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

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Abstract

This paper studies the behavior of the CDS-bond basis - the difference between the CDS and the bond spread - during the 2007/08 financial crisis, for a sample of investment-graded US firms. The objective is to show that during stress times asset prices depart materially farther 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.

We document that CDS and bond spreads have deviated from their parity condition (the basis has become persistently negative) and are no more moving together, in contrasts with what reported by other studies conducted prior to the crisis. We investigate the role played by the cost of trading the basis studying its relation with CDS and bond spreads. We find that the TED spread (Libor - 3 Month T-bill), which is our measure of the funding cost and risk of trading the basis, drives the basis dynamics, when it is negative, and also explains the difference in levels between CDS and bond spreads for lower rated entities.

Keywords: CDS; bond spread; funding rate, liquidity risk; counter-party risk; cointegration; financial crisis.

JEL Classification Numbers: (General Financial Markets)

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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 is down \$1bn, Ken Griffin of Citadel is down 50% and John Thain of Merril is said to be down by more than \$10bn. The big part of these losses is due to negative basis trades, meaning the basis trade is not a risk-free one.

The aim of the paper is twofold. First, study the behavior of the basis during the 2007/08 financial crisis. Second, investigate why investors have loosed money, on basis trades, during that period. We 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 (be cointegrated). Instead, we find that, during the crisis, CDS and bond spreads have deviated form the parity condition and are no more cointagrated. Implications have been dramatic for negative CDS-bond basis traders who where trading 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 their position, hence to close their trades, 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 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 the funding cost issue.

The relation between bond yields and CDS is a close-to-arbitrage one that holds when markets are relative 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 series 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 from their equilibrium relation. If this is not the case, the cointegrating relation should include the other cost and risk factors that explain the deviation. We investigate different variables that may capture cost and risk factors of implementing the basis trade, and find that the TED spread, i.e. the difference between the risky LIBOR rate and the risk-free U.S. Treasury bill rate, is able to recover the cointegration between CDS and bond spreads. The TED spread, turns out to be a good proxy that captures all together (i) the dynamics the funding cost and the risk of funding liquidity faced by investors, (ii) counter-party risk implicit into CDS spreads and (iii) corporate bond market liquidity deterioration (Brunnermeier 2009). More specifically we find that the cointegrating relationship with CDS and bond spreads is trivariate. This means that the TED spread, which explodes and becomes non-stationary during the crisis, drives the basis dynamics and also explains the difference in levels between CDS and bond spreads. We investigate other financial variables, but no one gives the same result of the TED spread.

Overall, our findings support the idea that during stress times asset prices depart materially farther from frictionless ideals due to funding liquidity risk faced by financial intermediaries and market operators. The deviation from parity does not imply the presence and persistence of arbitrage opportunities, in fact the basis trading is faceing liquidity and counter-party risk, hence it is not risk-free.

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

2 Review of the related literature

Our study 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). Compared to these, we look at a different time period, which goes from 1/3/2005 to 11/19/2009[1]. We concentrate on the impact of the 2007/08 financial crisis and 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. We find similar results for the period before July 2007, instead we find that 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, we find 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 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 at 27 of 33 firms; Zhu (2004) detects cointegration for 15 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 75% of the cases. Longstaff et.al. (2005) have studied 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

[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.

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. We use the same idea to show that when the CDS and the bond spread are not anymore cointagrated the cointagrating relation should include the cost and the risk of trading the basis.

To our knowledge, no empirical study has yet investigated the issue of price discrepancies in the market for credit risk during the crisis. We provide such an examination.

3 CDS and bond spreads on corporate bonds

3.1 CDS and bond spreads: a "close-to-arbitrage-relation"

Here we discuss the theoretical parity relationship that characterizes the CDS and the bond spread on the same reference entity; as derived by Duffie (1999). We also discuss how market frictions and various risk factors may influence differently CDS (derivatives contracts), and bond (cash instruments) allowing for deviations from parity.

Credit default swaps 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 credit default swap (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 credit swap 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.

What described above works in theory, in practice CDS contracts are traded in OTC markets. Dealers that sell a CDS (buy credit risk) hedge their position (buying protection) short-selling the risky bond that they obtain via reverse-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

$$U(bid) = Spread - (financingrate - riskfree) \tag{2}$$

When, the repos are special the basis persists to be positive. When there is a funding cost, namely when the funding rate is higher that the risk-free rate, the basis is persistently negative. The repo and the funding cost act as market frictions, which may be responsible for price discrepancies between the cash and the derivative market for credit risk.

In principle, an investor could take credit risk buying a corporate bond or selling protection on a reference entity. The point is that corporate bonds and CDS are not substitutes. Bond risk is affected by: default risk, interest rate risk, funding risk and liquidity risk, while CDS risk by risk of default 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. Liquidity risk is due 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. CDS are unfunded derivatives contracts, so 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. For the same reason, funding risk is not an issue and market liquidity has usually negligible impact. Let's assume market frictions are negligible, what is binding the dynamics of CDS and bond spreads in financial markets? Investors trading activities arbitrage away prices discrepancies, driving prices to their parity equilibrium relation. As soon as the basis persist in time and across numerous entities, there is the need to explain what is the systematic factor that it is driving it.

3.2 Negative basis trades: "arbitrage" and "speculation"

This paper focuses on explaining the negative basis during the 2007/08 financial crisis. In this subsection we describe how the negative basis trades work.

If a bond is trading cheaper than the CDS (bond spreads larger than CDS) an investor can profit implementing a negative basis trade in two ways. A first way is with a long run focus. He buys the bond, buys the CDS (to hedge credit risk), 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" because 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. An investor may trade the basis and speculate on its variation in a short leg of time. Basically, 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 [3] (zero).

The "arbitrage-nagative-basis-trade" is "risk-free" because investors do not care if the underlying name defaults, since what they loose on the bond they make back from the short risk position in the CDS. But, it is more complicated than that. The hedge in not perfect, in fact the bond carries additional risks such as funding and mark-to-market loss risk[4], interest rate risk and counter-party risk[5] and, at any given time, technical factors can overwhelm the basis. In an environment in which funding liquidity has dried up and there are tension in the inter-bank-lending market and risk aversion is high, the basis may be negative.

What is the yield on an "arbitrage-nagative-basis-trade"? In order to buy the cash-bond investors need to borrow money at the Libor plus something.[6] Hence, if an investor holds the position till maturity, the yield on the trade is given by

$$[YTM - (Libor + fundingCost) - CDS]. \tag{3}$$

Basically, he gains the YTM (calculated from the ask price of the bond since the basis trader is buying the bond) by holding the bond, he does finance the purchase of the bond at Libor+funding cost and he pays the CDS premium (ask price) in order to hedge credit risk. Since he also needs to hedge interest rate risk he swaps the Libor with a 5y fix swap rate. Hence, the negative-basis-yield

[3] In the paragraph "Implementing real world basis trades during the crisis" we provide details on how to calculate profits on these kinds of basis trades.

[4] Whenever traders leverage up their position the maybe forced to delevarege in case of large mtkt losses.

[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] A spread over the Libor, i.e. a funding cost, which depends both on your credit worthiness, and on the underlying of the basis trade, i.e. the likelihood of default of the bond.

is

$$Yield = [YTM - (5yswap + FundingCost) - CDS], \tag{4}$$

in equilibrium CDS and bond spreads should adjust such that this quantity is zero. Let's define I spread=(YTM - 5y swap). Hence we have:

$$Yield = (Ispread - CDS - FundingCost) = 0, \tag{5}$$

since we calculate the CDS-bond basis as: (CDS - I Spread), and the negative-basis yield has to be zero, we can rewrite:

$$Basis = -FundingCost \tag{6}$$

We may allow also for risk factors such as counter-party risk and bond liquidity risk to have an impact on the basis:

$$Basis = -(FundingCost + CDSDiscount + BondLiquidityRisk) \tag{7}$$

The CDS discount is due to the fact that CDS buyers are willing to pay less for protection because of counter-party risk, while bond liquidity risk increases yields driving the basis negative. In a high liquidity regime the funding cost is very low and not volatile, counter party risk and bonds market liquidity are not relevant issues. In such an environment, the negative-basis-trade-till-maturity is not perceived to be risky and a zero expected returns is asked; deviations from parity are short-lived because they are quickly arbitraged away by investors; these trades provide a "risk-free" reward. Differently, in a low liquidity regime, the negative basis trade is costly and exposes investors to some risk factor, hence they require a yield in order to implement the negative-basis-trade.

To summarize, there are a number of possible reasons of why the behavior of the CDS-bond basis may have deviated from zero. First, a dramatic increase of cost of financing has affects 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. 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 arbitrageur 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. Second, 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 import 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 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.

