (1-R) where R is the recovery rate; otherwise it pays zero. The probability that the underlying entity of the CDS contract defaults between t-1 and t is $(q_{t-1} - q_t)$, so the value of the protection payment is:

$$\text{(1-R) D}_t(q_{t-1} - q_t) \tag{7}$$

Hence the PV of the protection leg is:

$$\text{(1-R)}\sum_{t=1}^{N} D_t(q_{t-1} - q_t) \tag{8}$$

The CDS spread is the value of the premium, S_N, that makes the value of the contract zero, i.e., makes the value of the premium leg equal to the value of the protection leg:

$$\frac{S_N}{2}\sum_{t=1}^{N} D_t(q_{t-1} + q_t) = (1 - R)\sum_{t=1}^{N} D_t(q_{t-1} - q_t) \tag{9}$$

and so the CDS spread is given by:

$$\text{S}_N = \frac{(1-R)\sum_{t=1}^{N} D_t(q_{t-1}-q_t)}{\Delta\sum_{t=1}^{N} D_t(q_{t-1}+q_t)} \tag{10}$$

Risk-neutral survival probabilities are calculated from CDS spreads by mean of the "bootstrapping procedure". Starting with a 1-period CDS contract the implied value of q_1 is worked out. For a 2-period CDS contract, knowing q_1, q_2 is worked out and so forth.

The followings are the formulas for working out the risk-neutral-survival probabilities from CDS spreads:

$$\mathrm{M}_N = \sum_{t=1}^{N} D_t q_{t-1},\ \hat{M}_N = \sum_{t=1}^{N} D_t q_t\ ,\ \alpha = \frac{S_N \Delta}{2(1-R)} \tag{11}$$

$$\mathrm{q}_N = \frac{1}{D_N}\left[M_N\left(\frac{1-\alpha_N}{1+\alpha_N}\right) - \hat{M}_{N-1}\right] \tag{12}$$

3.4 Calculating the basis

The methodology applied to calculate the CDS-bond basis is based on the bonds' cash-flows replication argument. The bond is priced according to the risk-neutral valuation paradigm using the Libor curve as the risk-free benchmark, risk-neutral default probabilities implied from the CDS curve, an assumed recovery rate. The basis is calculated by shifting the entire Libor curve, in the bond pricing model, up or down until the present value of the cash flows of the bond equals the market price of the bond; the basis is exactly the shift of the Libor curve measured in basis points. For example, if the Libor curve has to be shifted up it means that the market price of the bond is lower than the price of the bond gotten using information from the CDS curve, meaning that the bond trades cheaper than CDS, i.e. the basis is negative. In a similar way, if the Libor curve has to be shifted down it means that the market price of the bond is higher than the price of the bond gotten get using information from the CDS curve, i.e the basis is positive.

Since the cash-flow replication argument is used each coupon is "hedged". Additionally, this methodology accounts the fact that the bond has fixed coupon and that it may trade away from par because the level of the interest rate curve (risk free rate and CDS) may change after the bond has been issued; and also that the curve may have different shapes.

4 Numerical applications

In the subsequent numerical application the "I-basis" is calculated, basing on the argument of section 3, as the difference between the CDS and the bonds' yield spread[6], given by yield-to-maturity minus swap rate, all having the same maturity. Instead, the "basis" is calculated by mean of the replication argument described in section 4.1. We take the "basis" as the benchmark and we define as the "basis-error" as the difference between the I-basis and the basis.

4.1 The "basis-error"

The objective of this section is to show the behavior of basis-error under different assumptions on the level, the change in the level and the shape of the swap rate and of the CDS curves. Interpretations of the results are provided then in the subsequent dedicated sections.

As a starting point, consider a 4-years maturity bond, with a 7% coupon, a face value of 100 and a recovery rate of 40%. One at a time the following operations are applied: the level of swap rate curve is shifted from 2 to 8%, the level of the CDS curve is shifted from 2 to 12%, the basis is set in the range between 100 bps and -300 bps, and the shapes of the swap rate and the of CDS curves are changed. Then the basis-errors for all the cases are reported.

Table 1 shows the basis-errors when both the swap rate and the CDS curves are flat and their level is such that the bond is at par. The basis-errors are reported in the following three cases: when the swap rate and the CDS curves have an intermediate level, when the swap rate curve is low and the CDS curve is high, and when the swap rate curve is high and the CDS curve is low.

INSERT TABLE 1 HERE

Table 1, Part (a) shows that, even in the "base case", when the swap rate and the CDS curves are flat, the bond is at par, and the basis is set to be zero, the basis-error is

[6] The CDS contract is written on the same entity that has issued the bond.

negative and substantial. This is due to ”coupon risk”. Table 1, Parts b) and c) show that for the same bond when the CDS curve is proportionally higher then the swap rate curve the basis-error is larger. Table 1, Parts a) and d) show that for the same level of the CDS curve when the coupon of the bond is higher the basis-error is larger. Both a higher CDS curve, i.e. higher risk neutral probabilities, and a higher coupon make the ”coupon risk” issue more relevant.

Table 2 shows the basis-errors when both the swap rate and the CDS curves are flat, at different levels, and for different levels of the basis.

INSERT TABLE 2 HERE

The impact of a swap curve shift depends on the shape of the CDS curves. For example, as shown in Table 2, Part a), b), c), d) and e) in the situation in which the CDS curve is flat the impact of a shift in the level of the swap curve is small. As shown in Table 5, Part a), b), c), d) and e), when the CDS curve is not flat the impact of a change of the swap rate curve is quite substantial.

The impact of increasing the level of the CDS curve is quite relevant. For example, as shown in Table 2 Part a), in the case in which the basis is 0 and both the swap rate and CDS curves are flat: when the level of the CDS curves increases from 2 to 12% the basis-error goes first from -18.6 to -39.5 and then it decreases it, -18.4. Note that this convexity effect holds for each level of the swap curve.

Table 3 shows the basis-errors when the swap rate curve is positively sloped at 20 bps per year while the CDS curve is flat, for different level of the basis.

INSERT TABLE 3 HERE

Table 4 shows the basis-errors when the swap rate curve is negatively sloped at -20 bps per year while the CDS curve is flat, for different level of the basis.

INSERT TABLE 4 HERE

As shown in Tables 2, 3 and 4 the shape of the swap curve affects the size of the basis-errors.

Table 5 shows the basis-errors when the swap rate curve is flat while the CDS curve is positively and negatively sloped.

INSERT TABLE 5 HERE

As shown in Table 5, the shape of the CDS curve affects the size of the basis-errors.

For fixed levels of the swap and of the CDS curves, in all the examples reported above, the basis size has a small impact on the basis error, below 5 bps.

Note that, in the different cases the basis-errors are quite relevant. The sign of the error is generally negative and size goes from -45 bps to +98 bps.

The basis-errors originates from two order of reasons. First, as shown in section 3, in the arbitrage argument that supports the relation between the CDS and the yield spread the hedge is not perfect, because there is the "coupon risk" issue. Second, the parity relation between CDS and the bond spread is based on the assumptions that, the level of the swap rate and of the CDS curves are constant in time, hence the bond stays always at par, and that the curves are flat; which is not true in general. If the bond is a floating rate bond, there is no need of the assumption of constant curves, but the focus of the paper is on fixed rate bonds that are the vast majority. Since fixed rate bonds may go far away from par, when the level of the interest rate curve changes dramatically, an additional risk factor that comes into play, in the arbitrage trade discussed in paragraph 3, is the recovery assumed on the corporate bond. The basis calculation methodology proposed in section 4, hedges both coupon and recovery risk and accounts for the fact that the swap rate and CDS curves may be not flat.

The rest of this section discusses the size of the basis-error under different assumption on the level the change of the level and the shape of the interest rate curves.

4.2 Coupon risk

The arbitrage argument that supports the I-basis calculation methodology, discussed in paragraph 3, is only approximate, because default may happen at any time and there is the "accrued coupon" issue. In practice, the synthetic CDS position does not hedge against coupon risk. As shown Table 1, Part a) even in the "base case", when the swap rate and the CDS curves are flat and the bond is at par, the basis-error is substantial. The basis-error is negative because the long synthetic CDS spread, given by YTM-swap rate is larger than the CDS observed in the market, which is the one used to calculate the I-basis. This is due to the fact that, an arbitrageur that buys a n-year risky bond and buys protection on it is not compensated for the accrued coupon in case of default. In the synthetic CDS trade the coupons should be hedged, during all the life of the bond; this is exactly what the bonds' cash flow replication argument, proposed in paragraph 4, does.

As shown in Table 1, Parts b) and c) when the level of the CDS curve is proportionally higher than the swap curve, and the level of the swap rate curve adjusts to keep the bond at par, the basis-error increases. When the CDS curve level is high risk neutral default probabilities are higher and "coupon risk" increases. As shown in Table 1, Parts a) and d) when the the coupon of the bond is larger, the level of the CDS curve does not change and the level of the swap rate curve adjusts to keep the bond at par, the basis-error increases. Again the "coupon risk" is higher.

In the numerical application discussed above, the swap rate and the CDS curves are flat and the corporate bond is always at par, in such a way to highlight the effect of the level of the curves and of the coupon size. As a consequence of the "coupon risk" issue we observe a larger basis-error for a bond when default risk increases, but also we also observe a larger basis-error, in the cross-section, for lower rated bonds that have generally higher coupons and higher default probabilities.

4.3 Shifting the swap-rate curve

What is the impact on the basis-error of a shift of the swap curve?

The answer depends on the shape of the CDS curve. For example, as shown in Table

2, in the situation in which the CDS curve is flat the impact of a change in the level of the swap curve is negligeble. When CDS curve is flat the risk neutral default probabilities (Q's) are independent from the swap rate curve. The proof of this proposition can be found in the Appendix A. Hence, if a bond is initially at par, a swap curve shift has the only effect of driving the bond away from par. As shown in Table 6, Part a) the effect of shifting the swap curve when the CDS curve is flat is only few basis points. The error goes from - 24.3 to -26.bps.

INSERT TABLE 6 HERE

When the bond gets below par the basis-error is larger slightly larger. The I-basis calculation methodology is based on the YTM, hence the basis error is due to the fact that the bond goes respectively above and below par, hence the YTM slightly decreases or increases.

When the CDS curve is not flat the impact of a shift in the level of the swap rate curve is quite substantial. As shown in Table 6, Part b) and c) the error goes from -18.1 to -39.5 bps and from -30.1 to -13.8 bps depending on whether the CDS curve is positively sloped or negatively sloped. When the CDS curve is not flat it is built in such a way that the CDS having the maturity of the bond is always the same. So in the case of Table 6, the 4-year CDS is at a 2.75% in all three cases: when the curve is flat, when the curve is upward sloping and when it is downward sloping.The purpose of doing this is to show that the I-basis calculation methodology is not sensitive to the fact that curves may have different shapes[7].

