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Abstract

The misalignment between corporate bond and credit default swap (CDS) spreads (i.e., CDS-bond basis) during the 2007-09 financial crisis is often attributed to corporate bond dealers shedding off their inventory, right when liquidity was scarce. This paper documents evidence against this widespread perception. In the months following Lehman's collapse, dealers, including proprietary trading desks in investment banks, provided liquidity in response to the large selling by clients. Corporate bond inventory of dealers rose sharply as a result. Although providing liquidity, limits to arbitrage, possibly in the form of limited capital, obstructed the convergence of the basis. We further show that the unwinding of precrisis "basis trades" by hedge funds is the main driver of the large negative basis. Price drops following Lehman's collapse were concentrated among bonds with available CDS contracts and high activity in basis trades. Overall, our results indicate that hedge funds that serve as alternative liquidity providers at times, not dealers, caused the disruption in the credit market.

Key words: CDS-bond basis, limits to arbitrage, credit default swaps, liquidity, corporate bonds, Volcker rule

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1 Introduction

In the months following Lehman Brothers' bankruptcy in 2008, the previously close relationship between corporate bond and CDS spreads, i.e. the CDS-bond basis, broke down. As the mispricing widened, many questioned the role of dealers in the corporate bond market (e.g., Duffie (2010), and Bai and Collin-Dufresne (2010)). As market-makers, corporate bond dealers are supposed to "lean against the wind" by absorbing liquidity shocks and providing immediacy to liquidity demanders (Weill (2007)). Whether dealers performed their role as liquidity providers during the crisis is an open empirical question.

Both academics and regulators point fingers at dealers for not providing liquidity and even destabilizing the corporate bond and CDS markets. In particular, they argue that the unwinding of arbitrage trading by dealers was one of the main causes of the large negative basis. For example, Mitchell and Pulvino (2012) suggest that investment banks, typically being dealers in these over-the-counter (OTC) markets, were forced to sell large amounts of corporate bonds and unwind CDS positions, which led to the large negative CDS-bond basis. In addition, the aggregate holdings of primary dealers published by the Federal Reserve Bank of New York (see Figure 6.1) are taken by various studies, for example, Bai and Collin-Dufresne (2010), as evidence of the excessive risk-taking of dealers followed by deleveraging, leading to dealers failure to provide liquidity.

Given this backdrop, regulators under the Volcker rule are beginning to rein in dealers' risk taking in OTC markets. The rule prohibits proprietary trading by banks except for market-making activities. As Duffie (2012) and Acharya and Richardson (2009) point out, however, the proposed rule would reduce the liquidity provision capacity of market-makers, and, eventually, other institutional investors will fill the void. Whether such market-making by non-dealer institutional investors would result in a more stable financial system is unclear.

We tackle this issue in this paper. Employing unique databases for CDS and corporate bond trades, we examine dealers' concurrent trading in these markets during the 2007-2009 financial crisis when demand for liquidity was supposedly very high. In particular, we ask the following questions: Were dealers in the OTC markets seeking rather than providing liquidity and thereby exacerbating the CDS-bond basis? Did deleveraging by corporate bond dealers drive the large negative basis in the aftermath of Lehman Brothers bankruptcy? Who or what were then driving the negative basis? These questions are important in light of the recent regulatory debate over whether dealers should be given less discretion in liquidity provision.

First, we show that dealers in the corporate bond market were indeed deleveraging at the onset of the financial crisis until the fall of Bear Stearns. However, contrary to the common perception that dealers were unloading corporate bonds following liquidity shocks due to the Lehman Brothers collapse, we find that the unloading of bonds came to an end and dealers actually tended to increase their corporate bond holdings in 2008. During the period following the collapse of Lehman Brothers, when corporate bond prices were severely distressed, dealers' bond inventory increased sharply. The evidence suggests that dealers were performing their customary role as liquidity providers when their clients were demanding liquidity.

We then formally examine whether dealers provided liquidity when corporate bond and CDS prices deviated from no-arbitrage pricing levels. Our empirical results provide very strong evidence for liquidity provision by corporate bond dealers. Specifically, dealers' trades are negatively associated with corporate bond price changes, an indication that bond dealers provided liquidity by trading against the tide when other traders drove prices away from no-arbitrage pricing. Liquidity provision by corporate bond dealers was strong, especially after Lehman Brothers' collapse, when clients were desperately dumping bonds in the market and seeking liquidity. These results contrast with the common notion that dealers dumped their cash bond positions after the collapse, as suggested by Mitchell and Pulvino (2012) and Bai and Collin-Dufresne (2010).

Next, we investigate dealers' liquidity provision in greater depth. Although clients demanded liquidity following the Lehman collapse, it is possible that this demand was due to convergence trading, which closes price gaps between CDSs and bonds. For example, clients could have bought and pushed up bond prices when bonds were cheap relative to

CDSs and, as a result, the price gap between the bonds and CDSs would have shrunk. In our regression analysis, however, we do not find evidence that clients engaged in convergence trading following the collapse of Lehman. Rather, clients widened the price gaps, especially when the basis was large and negative.

Although corporate bond dealers provided liquidity, the level of provision was insufficient, as evidenced by the large price changes associated with clients' net order flows. Also, we do not find that dealers traded aggressively to close the price gaps when bond prices fell significantly, possibly because financial intermediaries lacked sufficient capital, as noted by Brunnermeier and Pedersen (2009) and Duffie (2010).

Having shown that dealers were engaged in liquidity provision, we address the following question: who or what drove the negative basis? Proprietary trading desks at investment banks are unlikely to be the main culprit, since our measure of dealers' trades includes those of proprietary trading desks by the same dealer banks. We hypothesize that the unwinding of CDS-bond basis trading by other highly levered traders, e.g. hedge-funds, was the driver.[1] In a so-called negative basis trade, arbitrageurs buy relatively cheap cash bonds with funding and hedge the long position with CDSs. Simultaneous exits of arbitrageurs following the Lehman Brothers collapse might have caused massive selling pressure in the corporate bond market. If that had occurred, we should observe that liquidity demand and price declines were greater for bonds with actively traded CDS contracts.

We find evidence consistent with the hypothesis that the unwinding of basis trades by non-dealer arbitrageurs drove the negative basis following the Lehman collapse. We find that dealers' corporate bond inventories rose sharply for bonds with traded CDS contracts, compared with bonds without traded CDS. Hedge funds unwound their long CDS positions substantially, while dealers increased long CDS positions. Other institutional investors did not, however, exhibit strong liquidity demand following the collapse. For example, insurance companies' liquidity demand did not exacerbate the negative basis. Mutual

[1] Mitchell and Pulvino (2012) describes how the deleveraging of highly levered hedge funds, instigated by the failure in the rehypothecation lending market, could be a reason for liquidity demand in the corporate bond market, following the Lehman collapse.

funds sold bonds without associated traded CDS instead of bonds with traded CDS.

More importantly, we find that prices of bonds with available CDS contracts declined more than non-CDS bonds. Specifically, returns of bonds with traded CDS contracts were 8% lower on average in September of 2008. Moreover, both for bonds with more negative basis and for supposedly easier-to-arbitrage bonds we find that prices fell more at the end of August 2008, the month before the Lehman Brothers collapse. We proxy the ease of basis trading using the maturity of bonds at that time. Since five-year maturity CDS contracts are the most prevalent, if a bond maturity was close to five years at the end of August 2008 and its basis was also large and negative, it was more likely that active basis trading was involved with the bond. Following the negative funding shock in September 2008, price declines would have been concentrated for those bonds, which we confirm in our empirical analysis. These results combined suggest that the large negative basis was driven by non-dealer arbitrageurs. The results are also consistent with the findings of Franzoni and Plazzi (2013), which document liquidity demand by hedge funds in the equity market during the financial crisis.

Our empirical evidence strongly suggests that the disruption in the cash market was due to excessive arbitrage trading by hedge-funds that was enabled by the presence of derivative contracts. This reveals a new aspect such that the CDS market can affect the cash market and adds to the growing literature on the impact of CDS on the real economy. For example, Bolton and Oehmke (2011) show the implications of the empty creditor problem when debtors have access to CDS contracts, and Kim (2013) provides some empirical evidence regarding the ex-ante impact of empty creditors on corporate debt contracting. Saretto and Tookes (2013) show that firms have lower financing costs and can lengthen debt maturity when there are available CDS contracts. Subrahmanyam et al. (2012) show that CDS contracts can exacerbate the credit risk of the reference entity. We add to this literature by providing novel evidence that the existence of derivative contracts can disrupt the underlying cash market.