Third, 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.

4 Data

The analysis is conducted on a sample of 37 U.S. firms, that are listed on Table 1 with indication of sector and rating. 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 November 19, 2008, right few months after Lehman collapse. The period is further partitioned into two considering that troubles for financial markets started approximately at the end of July 2007.

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 and over Treasuries 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, we have to create a synthetic constant 5 years maturity bond spread. At every point in time in the sample, for each entity with suitable CDS data, we 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 we approximate a five-year to maturity bond spread. When we have the choice we 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 [7].

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.

Time series data for the Libor, the 5 year swap rates and other variables used in the empirical

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

analysis such as the T-Bill rate, the financial and non financial commercial paper rates, the OIS and the TED spread, are also provided by the Federal Reserve. The VIX is downloaded from Datastream.[8]

5 Empirical Analysis

5.1 The average basis before and during the crisis period

If both credit default swaps and bonds price credit risk equally then, subject to arbitrage imperfections noted in section 3.1, the spread on a risky bond over the swap rate should be approximately equal to the CDS of the same maturity. Table 3, shows the average CDS-bond basis, across ratings, separately for the financial and the industrial sector, for three different periods: 1/3/2005 to 7/30/2007 is the period before crisis (BF), 7/30/2007 to 8/1/2008 is the crisis period (BF L) Lehman and 8/1/2008 to 11/19/2008 (DG L) is the crisis period after Lehman collapsed. The CDS-bond bases behave quite differently before, during crisis and during the Lehman collapse period. The basis tends to be generally positive and small prior to the crisis, instead it is negative during the initial crisis period and it becomes even more negative in the period following the Lehman collapse [9]. Differently, the basis of AAA rated entities is positive also during the crisis. For industrials, both before and during the crisis, there is evidence of the so called basis smile i.e. the basis for the A rating category is the lowest (BC -1.59, BL -21.57 and DG Lehman -97.25). Concerning AAA rating (13.15, 15.91 and 3.88) the basis stays positive because CDS are floored at zero, while bond spreads are very low. For the BBB (1.03, -16.09 and -69.39) instead, the "Cheapest to Delivery option" increases the CDS premium narrowing the basis. For the AA rating the basis are between AAA and A (7.68, -14.83 and -74.43). The negative basis for financial is wider than for industrials. We can see also, in Figures 3 and 4, that for the financial sector spreads are generally higher than for the industrial one, because of higher default risk due to stress in the inter-bank-lending market. According to previous studies on the CDS-bond basis, in normal market conditions, CDS trade slightly higher then the cash spread. During the 2007/08 financial crisis the CDS-bond basis

[8] We provide more details on the economic meaning of these variables in the "Empirical analysis" section.

[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.

is persistently negative (bond spreads are on average larger than CDS spreads), meaning special factors are at work.

As illustrated in Figure 2, the CDS and the bond spread, of a reference entity, like for example Citigroup, tend to move together in time. All the other CDS and bond spreads exhibit a similar pattern. To verify the parity relation of CDS and bond spreads we need to look at these variables in levels. For studying long-term relationships among series that have a unit root, cointegration analysis is the appropriate framework. As a first step, we 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. We use the augmented Dickey-Fuller test in order to test for the presence of a unit-root. We run this test for each of the 37 CDS and bond spread series independently and we summarize results in a panel unit-root test analysis form in table 4, for CDS, and in table 5 for bond spreads. As expected, we are not able to reject the null hypothesis of a unit root for all series, i.e. all series are integrated once, I(1).

5.2 Implementing "real world" speculation negative basis trades during the crisis

In this paragraph, we analyze the performance of negative basis trades, done for speculation, i.e with a short term view, in the period during the crisis.

According to the financial newspapers, during the crisis, negative CDS-bond basis traders realized large losses. The connection between CDS and bonds spreads strongly depends, among other things, on high leverage, abundant liquidity and a well functioning inter-bank-lending market; hence the negative basis trade is not a risk-free one. Basis traders where operating basing on the belief that deviation where risk-free arbitrage opportunities and that funding liquidity, and the risk implicit in the basis trade, were not relevant issues. Suddenly, they have been forced to de-leverage their positions closing basis trades that where reporting mark-to-market losses driving the basis more into negative territory. Here, we document trough the implementation of real world negative basis trades, by mean of some reasonable assumptions, what happened in terms of profit and losses during the crisis. The speculative basis trade is not arbitrage because if the basis does not converge to zero quickly there is the risk that the investors are forced into interim liquidation when a time limit is met, or that they get a margin call for the collateral by the dealers. Even if investors are able to roll-over, the funding cost, but also hair-cuts and margins on long CDS[10], might suddenly explode having an negative impact on the profit of the trade.

What is a speculation negative basis trade? How to calculate profits?

Investors can trade the basis and speculate on its variation in a short leg of time, if they believe the basis is going to narrow whenever it is there. The strategy consists of the following transactions. If the basis is negative and below a certain threshold, the investor purchases the corporate bond and relative protection. Once the exit trigger (certain level of profit) is met he unwinds his position. The profit consist of the net difference between the purchasing and the selling price of the bond, unwinding the CDS contract and repaying back the overnight loan. The bond spread is expected to decrease while the CDS spread is expected to increase, in a net sense, in order for the basis to narrow. The profit on the bond is given by the variation of its market price, plus the accrued interest capitalized during the basis trading period. Since the CDS contract has a maturity of 5 years, the profit from the CDS is given by the value of the contract at the unwinding date which is: $\sum \beta^i_{cds}(CDS_1 - CDS_0)$. The present value of the payment from CDS is calculated with a risk adjusted discount factor, $1/(swap_i + CDS_1)$, where $swap_i$ is the swap for maturity i. This adjustment has to be done because the cash of the CDS flow may stop in the event of a default. We consider bid and ask prices of CDS and bonds for the transactions on the basis. The cost of financing is accounted, on a daily basis, for the duration of the strategy.

Data, methodology and assumptions

The sample period of this analysis goes from 7/30/2007 to 3/15/2009, it covers the Lehman collapse period and the subsequent stabilization period. We focus on basis trades of a sub-sample, of our data set, made by 5 financial entities: Citygroup, Wells Fargo J.P Morgan, Goldman Sachs and Morgan Stanly; for each entity we observe approximately 4 bases. The basis is here defined as the difference between the 5 year CDS and the I-spread on a bond with approximately 5 years to maturity[11]. We believe, for these short term speculative strategies, the most relevant issues to be the ones concerning roll-over risk, the cost of financing the basis trade and the risk implicit in the basis variation (i.e basis volatility). If the basis does not narrow within the financing period or

[10] All factors such as hair-cuts and margin do impact on the availability of funding, not just the funding rate.

[11] We look at a real, not synthetic bond, in the time period in which this bond has a maturity of approximately 5 years. The I-spread is the difference between the yield to maturity and the swap rate.

shifts adversely investors are forced to close their position realizing losses. For these reasons we analyze the impact of making the time limit shorter (roll-over risk) and the impact of an increase of the funding cost on the performance of these strategies.

We make the following assumptions. Investors have no initial capital but they are able to finance the investment in the overnight market; they enter in one basis trade at a time buying 100 bonds for a notional of 10.000 $ and 1 CDS contract for a notional of 10.000 $ [12]. When the basis is higher than a certain level, that we define as 25% (basis over CDS), trade orders will be placed, when the closing cushion is hit investors close their position. The closing cushion is a profit of 10 $ or 1$, which is the equivalent of 10 bps or 1 bps gain on the notional invested. If the time period limit is met investors are forced to close their position even if they are loosing. In order to study the impact, of the holding period limit, on the average performances, we assume three different time limit, 10, 30 and 60 days. We have bid ask prices for CDS in our data set, but we need to assume bid-ask, of 50 bps[13], on corporate bonds.

Results and comments (very preliminary analysis)

Table 6, shows average profits on basis trades on the Wells Fargo Cds-bond basis during the period that goes from 7/30/2007 to 3/15/2009. Average profits are reported in basis points. Given the notional amount invested in the basis is 10.000 $, 1 bp is equivalent to 1$ profit. Chart A, reports average profit and losses (for a profits level that trigger exit of 1$ and a funding cost =10 bps) for strategies that have different holding period limits of 10, 30 and 60 trading days). We also indicate the number of basis trades on each specific basis. Strategies that have longer period limits are more likely to get positive profits, while the strategies with the shortest time limit (10 days) get negative profits. The idea is that in a longer time period it is more likely that the negative basis goes into the expected direction.