Note that when the CDS curve is not flat and the swap rate curve shifts the risk neutral default probabilities in the bootstrapping formula (9) in section 4.4, for calculating the basis, do change. As shown in Table 7, Part a) when the CDS curve is positively sloped, the risk-neutral default probabilities, are low on the short hand of the curve and they are high on the long hand of the curve they, but most importantly they increase when the

[7]Hence, the effect of shifting the swap rate curve on the basis-error originates from the violation of the assumptions on which the I-basis calculation is based; the assumption of a flat interest rate curve

swap rate curve shifts upward, driving the basis-error larger, because the "coupon risk" increases.

INSERT TABLE 7 HERE

Differently, as shown in Table 7, Part b) when the CDS curve is negatively sloped, the risk-neutral default probabilities are high in the short hand of the curve and they are low on the long hand of the curve and when the swap rate curve shifts upward they decrease driving the basis-error smaller, because the "coupon risk decreases". As a result, in the case of bond at par, when the swap rate curve shifts upward from 4% to 6%, if the CDS curve is positively sloped the basis error increases from -25.2 to -32.4 bps, if the the CDS curve is negatively sloped the basis error decreases from -25.2 to -19.8 bps. When the swap rate curve shifts downward from 4% to 2%, if the CDS curve is positively sloped the basis error decreases from -25.2 to -18.1 bps, if the the CDS curve is negatively sloped the basis error increases from -25.2 to -30.1 bps.

The same effect of the swap curve shift on the basis error can be seen in Table 5, Parts a) and b). Basis-errors originate from the different risk-neutral default probabilities that are implied in CDS curves with different shapes.

When the swap rate curve shifts the impact on the basis-errors for bonds with different rating is different. In fact, generally low rating categories have inverted[8] CDS curves.

4.4 Shifting the CDS curve: bond away from par and recovery risk

As shown in Table 2, the impact of increasing the level of the CDS curve is relevant. In the case in which the basis is 0 and both the swap rate and CDS curves are flat: when the level of the CDS curves increases from 2 to 12% the basis-error goes first from -18.6 to -39.5 and then when the CDS curve is extremely high it decreases it, -18.4. This convexity effect is the result of the interaction between the "coupon risk" and the "recovery risk": as the CDS curve increases and the risk neutral probabilities of default become higher the "coupon risk" increases, with a negative effect on the basis-error, but at the same time

[8] An inverted interest rate curve is a curve which is downward sloping.

the bond goes far below par and the ”recovery rate risk ” comes into play with a positive effect on the basis error. The impact is the greatest for bonds that are significantly away from par. The idea is that in the arbitrage argument, discussed in section 3 the recovery is not hedged, and this impacts on the profit-loss loss position.

This is illustrated by mean of the following example. Consider a bond with a price of 60 and a par value of 100. To hedge a long position on this bond an investor buys 0.6 CDS contracts. If he would buy 1 CDS he would be over-hedged. Now consider, in the event of default, the two following recovery rates 0, and 0.4. In the case of zero recovery the investor would receive 60 on the CDS and loose 60 on the bond; the net is zero. In the case of 0.4 the investor would receive 36 on the CDS (0,6*60) and loose 20 on the bond (bought the bond for 60 and gets 40 in default), with a net gain of 16. But for different recoveries profit and losses may be different.

As shown in Table 8, Part a) the ”recovery risk” dominates the ”coupon risk” only when the level of the CDS curve is very high, at 12%, because the bond is far from par.

INSERT TABLE 8 HERE

Table 8, Part b) shows that in the case of 0 recovery the only effect at work, when the CDS increases, is ”coupon risk”, while when the recovery rate is 0.4 or 0.6, ”recovery risk” comes into play. This effect is larger when the recovery rate is higher. In Table 8, Part b) the reason why, for lower recoveries and the swap rate and the CDS rate at 2% the basis error is smaller, is because, in the pricing model, for the same level of CDS when we decrease recovery, risk neutral default probability becomes smaller hence also ”coupon risk”.

When the CDS curve shifts the impact on the basis-errors is non trivial because of the interaction of the ”coupon risk” and the ”recovery risk”. Generally low rating categories have higher coupons and lower recoveries making the basis-error more negative and more sensitive to changes of default risk.

4.5 The shape of the swap rate curve

Let's assume CDS curve is flat, so that movements of the swap curve do no impact on the risk neutral default probabilities. In such a situation the zero rate curve is given by the swap curve plus a constant spreads. Following the logic of the yield to maturity when the zero curve is flat, and the bond is at par, the YTM of the bond coincides with the zero curve. As already discussed, in such a situation, the negative basis-error is due to the "coupon risk" effect, the size of the error is shown in Table 2, Part a). When the zero curve is upward sloping the YTM (that is the weighted average of all zeros) is lower the zero rate curve. Since the I-basis is calculated as CDS-YTM-swap rate, the upward sloping swap rate has a positive effect on the basis-error, compensating, in part, the "coupon risk" effect. Differently, when the zero curve is downward sloping the YTM is higher than the zero rate curve, the effect on the basis-error is negative, and summed with the "coupon risk" effect it makes the basis-error more negative.

As shown in Table 2, 3 and 4, Part a). When the swap curve is upward sloping the basis error is negative, but smaller than in the case of a flat swap curve. When the swap curve is downward sloping the basis error is negative and larger than in the case of a flat swap curve.

4.6 The shape of the CDS curve

What is the impact of the shape of the CDS curve on the basis error ?

As shown in Table 9, Part a), b) and c) when the bond is at par, the basis-error is not affected by the shape of the CDS curve.

INSERT TABLE 9 HERE

While, when the bond is away from par the shape of the CDS curve matters. I recall the argument of section 4.3. When the CDS curve is not flat and the swap rate curve shifts the risk neutral default probabilities in the bootstrapping formula (9), for calculating the basis, do change. As shown in Table 7, Part a) when the CDS curve is positively sloped, the risk neutral default probabilities, are lower on the short hand of the curve and they are higher on the long hand of the curve, but most importantly they increase when the swap rate curve shifts upward, driving the basis-error larger, because the "coupon risk" increases. Instead, when the swap rate curve shifts downward risk neutral default probabilities decrease driving the basis-error smaller, because the "coupon risk" reduces.

Differently, as shown in Table 7, Part b) when the CDS curve is negatively sloped, the risk neutral default probabilities are high in the short hand of the curve and they are low on the long hand of the curve. When the swap rate curve shifts upward risk neutral default probabilities decrease driving the basis-error smaller, because the "coupon risk" decreases. When the swap rate curve shifts downward risk neutral default probabilities increase driving the basis-error larger, because the "coupon risk" increases.

As show in Table 9. Starting from the case of bond at par, when the swap rate curve shifts upward from 4% to 6%, if the CDS curve is positively sloped the basis error increases from -25.2 to -29.9 bps, and is larger than in the case of a flat CDS curve. If the CDS curve is negatively sloped the basis error decreases from -25.2 to -22 bps, and is smaller than in the case of a flat CDS curve. When the swap rate curve shifts downward from 4% to 2%, if the CDS curve is positively sloped the basis error decreases from -25.2 to -20.4 bps, and is smaller than in the case of a flat CDS curve, if the the CDS curve is negatively sloped the basis error increases from -25.2 to -27.9 bps, and is larger than in the case of a flat CDS curve.

When the CDS curve shifts upward, in the case in which the slope of the curve is positive, default probabilities increase proportionally more then in the case of a flat curve, while when the slope of the curve is negative default probabilities increase less proportionally. Hence, in the first case the basis error becomes larger, in the second it becomes smaller than when the curve is flat. When the CDS curve shifts downward, in the case in which the slope of the curve is positive default probabilities decrease proportionally more then in the case of a flat curve, while when the slope of the curve is negative default probabilities decrease proportionally less. Hence, in the first case the error becomes smaller, in the second it becomes larger the when the curve is flat.

To summarize, when the CDS curve is steep, risk-neutral default probabilities react more to changes in the level, than when the curve is flat. When it is inverted they reacts less. The effect on the basis-error goes trough the impact of risk neutral default probabilities on "coupon risk".

4.7 Is the size of the basis relevant?

As shown in Table 2, across Part a), b) c), d) and e), the basis-errors is not very sensitive to the level of the basis. The size of the basis is determined by the shift of the level of swap curve, in the bond pricing model. The impact of shifting the level of the swap curve has been already described. Both when the CDS curve is flat and when the CDS curve is not flat.

4.8 The I-basis vs the z-basis

Among others, one short fall of the I-basis calculation methodology is it assumes the swap rate curve is flat. A measure of the basis that takes into account the shape of the swap rate curve is the z-basis. The z-basis is defined as the difference between the CDS and the z-spread of the bond. The z-spread is the spread that would need to be added to the swap rate curve such that the discounted cash flows of the bond are equal to the market price of the bond. This measure of the basis, compared to the I-basis, takes into account the shape of the swap curve, hence the two measures are different only when the swap rate curve is not flat.

Table 10 shows the basis errors and in () the errors between the I-basis and the z-basis.

INSERT TABLE 10 HERE

The CDS curve is flat and is at 2.75 in all cases. In the first line, the swap rate is flat, then positively sloped at 20 bps per year, then positively sloped at 40 bps per year, then negatively sloped at -20 bps per year, finally negatively sloped at -40 bps per year. The basis is zero. When the swap curve is flat the error between the I basis and the z-basis is zero in all cases. This holds when the bond is below, or above par, for all the levels of the curves and whatever the shape of the CDS curve[9].

When the swap curve is positively sloped the z-basis is negative and larger then the I-basis, for example when the swap rate is 4% and the slope of the swap curve is 40 bps, the z-basis is -27.2 while the I basis is -20.4. The basis calculated with the bonds' cash flow replication argument is zero, hence the bases above corresponds to the basis-errors. When the swap curve is negatively sloped the z-basis is negative and smaller then the I-basis, for example when the swap rate is 4% and the slope of the swap curve is -40 bps the z-basis is -23.2 while the I-basis is -29.9.

This follows from the logic of the yield to maturity. When the zero curve is flat, and the bond is at par, the YTM of the bond coincides with the zero rate curve. As already discussed, in such a situation, the negative basis-error is due to the "coupon risk" effect, but the I-basis and the z-basis coincide. When the zero curve is upward sloping the YTM (which is the weighted average of all zeros) is lower than the zero rate at the maturity of the bond. Since the I-basis is calculated as [CDS-(YTM-swap rate)], the upward sloping swap rate curve has a positive effect on the basis-error, compensating, in part, the "coupon risk" effect. The z-basis calculation methodology accounts for the shape of the swap curve, hence, following the logic of the zeros, the z-spread is larger than the bond spread and the z-basis is negative and larger than the I-basis. Differently, when the swap curve is downward sloping the YTM is higher than the zero rate curve. It follows that the bond spread is larger than the z-spread and that the I-basis is negative and larger than the z-basis.