Our overall result has an important implication for the Volcker rule, the implementation of which is underway and which is to rein in dealers' risk-taking in the OTC market.

The rule prohibits proprietary trading by banks except for market-making activities. As Duffie (2012) points out, however, once the proposed rule is implemented, market-makers' capacity to provide liquidity will be reduced. Eventually, other institutional investors, including hedge funds, will fill the void. This is not a very desirable outcome, because our evidence points out that the unwinding of arbitrage positions can be detrimental to the cash market, and thus to the funding costs of corporations. Since dealers are typically banks that are regulated by capital requirements, they would be in a better position to provide liquidity. They also have incentives to provide liquidity even in the worst liquidity crisis to maintain their reputation as market-makers.

Our paper is organized as follows. Section 2 describes the main datasets and the sample construction. Section 3 shows that, although dealers de-levered on aggregate in the period leading to the crisis, the delevering paused in the period immediately after the Lehman debacle and dealers actually increased their corporate bond holdings sharply. Section 4 examines more formally whether dealers provided liquidity throughout the financial crisis. In Section 5 we propose an explanation for the existence of the large negative basis in the autumn of 2008. Section 6 concludes.

2 Data Description and Variable Construction

In this section, we first describe the corporate bond and single-name CDS datasets that provide traded prices and quantities for our analysis. We then describe the construction of key variables in our analysis, particularly for dealer flows and the bond-CDS basis.

2.1 Corporate Bond and CDS Data

Corporate bond prices and volumes are obtained from an enhanced version of the Trade Reporting and Compliance Engine (TRACE). The enhanced TRACE specifies whether a trade is carried out between two dealers, or between a customer and a dealer, as well as indicating the customer's trading direction. The dataset also includes untruncated volumes, information previously not disseminated to the public. These enhanced features allow us to track interdealer and dealer-client flows as well as the associated traded prices.

To obtain daily prices and volumes, we eliminate duplicate records and reversed and canceled trades, as described in Dick-Nielsen (2009). We also eliminate potential influential outliers in terms of price and/or trade size that deviate from the surrounding reports. These outliers usually result from manual errors in which the decimal point was entered incorrectly. After these filters, we construct daily bond prices by weighting each trade by its size after eliminating retail trades (trade size less than $100,000), following the recommendation of Bessembinder et al. (2009).[2]

The Mergent FISD provides bond characteristics as well as issuance and redemptions information on publicly traded corporate bonds in the United States. We obtain the terms and conditions, amount outstanding, ratings, and other relevant information of corporate bonds from this database.

The CDS spread data are provided by the Markit Group. We use CDS spreads on quoted modified restructuring clauses.[3] We exploit the full-term structure of CDS spreads in our calculation of the basis. Since the basis calculation requires the price difference between bonds and CDSs on the same underlying company, we carefully match each single-name CDS contract to bonds issued by the same reference entities. Bonds issued by subsidiaries are matched to their own CDS contracts if they have CDS contracts available. If not, they are matched to CDS contracts on the parent company.

For a subset of CDS contracts in the main sample we also use a unique transaction-level dataset, provided by the Depository Trust & Clearing Corporation (DTCC). The reference entities in this database are all financial firms for the period between February 2007 and June 2009. The database provides information on volumes and types of institutional investors (dealers, hedge funds, insurance companies, and so on) for each buy and sell CDS transaction. We use these transactions to construct the CDS positions of dealers

[2]Bessembinder et al. (2009) recommend this procedure for the construction of daily bond prices to minimize the effect of large bid-ask bounce associated with small trades.

[3]We use the modified restructuring clause as it was the most commonly traded until April 2009, which is the heart of our sample period and also minimizes the impact of the cheapest-to-deliver option.

and hedge funds on those financial reference entities.[4]

We obtain our main dataset by merging the aforementioned databases. Our sample period runs from July 2007 through June 2009, the period spanning the financial crisis.

2.2 Construction of Key Variables

2.2.1 Net Flows and Inventory

We construct the net order flow of corporate bond dealers, using the enhanced TRACE with untruncated trade size. Since each transaction identifies whether the reported trade is a buy, a sell, or an interdealer trade, we define the net order flow of bond issue i at day t as:

$$q(\text{Bond}, i, t) := \sum_{n=1}^{N_t} (\text{Buy}(\text{Bond}, i, n) - \text{Sell}(\text{Bond}, i, n)) \tag{2.1}$$

where the buy and sell orders reflect the dealer perspective and N_t is the total number of transactions on day t. Using the daily net flow, we then construct the dealers' inventories at the bond issue level:

$$I(\text{Bond}, i, t) := I(\text{Bond}, i, 0) + \sum_{\tau=1}^{t} q(\text{Bond}, i, \tau) \tag{2.2}$$

where $I(\text{Bond}, i, 0)$ is the initial inventory of bond i, before the existence of the TRACE system. Since we do not observe $I(\text{Bond}, i, 0)$, our analyses later focus on the variation in dealer inventories. Note also that our measure of dealers' net flows include those of proprietary trading desks or investment management subsidiaries in investment banks.[5]

Similarly, on the CDS market front, we calculate net order flows and inventories of

[4]For further details on the dataset, see Shachar (2013).

[5]FINRA member subsidiaries of registered dealers are subject to the dual-side reporting obligation under the Rule 6700 as any other FINRA member firm. See http://www.finra.org/Industry/Compliance/MarketTransparency/TRACE/FAQ.

dealers for the sub-sample of financial firms. More formally, we define:

$$q(\text{CDS}, i, t) := \sum_{n=1}^{N_t} (\text{Buy}(\text{CDS}, i, n) - \text{Sell}(\text{CDS}, i, n)) \tag{2.3}$$

$$I(\text{CDS}, i, t) := I(\text{CDS}, i, 0) + \sum_{\tau=1}^{t} q(\text{CDS}, i, \tau) \tag{2.4}$$

where $I(\text{CDS}, i, 0)$ is the initial position of CDS i before it was reported to DTCC.

2.2.2 The CDS-Bond Basis

The CDS-bond basis at time-t is defined as the difference between the CDS premium, CDS(t), and the bond credit spread, CS(t): basis(t) = CDS(t)- CS(t). In calculating the basis, we follow the par-equivalent CDS spread (PECS) methodology of J.P. Morgan, which is also used in other studies (e.g. Bai and Collin-Dufresne (2010)).[6]

The PECS is essentially a bond credit spread that is consistent with the term structure of default probabilities priced in the CDS contracts of the issuer. Specifically, we apply a parallel shift to the survival probability curve from the CDS contracts to match the bond with the present value of cash flows.Once we match the bond price, we use the new survival probabilities to calculate implied CDS spreads, which are the abovementioned PECS. The detailed procedures for the PECS calculation is provided in Appendix A.

Consistent with common practice in the literature, we exclude from the basis calculation bonds with embedded options or special pricing conditions such as convertible, callable or putable bonds, and bonds with sinking funds provisions in order to eliminate pricing impacts from contractual differences. Since we calculate the basis for the most liquid five-year CDS contract, we include only bonds with 3-10 remaining years until maturity in the PECS calculation.

[6]There are several metrics that can be used to calculate the bond spread, including the Z-spread, par asset swap spread, and PECS. Blanco et al. (2005) and Fontana (2011) simply use the difference between the CDS price and the credit spread, which is calculated as the difference between the interpolated 5-year yield on risky bonds and the 5-year swap rate

3 Corporate Bond Position of Dealers during the Financial Crisis

It is commonly hypothesized that dealers accumulated highly levered positions in the cash market during the credit boom period before the financial crisis and subsequently de-levered significantly over the course of the financial crisis (e.g., Adrian and Shin, 2010, Acharya and Viswanathan, 2011, Acharya and Richardson, 2009). This argument is supported by the data on the aggregate holdings of primary dealers, published by the Federal Reserve Bank of New York, which we reproduce in Figure 6.1 (dotted line). However, these holdings data also include bonds issued by non-federal agencies (e.g. GSEs) and thus disguise the distinct trend of corporate bond holdings by dealers.[7]

Although dealers' holdings in corporate bonds have not been examined empirically yet, the potential accumulation and subsequent deleveraging of such bonds by dealers have been identified as one of the main drivers of the negative basis during the financial crisis (Bai and Collin-Dufresne, 2010, Mitchell and Pulvino, 2012, and Fontana, 2011). Large negative shocks can force levered financial institutions including dealers to unload bond positions. Given initially high long positions, the unwinding of corporate bonds by dealers might have placed heavy selling pressure during the period in which many investors were selling and demanding liquidity. If dealers who are supposed to lean against the wind also sell during this period, bond prices will drop significantly and potentially deviate from no-arbitrage pricing. This mechanism is often pointed out as the main reason for the large negative basis of non-AAA bonds during the financial crisis, as plotted in Figure 6.2.