Chart B, reports average profit and losses (funding cost =10 bps and holding period limit of 30 trading days) for a profits level that triggers exit of 10$. Increasing the exit profit threshold increases risk implicit in the negative basis trade in case of a 30 days time limit; it is likely to

[12] Financial news paper reports that basis traders usually leverage up their position to increase the return of the strategy. We assume they open just one position at a time. This has the effect to smooth gains and losses with respect to trades made in case of leverage

[13] Empirical studies conducted on the US corporate bond market, which use the TRACE data set, do report that for transactions of size of 100 bonds (notional of 10.000$) realized bid-ask spreads are of approximately 40 bps.

get higher profits or make higher losses. The basis needs time to narrow and increasing the exit threshold increases the risk to reach the time limit when the basis has not moved in the expected direction. In a long amount of time it is likely that the basis narrows, as expected, while in a short amount of time it may happen that investors are forced to close their position, before the basis narrows enough to get generate the profit.

Chart C, reports average profit and losses (profits level that trigger exit of 1$ and holding period limit of 30 trading days) when the funding cost is 100 bps. For strategies with a 30 days time limit and 1$ exit profit we report the average profit when the funding cost is 100 bps instead of 10 bps. On average the profit decreases by about 2 bps, which is equivalent of 2$ on an amount invested of 10.000 $. In a real world setting, the cost of funding the negative basis trade is adversely affected also from hair-cuts and margins requirements in buying the cash bond and the CDS. Unfortunately we do not have these data.

In Table 7, we report the average profits, in basis points, from trades on the basis of Wells Fargo, J.P Morgan, Goldman Sachs, Morgan Stanley and Citigroup. The sample period goes from 7/30/2007 to 5/12/2009 and is divided into 5 different period of the crisis. Given the notional amount invested in the basis is 10.000, $1 bp is equivalent to 1$ profit. We report average profit and losses for a profits level that trigger exit of 5 bps, and average profits and losses for strategies that have different holding period limits in table A, B and C (10 - 30 -60 trading days). We also indicate the number of basis trades in each period. The funding cost to implemet the basis trade is assumed to be 10 bps. Again, looking at the same periods across the three charts A, B and C for different holding periods, we can see that performances, of strategies that have longer period limits are more likely to get positive profits, while the strategies with the shortest time limit (10 days) get on average negative profits. Strategies with 10 holding period limit, give losses through out all the crisis period, but losses are the largest after the Lehman the collapse. Different time periods during the crisis basis trades perform differently pointing to the fact that they average performances depend very much on the availability of funding and the dynamics of the basis. The optimal strategy is the one with a larger time limit and a higher profit exit trigger. Throughout the crisis this strategy gives the maximum average profit or the minimum average loss across different entities and bases of the same entity.

We conjecture that shorter time limit strategies, and higher funding cost than what we apply, closer approximate the conditions in the funding market during the crisis period; driving performances of negative basis trades into negative territory. With this simple example, we show that basis traders where operating on the belief that deviation where risk-free arbitrages, ignoring funding liquidity, and risk implicit in the basis trade.

In the next section we show that the empirically observed negative CDS-bond basis is driven by the lack of funding liquidity in financial markets, tension in the inter-bank lending market and deterioration of liquidity in the corporate bond market.

5.3 Testing the parity relation between CDS and bond spreads: cointegration

Cointegration methodology has often been used to analyze the joint evolution of non-stationary economic and financial variables (Engle and Granger (1987)). It offers a convenient framework to test hypothesis such as the validity of the CDS-bond spread parity relationship. Following Blanco et. al (2005), let's suppose that the unobservable true price of credit risk, m_t, follows a random walk:

$$m_t = m_{t-1} + u_t \tag{8}$$

where u_t is a white noise. The observed price in each market j, with j=1 for CDS and j=2 for bond spread (BS), at time t, $p_{j,t}$, is equal to this efficient price plus a component containing microstructural noise, $s_{j,t}$, which can be the repo or funding cost or other market frictions, might be transient or persistent; this is an empirical issue. Finally, there is a component reflecting other possibly non-transient or constant factors included in the observed price, $c_{j,t}$:

$$p_{j,t} = m_t + s_{j,t} + c_{j,t}, \qquad j = \text{CDS, bond spread.} \tag{9}$$

If the two markets price credit risk equally in the long run, then the CDS and the bond spread should be cointegrated with cointegrating vector $[1, -1, c]$, suggesting an I(0) CDS-bond basis, and c, should equal zero. That is, we expect arbitrage activities to act in the direction of eliminating short-run deviations from these long-term relationship. Blanco *et al* (2005) noted that if the prices do not cointegrate with the $[1, -1, c]$ restriction imposed then either (i) the two markets price risk differently (in excess of a constant amount) (ii) at least one market price contains time-varying non-transient factors that reflect something other than credit risk or (iii) at least one market price contains time-varying non-transient measurement error. No cointegration implies that the cash and the derivatives markets of credit risk move in an unrelated way. However this is more likely to happen in the short run.

According to the "no-arbitrage" argument discussed in section 3, CDS bond spreads are approximately equal if that repo and funding rates, which are basically time-varying factors, are small and behave "nicely". This means that CDS and bond spreads should be not expected to move together if the "cost" and the risk to implement the CDS-bond basis trading is non-stationary. The correctly specified cointegrating equation has to make use of the theoretical relationship which might lead the CDS (derivative) and the bond spread (cash) to diverge from one another, meaning it has to include the cost and the risk of trading the basis.

Engle and Granger (1987) have argued that a set of variables are cointagrated if any linear combination of them is stationary. However in our specific case, following Zhu (2004), we search for a specific form of cointagration as theory predicts which linear combination we expect to be stationary, i.e the difference between CDS and bonds spreads, namely the basis. As a first step, we test for a unit-root in the basis series using the augmented-Dickey-Fuller test. When the test statistics is lower then a certain confidence level, the null hypothesis of a unit root is rejected. If this is the case CDS and bonds spread are the same in level and they move together.

Instead, in order to test for trivariate cointegration between CDS bond spreads and the cost of implementing the basis trade we use the multivariate framework proposed by Johansen (1988, 1991), because these variables are jointly determined and also because we allow for the cointegrating vector to be different, during the crisis, than the one described above. 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.[14]

[14]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.

5.4 Explaining the negative basis: the cost and risk of implementing the negative basis trade

In this paragraph, we examine whether there is consistency in the pricing of credit risk in the cash and in the derivatives markets and wether CDS and bond spreads move together using, as already anticipated, cointegration framework. We investigate both the pre-crisis and the crisis period focusing on explaining what happened during the 2007/08 financial crisis. The key idea is that, during the crisis, CDS and bond spreads have deviated from their parity condition because the cost of trading the negative basis has dramatically increased and because the "negative basis package" does carry counter-party risk.

First, we test for cointagration between CDS and bond spreads, on each single entity, separately for the period before the crisis and for the period during the crisis. According to Engle and Granger (1987) a set of variables are cointagrated if any linear combination of them is stationary. However in our specific case, following Zhu (2004), we search for a specific form of cointagration as theory predicts which linear combination we expect to be stationary, i.e the difference between CDS and bonds spreads, namely the basis. Therefore, we test for a unit-root in the basis series using the augmented-Dickey-Fuller test. When the test statistics is lower then a certain confidence level, the null hypothesis of a unit root is rejected. If this is the case CDS and bonds spread are the same in level and they move together.

The results of the cointegration test are shown in Table 8. According to the W-stat of the Im, Pesaran and Shin unit-root test, based on cross-sectional mean of the statistic test of the ADF, we reject the hypothesis of a unit root i.e. the bases in our sample are stationary, meaning CDS and bond spreads are in general cointagrated before the crisis. 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. We have shown in paragraph 5.1 that in this period the basis is small and positive, meaning that the parity relation between CDS and bond spreads approximately holds.[15] Differently, according to the W-stat in Table 9, during the

[15] For those entities for which we do not find cointegration CDS and bond spreads move in an unrelated way. This might be due to the fact that there is little variation in these variables, hence it might be that arbitrage forces do not enter into play to bring the variables back to their equilibrium relation: they move within the arbitrage bounds

crisis CDS and bond spreads are not cointegrated. The basis is stationary only for 3 out of 37 entities (with a 10% level of significance). During the crisis the basis widens and becomes generally negative. No cointegration implies that CDS and bond spreads move in an unrelated way, but does this imply the presence and persistence of arbitrage opportunities? Why are CDS and bond spreads deviating from their parity relation?

We have argued that, under the no-arbitrage argument, if the cost of implementing the CDS-bond basis trading explodes and becomes nonstationary, CDS and bond spreads can not be cointegrated. In our analysis we proxy the cost and the risk of implementing the basis trading, i.e. funding cost, and counter-party risk by mean of the TED spread. As we can see from Figure 1, the TED spread is stationary and narrow before the crisis and it explodes and becomes non stationary during the crisis. Results of the unit-root tests on the TED spread are reported in the Tables 10 and 11.