The z-basis is a measure that only marginally improves the measurement of the true size of the basis.

[9]We do not report tables for brevity of exposition.

5 An empirical exploration of the "basis error"

This section illustrates the behavior of the "arbitrage-free" basis and the I-basis, for a sample of US firms, in the period that goes from January 2006 to November 2008. The idea is to highlight the impact of the dramatic shift of the risk-free and the risky term structure, in the period during the financial crisis, on the basis error.

5.1 Calculating the basis

The CDS-bond basis is calculated using the bonds' cash-flows replication argument, presented in section 3, on a daily basis. For each entity on each day the risk-neutral survival probabilities for all maturities from the CDS curve are bootstrapped. This approach is such that the basis is calculated on bonds, with different maturities, that are actually traded. Most existing studies on the CDS-bond basis such as Longstaff et. al. (2005), Blanco et.al (2005), Zhu (2006) and Subrahmanyam et.al (2008) use only 5 year CDS data and focus on 5-year maturity bond, with constant maturity, constructed synthetically. This method might introduce an approximation error and allows to focus only on one maturity restricting the sample size; additionally it does not consider bonds that are actually traded, hence for this synthetic bonds there are no observable transaction data.

5.2 Data

Bonds' intraday transaction data are taken from NASD's TRACE (Trading Reporting and Compliance Engine), bonds' static information from Fixed Income Security Database(FISD), CDS data from Markit and the Libor/swap curve from the FED database. The sample runs from January 1, 2006 trough November 17, 2008. This period is characterized by three different market regimes. From January 2006 to August 2007 financial markets are stable. In the beginning of August 2007 the crisis started. After the Lehman crash (15 September 2008) the situation become even worst.

5.3 Sample selection

The bond price corresponds to the closing price defined as the last price observed in a day on an institutional trade[10]. Cusip ids (unique bond identifier number) are used to merge bond prices data with static info, such as coupon and maturity, from the FISD database. Only senior unsecured U.S dollar denominated bonds issued by U.S. firms that pay fixed semi-annual coupons are selected. Bonds that are callable, puttable or convertible are not considered [11]. Firm tickers (unique entity identifier number) are used to merge bond data with CDS premia provided by Markit. Markit provides CDS quotes with maturities from 6 month to 30 years.[12] Following common practice, the analysis is restricted to CDS corresponding to the modified restructuring clause for U.S. dollar denominated notional values.

INSERT TABLE 11 HERE

As shown in Table 11, the sample consist of 1477 bonds for 277 firms, with an average of 6.5 bonds per firm. The vast majority of the bonds are rated A and BBB.

INSERT TABLE 12 HERE

It is evident from Table 12 that bonds in general are thinly traded. The median bond trades on average between 2 and 4 times a day. The most actively traded bonds are those rated B. AAA and BBB are characterized by the highest trading volume. On average we observe two institutional trade, i.e. size of trade larger that 100 bonds, per day on a bond. In the analysis, the focus is on bonds with remaining maturity between 2 and 10 years. Moreover, each day a reference entity enters into the sample if CDS quotes are non-missing for maturities from 1 to 10 years.

[10]Usually the size of institutional transactions is larger than 100 bonds, corresponding to a par value of 100.000 $.

[11]Data errors are removed following the practice of other studies on the TRACE dataset such as Edwards, Harris, and Piwowar (2007), deleting observations when information are missing or prices are outliers.

[12]In Markit, daily quotes are averages of mid prices provided by at least three major dealers.

INSERT TABLE 13 HERE

As shown in Table 13, the final sample reduces to 695 bonds for 138 firms, with an average of 5 bonds per firm. The number of bonds vary by bond rating group. The vast majority of the bonds are rated A and BBB. As expected, the coupon is the highest for lower rated bonds. The maturity is approximately constant across rating groups. The recovery rate is slightly lower for lower rated bonds.

5.4 The I-basis, the basis and the "basis error"

Results on the classical BASIS (I-basis):

1) As shown in figure 1, the classical basis exhibit time-series variation and its behavior is differentiated for rating categories:

- It is positive for AAA. The AAA basis explodes during the crisis: this might be due to the flight to quality which drives bond spreads lower than CDS; also bond yields on AAA may be lower then the swap rate, while the CDS is bounded positive.
- It is negative for AA, A, BBB and BB: during the crisis, the lower the rating the more negative the basis.
- It is both positive and negative for B: One potential explanation of this result is the limits-to-arbitrage i.e. funding liquidity risk (rates and margins), and bond market liquidity deterioration, are more severe for lower rated bonds. In the case of B there might be a Cheapest to deliver option issue to inquire.

2) There is also a lot of cross-sectional variation within each rating class. Figure 2 shows the time-series of the p25, the median and the p75 for BBB basis. Figure 3 shows all the transactions on the 119 BBB bases in the sample, and gives an idea of the dispersion. These are examples, but a similar behaviour is observed also for the other ratings.

3) Table 14 reports the statistics of the distribution of the three different measures of the basis in the three different periods (pre-crisis, pre-Lehman and Lehman crash), for each rating.

- In the first period there is evidence of the so called basis smile. The basis is positive and substantial for AAA, it is smaller for AA, and it is just few basis points for A. It is slightly negative for BBB, negative for BB, but it is again positive for B.

- In the second period the basis for AAA increases, for AA and A it decreases slightly, while for BBB and BB it becomes negative. For B it reduces, but it is still positive. Note that the (adjusted) basis obtain via replication argument behaves differently then the classical I-basis.

- In the third period the AAA basis stays positive and also the B basis. For all the other rating the basis shifts dramatically into negative territory.

4) The three measures of the basis co-move in time. Figure 4 shows the time-series evolution of the median for the three different measures of the bases for the AA rating group. Figure 5 shows the time-series evolution of the I-basis and the arbitrage free (adj) basis for a single bond. These are representative cases for a rating group and a single bond. Before the crisis all measures of the basis are approximately the same, while since the onset of the crisis the adjusted basis is by far less negative than for the other two measures (basis and z basis), which are quite similar to each other.

5) The size of the basis error defined as the difference between the classical basis and the basis calculated with the replication argument is quite substantial. During the crisis the basis is generally less negative than the classical basis. Table 15 reports the statistics of the distribution of the errors between the three different measures of the basis in the three different periods (pre-crisis, pre-Lehman and Lehman crash), for each rating.

- In period one the error between the classical measure of the basis and the adjusted basis is generally small and negative, for BB and B it is negative (i.e. the classical basis is more negative than the adjusted basis) and quite substantial. For BB the median error between the basis and the adjusted basis is -27.21, the lowest 5th percentile is -55.74 the 95th percentile is -5.38. For B the median error is -72.37, the 5th percentile is -104.76 and the 95th is -26.13 bp.

- In the second period, except for AAA, the errors are still negative but they become larger: For BB the median error between the basis and the adjusted basis is -66.58, the lowest 5th percentile is -171.58 the 95th percentile is -15. For B the median error is -110.88, the 5th percentile is -358.02 and the 95th is -18.13bp.

- In the third period the errors are negative and become even larger. For BB the median error between the basis and the adjusted basis is -100.67, the lowest 5th percentile is -406.80 the 95th percentile is -41.93bp. For B the median error is -64.14, the 5th percentile is -545.67 and the 95th is -1257.77bp. Note the strange behavior of the B basis: the dispersion of the error is huge. In general factors that explain the error have a higher impact for lower rating categories and for periods in which default risk is higher.

6) As illustrated in section 4, the basis error is explained by factors such as the level of the swap rate and the CDS curves, their shape, the size of the coupon of the bond and the fact that bonds are generally away from par. Figure 6 shows the time evolution of the swap rate curve. And figure 7 shows the time evolution of the CDS curve for the AA rating group. Since August 2007 the swap rate curve has become steeper, while the CDS curve for AA has shifted dramatically upward. The movement of these curves before vs. during the crisis do explain the basis error” changes from one period to the other.

6 Conclusion

This paper has proposed a methodology for measuring the pricing differential between the CDS and the corporate bond market based on the bonds' cash flow replication argument, which is equivalent of putting on a series of coupon strips synthetically to hedge each coupon of the bond. The key contribution is that this methodology accounts for the fact that the bond may be away from par and that the interest curves may have different shapes.

Numerical applications show that this error could be very large and also show how this measure behaves with respect to the I-basis under different assumptions on the level and the shape of the risk-free and the CDS term structures. In particular, five are the stylized facts. First, because of the "coupon risk" issue a bond with higher default risk or a higher coupon has a larger basis error. Second, the shift of the swap rate curve has a different impact on the basis error depending on the shape of the CDS curve. Third, the shift of the CDS curve level has a convex impact on the basis-errors. The convexity is the result of the interaction between the "coupon risk" and the "recovery risk". Fourth, when the swap curve is upward sloping the basis error is negative, but slightly smaller than in the case of a flat swap curve. When the swap curve is downward sloping the basis error is negative and it slightly larger than in the case of a flat swap curve. Fifth, when the CDS curve is steep risk neutral default probabilities are more reactive to changes in the level, than when the curve is flat. When it is inverted they are less reactive.

Finally, an exploration of the empirical behavior of the basis is proposed. Using corporate bonds' transaction prices from the TRACE and CDS premia provided by Markit in the period between 2006 and 2008 it is shown that the "arbitrage-free" measure of the basis and the I-basis co-move and are approximately zero before the crisis, while during the crisis they have become both negative, but the "arbitrage-free" basis is smaller in absolute.

APPENDIX A

Proposition: When the CDS curve is flat the Q's are completely independent of the LIBOR curve.

The formula for "bootstrapping" the CDS curve to derive Risk-neytral-survival probabilities is:

(1) $q_N = \{\frac{1}{D_N}\} \left[M_N(\frac{1-\alpha_N}{1+\alpha_N}) - \widehat{M}_{N-1} \right]$ where:

(2) $M_N = \sum_{t=1}^{N} D_t q_{t-1}$ (2) $\widehat{M}_N = \sum_{t=1}^{N} D_t q_t$ (4) $\alpha_N = \frac{S_N}{2(1-R)}$

D_t and q_t are respectively the discount factor and the RN-survival probabilities for time t. S_N is the CDS spread with maturity N and R is the recovery rate.

Assume (5) $q_{(N-1)} = x^{(N-1)}$ i.e. risk neutral survival probabilities are constant (CDS curve is flat). Then $q_N = q_{(N-1)} * x = x^{(N-1)} * x = \frac{x^N}{x} * x$, i.e. (6) $q_N = x^N$.