Using our database, we document evidence against this widespread perception. The advantage of our database is that we can analyze dealers' corporate bond positions throughout the financial crisis period, whereas the data published by the Federal Reserve Bank of New York is based largely on the aggregate bond positions, including MBSs issued by non-federal agencies and GSEs.

[7] The Federal Reserve Bank of New York began collecting primary dealers' holdings of corporate bonds as a separate asset class only after April 3rd 2013. Thus, the data from the Federal Reserve Bank do not provide the exact corporate bond holdings of dealers, because the Fed extrapolates the corporate bond positions for the period leading up to April 3rd 2013 using the composition of corporate bond holdings on that date.

In Figure 6.1, we plot the time series for the corporate bond inventory of dealers by cumulating dealer transactions from the TRACE database (solid line). Since the dealers' initial position in corporate bonds is unavailable, we begin the plot at zero in Figure 6.1. Consistent with the notion that dealers accumulated cash bond positions, we find that the dealers' corporate bond inventory increases substantially (by around 80 billion dollars) until the summer of 2007, the period leading to the financial crisis.

After the summer of 2007, we observe a large decline in dealers' corporate bond holdings, again consistent with the deleveraging hypothesis. However, the unloading of corporate bonds suddenly ceases around the time when Bear Stearns collapsed. The dealers' positions remain within that range until the collapse of Lehman Brothers. After the Lehman Brothers collapse, the corporate bond positions start to increase rapidly and continue to do so until the end of 2008. It was during this period, from Lehman Brothers' collapse (September 2008) through the end of 2008, that the negative basis was the most severe for non-AAA investment grade bonds, as plotted in Figure 6.2. Dealers were buying bonds when bond prices were the most distressed as indicated by the negative basis.

This pattern in dealers' positions suggests that, contrary to the common notion that dealers demanded liquidity during the financial crisis, dealers in fact provided liquidity when corporate bond prices were in the state of greatest distress. It was clients, not dealers, who sold large quantities of corporate bond and demanded liquidity. We examine dealers' liquidity provision in greater depth in the next section.

4 Liquidity Provision by Dealers during the Financial Crisis

The results reported in the previous section show that corporate bond dealers increased inventory sharply after the Lehman collapse, suggesting that dealers provided liquidity when there was massive selling in the corporate bond market. In this section, we examine dealers' liquidity provision more formally.

We take our notion of liquidity provision and demand from the literature on the limits of arbitrage.[8] For example, in Brunnermeier and Pedersen (2009), liquidity providers are arbitrageurs who smooth price fluctuations when the price and fundamental values diverge due to liquidity shocks. Thus, liquidity providers tend to trade against price changes (lean against the wind). They buy low when prices fall and sell high when prices rise. Liquidity demanders, on the other hand, demand immediacy in trading and move prices in the direction of their trades. Keim and Madhavan (1997), Puckett and Yan (2011), and Campbell et al. (2009) also employ a similar notion of liquidity provision in interpreting transaction costs. In a recent paper, Franzoni and Plazzi (2013) employ the same notion of liquidity provision in examining liquidity provision by hedge funds.

Following this notion of liquidity provision, we examine how dealers' daily net flow in the CDS and bond markets are associated with daily changes in CDS and bond prices and in the basis. Specifically, we examine dealers trading against price pressure, which drives corporate bond and CDS prices away from each other. Liquidity provision is identified as negative association of price changes and net order flow.

4.1 Baseline Regression

4.1.1 Specification

The baseline model regresses daily changes in bonds' PECS and CDS spread on net order flows by dealers. Specifically, we consider the following specifications:

$$\Delta p(\text{Bond}, t) = c_1 + \beta_1(-q(\text{Bond}, t)) + \text{ctrls} + \varepsilon_{1t} \tag{4.1}$$

$$\Delta p(\text{CDS}, t) = c_2 + \beta_2 q(\text{CDS}, t) + \text{ctrls} + \varepsilon_{2t} \tag{4.2}$$

$$\Delta \text{basis}(t) = c_3 + \gamma_3 q(\text{Bond}, t) + \delta_3 q(\text{CDS}, t) + \text{ctrls} + \varepsilon_{3t} \tag{4.3}$$

where $p(\text{Bond}, t)$ is the PECS of a bond, $p(\text{CDS}, t)$ is the CDS spread of the same firm, and $\text{basis}(t)$ is the difference between the CDS and the par-equivalent bond spreads, $p(\text{CDS}, t) - p(\text{CS}, t)$. Since the five-year maturity CDS is the most liquid, we use five-year

[8] Shleifer and Vishny (1997), Vayanos and Gromb (2010) and many others.

maturity PECS and CDS spreads. $q(\text{Bond}, t)$ is the corporate bond net order flow of dealers and $q(\text{CDS}, t)$ is the CDS net order flow of dealers on day t.

The first two specifications (4.1) and (4.2) allow us to analyze whether dealers' trades provide or seek liquidity in each market. Negative signs on β_1 and β_2 imply that dealers trade to "lean against the wind," indicating liquidity provision. In (4.1), for example, a negative value for β_1 implies that dealers' buys are associated with an increase in credit spreads (because of the negative sign in front of $q(\text{Bond}, t)$), which in turn means that dealers tend to buy when bond prices fall. In (4.2), a negative β_2 implies that CDS spreads decrease when dealers buy, also signaling that dealers tend to trade against price movements.

The third regression specification, (4.3), reveals whether dealers provide liquidity when prices deviate from relative pricing, implied by the no-arbitrage principle between CDS and corporate bonds. As in Equations (4.1) and (4.2), negative signs on γ_3 and δ_3 imply that dealers provide liquidity in the bond and CDS market, respectively. Examining basis changes enables us to examine whether dealers were acting differently when prices diviated from the no-arbitrage relationship.

We include control variabls, ctrls, which include changes in Libor-OIS and Repo-Treasury spreads (3 months) for uncollateralized and collateralized funding conditions, respectively, as well as the change in VIX to capture aggregate uncertainty. We also include a lagged basis to capture the idea that CDS and bond prices are cointegrated (Blanco et al., 2005). Prices could deviate from equilibrium, and the error correction (or convergence) will depend on how far prices are from relative pricing. Even without trading volumes, prices can adjust to the equilibrium level, because dealers will adjust their quotes accordingly. This error correction, or the lagged basis term, captures this convergence effect.

To examine liquidity provision throughout the successive phases of the financial crisis, we divide the sample period into three sub-periods. The first sub-period, *Crisis 1*, runs from July 1st 2007 through September 15th 2008 when Lehman Brothers' collapsed. This period marks the beginning of the meltdown of the financial market and includes the collapse of Bear Stearns. Although volatility was elevelated, the CDS-bond basis was in a moderate range. The second period, *Crisis 2*, is the period from the Lehman collapse when the basis was large and negative. The third period, *Crisis 3*, is the recovery period running from February 2009 through June 2009, during which large gaps in basis started to narrow.

4.1.2 Baseline Regression Results

We first provide statistics on dealer volumes and trades in Table 1. We report averages and standard deviations for the basis, CDS spreads, PECS, and dealers' buy and sell quantities in both the bond and CDS markets. On average, bond dealers buy \$3-\$5 million dollars worth of bonds at face value each day. Corporate bond dealers tend to sell more in periods other than *Crisis 2*, which is consistent with the idea of deleveraging. However, in the *Crisis 2* period, buy quantities in non-AAA bonds are greater than sell quantities, indicating that bond dealers were providing liquidity during the post-Lehman period.