Therefore, we test for cointagration between CDS and bond spreads, during the crisis, accounting for the cost of trading the negative basis. The advantage of this cointegrating relation over the standard one is that it makes use of the theoretical relationship which might lead CDS and bond spreads to diverge from one another. We report the analysis conducted on the averages of CDS and bond spreads within each class of the four rating AAA, AA, A and BBB. During the crisis, bases exhibit common movements and are driven by common factors, hence results obtained on single entities also hold for averages within groups. In Figures 3 and 4, we can see CDS, bond spreads and bases, separately for industrials and for financial, for each rating group. As expected CDS spreads and bond spreads reflect cross sectional differences of default risk of the underlying, also spreads for financial are higher. Moreover, for the bases there are cross sectional differences. The lower the rating the more negative the basis. For the AAA industrial rating group the basis stays positive also during the crisis.

Results of the Johansen cointegration test are given in Tables 12 and 13. Table 12, shows that during the crisis CDS and bond spreads, for all ratings, are not cointagrated. Differently, as we can see from Table 13, for all rating category we find a trivariate cointegration between CDS, bond spreads and the TED. This means that CDS and bond spreads wander widely and drift apart

determined for example by bid ask spreads. In might also be, in some cases, that we do not find cointagration because of measurement errors in the bond spreads.

because of the explosion of the cost and the risk of implementing the negative basis trade.

In Table 14, we can see the cointegrating vector with restrictions imposed such that the basis is stationary [1 -1 c]. We are not able to reject this restriction only for the AAA industrial group and for the AA financial group. For AAA industrial group the constant, i.e the basis is positive, while for the AA financial group it is not significantly different from zero. For all other groups the cointegratign vector restrictions are rejected and the bases are negative.

To understand the impact of the TED on the basis, we perform the trivariate cointegration analysis, with CDS bond spreads and the TED, with restrictions on the cointegrating vector [1 -1 c]. Results are reported in Table 15. The TED spread is both economically and statistically significant for all rating groups and it has, as expected, a negative sign. The higher the TED spread, meaning the higher the cost of trading the negative basis, the higher its implicit counter-party risk and the lower bond market liquidity, the more negative is the basis.

For the A and BBB industrial rating group, the TED not only drives the basis but also explains the deviations between CDS and bond spreads in levels, as the constant in the cointegrating vector is not significantly different from zero[16]. Since there are differences in the bases across ratings, the TED spreads does not explain differences in levels between CDS and bond spreads for all groups. This allows to conjecture that funding issue, counter-party risk of trading the basis and bond liquidity do differ across different segments. For example, it is reasonable to assume that it is less costly to finance the purchase of a highly rated bond, at the same time the basis trade carries less counterparty risk because the joint probability of default of both the underlying of the bond and the protection provider is lower. Also, because of the "flight to liquidity" issue highly rated bonds might be more liquid.

The CDS-bond basis of the AAA rating group is positive also during the crisis. This is due to the fact that AAA rated bond trade at spreads that are lower than the swap rate (which is related to the Libor), while the CDS spreads by their nature are always positive. Again this is some how related to the "flight to quality" issue.

What is the role played by the TED spread in our empirical analysis? From an economic point

[16] In this case the constant would have to be excluded from the cointagrating vector in order to estimate the correctly specified model.

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, the problem is that during periods of financial turmoil the Libor itself dramatically increases with respect to a risk free rate, and often funding is even not available. The funding cost hence refers to the spread, but also to hair cuts on repos to finance the purchase of the bond (hence on the risk underlying the bond) and to the availability of funding, in general, in the inter-bank-lending market. We take the difference between the 3 month interest rate on inter-bank loans and short-term U.S. government debt ("T-bills") i.e. the TED spread, as an indicator of both the funding cost and counter-party risk in CDS contracts, which may explain the negative basis during the crisis. The TED spread has two components 1) the 3month OIS-Libor spread and 2) the 3 month TBill-OIS spread. The first is the cost of 3 month banking liquidity, i.e. lending unsecured for three months vs lending unsecured for one day. This is the "banking liquidity" component of the TED spread, and comes purely from banks' perception of liquidity. The second component, on the other hand, is demand-driven, one leg, the short term T-bill, being in fixed-supply. This is the "flight to quality" part of the TED spread, because in times of crisis, fund managers prefer to switch to safe investments. When there is uncertainty, lenders in the inter-bank market charge higher interest for unsecured loans, increasing the LIBOR rate. Further, banks want to get first-rate collateral, which makes holding Treasury bonds more attractive and lowers the Treasury bond rate (Brunnermaier 2009). For these reasons, the TED spread widens in times of crises. All together the TED spread is an indicator of perceived risk in the economy. The 3 month T-bills are considered risk-free while LIBOR reflects the credit risk of lending to commercial banks. When the TED spread increases, that means that lenders believe the risk of default on interbank loans (counterparty risk that is also priced in CDS contracts since big banks are the CDS providers) is increasing. Interbank lenders therefore demand a higher rate of interest, or accept lower returns on safe investments such as T-bills. When the risk of banks default is considered to be decreasing, the TED spread decreases. In figure 1, we can see the dynamics of the Libor, the 3 month T-bill rate and the TED spread

The TED captures deterioration of funding liquidity, hence higher funding cost, in the inter-bank lending-market (funding liquidity risk) because of its Libor-OIS component. TED spreads captures also the counterparty risk implicit in the CDS contract, because, as explained in the data

Section 4, banks are providing CDS. The TED spread captures also the liquidity deterioration in the corporate bond market, which drives yields high irrespective of the default intensity, due to the flight to quality. i.e. a flow of funds into safe assets such as the short term US Treasuries.

After since the explosion of the crisis, in July 2007, the perceived credit risk in the economy has increased and also the risk of default on interbank loans (also known as counterparty risk) has increased. What happened is the following. First, because of their increased default risk, CDS dealers (which are financial institutions such as banks, insurance companies or hedge funds) are paying higher funding rates and this does impact on the CDS pricing by arbitrage; the high funding cost also lowers returns for basis traders. Second, during the crisis protection sellers counter-parties (dealers) have higher default correlation to the assets being protected. This risk is priced into CDS contracts driving their spreads lower irrespective of the actual default intensity. This is one of the reasons why bond spreads are on average larger than CDS spreads during the crisis. Third, liquidity has migrated from corporate bond market to the Treasury market, driving bond yield larger.

5.5 Other proxy variables for funding cost and risk factors

In the empirical analysis, we have used other proxies for the funding cost and risk of trading the basis in order to try explain the deviation from parity of CDS and bond spreads, but none has given the same result as the TED spread.

We have tested for trivariate cointegration (between CDS bond spreads and a third factors that bounds the two variable together) using the 3 month Libor rate and 30 day AA-financial and AA-non-financial commercial paper rates. Commercial papers are money-market securities issued by large banks and corporations to get money to meet short term debt obligations, and are a form of unsecured lending. Given that they are not backed by a collateral, only creditworthy firms will be able to sell their commercial papers at a reasonable price. The Libor and CP rates are funding rates not funding costs. Instead, what we need in to estimate the fully specified theoretical cointegrating relation is a proxy for the cost of implementing the negative basis trade, which captures funding liquidity, counter-party risk, and liquidity deterioration in the corporate bond market.

Hence, we have tried the 3 month Libor over the (OIS) overnight interest rate swap. We have tried spread between 30-day financial and non financial CP rate and the OIS, the OIS over the

3 month T-bill, and finally just the OIS by its own [17]. OIS rates and in particular, the spread between OIS rates and LIBOR rates are an important measure of risk and liquidity in the money market, considered to be a strong indicator for the relative stress in the money markets. A higher spread is an as indication of a decreased willingness to lend by major banks, while a lower spread indicates higher liquidity in the market. The spread gives indication of banks' perception of the creditworthiness of other financial institutions and the availability of funding. Also the VIX, which is an indicator of liquidity and risk aversion in financial markets, turns out not to be cointegrated to the CDS-bond basis, at least for our sample period.

In our analysis, the correctly specified cointegrating vector must include that peculiar factor that causes a persistent and time-varying deviation form parity. If this is not the case, CDS and bond spreads apparently wonder apart.

5.6 The lead-lag relationship between CDS and bond spreads: price discovery

One important function of financial markets is price discovery, defined to be the efficient and timely incorporation of the information implicit in investor trading into market prices. When closely related assets trade in different locations, order flow is fragmented and price discovery is split between markets. Which of the two markets contributes most to the credit risk price discovery process and what happens during the 2007/08 financial crisis are the questions that we attempt to answer in this section. In the period before the crisis, we estimate a bivariate Error Correction Model on CDS and bond spreads in the style of Blanco et.al. During the crisis, CDS and bond spreads are no more cointegrated, hence we introduce into the model the proxy for the cost and risk (TED spread), for trading the basis, that bounds together CDS and bond spreads and allows to estimate the trivariate Vector Error Correction Model in order to study the lead-leg relationship between these variables.