From (1) and (2) we get that $q_1 = (\frac{1-\alpha_1}{1+\alpha_1})$ and, since the CDS curve is assumed to be flat (7) (i.e. $\alpha_1 = \alpha_2 ... = \alpha_n$) $q_1 = x^1 = x^2 .....x^N = (\frac{1-\alpha}{1+\alpha})^N$. Hence the Q's are completely independent of the LIBOR curve.

I facts, when $Q_N = x^N$ the relation between M and $\widehat{M}$ is such that (8) $M_N = \frac{\widehat{M}_N}{x}$.

Now take (1): $\mathrm{q}_N = \{\frac{1}{D_N}\} \left[M_N(\frac{1+\alpha_N}{1-\alpha_N}) - \widehat{M}_{N-1} \right]$ using(8) :

$\mathrm{q}_N = \{\frac{1}{D_N}\} \left[\frac{\widehat{M}_N}{x}(\frac{1+\alpha_N}{1-\alpha_N}) - \widehat{M}_{N-1} \right]$, substituting $\widehat{M}_n$we get:

$\mathrm{q}_N = \{\frac{1}{D_N}\} \left[\sum_{t=1}^{N} \frac{D_t q_t}{x}(\frac{1+\alpha_N}{1-\alpha_N}) - \sum_{t=1}^{N-1} D_t q_t \right]$ using(6) :

$\mathrm{q}_N = \{\frac{1}{D_N}\} \left[\sum_{t=1}^{N} \frac{D_t x^t}{x}(\frac{1+\alpha_N}{1-\alpha_N}) - \sum_{t=1}^{N-1} D_t x^t \right]$

$\mathrm{q}_N = \{\frac{1}{D_N}\} \left[\sum_{t=1}^{N} D_t x^{t-1}(\frac{1+\alpha}{1-\alpha}) - \sum_{t=1}^{N-1} D_t x^t \right]$ using(7) :

$\mathrm{q}_N = \{\frac{1}{D_N}\} \left[\sum_{t=1}^{N} D_t x^t - \sum_{t-1}^{N-1} D_t x^t \right]$

Finally: $q_N = \{\frac{1}{D_N}\} \left[D_N x^N \right] \dot{s}o$ $\mathrm{q}_N = x^N$ and $\mathrm{q}_N = (\frac{1-\alpha}{1+\alpha})^N$.

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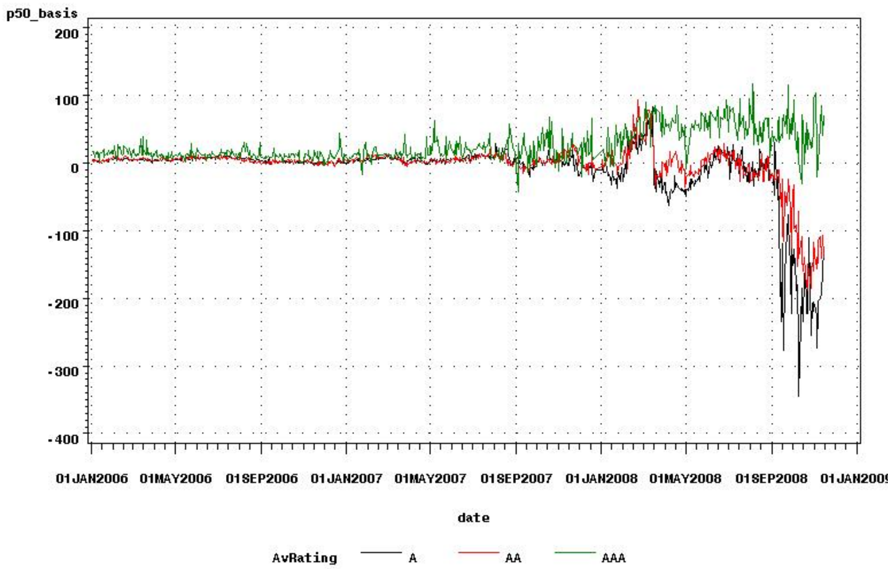
Figure 1: **Time-series of the I-basis by rating**. The first graph shows data for AAA, AA and A rating, while the second graph shows data for BBB, BB and B rating.



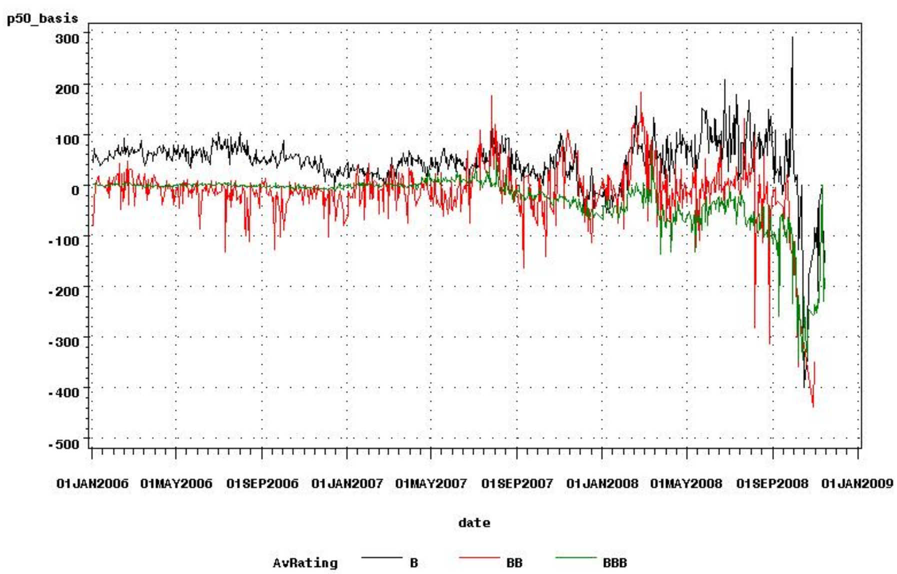


Figure 2: **Time-series of the I-basis**. This graph shows the time-series of the p25, the median and the p75 for the I-basis of the BBB rating group.

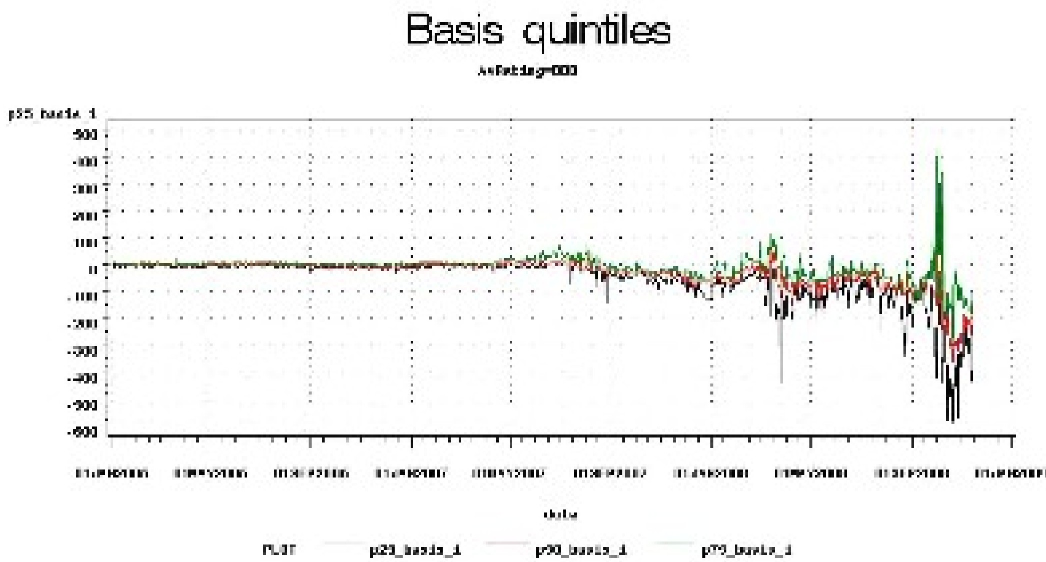


Figure 3: **Time-series of the I-basis**. This graph shows the basis for all the transactions on the 119 BBB bonds in the sample.

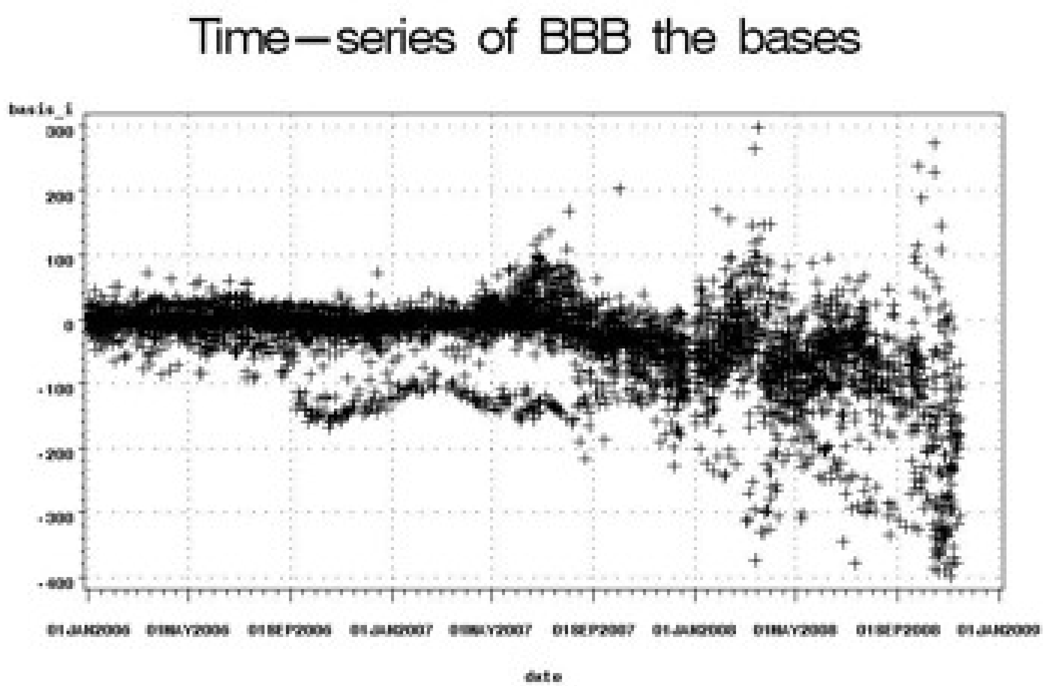


Figure 4: **Median basis for the AA rating group.** These graph shows the time-series evolution of the median for the three different measures of the bases: the adjusted basis (arbitrage-free), the z-basis and the I-basis.