In Table 2, we report the liquidity provision results from regressions (4.1), (4.2), and (4.3) for each sub-period. The results show liquidity provision by dealers, especially in the bond market. In the first columns of each panel of the sub-periods (Δp(Bond) and Δp(CDS)), bond dealers' trades are always negatively associated with bond price changes. The large negative coefficients imply that bond dealers provide liquidity to non-dealer traders but market liquidity is scarce. The economic magnitudes of the coefficients are sizable. During the peak of the financial crisis, a one standard deviation change in dealer trades is associated with a six basis points change in bond prices. In the CDS market, CDS quantities do not have large negative coefficients except in the *Crisis 3* period, implying that CDS dealers tend to absorb the demand and the market is relatively liquid.

We move on to the next two columns (titled $\Delta basis$) in each sub-period panel to investigate dealers' liquidity provision when prices deviate from relative pricing. Similar to the previous results, bond dealers provide liquidity when bond prices fall or rise relative to CDS prices, which can be seen from the negative coefficients on net bond order flows.

This indicates that dealers serve as an important liquidity provider when there are large changes in bond prices. The flip side of this result is that other traders in the bond markets were driving prices away, or widening the basis. Overall, the results are inconsistent with the common belief that bond dealers were driving the basis.

In contrast to the bond market results, we find no indication that CDS trades are associated with basis changes, and thus CDS dealers' trades were not particularly associated with liquidity provision. In the basis regressions, shown in the fourth columns, we find that dealers' trades are not statistically significant in all sub-periods.

4.2 Stabilizing vs. Destabilizing Liquidity-Seeking

Depending on the sign of the basis, liquidity seeking does not necessarily widen the bond-CDS price gaps. For example, when the basis is negative, liquidity-seeking sell orders in bonds will drive bond prices further down, which can be seen as destabilizing liquidity-seeking in the sense that it exacerbates the breakdown of the law of one price. In contrast, if clients buy bonds and drive prices up when the basis is negative, this liquidity demand of clients can be viewed as stabilizing-liquidity seeking, because clients' trades move prices back to their parity relationship.

Although dealers provide liquidity on average, it is possible that they are engaged in destabilizing liquidity-seeking and thereby drive the basis deeper into negative territory. To investigate this possibility, we divide the sample into positive and negative basis cases and examine how dealers' buy and sell quantities are associated with price changes. Specifically, we investigate the following regression specification, separately for cases in which the lagged basis basis$(t-1)$ is positive and negative:

$$\begin{aligned} \Delta \text{basis}(t) &= c + \beta_1 q(\text{CDS}, \text{buy}, t) + \beta_2 q(\text{CDS}, \text{sell}, t) \\ &\quad + \gamma_1 q(\text{Bond}, \text{buy}, t) + \gamma_2 q(\text{Bond}, \text{sell}, t) + \text{ctrls} + \varepsilon_t \end{aligned} \tag{4.4}$$

The buy and sell flows are defined as positive and negative quantities: $q(\text{buy}, t) \equiv q(t) 1_{q(t)\geq 0}$ and $q(\text{sell}, t) \equiv q_t 1_{q_t<0}$. Similar to the previous specifications, the negative signs on the coefficients indicate that dealers trade to provide liquidity when clients seek liquidity. For example, negative coefficients on β_1 and β_2 indicate that dealers' CDS buys are associated with a decline in the basis (CDS spreads are cheap relative to bond spreads) and their CDS sells are associated with an increase in the basis (CDS spreads are expensive relative to bonds). Similarly, a positive γ_1 indicates that dealers' bond buys are associated with a decline in the basis (bonds are cheap relative to CDS) and their bond sells are associated with an increase in the basis (bonds are expensive relative to CDS).

Table 3 provides the results of regression (4.4). Throughout the financial crisis, bond dealers were providing liquidity whether the basis was positive or negative. Dealers did not demand liquidity or widen the price gaps. For example, in *Crisis 2* when the basis is negative, dealers' buy volume shows strong liquidity provision with a highly statistically significant coefficient of –12.09. When bond prices were severely distressed and the basis widened to a large negative number following the collapse of Lehman Brothers, clients dumped corporate bonds and drove the basis even farther into negative territory, while dealers tended to stabilize the market by providing liquidity. In comparison, dealers' sells are not associated with strong liquidity provision except in the case of a negative basis case in the *Crisis 3* period. In that period, the coefficient of the sell net flow is –5.86 and is statistically significant at the 1% level. This provides only weak evidence of stabilizing liquidity-seeking by clients, who were presumably correcting the negative basis by buying bonds aggressively.

For the CDS market, we find some evidence of destabilizing liquidity-seeking by dealers. For example, in the *Crisis 3* period when the basis is negative, CDS dealers' sell net flow has a coefficient of 5.41 with statistical significance at the 1% level. These sell trades by dealers narrowed CDS spreads, which might have exacerbated the negative basis.

4.3 Liquidity Provision when Mispricing is Large

In this section, we investigate whether dealers provide liquidity when the market needs it most or when the price gap between CDS and bonds is wide. Given large selloffs in the bond market and a large negative basis, dealers could have suffered from reduced funding liquidity and started selling bonds in the market, similar to the liquidity spiral channel of Brunnermeier and Pedersen (2009). This mechanism implies that, although dealers tend to provide liquidity, they might seek liquidity when the basis is very negative. To that end, we interact a lagged absolute basis with volumes:

$$\Delta\text{basis}(t) = (\beta_1 + \beta_2 \cdot |\text{basis}(t-1)|)\, q(\text{CDS}, \text{buy}, t) + (\beta_3 + \beta_4 \cdot |\text{basis}(t-1)|)\, q(\text{CDS}, \text{sell}, t) + (\gamma_1 + \gamma_2 \cdot |\text{basis}(t-1)|)\, q(\text{Bond}, \text{buy}, t) + (\gamma_3 + \gamma_4 \cdot |\text{basis}(t-1)|)\, q(\text{Bond}, \text{sell}, t) + \text{ctrls} + c + \varepsilon_t \quad (4.5)$$

If liquidity provision is stronger when the basis is larger, we expect the coefficients of the interaction terms (β_2, β_4, γ_2, and γ_4) to be negative.

The results are provided in Table 4 and indicate that bond dealers' liquidity provision is stronger when the basis is wider, especially when the basis is negative. For example, in the *Crisis 2* period when liquidity is supposedly is scarcest, the coefficient on the interaction of the bond buy with $|\text{basis}(t-1)|$ is –8.92, which is statistically significant at the 1% level. Also in *Crisis 3*, we observe a coefficient on the interaction term of –14.20, which is also statistically significant at the 1% level. These results indicate that bond dealers were providing liquidity when bond prices were very distressed, a period during which the market was in a great need for liquidity.

However, the results also exhibit interesting liquidity-seeking on the part of corporate bond dealers. We find that dealers seek liquidity in some cases when the basis is large. The first case is when the lagged basis is negative in *Crisis 1*. The coefficient is 19.35, showing that dealers were buying to drive bond prices up. This can be viewed as stabilizing liquidity-seeking by bond dealers when the basis is negative (bonds are cheap relative to CDS). During the *Crisis 1* period, when dealers have relatively greater flexibility, they try to narrow the pricing gaps. Additional interesting liquidity-seeking cases occur during *Crisis 2* and *Crisis 3* when the lagged basis is positive, possibly representing a flight-to-quality by dealers. Note that the positive basis is concentrated in AAA bonds. Dealers were also chasing these AAA bonds along with other traders. Since AAA bonds were coveted, there was little selling pressure for AAA bonds, and thus even when dealers were buying them prices went up.

In the CDS market, we find weaker results for liquidity-seeking, similar to results shown in previous tables. We find that CDS dealers seek liquidity during the *Crisis 2* period. This liquidity-seeking occurs when the basis is negative and dealers buy CDS, which narross the price gaps and thus stabilizes the market. The overall results again suggest that dealers in both the markets tend to provide liquidity when the market needed it most, except for the possible flight-to-quality cases for AAA bonds.

4.4 Liquidity-Seeking by Insurance Companies

The results so far demonstrate that, contrary to the common perception, dealers in the corporate bond markets provided liquidity when their counterparties were seeking liquidity. Who are these counterparties who seek liquidity?

Insurance companies, pension companies, mutual funds, and hedge funds are major investors in the corporate bond market. Regarding these players, we investigate the daily trading behavior of insurance companies, using their secondary market trading volumes as recorded in the NAIC database.Figure 6.3 depicts buy (positive) and sell (negative) flows by insurance companies. At the daily volume level, the trading activity of insurance companies is highly volatile. We find some weak evidence for a sell-off following the Bear Stearns and Lehman Brothers' collapses, although one that is not very pronounced.