The method we use to investigate the mechanics of price discovery is a factor model due to Gonzalo and Granger (1995) which relies on vector error correction models of market prices. Gonzalo and Granger's approach attributes superior price discovery to the market that adjusts least to price movements in the other market. To compute the measures of the contributions to price

[17] We have decided not to report, in the paper, tables with results of these trivariate cointegration test. Results can be provided upon request. No other variable, beside the TED bounds CDS and bonds spreads together giving cointegration.

discovery it is necessary first to estimate the following vector error correction model (VECM):

$$\Delta CDS_t = \lambda_1(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1}) + \sum_{j=1}^{q} \alpha_{1j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{1j}\Delta BS_{t-j} + \epsilon_{1t} \quad (10)$$

$$\Delta BS_t = \lambda_2(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1}) + \sum_{j=1}^{q} \alpha_{2j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{2j}\Delta BS_{t-j} + \epsilon_{2t} \quad (11)$$

We specify the model with the optimal 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). To measure the contribution of the two markets to price discovery we use the Gonzalo-Granger measure defined as the ratio: $\frac{\lambda_2}{\lambda_2 - \lambda_1}$.

First, we estimate the model in the period before crisis. The price discovery statistics on averages within rating groups are reported on Table 16. Before the crisis, λ_2 is significantly positive for all rating groups, while λ_2 is not significant, indicating that the CDS market contributes significantly to price discovery. The average Granger-Gonzalo measure, we find, is 0.773 compared to 0.79 reported by Blanco et.al, for the period 2001-2002.

Now, we estimate the model in the period during the crisis. According to our previous results, the cointagration is trivariate hence we based on the following Vector Error Correction Model regressions:

$\Delta CDS_t = \lambda_1(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1} - \alpha_2 TED_{t-1}) + \sum_{j=1}^{q} \alpha_{1j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{1j}\Delta BS_{t-j} + \sum_{j=1}^{q} \gamma_{1j}\Delta TED_{t-j} + \epsilon_{1t}$

$\Delta BS_t = \lambda_2(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1} - \alpha_2 TED_{t-1}) + \sum_{j=1}^{q} \alpha_{2j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{2j}\Delta BS_{t-j} + \sum_{j=1}^{q} \gamma_{2j}\Delta TED_{t-j} + \epsilon_{2t}$

$\Delta TED_t = \lambda_3(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1} - \alpha_2 TED_{t-1}) + \sum_{j=1}^{q} \alpha_{3j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{3j}\Delta BS_{t-j} + \sum_{j=1}^{q} \gamma_{3j}\Delta TED_{t-j} + \epsilon_{3t}$

As before, the cost of implementing the CDS-bond basis strategy is the TED spread hence it has to be included in the cointegrating equation together with the CDS and the bond spread. We specify the model with the optimal number of lags for each cointegrating relation. We report the analysis on averages of CDS and bond spreads within each rating group in Table 17. λ_2 is significantly positive for all rating groups, while λ_1 and λ_3 are not significant. This means that the lagged error term (deviations from the equilibrium cointagrating equation) in the VECM, does predict the movements of bond spreads, but not the movements of the TED and the CDS, meaning bond spreads adjust to changes of the CDS and the TED that generate deviations form the parity relation. Also, during the crisis, CDS prices are the most relevant source of the information. The Granger-Gonzalo measure is 0.919, which is a bit higher than in the period before crisis. Again, also during the crisis the CDS market is where price discovery takes place.

Price discovery occurs in the market where informed investors trade at most. Credit default swaps 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). The sharp increase of the cost of financing the purchase of corporate bonds, obviously, acts in favor of the derivative market for credit risk. But, this price discovery does not give rise to systematic profitable opportunities. Since CDS and bond spreads are cointegrated the market for credit risk is informationally efficient. It is likely that financing cost of trading the basis, bid-ask spreads, funding liquidity risk and counter-party risk, as shown above, make profits from strategies based on price discrepancies zero or negative.

6 Conclusion

In this paper we document that during the crisis, from July 2007 on, there are relevant price discrepancies in the markets for credit risk: the basis is persistently negative (bond spreads are on average larger than CDS spreads), meaning that it would be cheaper to take credit risk in the cash market. This has been quite unfrequent in the past. We find that the basis is driven by the the cost and risk that investors have to sustain to implement the CDS-bond basis trading or the dealers have to sustain in order to provide CDS contracts; as the funding cost and risk increase the basis goes more negative and vice versa. We proxy the cost of trading the negative basis and its implicit risk by mean of the TED spread. The interesting point is that the TED spreads drives the basis dynamics, when it is negative, and also explains the difference in levels between CDS and bond spreads for lower rating categories. We also find that the CDS market moves ahead of the bond market in price adjustment, both before and during crisis. Its liquid nature is due to the fact that CDS contracts are an unfunded way to buy and sell credit risk. During the crisis the comparative advantage of the derivative market, in terms of liquidity, becomes even sharper.

First, because of their increased default risk, CDS dealers (which are financial institutions such as banks) are paying higher funding rates and this does impact on the CDS pricing, at the same time a lack of funding liquidity has impacted on the basis trading by the side of traders, who where in many case forced to de-leverage their positions and found it more costly to finance the purchase of bonds. Second, during the crisis protection sellers counterparties (dealers) have higher default correlation to the assets being protected. This risk is priced into CDS contracts driving their spreads lower irrespective of the actual default intensity making bond spreads are on average larger than CDS spreads during the crisis. Third, liquidity in the corporate bond dried up and migrated to the Treasury market, driving corporate bond yields very high. We believe the TED spread to capture these three effects which drive the basis.

In our empirical analysis, we have also used other proxies for the funding cost in order to explain the deviation from parity of CDS and bond spreads during the crisis but none has given the same result (cointegration) as the TED spread. We have used Libor and commercial paper rates. We have also used the spreads of the Libor and commercial paper rates over the (OIS) overnight interest rate swap, the OIS over the 3 month T-bill, and finally just the OIS by its own.

We find 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 so their spreads are driven larger by the cost of funding, while CDS spreads, which are unfunded, are sold at discount because of counter-party risk. Both the described effects contribute to narrow the basis.

To conclude, the cointegration between CDS, the bond spreads and the funding cost and risk of trading the basis always holds, this implies the absence of persistent profit opportunities even if the basis is non-zero.

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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 basis before and during crisis**. This table provides descriptive statistics 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 7/30/2007 is the period before crisis (BF), 7/30/2007 to 8/1/2008 is the crisis period (BF) Lehman and 8/1/2008 to 11/19/2008 (DG) is the crisis period after Lehman collapsed. Crossectional mean is provided, for groups of entities according to rating, separately for the financial and industrial sector

Average of Bases	BF crisis	Crisis BF Lehman	Crisis DG Lehman
Financials			
AA	-0.77	-21.44	-112.24
Industrials			
AAA	13.15	15.91	3.88
AA	7.68	-14.83	-74.43
A	-1.59	-21.57	-97.25
BBB	1.03	-16.09	-69.39

Table 4: **Unit root tests on credit default swap spreads**. Sample period 1/3/2005 to 11/19/2008. Automatic selection of lags based on SIC: 0 to 21. The approach by Im, Pesaran and Shin is based on the cross sectional mean of the statistics test of the ADF. This test assume asymptotic normality. The Fisher test instead combines the p-values of the N tests in cross-section. ** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution.

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	21.2991	1	37	37287
ADF - Fisher Chi-square	15.6829	1	37	37287

Table 5: **Unit root tests on bond spreads**. Sample period 1/3/2005 to 11/19/2008. Automatic selection of lags based on SIC: 0 to 17. The approach by Im, Pesaran and Shin is based on the cross sectional mean of the statistics test of the ADF. This test assume asymptotic normality. The Fisher test instead combines the p-values of the N tests in cross-section. ** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution.

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	22.177	1	37	37324
ADF - Fisher Chi-square	16.9797	1	37	37324

Table 6: **Average profits on basis trades on the Wells Fargo Cds-bond basis**. The sample period goes from 7/30/2007 to 3/15/2009. This table reports the average profits from trades on 4 Wells Fargo bases, in basis points. Given the notional amount invested in the basis is 10.000 $, 1 bp is equivalent to 1$ profit. Chart A, reports average profit and losses (for a profits level that trigger exit of 1$ and a funding cost =10 bps) for strategies that have different holding period limits of 10, 30 and 60 trading days). We also indicate the number of basis trades on each specific basis. Chart B, reports average profit and losses (funding cost =10 bps and holding period limit of 30 trading days) for a profits level that triggers exit of 10$. Chart C, reports average profit and losses (profits level that trigger exit of 1$ and holding period limit of 30 trading days) when the funding cost is 100 bps.