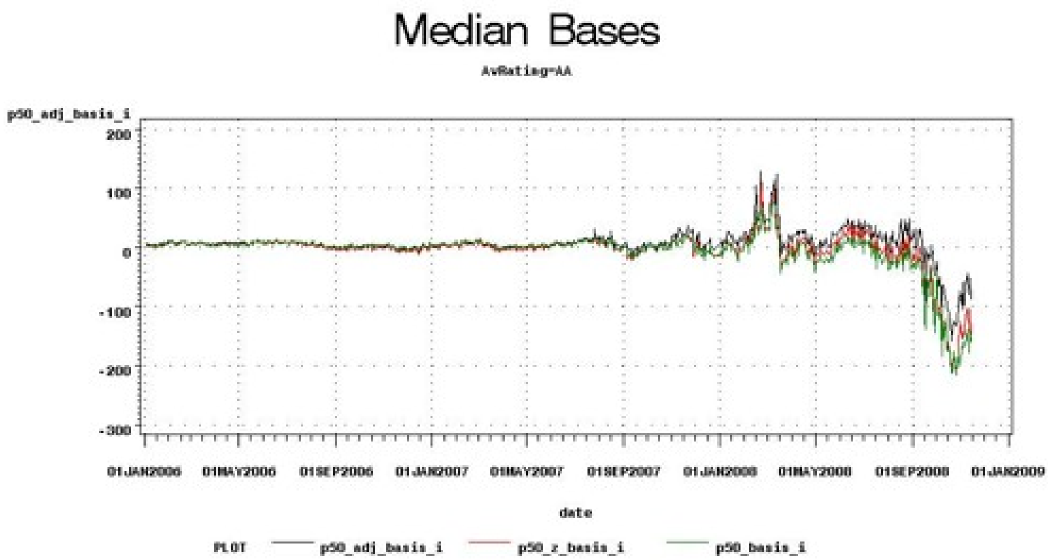


Figure 5: **Daily basis on a single bond.** This graph shows the time-series evolution of the I-basis and the adjusted basis (arbitrage-free) in the period January 2006 - November 2008

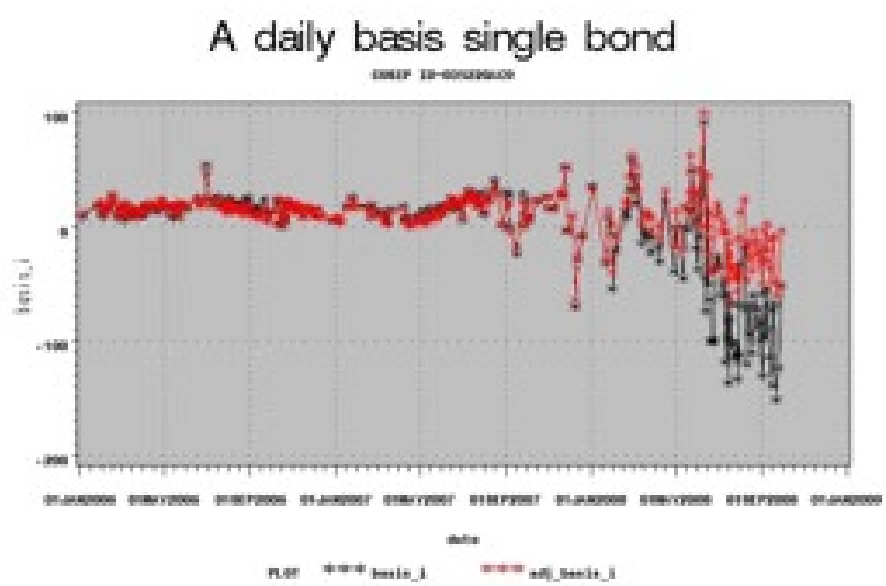


Figure 6: **Time evolution of the swap rate curve.** This graph shows the time-series evolution of the swap rates with maturities from 1 to 10 years in the period that goes from January 2006 to November 2008

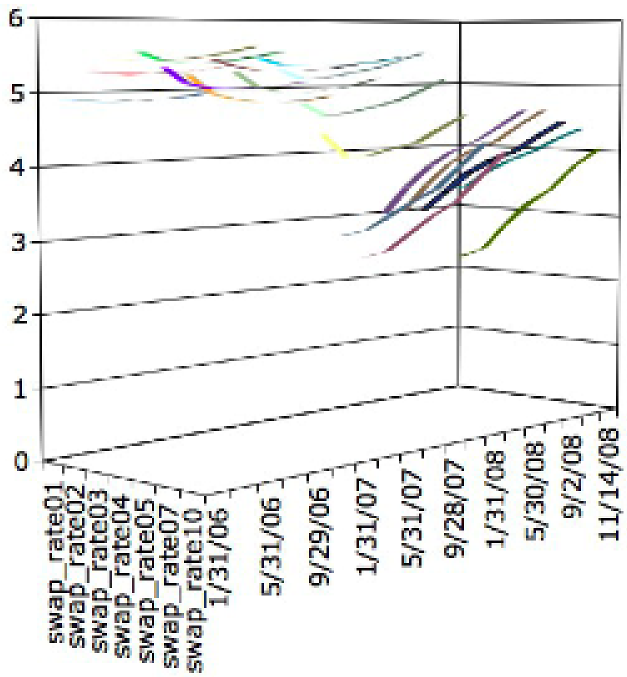


Figure 7: **Time evolution of the AA rating CDS curve.** This graph shows the time-series evolution of the CDS premia, for the AA rating group, with maturities from 1 to 10 years in the period that goes from January 2006 to November 2008.

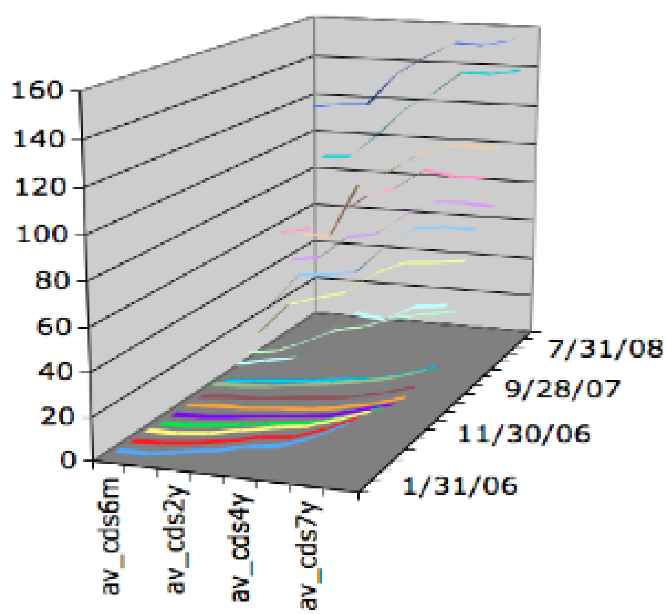


Table 1: **Basis-errors. Both the swap rate and the CDS curves are flat, the bond is at par, and the basis is set to be zero; "base case".** This table shows the basis-errors, expressed in basis points. Chart a) shows the basis error when the swap rate and the CDS curves have an intermediate level. Chart b) shows the basis error when the swap rate curve is low and the CDS curve is high. Chart c) shows the basis-error when the swap rate curve is high and the CDS curve is low. Chart d) shows the basis-error when the CDS curve is as in chart a), the swap rate adjusts to keep the bond at par, but the coupon of the bond is at 10%. In all cases the bond has 4-years to maturity, a recovery rate of 40% and a face value of 100. In a), b) and c) the coupon in 7% while in d) the coupon is 10%.

a) Bond at par p=100

Swap rate	4.00%
Cds	2.75%
Basis-error	-25.2

b) Bond at par p=100

Swap rate	1.00%
Cds	4.50%
Basis-error	-34.9

c) Bond at par p=100

Swap rate	5.00%
Cds	0.90%
Basis-error	-9.8

d) Bond at par p=100
Coupon=10%

Swap rate	6.85%
Cds	2.75%
Basis-error	-38.6

Table 2: **Basis-errors. Both the swap rate and the CDS curves are flat.** This table shows the basis-error, expressed in basis points. I report five cases in which the basis, has different sizes: chart a) 0, chart b) 100, chart c) -100, chart d) -200 and chart e) -300. The bond has 4-years to maturity, a 7% coupon a recovery rate of 40% and a face value of 100.

a)

Basis=0

Cds/Swap	2%	4%	6%	8%
2%	-18.6	-19.4	-20	-20.4
4%	-31.9	-32.9	-33.5	-33.8
8%	-39.5	-39.6	-38.8	-37.1
12%	-18.4	-15.5	-11.2	-5.6

b)

Basis=-100

Cds/Swap	2%	4%	6%	8%
2%	-19	-19.7	-20.2	-20.5
4%	-32.4	-33.3	-33.7	-33.7
8%	-39.7	-39.3	-38	-35.9
12%	-17.1	-13.5	-8.6	-2.4

c)

Basis=-200

Cds/Swap	2%	4%	6%	8%
2%	-19.4	-20	-20.4	-20.5
4%	-32.9	-33.5	-33.8	-33.5
8%	-39.6	-38.8	-37.1	-34.5
12%	-15.5	-11.2	-5.6	1.2

d)

Basis=-300

Cds/Swap	2%	4%	6%	8%
2%	-19.7	-20.2	-20.5	-20.5
4%	-33.3	-33.7	-33.7	-33.3
8%	-39.3	-38	-35.9	-32.9
12%	-13.5	-8.6	-2.4	5.2

e)

Basis=+100

Cds/Swap	2%	4%	6%	8%
2%	-18.2	-19	-19.7	-20.2
4%	-31.2	-32.4	-33.3	-33.7
8%	-39.2	-39.7	-39.3	-38
12%	-19.4	-17.1	-13.5	-8.6

Table 3: **Basis-errors. The swap rate curve is positively sloped at 20 bps per year while the CDS curve is flat.** This table shows the basis-error, expressed in basis points. I report five cases in which the basis, has different sizes: chart a) 0, chart b) 100, chart c) -100, chart d) -200 and chart e) -300. The bond has 4-years maturity, a 7% coupon a recovery rate of 40% and a face value of 100.

a)

Basis=0

Cds/Swap	2%	4%	6%	8%
2%	-15.7	-17.3	-18.7	-19.9
4%	-28.1	-30	-31.4	-32.4
8%	-34	34.8	34.7	-33.7
12%	-11	-8.7	-5	0

b)

Basis=+100

Cds/Swap	2%	4%	6%	8%
2%	-14.8	-16.5	-18.1	-19.4
4%	-27.1	-29.1	-30.7	-32
8%	-33.3	-34.5	-34.8	-34.3
12%	-11.6	-10	-7	-2.7

c)

Basis=-100

Cds/Swap	2%	4%	6%	8%
2%	-16.5	-18.1	-19.4	-20.5
4%	-29.1	-30.7	-32	-32.7
8%	-34.5	-34.8	.34.3	-32.8
12%	-10	-7	-2.7	2.9

d)