In Table 5, we formally investigate liquidity demand by insurance companies by estimating Equation (4.4). We find, on aggregate, that insurance companies are liquidity seekers on average, as reflected by the positive coefficients of their sell net flows. Their trades, however, are not associated with price declines in *Crisis 2* in a statistically significant way. This is an indication that insurance companies, along with dealers, did not drive the large negative basis following the Lehman collapse.

5 The CDS Market and the Negative Basis During the Financial Crisis

The results discussed in the previous section show strong liquidity demand by non-dealer corporate bond traders. Still, these results do not answer the question as to what drove the negative basis during the financial crisis. Several studies have tackled this question, for example, Gârleanu and Pedersen (2011), Augustin (2012), Fontana (2011), Duffie (2010), and Bai and Collin-Dufresne (2010). Although the conclusions of the papers differ slightly, the common theme is that many factors that might have driven the basis were not able to resolve the question completely.

In this section, we propose a new channel that can help explain the large negative basis during the financial crisis. We focus on the role of CDS-bond arbitrage trading. Specifically, we show that the high level of liquidity-seeking in the corporate bond market was concentrated on bonds with available CDS contracts. For these bonds, highly levered non-dealer players in the market, most likely to be hedge funds, had to de-lever their corporate bond positions following Lehman Brothers' collapse, and as a result, corporate bond dealers had to provide liquidity by buying the bonds dumped by CDS-bond basis traders. In contrast, bonds with no CDS contracts available might not have experienced heavy selling pressure from non-dealer clients and the corresponding price declines might not have been severe. We provide results supporting this hypothesis.

5.1 Dealers' Inventory of Bonds with CDS Available vs. those with no CDS Available

In Figure 6.4, we show the difference between dealers' holdings of corporate bonds with available CDS and those without available CDS. The pattern in the figure indicates clearly that dealers increased inventory only for bonds with available CDS in the period immediately after Lehman Brothers' collapse, which in turn means that clients sold bonds with CDS available. The pattern is also consistent with the hypothesis that high liquidity demand and also wide basis deviation during the financial crisis resulted from the unwinding undertaken by bond-CDS arbitrageurs.

In Figure 6.5, we examine the holdings of corporate bonds by open-end domestic mutual funds, as provided in the MorningStar database. Specifically, we plot mutual funds' holdings of bonds with CDS available vs. those with CDS unavailable. We find that mutual funds did not significantly change holdings of bonds with CDS contracts available. Rather, they sold non-CDS bonds, indicating that mutual funds are unlikely to have driven the large negative CDS basis following the Lehman collapse.

In sum, the evidence suggests that bonds with CDS contracts available were sold in great volumes after the Lehman Brothers collapse and were sold by non-dealer, non-insurance companies, and non-mutual fund investors. Who were those liquidity-demanding investors? The overall evidence suggests they were non-dealer basis arbitrageurs. Typically, arbitrageurs are dealers, proprietary trading desks in investment banks, or hedge-funds. Our measures for dealer trades available in the TRACE includes those made by proppprietary trading desks in investment banks, which leaves hedge-funds as the most likely liquidity demanders during the months following the Lehman collapse. Mitchell and Pulvino (2012) demonstrates in greater detail how hedge funds demanded liquidity.

Another piece of compelling evidence pointing towards hedge funds comes from Figure 6.6, in which we plot the aggregate positions in CDS held by dealers, hedge funds, and insurance companies, which available in the DTCC database. We find CDS positions of hedge funds are almost the mirror image of those of the dealers, indicating that, at least in the CDS market, hedge funds are the major counterparty to dealers. More importantly, hedge funds' CDS positions decline significantly after the Lehman Brothers collapse, which is also consistent with the idea that CDS-bond basis arbitrage unwinding was the cause of the large negative basis.

5.2 Bond Returns Following Lehman Brothers' Collapse

We compare corporate bond returns on bonds with CDS available with those with CDS unavailable following the Lehman Brothers collapse. According to our hypothesis that the unwinding of the basis arbitrage drove the negative basis, declines in bond prices should be more severe for the bonds with CDS contracts available following the collapse. Our measure for CDS availability is based on Saretto and Tookes (2013), who assume that a CDS exists if they find a quote in Bloomberg.

In addition, we also employ a measure for basis arbitrage activity. If the unwinding of basis arbitrage triggers the sell-off, then the greater the arbitrage activity is, the stronger is the selling pressure on corporate bonds. We use the maturity of the bonds multiplied by the basis as a proxy for basis trading activity. CDS contracts with five-year maturity are the most prevalent ones. If the bond maturity is five-years at the end of August 2008 and the basis is also large and negative, it is more likely that basis arbitrage trading was involved with the bond and the subsequent exits by arbitrageurs might have been more severe.

We first plot cumulative returns through 2008 for corporate bonds with available CDS and unavailable CDS. Figure 6.7 shows that bond prices fell dramatically following the Lehman Brothers collapse. Moreover, consistent with our hypothesis, the decline in bond price is more severe for bonds with CDS contracts, by almost 8%. Around the end of January of 2009, the bond prices rebound, and the recovery is stronger for bonds with CDS available.

To examine bond returns more formally, we run the following regression:

$$\mathrm{Ret}(t) = c_1 + \beta_1 \mathrm{CDS}^{\mathrm{exists}} + \beta_2 \mathrm{basis(Aug)Mat5Y(Aug)} + \mathrm{Controls} + \varepsilon_t \qquad (5.1)$$

where $\mathrm{Ret}(t)$ is monthly bond returns constructed from TRACE; $\mathrm{CDS}^{\mathrm{exists}}$ is a dummy variable that equals 1 if the bond has a CDS contract with a quote in Markit from 2002 to 2009, and zero otherwise; and basis(Aug)Mat5Y(Aug) is the basis level at the end of August of 2008 times an indicator variable that takes the value of 1 if the bond's maturity at the end of August of 2008 is in the range of 4.5 to 5.5 years and zero otherwise. As control variables, we include bond-specific variables including time-to-maturity and the illiquidity measures of Amihud (2010) and Bao et al. (2011). For firm-specific measures, we include market leverage, stock returns, and monthly stock volatility. Since these firm-specific variables are available only for public firms, the sample shrinks substantially when we include them. For macro variables, we include change in VIX and repo rates. We also include bond-level rating dummy variables. We run the regression for the period running from September 2008 through December 2008, since that was the period when bond prices experienced the heaviest selling pressure following Lehman Brothers' bankruptcy.

Table 6 details the regression results. Consistent with our hypothesis that the unwinding of basis trading caused the severe negative basis following the Lehman collapse, we find that bonds with available CDS contracts experience much lower returns in September and October of 2008. Specifically, we find that monthly returns on bonds are 2% lower monthly if the bond has available CDS contracts (see the first column of Table 6). The coefficient is statistically significant at the 1% confidence level.

Furthermore, we find a positive and highly statistically significant coefficient for the interaction term basis(Aug)Mat5Y(Aug), which also strongly support our hypothesis. The coefficient implies that bond returns are lower if the bonds' maturity is close to five years at the end of August 2008 and they have a more negative basis, in which case there are supposedly active basis arbitrage trading immediately before Lehman Brothers' collapse. Given the negative shock at the default, there might have been dramatic unwinding of basis trading, which could have caused massive selling in corporate bonds. Overall, the results support the hypothesis that the unwinding of basis trading caused the large negative basis during the financial crisis.

In Table 7, we perform the regression separately for each month from August 2008 through February 2009. Before the Lehman Brothers collapse (August), there is no effect of CDS availability on bond returns ($\text{CDS}^{\text{exists}}$). Arbitrage activity (Mat5Y(Aug)) is negatively related to bond returns, meaning more basis trading is associated with higher bond returns.

Moving on to subsequent months, however, we find that the presence of CDS contracts and proxy CDS arbitrage activity are strongly associated with bond returns. In September, for example, bonds with CDS available yield on average 8% lower returns than bonds with CDS unavailable. Furthermore, bonds with heavy negative basis trading experienced large price declines. In the following months, as the selling pressure calms down, we do not find significant negative returns for bonds with available CDS contracts, except for February. In October, bonds with heavy basis trading yield higher returns, suggesting the possible return of arbitrageurs to the bond market.