A. Exit profit 1$ and funding cost=10 bps.

Wells Fargo	N. Tradings		Time Limit	
		10	30	60
Bond 1	178	-42.43	-10.3	26.24
Bond 2	37	-2.59	11.37	11.71
Bond 3	37	1.48	10.25	10.65
Bond 4	29	-2.56	9.7	13.5

B. Exit profit 10$ and funding cost=10 bps.

Wells Fargo	N. Tradings	Time Limit
		30
Bond 1	178	-15
Bond 2	37	15.13
Bond 3	37	15.39
Bond 4	29	15.35

C. Exit profit 1 $ funding cost=100 bps.

Wells Fargo	N. Tradings	Time Limit
		30
Bond 1	178	-12.31
Bond 2	37	9.91
Bond 3	37	8.7
Bond 4	29	8.27

Table 7: **Average profits on basis trades**. The sample period goes from 7/30/2007 to 3/15/2009 and is divided into 5 different period of the crisis. This table reports the average profits, in basis points, from trades on the basis of Wells Fargo, J.P Morgan, Goldman Sachs, Morgan Stanley and Citigroup. Given the notional amount invested in the basis is 10.000, $1 bp is equivalent to 1$ profit. We report average profit and losses for a profits level that trigger exit of 5 bps, for strategies that have different holding period limits in table A, B and C (10 - 30 -60 trading days). We also indicate the number of basis trades in each period. The funding cost to implemet the basis trade is assumed to be 10 bps.

A. Average profits with 60 days time limit.

Period	Stage 1	Stage 2	Stage 3	Stage 4	Tot
Dates	7/20/07- 3/1/08	3/1/08 - 9/15/08	9/15/08 - 10/29/08	10/29/08 - 3/15/09	
n.trading	360	315	95	794	1719
Average profit	21.55	11.39	96.80	24.77	16.11

B. Average profits with 30 days time limit.

Period	Stage 1	Stage 2	Stage 3	Stage 4	Tot
Dates	7/20/07- 3/1/08	3/1/08 - 9/15/08	9/15/08 - 10/29/08	10/29/08 - 3/15/09	
n.trading	360	316	109	781	1784
Average profit	5.95	-5.08	64.41	-15.14	-13.04

C. Average profits with 10 days time limit.

Period	Stage 1	Stage 2	Stage 3	Stage 4	Tot
Dates	7/20/07- 3/1/08	3/1/08 - 9/15/08	9/15/08 - 10/29/08	10/29/08 - 3/15/09	
n.trading	360	316	146	744	1810
Average profit	-7.69	-16.69	-79.55	-27.96	-36.67

Table 8: **CDS and bond spread cointegration test before crisis.** Sample period 1/3/2005 to 7/30/2007. Automatic selection of lags based on SIC: 0 to 6. The approach by Im, Pesaran and Shin is based on the cross sectional mean of the statistics test of the ADF. Probabilities are computed assuming asympotic normality. In the intermediate ADF test results when t-stat higher that 2.569 we have a 10% level of significance.

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	-6.11588	0

Intermediate ADF test results

Series	t-Stat	Prob.	E(t)	E(Var)	Max Lag	Lag	Obs
BASIS ABB	-2.5818		-1.512	0.761	3	19	667
BASIS AIR	-2.1847		-1.512	0.761	3	19	667
BASIS ANH	-1.5817		-1.512	0.761	3	19	667
BASIS ARC	-2.5964		-1.512	0.761	3	19	667
BASIS AVN	-1.6336		-1.512	0.761	3	19	667
BASIS BEL	-2.8597		-1.514	0.754	2	19	668
BASIS CAG	-2.6275		-1.514	0.754	2	19	668
BASIS CAT	-2.0244		-1.495	0.771	4	19	666
BASIS CCL	-1.7217		-1.476	0.795	6	19	664
BASIS CIT	-2.8296		-1.494	0.781	5	19	665
BASIS CLG	-2.3838		-1.512	0.761	3	19	667
BASIS DEE	-2.0386		-1.512	0.761	3	19	667
BASIS DOW	-2.612		-1.53	0.745	1	19	669
BASIS EMR	-2.1741		-1.512	0.761	3	19	667
BASIS GML	-1.3712		-1.512	0.761	3	19	667
BASIS HOS	-2.8922		-1.53	0.745	1	19	669
BASIS HSS	-2.4887		-1.514	0.754	2	19	668
BASIS JON	-1.9		-1.512	0.761	3	19	667
BASIS JPM	-1.9213		-1.514	0.754	2	19	668
BASIS KFT	-2.0072		-1.476	0.795	6	19	664
BASIS LBZ	-3.6708		-1.512	0.761	3	19	667
BASIS MLY	-2.0836		-1.512	0.761	3	19	667
BASIS MST	-0.3871		-1.514	0.754	2	19	668
BASIS MTT	-1.9861		-1.514	0.754	2	19	668
BASIS NLL	-2.4926		-1.514	0.754	2	19	668
BASIS PFZ	-2.6152		-1.512	0.761	3	19	667
BASIS PPG	-1.7588		-1.514	0.754	2	19	668
BASIS PRG	-2.9293		-1.512	0.761	3	19	667
BASIS SBC	-2.403		-1.476	0.795	6	19	664
BASIS SUN	-2.6809		-1.514	0.754	2	19	668
BASIS TXT	-2.7477		-1.514	0.754	2	19	668
BASIS TYC	-1.5651		-1.514	0.754	2	19	668
BASIS UNT	-3.4771		-1.514	0.754	2	19	668
BASIS VAL	-3.6969		-1.53	0.745	1	19	669
BASIS WAC	-2.6113		-1.512	0.761	3	19	667
BASIS WRP	-2.7778		-1.53	0.745	1	19	669
BASIS WST	-4.0249		-1.514	0.754	2	19	668

Table 9: **CDS and bond spread cointegration test during crisis.** Sample period 7/30/2007 to 11/19/2008. Automatic selection of lags based on SIC: 0 to 6. The approach by Im, Pesaran and Shin is based on the cross sectional mean of the statistics test of the ADF. This test assume asymptotic normality. In the intermediate ADF test results when t-stat higher that 2.569 we have a 10% level of significance.

Method	Statistic	Prob.**
Im, Pesaran and Shin W-stat	3.44349	0.9997

Intermediate ADF test results

Series	t-Stat	Prob.	E(t)	E(Var)	Max Lag	Lag	Obs
BASIS ABB	-0.7925		-1.53	0.745	1	16	343
BASIS AIR	0.1498		-1.532	0.735	0	16	343
BASIS ANH	-0.4437		-1.532	0.735	0	16	343
BASIS ARC	-0.3831		-1.53	0.745	1	16	343
BASIS AVN	0.3381		-1.53	0.745	1	16	343
BASIS BEL	0.2802		-1.53	0.745	1	16	343
BASIS CAG	0.4865		-1.532	0.735	0	16	343
BASIS CAT	-0.8895		-1.53	0.745	1	16	343
BASIS CCL	1.1875		-1.53	0.745	1	16	343
BASIS CIT	-1.9139		-1.53	0.745	1	16	343
BASIS CLG	-0.4077		-1.53	0.745	1	16	343
BASIS DEE	-1.4792		-1.53	0.745	1	16	343
BASIS DOW	-1.6801		-1.53	0.745	1	16	343
BASIS EMR	-1.0009		-1.53	0.745	1	16	343
BASIS GML	0.33		-1.532	0.735	0	16	343
BASIS HOS	0.9262		-1.53	0.745	1	16	343
BASIS HSS	-1.2935		-1.532	0.735	0	16	343
BASIS JON	-2.5182		-1.514	0.754	2	16	343
BASIS JPM	-1.7704		-1.53	0.745	1	16	343
BASIS KFT	0.1039		-1.53	0.745	1	16	343
BASIS LBZ	0.028		-1.532	0.735	0	16	343
BASIS MLY	-1.1007		-1.514	0.754	2	16	343
BASIS MST	-2.3586		-1.512	0.761	3	16	343
BASIS MTT	-1.2567		-1.53	0.745	1	16	343
BASIS NLL	-1.4354		-1.532	0.735	0	16	343
BASIS PFZ	-1.3727		-1.514	0.754	2	16	343
BASIS PPG	-3.1556		-1.532	0.735	0	16	343
BASIS PRG	-2.623		-1.514	0.754	2	16	343
BASIS SBC	-1.7723		-1.532	0.735	0	16	343
BASIS SUN	-1.6032		-1.532	0.735	0	16	343
BASIS TXT	-3.6324		-1.532	0.735	0	16	343
BASIS TYC	-0.629		-1.532	0.735	0	16	343
BASIS UNT	-1.2488		-1.532	0.735	0	16	343
BASIS VAL	-0.8952		-1.532	0.735	0	16	343
BASIS WAC	-1.1131		-1.474	0.806	7	16	343
BASIS WRP	-2.8807		-1.532	0.735	0	16	343
BASIS WST	-0.6153		-1.53	0.745	1	16	343

Table 10: **Unit root tests on the TED spread before crisis**. Sample period 1/3/2005 to 7/30/2007. Null Hypothesis: TED has a unit root. Automatic based on SIC, MAXLAG=18. Results: in this period the TED spread is stationary.