Basis=-200

Cds/Swap	2%	4%	6%	8%
2%	-17.3	-18.8	-19.9	-21.1
4%	-30	-31.4	-32.4	-33
8%	-34.8	-34.7	-33.7	-31.8
12%	-8.7	-0.5	0	6.2

e)

Basis=-300

Cds/Swap	2%	4%	6%	8%
2%	-18.1	-19.4	-20.5	-21.4
4%	-30.7	-32	-32.7	-33.1
8%	-34.8	-34.3	-32.8	-30.5
12%	-7	-2.7	2.9	9.9

Table 4: **Basis-errors. The swap rate curve is negatively sloped at 20 bps per year while the CDS curve is flat.** This table shows the basis-error, expressed in basis points. I report five cases in which the basis, has different sizes: chart a) 0, chart b) 100, chart c) -100, chart d) -200 and chart e) -300. The bond has 4-years maturity, a 7% coupon, a recovery rate of 40% and a face value of 100.

a)

Basis=0

Cds/Swap	2%	4%	6%	8%
2%	-21.5	-21.5	-21.2	-20.8
4%	-35.5	-35.8	-35.7	-35.1
8%	-45	-44.3	-42.8	-40.4
12%	-25.5	-22.2	-17.3	-11.2

b)

basis=+100

Cds/Swap	2%	4%	6%	8%
2%	-21.4	-21.5	-21.4	-21
4%	-35.2	-35.7	-35.8	-35.4
8%	-45	-44.7	-43.7	-41.7
12%	-27	-24.4	-19.9	-14.4

c)

Basis=-100

Cds/Swap	2%	4%	6%	8%
2%	-21.5	-21.4	-21	-21.5
4%	-35.5	-35.8	-35.4	-34.7
8%	-44.7	-43.7	-41.7	-38.9
12%	-24.4	-19.9	-14.4	-7.6

d)

Basis=-200

Cds/Swap	2%	4%	6%	8%
2%	-21.5	-21.2	-20.8	-20.1
4%	-35.8	-35.7	-35.1	-34.1
8%	-44.3	-42.8	-40.4	-37.2
12%	-22.2	-17.3	-11.2	-3.7

e)

Basis=-300

Cds/Swap	2%	4%	6%	8%
2%	-21.4	-21	20.5	-19.7
4%	-35.8	-35.4	-34.7	-33.4
8%	-43.4	-41.7	-38.9	-35.2
12%	19.9	14.4	-7.6	0.5

Table 5: **Basis-errors. The swap rate curve is flat in all cases while the CDS curve is positively and negatively sloped.** This table shows the error, expressed in basis points. I report five cases. In chart a) the basis is 0 and the CDS curve is positively sloped at 20 bps per year. In chart b) the basis is 0 and the CDS curve is at -20 bps per year. In chart c) the basis is 0 and the CDS curve is at -100 bps per year. In chart d) the basis is -200 and the CDS curve is at -200 bps per year. In chart e) the basis is -100 and the CDS curve is at is -200 bps per year. The bond has 4-years maturity, a 7% coupon and a recovery rate of 40% and a face value of 100.

a) Cds+ 20 Bps

basis=0

Cds/Swap	2%	4%	6%	8%
2%	-16.5	-18.8	-20.9	-23
4%	-31.3	-33.9	-36.2	-38.1
8%	-42.2	-43.8	-44.7	-44.8
12%	-24	-22.8	-20.3	-16.5

b) Cds- 20 Bps

basis=0

Cds/Swap	2%	4%	6%	8%
2%	-20.7	-20	-19.1	-17.8
4%	-32.2	-31.9	-30.9	-29.5
8%	-36.9	-35.4	-32.9	-29.4
12%	-12.9	-8.3	-2.3	5

c) Cds -100 Bps

basis=0

Cds/Swap	2%	4%	6%	8%
3%	-32.2	-26	-19	-11.5
4%	-34.3	-28	-20.9	-13.1
8%	-27	-19.2	-10.3	-0.3
12%	8.4	19.3	31.8	45.8

d) Cds -200 Bps

basis=0

Cds/Swap	2%	4%	6%	8%
2%	-38.1	-25.1	-11.3	3.3
4%	-36.6	-23.4	-9.2	6
8%	-15.3	-0.4	15.9	33.6
12%	33.2	51.4	71.3	92.9

e) Cds -200 Bps

basis=-100

Cds/Swap	2%	4%	6%	8%
2%	-36.8	-23.5	-9.4	5.5
4%	-35.5	-21.8	-7.2	8.5
8%	-13.5	2	18.9	37.1
12%	36.4	55.5	76.1	98.4

Table 6: **Basis-errors. This table show the effect of the change in the level of the swap curve** The basis-error is expressed in basis points. Chart a) shows the basis error when the swap rate curve shifts and the CDS curve is flat. Chart b) shows the basis-error when the swap rate curve shifts and the CDS is positively sloped at 80 bps per year. Chart c) shows the basis-error when the swap rate curve shifts and the CDS is negatively sloped at 80 bps per year. The basis is zero in both cases. The bond has 4-years to maturity, a 7% coupon and a recovery rate of 40% and a face value of 100.

a) Swap curve flat
CDS curve flat

basis=0

Cds/Swap	2%	4%	6%	8%
2.75%	**-24.3**	**-25.2**	**-25.7**	**-26.2**
Bond price	107.1	100	93.5	87.5

b) Swap curve flat
CDS curve +80 bps

basis=0

Cds/Swap	2%	4%	6%	8%
2.75%	**-18.1**	**-25.2**	**-32.4**	**-39.5**
Bond price	107.4	100	93.3	87.2

c) Swap curve flat
CDS curve -80 bps
basis=0

Cds/Swap	2%	4%	6%	8%
2.75%	**-30.1**	**-25.2**	**-19.8**	**-13.8**
Bond price	106.9	100	93.7	87.9

Table 7: **Shifting the swap rate curve when the CDS curve is not flat.** This table shows the Risk-neutral-default probabilities (Q_s) for the all the four years of the maturity of the bond, obtained by mean of the bootstrapping procedure described in paragraph 4.4., for different levels of the swap rate curve. For example RNQ_4 is the risk neutral probability of default in the time period between year 3 and 4. The swap rate curve is flat in both cases. Chart a) shows the Q_s when the swap rate curve shifts and the CDS is positively sloped at +80 bps per year. Chart b) shows the Q_s when the swap rate curve shifts and the CDS is negatively sloped at -80 bps per year. The basis is zero in both cases cases. The bond has 4-years to maturity, a 7% coupon and a recovery rate of 40% and a face value of 100.

a) CDS +80 bps

	RN Q_s 1	RN Q_s 2	RN Q_s 3	RN Q_s 4
Swap rate				
2%	0.0058	0.0325	0.0597	0.0884
4%	0.0058	0.0328	0.0606	0.0902
6%	0.0058	0.0330	0.0614	0.0921
8%	0.0058	0.0333	0.0623	0.0940

b) CDS -80 bps

	RN Q_s 1	RN Q_s 2	RN Q_s 3	RN Q_s 4
Swap rate				
2%	0.0823	0.0563	0.0289	0.0012
4%	0.0823	0.0560	0.0281	0.0000
6%	0.0823	0.0557	0.0272	0.0000
8%	0.0823	0.0554	0.0264	0.0000

Table 8: **Shifting the CDS curve.** Chart a) shows the basis-errors for different levels of the swap rate and the CDS curve. The curves are flat. The bond is at par when swap curve is at =4% and the CDS curve at 2.75% The bond has 4-years to maturity, a 7% coupon and a recovery rate of 40% and a face value of 100. Chart b) shows the basis-errors when the CDS curve shifts for different recovery rates. The swap rate and the CDS curves are flat. The bond has 4-years to maturity, a 7% coupon and a recovery rate of 60, 40, 25 and 0% and a face value of 100.

a)

Cds/Swap	2%	4%	6%	8%
2.00%	-18.6	-19.4	-20	-20.4
2.75%	-24.3	**-25.2**	-25.7	-26.2
4.00%	-31.9	-32.9	-33.5	-33.8
8.00%	-39.5	-39.6	-38.8	-37.1
12.00%	-18.4	-15.5	-11.2	-5.6

b)

CDS	Swap rate	R=0.6	R=0.4	R=0
2.00	4.00	-30.5	-19.40	-10.1
2.75	4.00	-37.1	-25.20	-15
4.00	4.00	-42.1	-32.90	-24.5
8.00	4.00	-8.7	-39.60	-66.7
12.00	4.00	96.3	-15.50	-127.7

Table 9: **The shape of the CDS curve.** Chart a) shows the basis-errors for different levels of the swap rate and the CDS curve when the CDS curve is flat. Chart b) shows the basis-errors for different levels of the swap rate and the CDS curve when the CDS curve is upward sloping + 50 bps per year. Chart c) shows the basis-errors for different levels of the swap rate and the CDS curve when the CDS curve is downward sloping -50 bps per year. The swap curve is flat in all cases. The bond is at par when swap curve is at 4% and the CDS curve at 2.75% The bond has 4-years to maturity, a 7% coupon and a recovery rate of 40% and a face value of 100.

a) CDS curve flat

Cds/Swap	2%	4%	6%	8%
2%	-18.6	-19.4	-20	-20.4
2.75%	-24.3	**-25.2**	-25.9	-26.2
4%	-31.9	-32.9	-33.5	-33.8
8%	-39.5	-39.6	-38.8	-37.1
12%	-18.4	-15.5	-11.2	-5.6

b) CDS curve+ 50 bps

Cds/Swap	2%	4%	6%	8%
2.00%	-13.3	-17.9	-22.4	-26.9
2.75%	-20.4	**-25.2**	-29.9	-34.5
4.00%	-30.5	-35.5	-40.3	-44.8
8.00%	-46.2	-50.4	-53.9	-56.7
12.00%	-36.2	-34	-34.1	-33.1

c) CDS curve- 50 bps

Cds/Swap	2%	4%	6%	8%
2.00%	-23.7	-20.9	-17.7	-14.1
2.75%	-27.9	**-25.2**	-22	-18.4
4.00%	-33.1	-30.4	-27.1	-23.2
8.00%	-33.1	-29.9	-24.2	-18.3
12.00%	-4.7	2.3	10.7	20.6

Table 10: **Basis errors.** This table shows the basis errors between the I-basis and the basis, as in the previous tables, and in () the errors between the I-basis and the z-basis. The CDS curve is flat and is at 2.75 in all cases. In the first line, the swap rate curve is flat, then positively sloped at 20 bps per year, then positively sloped at 40 bps per year, then negatively sloped at -20 bps per year, finally negatively sloped at -40 bps per year. The basis is zero.