The overall results suggest that the severe negative basis was due to the exits from excessive arbitrage trading. Although we cannot pinpoint exactly who these arbitrageurs were, it is likely that they were mostly hedge funds. In the bond market, dealers including prop trading desks on aggregate did not seek liquidity, nor did mutual funds and insurance companies. In the CDS market, hedge funds were the typical counterparties of dealers and also unwound long CDS positions significantly. Moreover, bond price declines were concentrated on bonds with CDS and supposedly high arbitrage activities.

6 Conclusion

In this paper we examine liquidity provision by dealers in the corporate bond and CDS markets during the 2007-2009 financial crisis. We use unique corporate bond and CDS transactions datasets to construct the positions of dealers in both markets over time as well as the positions of hedge funds in the CDS market. We find that, contrary to the common perception, dealers were engaged in liquidity provision in the corporate bond market throughout the financial crisis. Also, we find evidence that declines in bond prices are concentrated on bonds with available CDS contracts and high levels of activity in basis trades, indicating that the exits of arbitrageurs from pre-existing basis trades triggered the large negative basis following Lehman Brothers' collapse.

Our results have an important implication for the Volcker rule. Once the proposed rule is implemented, market-makers' capacity to provide liquidity will be reduced. Given that market-making is a profitable business, other institutional investors, who are typically arbitrageurs, will potentially fill the void. We doubt whether this is a desirable outcome, because our evidence points out that the unwinding of arbitrage positions by these institutional investors can be detrimental to the cash market, and thus to the funding costs of corporations.

Our paper also adds to the literature on the role of CDS contracts in the real economy. Our empirical evidence suggests that the disruption in the cash market was enabled by the presence of derivative contracts. This reveals a new aspect such that the CDS market can affect the underlying market when arbitrageurs exit at the same time.

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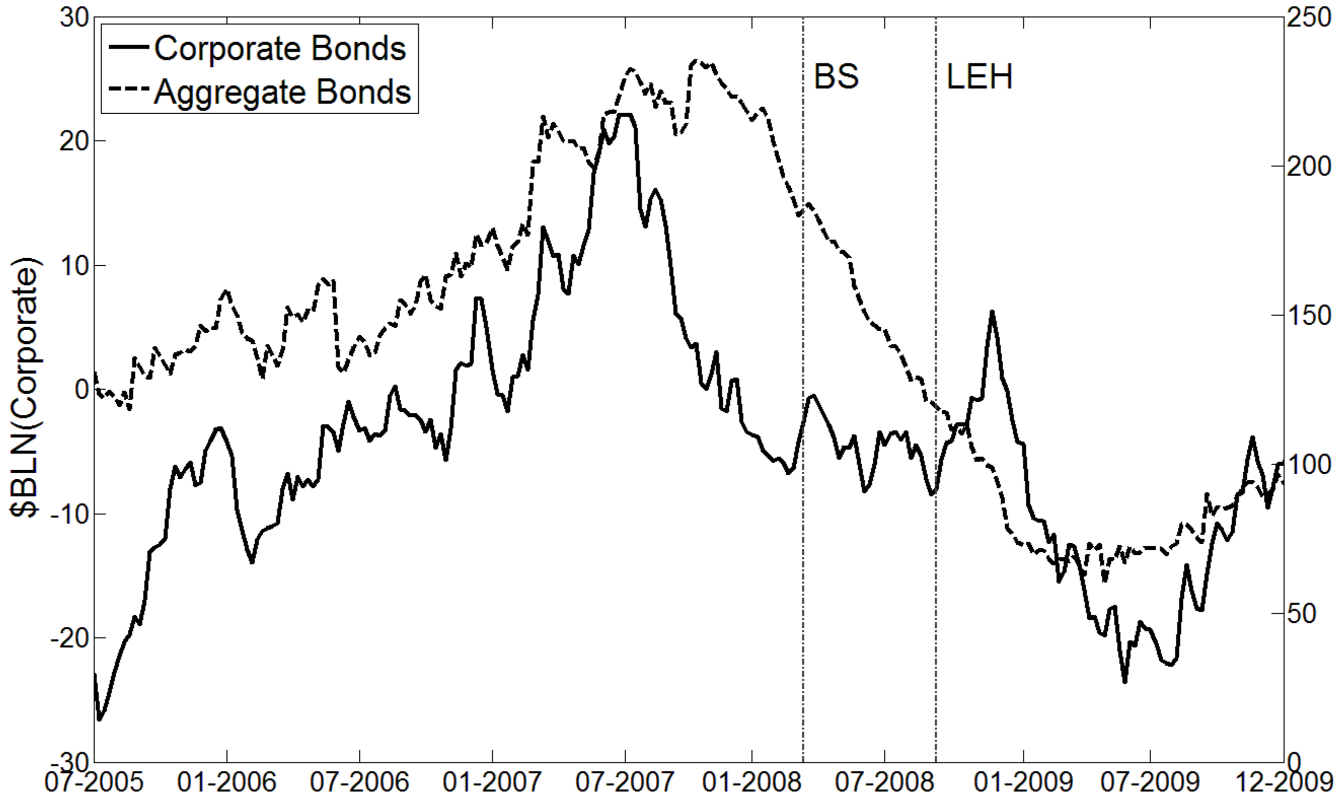

Figure 6.1: Long-Term Corporate Securities Position of Dealers

This figure plots primary dealers' aggregate positions in corporate securities with maturity greater than one year as reported in the Federal Reserve Bank of New York weekly survey (the y-axis on the right) and also plots FINRA member dealers' aggregate position in corporate bonds with maturity greater than one year as constructed from trades that are reported in the TRACE (the y-axis on the left). The aggregate position reported in the Federal Reserve Bank includes non-federal agency and GSE-issued MBS. The aggregate position constructed from TRACE includes only TRACE eligible corporate bonds.

Figure 6.2: CDS-Corporate Bond Basis

This figure depicts the CDS-bond basis for AAA and non-AAA grade (including high yield) bonds. The basis is defined as CDS spreads minus par-equivalent CDS spreads following the methodology by J.P. Morgan. Both the CDS and par-equivalent spreads are five-year maturity. We plot the weekly average values in basis points.