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.437	0.0101*
Test critical values:	1% level	-3.441	
	5% level	-2.866	
	10% level	-2.569	

*MacKinnon (1996) one-sided p-values.

Table 11: **Unit root tests on the TED spread during the crisis**. Sample period from 7/30/2007 to 11/19/2008. Null Hypothesis: TED has a unit root. Automatic based on SIC, MAXLAG=14. Results: in this period the TED spread is non-stationary.

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.655	0.8547
Test critical values:	1% level	-3.449	
	5% level	-2.87	
	10% level	-2.571	

*MacKinnon (1996) one-sided p-values.

Table 12: **Test for cointegration in the market for credit risk: no cost to implement the CDS-bond the trading**. These table reports the Johansen cointegration test between the average of CDS and the average of bond spreads, within each rating group, for the industrial and the financial sectors. The sample is the period during the crisis 7/30/2007 to 11/19/2008. Critical values are from Johansen (1991)

Rating group	Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
AAA Ind	None	0.013487	7.8264	20.26184	0.8383
	At most 1	0.009196	3.1687	9.164546	0.5497
AA Ind	None	0.037744	16.914	20.26184	0.1358
	At most 1	0.010778	3.7168	9.164546	0.4559
A ind	None	0.035693	15.533	20.26184	0.1974
	At most 1	0.008899	3.0661	9.164546	0.5684
BBB Ind	None	0.037697	17.635	20.26184	0.1105
	At most 1	0.012904	4.4549	9.164546	0.3486
AA Fin	None	0.026544	14.1525	20.26184	0.279
	At most 1	0.014255	4.924786	9.164546	0.2918

Table 13: **Test for cointegration in the market for credit risk taking into account the cost to implement the CDS-bond basis trading**. These tables report the Johansen cointegration test between the average of CDS and the average of bond and the TED, for each rating group, for the industrial and the financial sectors. The sample is the period during the crisis 7/30/2007 to 11/19/2008. The cost to implement the CDS-bond basis strategy if the funding cost, proxied by the TED spread. Critical values are from Johansen (1991).

Rating group	Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
AAA Ind	None **	0.075121	35.904	35.19275	0.0418
	At most 1	0.017194	9.1185	20.26184	0.7252
	At most 2	0.009198	3.1696	9.164546	0.5495
AA Ind	None*	0.070496	33.505	35.19275	0.0752
	At most 1	0.013905	8.4301	20.26184	0.788
	At most 2	0.010519	3.6271	9.164546	0.4705
A Ind	None*	0.064693	34.221	35.19275	0.0634
	At most 1	0.038338	14.157	20.26184	0.2788
	At most 2	0.008064	2.429	9.164546	0.6917
BBB Ind	None **	0.068723	35.788	35.19275	0.0431
	At most 1	0.02255	11.367	20.26184	0.5071
	At most 2	0.010279	3.5439	9.164546	0.4843
AA Fin	None *	0.070618	39.646	35.19275	0.0155
	At most 1	0.032895	14.52659	20.26184	0.2548
	At most 2	0.008864	3.053789	9.164546	0.5707

Table 14: **Cointegrating vector with restrictions and no TED**. Crisis sample period from 7/30/2007 to 11/19/2008. This table shows the cointegarating vector, for the relation between CDS and bond spreads, with restriction such that the basis is stationary [1 -1 c]. We report standard errors and t-statistics in [ ]. LR is the log-likelihood ratio test for binding restrictions.

Rating group	Cds	Bond spread	Constant	LR test prob
AAA Industrial	1.000	-1.000	-22.100	0.507
			[-3.18518]	
AA Industrial	1.000	-1.000	28.886	0.006
			[3.16317]	
A Industrial	1.000	-1.000	39.527	0.012
			[3.82818]	
BBB Industrial	1.000	-1.000	52.164	0.017
			[3.64953]	
AA Financial	1.000	-1.000	-20.527	0.120
			[-0.83411]	

Table 15: **Cointegrating vector with restrictions and the TED**. Crisis sample period from 7/30/2007 to 11/19/2008. This table shows the cointegarating vector, for the relation between CDS, the bond spread and the TED, with restriction such that the basis is stationary [1 -1 TED c]. We report standard errors and t-statistics in [ ]. LR is the log-likelihood ratio test for binding restrictions.

Rating group	Cds	Bond spread	TED	Constant	LR test prob
AAA Industrial	1.000	-1.000	0.451	-78.985	0.012
			[3.93655]	[-4.96530]	
AA Industrial	1.000	-1.000	0.499	-49.215	0.004
			[3.77836]	[-2.70631]	
A Industrial	1.000	-1.000	0.475	-33.921	0.005
			[3.10482]	[-1.54973]	
BBB Industrial	1.000	-1.000	0.390	-23.698	0.001
			[2.79397]	[-1.23418]	
AA Financial	1.000	-1.000	1.361	-146.703	0.205
			[4.37943]	[-3.41477]	

Table 16: **Cds-bond spread lead-lag relationship before crisis.** Sample period to 1/3/2005 7/30/2007. This table reports a measure of contribution of the credit risk price discovery made by the CDS and bond spreads for those reference entities where there is a long run relationship between the CDS and the bond spread. 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 column reports 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.

Rating group	λ_1	t-stat in[]	λ_2	t-stat in[]	GG measure
AA Industrial	-0.003	[-1.08799]	0.021	[1.67575]	0.857
A Industrial	0.024	[0.81098]	0.058	[3.09951]	1.000
BBB Industrial	0.004	[0.74743]	0.047	[3.29887]	1.000
AA Financial	0.013	[1.91537]	0.085	[4.25052]	1.000
Average	0.009		0.053		0.773

Table 17: **Cds-bond spread lead lag relationship during the crisis.** Sample period to 7/30/2007 11/19/2008. This table reports a measure of contribution of the credit price discovery made by the CDS and bond spreads for those reference entities where there is a long run relationship. The analysis is on averages of CDS and bond spreads within each rating group. In the period during the crisis, according to our previous results the cointagration is trivariate and includes the funding cost (TED). Hence we based on the following Vector Error Correction Model regressions:

$\Delta CDS_t = \lambda_1(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1} - \alpha_2 TED_{t-1}) + \sum_{j=1}^{q} \alpha_{1j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{1j}\Delta BS_{t-j} + \sum_{j=1}^{q} \gamma_{1j}\Delta TED_{t-j} + \epsilon_{1t}$

$\Delta BS_t = \lambda_2(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1} - \alpha_2 TED_{t-1}) + \sum_{j=1}^{q} \alpha_{2j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{2j}\Delta BS_{t-j} + \sum_{j=1}^{q} \gamma_{2j}\Delta TED_{t-j} + \epsilon_{2t}$

$\Delta TED_t = \lambda_3(CDS_{t-1} - \alpha_0 - \alpha_1 BS_{t-1} - \alpha_2 TED_{t-1}) + \sum_{j=1}^{q} \alpha_{3j}\Delta CDS_{t-j} + \sum_{j=1}^{q} \beta_{3j}\Delta BS_{t-j} + \sum_{j=1}^{q} \gamma_{3j}\Delta TED_{t-j} + \epsilon_{3t}$

The final column reports 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.

Rating group.	λ_1	t-stat in[]	λ_2	t-stat in[]	λ_3	t-stat in[]	GG measure.
AAA Ind	-0.001	[-0.757]	0.017*	[4.862]	-0.003	[-0.409]	0.969
AA Ind	-0.009	[-0.775]	0.233*	[4.668]	-0.185	[-1.375]	0.964
A Ind	-0.012	[-1.435]	0.100*	[4.148]	0.007	[0.111]	0.895
BBB Ind	-0.002	[-0.144]	0.082*	[4.047]	-0.031	[-0.282]	0.974
AA Fin	-0.021	[-0.795]	0.071*	[3.218]	0.001	[0.059]	0.773
Average	-0.009		0.100		-0.036		0.919

Figure 1: **Time series of the Libor, the 3 month T-Bill rate and the TED spread**. The TED spread is the difference between the interest rates on interbank loans (Libor) and short-term U.S. government debt ("T-bills"). When the TED spread increases, that is a sign that lenders believe the risk of default on interbank loans (also known as counterparty risk) is increasing.