Swap rate Slope/Level	CDS	2%	4%	6%	8%
0	2.75%	-24.3 (0)	**-25.2 (0)**	-25.9 (0)	-26.2 (0)
20 bps	2.75%	-21.1 (-3.3)	-22.8 (-3.4)	-24.3 (-3.5)	-25.5 (3.6)
40 bps	2.75%	-17.8(-6.6)	-20.4 (-6.8)	-22.7 (-6.1)	-24.7 (-7.3)
- 20 bps	2.75%	-27.4 (3.2)	-27.6 (3.4)	-27.4 (3.5)	-27 (3.3)
-40 bps	2.75%	-30.6 (6.5)	-29.9 (6.7)	-29.0 (6.9)	-27.8 (7.2)

Table 11: **Summary statistics for the bond dataset.** The sample is constructed by merging information from the TRACE and Mergent FISD database for the period from January 1, 2006 to November 17, 2008. Only senior unsecured U.S. dollar-denominated bonds issued by U.S. firms that pay fixed semi-annual coupons are retained. Bonds that are callable, puttable and convertible are not considered. T-t is the time to maturity (in years) remaining on the date of each observation. The annual coupon rate is in percent. The rating is the one assigned to the bond the first time it is observed in our sample. Data source: TRACE

	All	AAA	AA	A	BBB	BB	B
No. Days obs	125375	2580	17403	66903	15299	4231	18959
No. Issuers	227	3	18	79	72	27	19
No. Issues	1477	22	148	790	251	101	120
Mean T-t	5.4	7.7	3.8	5.1	6.3	6.4	8.3
Median T-t	2.8	3.8	2.3	2.6	3.3	2.9	4.3
Mean coupon	5.7	5.0	4.4	5.2	6.3	6.9	3.4
Median Coupon	5.6	4.3	4.3	4.8	6	6.7	7.3
Mean recov	0.39	0.4	0.4	0.4	0.39	0.39	0.38
Median recov	0.4	0.4	0.4	0.4	0.4	0.4	0.39

Table 12: **Bond trading activity.** This table reports the trading frequency, in volume and trade counts, of the bonds in the sample. Total bond volume, total trade count and N. of trading days are values that refer to a single bond on the entire sample. N. of prices per day is the number of institutional transactions, among which the last one is selected to calculate the daily price of a bond. The bonds are examined over the period that goes from January 1, 2006 to November 17, 2008. Data source: TRACE.

		All	AAA	AA	A	BBB	BB	B
Aver. daily volume	Mean	1868	2966	1481	1672	2611	1705	1586
	Median	1370	2330	1472	1170	2500	1000	1307
Aver. daily trade count	Mean	4.6	4,3	4.9	4.3	4	3.6	8.4
	Median	3	4	3.5	3	2.5	3	4.2
Tot bond volume	Mean	290204	290304	364094	258068	297541	103059	497187
	Median	26436	200104	10528	16496	35094	15391	107911
Tot trade count	Mean	1271	1122	1524	1085	1013	589	3463
	Median	231	1067	180	208	140	267	677
N. trading days	Mean	193	292	217	180	172	158	320
	Median	95	262	76	88	64	119	236
N. of prices per day	Mean	2.1	2	2.1	2	2.1	2	2.5
	Median	2	2.1	2	2	1.9	2	2.4

Table 13: **Summary statistics for the CDS-bond basis dataset: final sample.** The sample is constructed by merging information from the TRACE and Markit Partners CDS database for the period from January 1, 2006 to November 17, 2008. Only senior unsecured U.S. dollar-denominated bonds issued by U.S. firms that pay fixed semi-annual coupons with maturity between 2 and 10 years are retained. Bonds that are callable, puttable and convertible are not considered. When CDS quotes for maturities between 1- and 10-year are missing the basis is not calculated. T-t is the time to maturity (in years) remaining on the date of each observation. The annual coupon rate is in percent.

	All	AAA	AA	A	BBB	BB	B
No. Days obs	61489	1342	10149	32470	8175	1401	7952
No. Issuers	138	3	13	57	40	12	13
No. Issues	695	10	68	396	119	39	63
Mean T-t	4.8	4	4.5	4.3	5	5	4.7
Median T-t	4.0	3.8	4.1	3.6	5	3.7	4.1
Mean coupon	6.8	4.7	4.3	5.1	5.8	6.7	7.2
Median Coupon	6.8	4.3	4.4	4.8	5.8	6.7	7.2
Mean recov	0.39	0.4	0.4	0.4	0.39	0.39	0.38
Median recov	0.4	0.4	0.4	0.4	0.4	0.4	0.39

Table 14: **I basis, adj basis (arbitrage-free) and z-basis.** Distribution of the three measures of the basis in the three different periods: 1) pre-crisis, 2) pre-Lehman and 3) Lehman crash), for each rating

Period 1

Rating	N Obs	Variable	Mean	Std Dev	P. Value	5th Ptcl	25th Pctl	50th Pctl	75th Pctl	95th Pctl
AAA	886	I-basis	16.27	13.48	.0001	2.17	9.55	13.58	20.42	38.72
		z basis	14.36	16.43	.0001	-2.82	5.95	11.30	18.88	39.65
		adj basis	13.56	14.07	.0001	-1.32	5.97	11.01	17.77	37.45
AA	5941	I-basis	22.49	83.35	.0001	-9.62	-0.77	4.94	11.41	48.69
		z basis	25.50	112.77	.0001	-11.69	-2.96	2.90	9.60	57.02
		adj basis	26.24	101.33	.0001	-7.69	0.22	5.01	10.76	61.42
A	22909	I-basis	3.33	55.85	.0001	-12.21	-2.51	3.61	9.26	20.55
		z basis	1.87	29.59	.0001	-15.24	-4.90	1.47	7.61	19.74
		adj basis	5.45	22.60	.0001	-9.61	-0.72	4.79	10.40	22.20
BBB	5727	I-basis	-5.07	27.27	.0001	-37.49	-9.34	-3.17	3.52	25.73
		z basis	-6.82	27.14	.0001	-40.36	-11.29	-4.88	1.86	24.85
		adj basis	2.68	29.00	.0001	-25.02	-4.86	1.04	8.22	46.94
BB	898	I-basis	-30.67	50.87	.0001	-127.23	-45.96	-20.18	-3.36	28.10
		z basis	-31.97	51.75	.0001	-129.12	-48.28	-21.01	-3.91	27.91
		adj basis	-1.59	47.27	0.31	-87.61	-19.30	2.38	25.04	65.15
B	5834	I-basis	61.89	167.30	.0001	-44.28	-6.64	20.35	60.10	360.91
		z basis	58.05	164.58	.0001	-47.36	-9.82	17.62	56.87	358.21
		adj basis	125.66	129.21	.0001	2.79	57.54	96.56	149.12	410.41

Period 2

Rating	N Obs	Variable	Mean	Std Dev	P. value	5th Ptcl	25th Pctl	50th Pctl	75th Pctl	95th Pctl
AAA	390	I-basis	41.18	34.63	.0001	-9.42	19.99	42.53	62.84	89.71
		z basis	45.80	38.35	.0001	-12.38	20.90	47.76	70.74	102.99
		adj basis	45.43	36.49	.0001	-6.42	20.63	45.92	68.41	95.36
AA	3688	I-basis	8.98	95.99	.0001	-83.97	-22.68	-0.75	20.41	121.63
		z basis	21.18	130.91	.0001	-75.82	-17.66	2.57	27.13	139.43
		adj basis	36.90	105.65	.0001	-45.13	-4.33	13.63	42.74	179.52
A	8820	I-basis	3.75	151.67	0.02	-90.32	-38.35	-8.66	22.05	122.83
		z basis	7.57	134.41	.0001	-85.40	-34.79	-6.65	25.24	127.96
		adj basis	35.54	113.03	.0001	-54.98	-14.37	11.50	53.10	203.69
BBB	2151	I-basis	-55.56	67.49	.0001	-174.37	-81.63	-45.22	-21.96	29.60
		z basis	-52.52	67.92	.0001	-168.72	-78.03	-41.98	-19.14	31.53
		adj basis	-14.47	70.59	.0001	-125.69	-45.01	-16.69	14.57	101.49
BB	482	I-basis	-29.18	78.91	.0001	-164.93	-70.27	-31.07	16.09	95.70
		z basis	-27.79	80.20	.0001	-171.80	-70.92	-28.32	17.00	102.11
		adj basis	41.56	102.01	.0001	-141.28	-7.34	45.94	102.12	202.12
B	1822	I-basis	38.65	124.04	.0001	-109.97	-33.04	15.76	77.81	283.69
		z basis	33.43	126.29	.0001	-113.77	-37.83	11.24	77.25	281.13
		adj basis	173.67	166.41	.0001	-32.84	58.40	144.34	250.07	446.56

Period 3

Rating	N Obs	Variable	Mean	Std Dev	P. value	5th Ptcl	25th Pctl	50th Pctl	75th Pctl	95th Pctl
AAA	66	I-basis	46.14	50.81	.0001	-27.65	1.71	38.12	80.14	137.41
		z basis	53.67	50.45	.0001	-19.41	9.57	45.19	84.61	140.67
		adj basis	65.64	56.09	.0001	-9.87	16.76	56.66	103.22	161.50
AA	520	I-basis	-127.23	112.99	.0001	-273.45	-202.89	-127.40	-56.54	32.32
		z basis	-126.29	157.56	.0001	-271.53	-196.72	-122.68	-46.91	45.15
		adj basis	-74.38	99.51	.0001	-215.07	-145.05	-69.17	-10.72	75.47
A	741	I-basis	-314.93	624.29	.0001	-1647.60	-342.73	-188.47	-92.36	445.45
		z basis	-275.17	510.79	.0001	-1421.39	-332.04	-185.11	-87.04	368.67
		adj basis	-218.89	442.41	.0001	-1344.45	-230.64	-117.37	-46.90	225.14
BBB	297	I-basis	-207.28	289.39	.0001	-685.41	-326.80	-185.50	-74.73	228.39
		z basis	-235.08	310.49	.0001	-788.75	-333.63	-200.26	-80.68	201.69
		adj basis	-195.11	200.44	.0001	-514.15	-280.38	-182.67	-76.19	95.08
BB	21	I-basis	-331.15	291.26	.0001	-1058.83	-423.68	-296.80	-132.30	-41.69
		z basis	-343.56	306.82	.0001	-1117.69	-439.05	-307.98	-135.73	-41.82
		adj basis	-220.66	255.70	0.00	-659.66	-375.10	-166.14	-21.00	56.15
B	296	I-basis	118.10	567.66	0.00	-646.46	-202.55	-4.98	392.73	1254.68
		z basis	85.44	578.99	0.02	-644.17	-225.49	-25.34	292.31	1301.24
		adj basis	20.51	420.90	0.43	-572.63	-183.38	-5.17	141.24	812.34

Table 15: **Basis error.** This table reports the statistics of the distribution of the errors between the three different measures of the basis (I basis, adj basis (arbitrage-free) and z-basis) in the three different periods: 1) pre-crisis, 2) pre-Lehman and 3) Lehman crash, for each rating group.