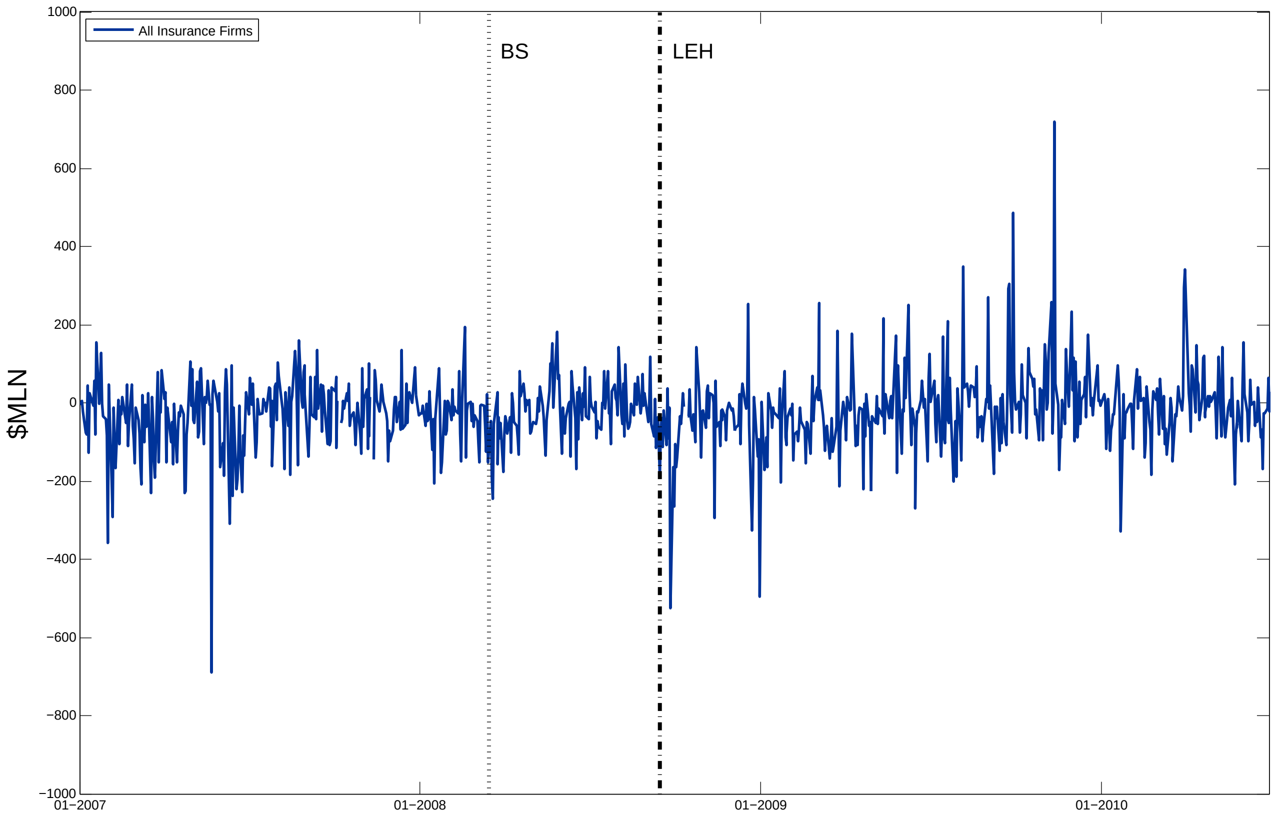

Figure 6.3: Flows by Insurance Companies

This figure shows aggregate corporate bond daily net flows by US insurance companies, as reported to the National Association of Insurance Commissioners (NAIC). The net flow is total daily buy volume minus sell volume by insurance companies excluding transactions related to corporate actions.

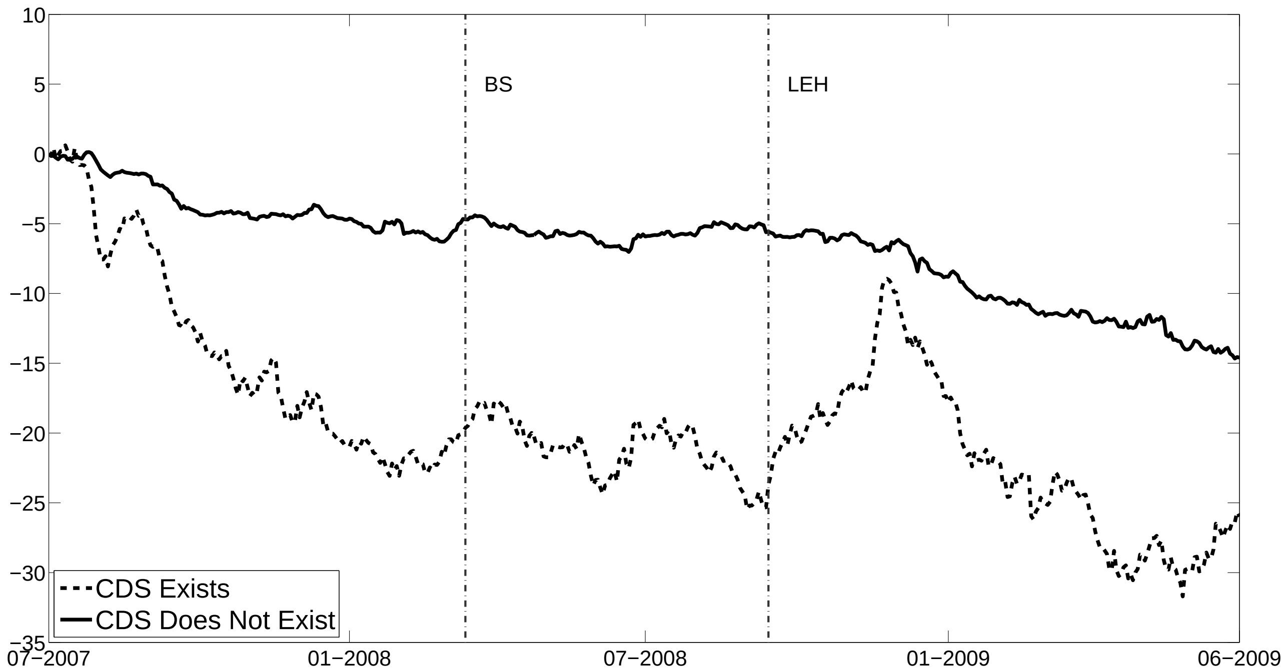

Figure 6.4: Inventory of Corporate Bonds with Available CDS vs. Corporate Bond without Available CDS

This figure plots the aggregate inventories of dealers both for bonds with available CDS and bonds without available CDS. The availability of CDS is determined by the presence of a CDS spread quote for the period from January 2002 through June 2009 in the Markit database.

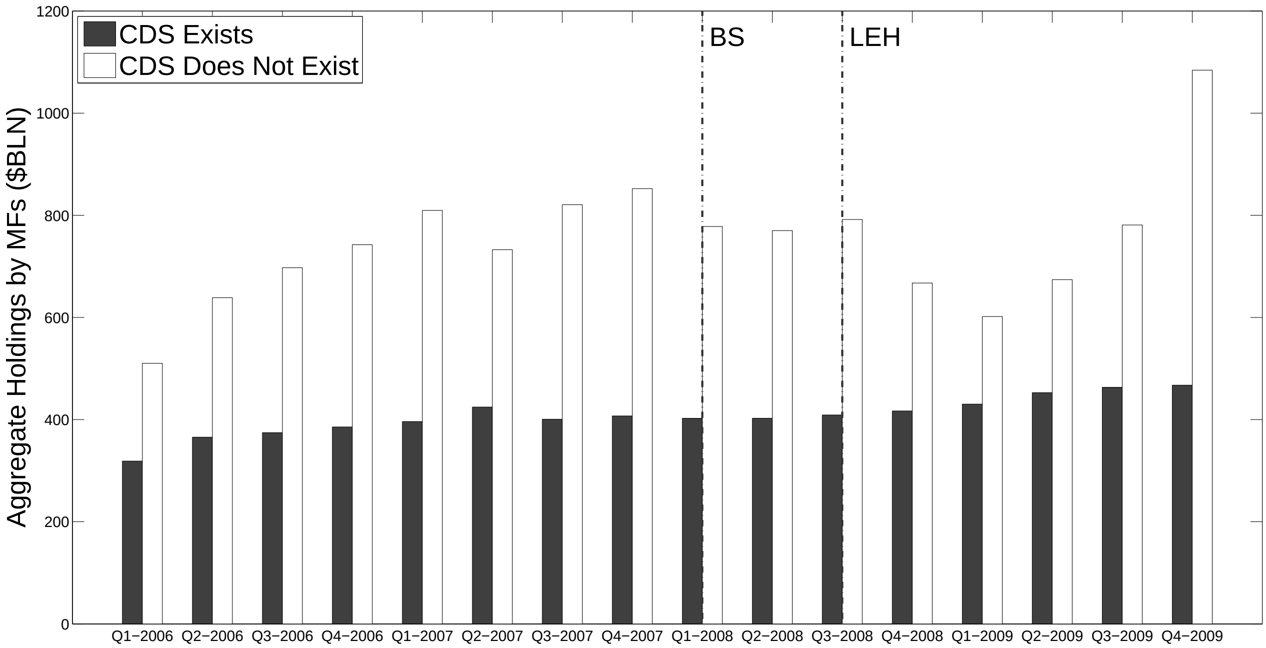

Figure 6.5: Mutual Funds' Holdings of Corporate Bonds with Available CDS vs. Corporate Bond without Available CDS

This figure shows the holdings of mutual funds in corporate bonds as reported in the MorningStar database. The figure contrasts the inventory of corporate bonds with available CDS with the inventory of corporate bonds without available CDS. The availability of a CDS is determined by the existence of a quote in Markit. The availability of a CDS is determined by the existence of a quote in Markit for the period from 2002 to 2009.