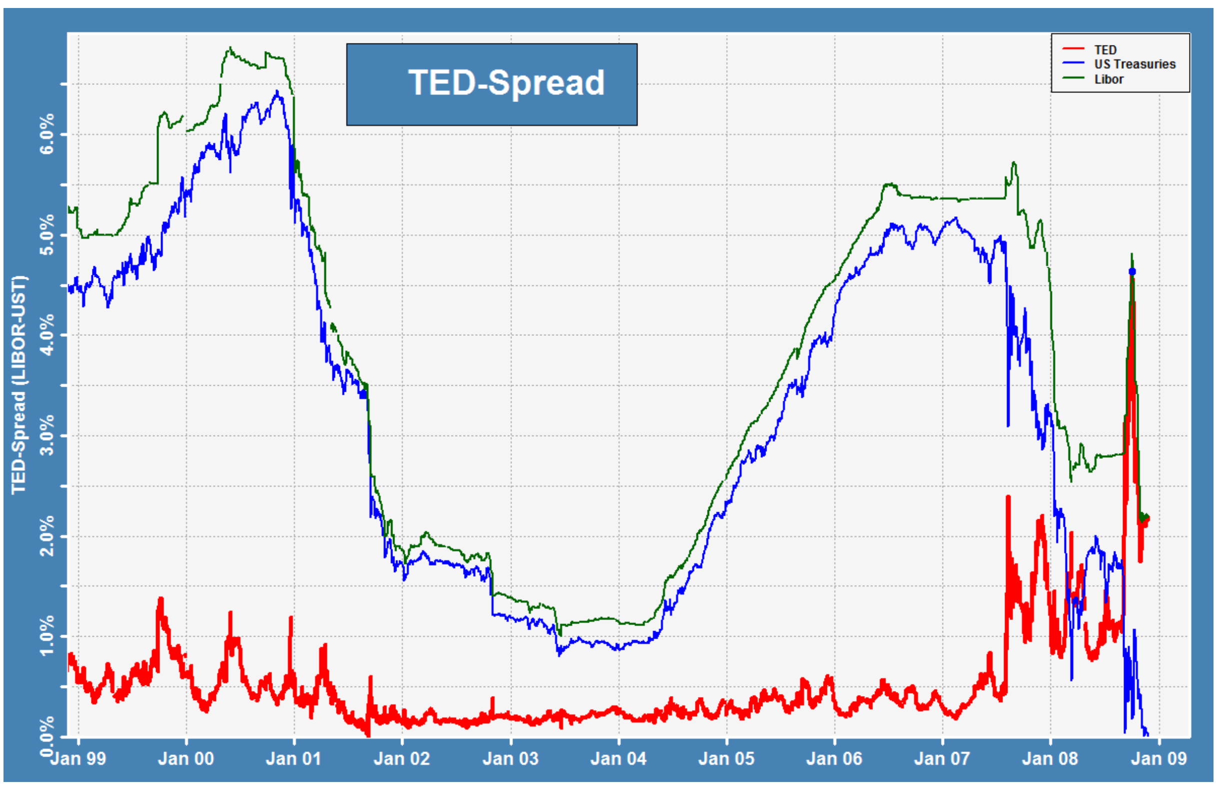

Figure 2: **Time series of Citigroup' s CDS, bond I spread and basis** The bond I-spread is calculated over the 5 year swap rate. Sample period 1/3/2005 - 11/19/2008.

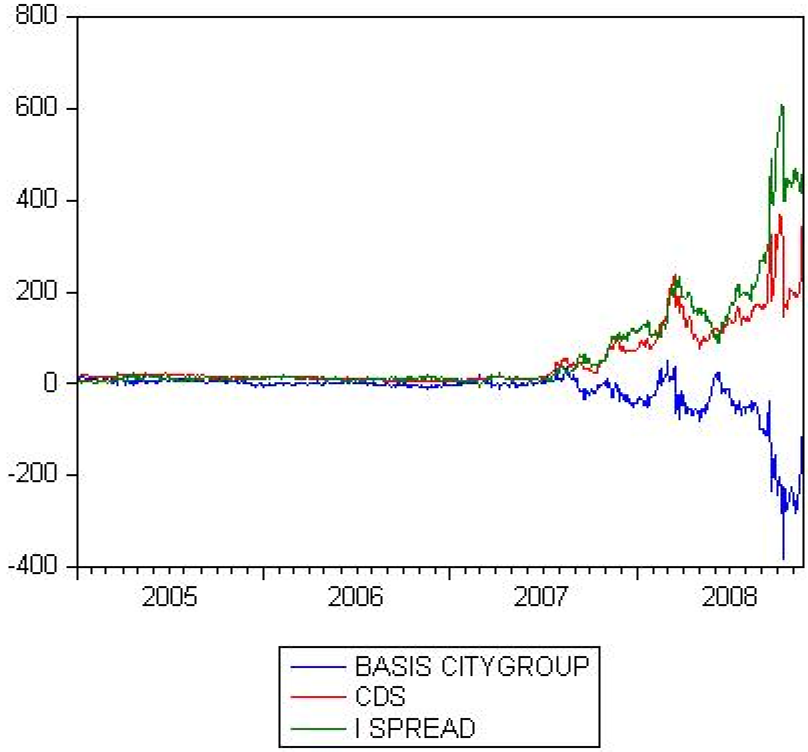

Figure 3: **CDS spreads, bond I spreads and the basis for industrials.** Time series of the cross-sectional averages by rating. Sample period 1/3/2005 - 11/19/2008.

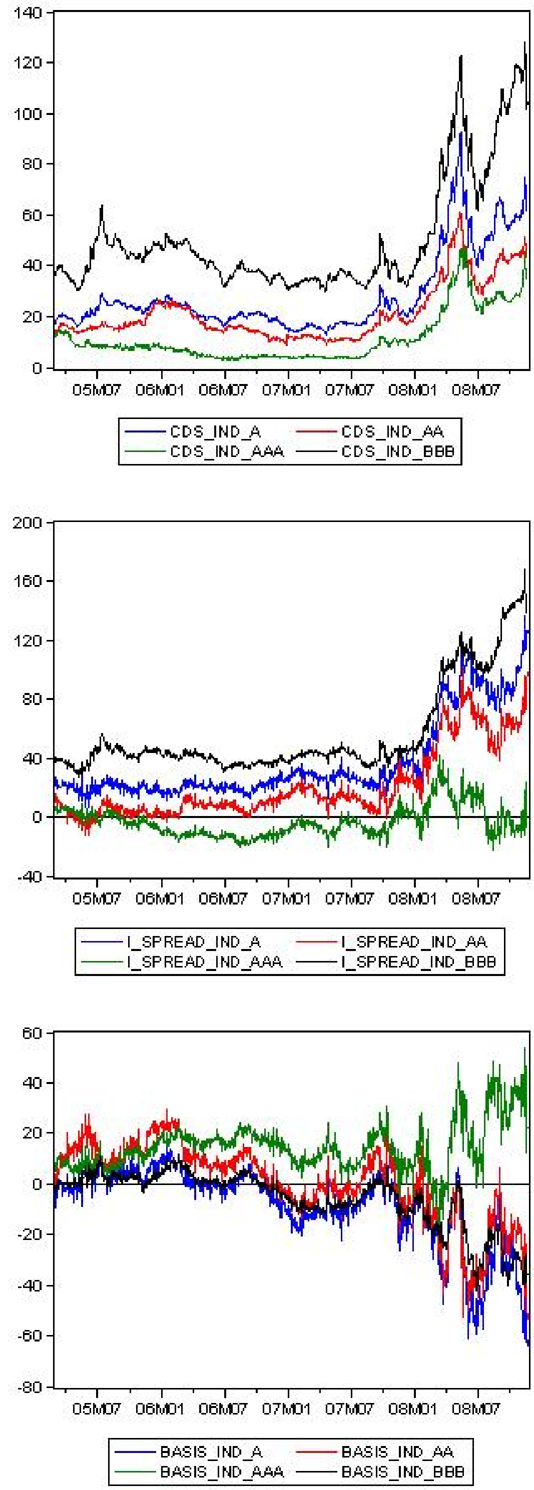

Figure 4: **CDS spreads, bond spreads and the basis for financials** Time series of the cross-sectional averages by rating. Sample period 1/3/2005 11/19/2008.