Period 1

Rating	N Obs	Error	Mean	Std Dev	P. value	Median	5th Ptcl	25th Pctl	50th Pctl	75th Pctl	95th Pctl
AAA	886	basis vs adj b.	2.71	9.42	.0001	2.77	-0.04	1.26	2.77	4.85	8.77
		basis vs z b.	1.90	10.99	.0001	1.99	-0.46	0.89	1.99	4.26	9.02
		z basis vs adj b	0.80	2.94	.0001	0.20	-1.41	-0.34	0.20	1.40	3.95
AA	5941	basis vs adj b.	-1.92	39.51	0.00	-0.47	-6.81	-1.95	-0.47	1.90	7.69
		basis vs z b.	-1.98	40.17	0.00	1.32	-1.54	0.30	1.32	3.01	7.27
		z basis vs adj b.	0.30	23.92	0.33	-1.91	-6.64	-3.09	-1.91	-0.73	5.70
A	22909	basis vs adj b.	-1.51	7.85	.0001	-1.51	-7.30	-3.60	-1.51	0.60	4.82
		basis vs z b.	2.06	5.44	.0001	1.36	-1.58	0.19	1.36	3.39	8.41
		z basis vs adj b.	-3.54	12.17	.0001	-3.15	-8.03	-4.93	-3.15	-1.82	-0.39
BBB	5727	basis vs adj b.	-7.75	10.13	.0001	-4.80	-27.80	-9.89	-4.80	-2.24	1.41
		basis vs z b.	1.75	2.73	.0001	1.22	-1.52	-0.06	1.22	2.85	7.46
		z basis vs adj b.	-9.49	10.13	.0001	-6.12	-30.95	-10.44	-6.12	-4.00	-1.86
BB	898	basis vs adj b.	-29.05	17.69	.0001	-27.21	-55.74	-41.30	-27.21	-16.42	-5.38
		basis vs z b.	1.37	2.74	.0001	0.59	-2.05	-0.39	0.59	2.65	7.08
		z basis vs adj b.	-30.38	18.27	.0001	-28.67	-58.66	-42.57	-28.67	-17.11	-5.10
B	5834	basis vs adj b.	-82.66	50.35	.0001	-72.37	-169.16	-104.76	-72.37	-49.75	-26.13
		basis vs z b.	3.83	6.56	.0001	2.69	-1.39	0.65	2.69	5.19	10.78
		z basis vs adj b	-85.89	52.99	.0001	-75.24	-175.50	-110.10	-75.24	-51.92	-27.38

Period 2

Rating	N Obs	Variable	Mean	Std Dev	P. value	Median	5th Ptcl	25th Pctl	50th Pctl	75th Pctl	95th Pctl
AAA	390	basis vs adj b.	-4.30	11.52	.0001	-3.95	-14.08	-8.34	-3.95	-0.36	11.51
		basis vs z b.	-4.67	7.69	.0001	-4.05	-18.08	-11.52	-4.05	0.41	7.65
		z basis vs adj b.	0.37	10.94	0.50	0.21	-7.29	-1.39	0.21	4.41	10.56
AA	3688	basis vs adj b.	-27.12	43.19	.0001	-17.32	-70.92	-33.82	-17.32	-7.18	-1.89
		basis vs z b.	-9.84	47.27	.0001	-2.82	-19.82	-11.01	-2.82	0.30	5.09
		z basis vs adj b.	-17.35	39.25	.0001	-12.24	-55.17	-22.55	-12.24	-6.17	-1.67
A	8820	basis vs adj b.	-36.02	45.86	.0001	-22.41	-116.12	-44.14	-22.41	-10.74	-3.44
		basis vs z b.	-3.19	8.31	.0001	-1.31	-18.31	-8.38	-1.31	1.66	8.02
		z basis vs adj b.	-33.11	47.37	.0001	-19.47	-110.68	-37.63	-19.47	-10.05	-3.81
BBB	2151	basis vs adj b.	-41.14	42.07	.0001	-31.32	-121.99	-52.74	-31.32	-14.13	-5.04
		basis vs z basis	-3.06	7.71	.0001	-1.11	-17.43	-7.99	-1.11	2.11	6.88
		z basis vs adj b.	-38.06	41.69	.0001	-25.36	-112.03	-43.71	-25.36	-14.49	-5.42
BB	482	basis vs adj b.	-70.74	63.40	.0001	-66.58	-171.58	-103.74	-66.58	-41.15	-15.00
		basis vs z b.	-1.39	8.95	0.00	-0.43	-14.91	-7.04	-0.43	2.48	9.47
		z basis vs adj b.	-69.34	56.83	.0001	-66.43	-161.87	-97.62	-66.43	-41.54	-19.43
B	1822	basis vs adj b.	-136.42	114.51	.0001	-110.88	-358.02	-192.48	-110.88	-63.01	-18.13
		basis vs z b.	4.49	9.85	.0001	3.92	-11.59	-0.14	3.92	8.64	21.63
		z basis vs adj b.	-141.08	115.31	.0001	-112.67	-365.84	-195.81	-112.67	-64.12	-24.05

Period 3

Rating	N Obs	Variable	Mean	Std Dev	P. value	Median	5th Ptcl	25th Pctl	50th Pctl	75th Pctl	95th Pctl
AAA	66	basis vs adj b.	-19.49	13.34	.0001	-16.59	-52.11	-22.00	-16.59	-11.26	-4.55
		basis vs z b.	-7.53	3.82	.0001	-6.86	-13.84	-11.05	-6.86	-4.74	-2.63
		z basis vs adj b.	-11.96	12.94	.0001	-7.23	-43.21	-13.20	-7.23	-4.76	1.23
AA	520	basis vs adj b.	-54.58	37.23	.0001	-44.93	-124.81	-78.25	-44.93	-23.13	-12.87
		basis vs z b.	-7.44	6.83	.0001	-6.72	-20.64	-12.02	-6.72	-1.67	1.68
		z basis vs adj b.	-54.05	79.87	.0001	-37.26	-127.65	-67.82	-37.26	-18.55	-6.90
A	741	basis vs adj b.	-59.90	291.59	.0001	-56.81	-575.27	-121.01	-56.81	-25.39	546.90
		basis vs z b.	27.65	65.85	.0001	-1.27	-16.02	-8.05	-1.27	30.87	195.74
		z basis vs adj b.	-72.95	278.39	.0001	-51.62	-599.92	-109.92	-51.62	-25.23	427.92
BBB	297	basis vs adj b.	-21.01	128.71	0.01	-42.76	-194.10	-73.22	-42.76	4.98	244.89
		basis vs z b.	9.81	26.57	.0001	2.59	-15.09	-6.24	2.59	21.06	52.70
		z basis vs adj b.	-40.78	137.30	.0001	-35.29	-334.45	-85.25	-35.29	-9.13	196.22
BB	21	basis vs adj b.	-110.49	154.31	0.00	-100.67	-406.80	-137.24	-100.67	-95.43	-41.93
		basis vs z b.	12.41	18.52	0.01	6.61	-0.85	2.24	6.61	12.72	58.86
		z basis vs adj b.	-122.90	159.25	0.00	-103.11	-465.66	-148.42	-103.11	-94.96	-44.38
B	296	basis vs adj b.	59.79	555.67	0.09	-64.14	-545.67	-192.57	-64.14	165.50	1257.77
		basis vs z b.	52.89	61.30	.0001	26.34	-7.89	1.99	26.34	97.47	175.22
		z basis vs adj b.	50.16	571.38	0.16	-65.77	-554.22	-198.98	-65.77	90.06	1225.07

Estratto per riassunto della tesi di dottorato

(L'estratto va firmato e rilegato come ultimo foglio della tesi)

Studente: Alessandro Fontana matricola: 955139

Dottorato: Dottorato di ricerca d'eccellenza in Economia ed Organizzazione

Ciclo: 21°

Titolo della tesi[1] : Essays on Credit Spreads

Abstract

This thesis consists of three interdependent and original works on the relationship between Credit Default Swaps (CDS) and bond spreads.

Chapter 1 studies the behaviour of the CDS-bond basis, i.e. the difference between the CDS and the bond spread, for a sample of investment graded US firms. During the 2007/09 financial crisis it has deviated from zero and has become persistently negative. The basis dynamics is driven by economic variables that are proxies for funding liquidity, credit markets liquidity and risk in the inter-bank lending market.

Chapter 2 studies the determinants of market prices of Euro area sovereign CDS and the linkages between the CDS and the underlying government bond. Results support the evidence that there are major commonalities as well as differences between the corporate and sovereign CDS and bonds.

Chapter 3 proposes a methodology for measuring the CDS-bond basis based on the bonds' cash-flows replication argument. A series of tests performed, on an hypothetical bond, shows how the error between this "arbitrage-free" measure and the standard measure of the basis depends on the term structure. An empirical application, on US corporate bonds, shows that the two measures exhibit a common behaviour and since the onset of the crisis in August 2007 they have become both negative, but the "arbitrage free" basis remains smaller in absolute terms.

Abstract

Questa tesi consiste di tre lavori interdipendenti e originali sulla relazione tra il Credit Default Swap (CDS) e lo spread su obbligazioni.

Il capitolo 1 studia il comportamento della "base" CDS vs. bond, i.e. la differenza tra CDS e spread su obbligazioni, per un campione di societá americane. L'analisi condotta mostra che durante la crisi finanziaria del 2007/09 la "base" é diventata persistemente negativa e che essa é determinata da variabili economiche che sono proxy per la liquiditá finanziaria, la liquiditá dei mercati creditizi e il rischio nel mercato interbancario.

Il capitolo 2 studia le determinanti dei prezzi di mercato dei CDS degli stati sovrani dell'area euro e i legami tra il CDS e il titolo di stato sottostante. L'analisi empirica mostra come ci siano analogie e differenze tra il comportamento dei CDS e delle obbligazioni su entitá sovrane e societá private.

Il capitolo 3 propone una metodologia per misurare la "base" CDS vs. bond basata sulla condizione di non arbitraggio. Una serie di test, implementata su una obbligazione ipotetica, mette in evidenza come l'errore tra questa misura e quella classica, utilizzata in letteratura, dipenda dal comportamento della struttura a termine dei tassi di interesse. Un' applicazione empirica, su obbligazioni corporate US, mostra che le due misure della "base" hanno generalmente un comportamento simile e che dall'inizio della crisi (agosto 2007) la base é diventata negativa, tuttavia la base "arbitrage free" é minore in termini assoluti.

Firma dello studente________________

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