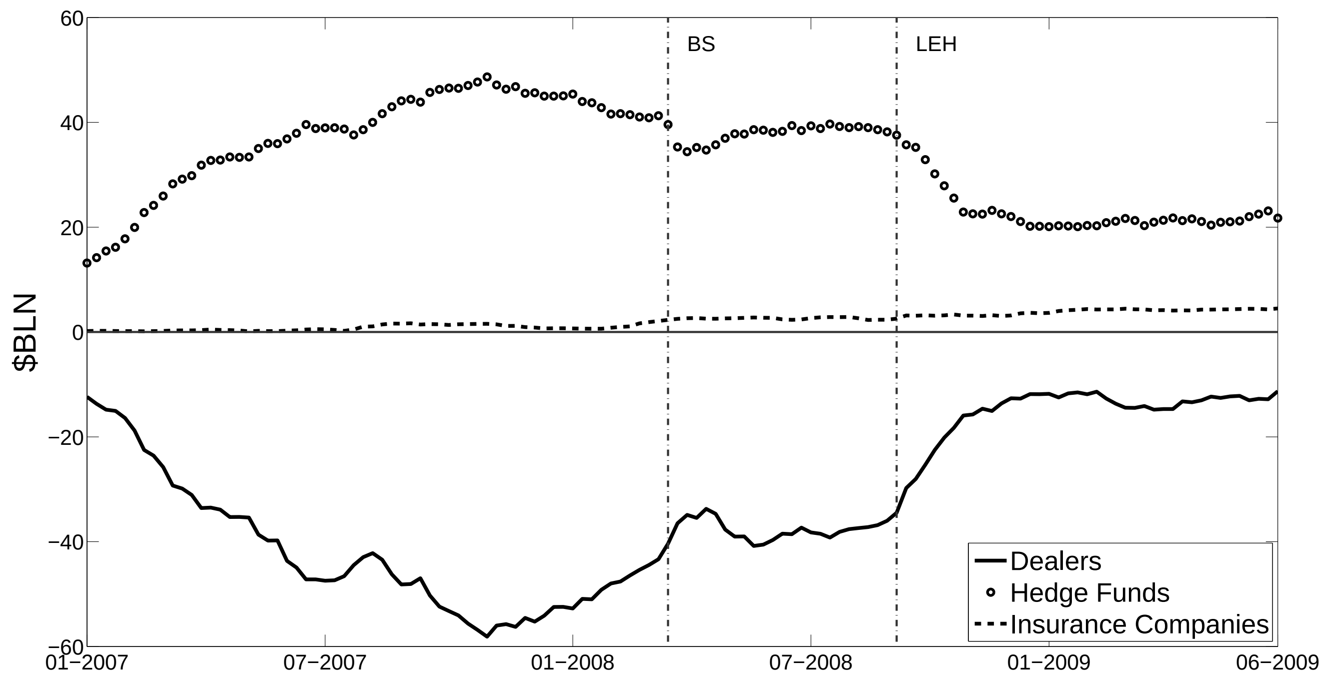

Figure 6.6: Aggregate CDS Positions by Dealers, Insurance Companies, and Hedge Funds

This figure shows the long positions in CDS held by dealers, insurance companies, and hedge funds, as reported in DTCC. We plot aggregate holdings of single name CDS across all maturities. The underlying entities for CDS contracts are financial firms.

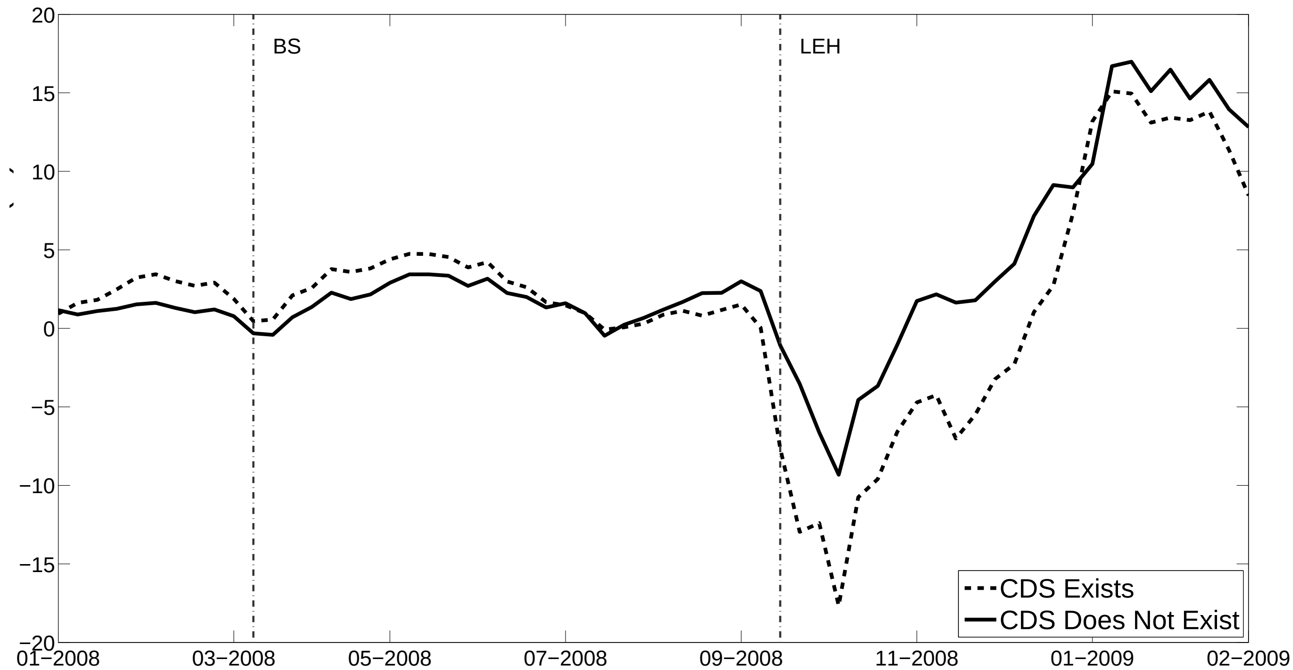

Figure 6.7: Cumulative Returns for Corporate Bonds With CDS Available vs. Unavailable

This figure plots cumulative weekly corporate bond returns available from the TRACE. We plot two return series based on the availability of CDS quotes in Markit. The availability of a CDS is determined by the existence of a quote in Markit for the period from January 2002 through June 2009.

Table 1
Summary Statistics

This table provides summary statistics for the following three periods: *Crisis 1* from July 2007 through Sep 14 2008, *Crisis 2* from Sep 15 2008 through Feb 28, 2009, and *Crisis 3* from March 2009 through June 2009. $basis(\equiv p_{CDS} - p(\text{Bond}))$ is the CDS-bond basis in basis points. p(CDS) is the CDS spread and p(Bond) is the par-equivalent CDS spread (PECS) in basis points. $q(\text{CDS, buy})$ and $q(\text{CDS, sell})$ are daily quantities (in million dollars) bought and sold by dealers in the CDS market, respectively. $q(\text{Bond, buy})$ and $q(\text{Bond, sell})$ are daily quantities (in million dollars) bought and sold by dealers in the corporate bond market, respectively.

Panel A: AAA

	Crisis 1			Crisis2			Crisis3		
	Mean	Stdev	N	Mean	Stdev	N	Mean	Stdev	N
basis	28.63	39.57	7,362	144.99	123.70	3,023	219.09	138.73	4,160
p(CDS)	90.25	49.23	7,362	411.91	137.54	3,023	455.69	235.94	4,160
p(Bond)	61.67	45.54	7,362	264.38	145.21	3,023	219.70	246.80	4,160
q(CDS, buy)	47.04	55.09	6,418	100.21	130.46	2,585	43.52	62.01	3,733
q(CDS, sell)	27.43	33.92	6,332	72.83	95.39	2,450	41.62	63.74	3,567
q(Bond, buy)	3.35	10.17	7,362	5.85	17.51	3,023	8.12	22.75	4,160
q(Bond, sell)	3.66	10.39	7,362	5.86	16.02	3,023	8.21	19.14	4,160

Panel B: Investment Grade exc. AAA

	Crisis 1			Crisis2			Crisis3		
	Mean	Stdev	N	Mean	Stdev	N	Mean	Stdev	N
basis	-30.91	124.59	50,188	-290.99	349.01	15,572	-199.50	330.65	19,321
p(CDS)	146.84	166.12	50,188	362.65	425.39	15,572	382.76	389.83	19,321
p(Bond)	179.13	240.60	50,188	699.03	932.52	15,572	583.84	658.56	19,321
q(CDS, buy)	53.63	82.59	39,156	53.97	103.25	12,808	32.09	61.21	15,960
q(CDS, sell)	59.80	86.28	34,268	61.13	93.85	10,578	38.07	67.91	13,908
q(Bond, buy)	3.02	8.94	50,188	3.84	11.02	15,572	3.27	8.29	19,321
q(Bond, sell)	3.16	8.69	50,188	3.75	10.49	15,572	3.42	9.78	19,321

Panel C: High Yield

	Crisis 1			Crisis2			Crisis3		
	Mean	Stdev	N	Mean	Stdev	N	Mean	Stdev	N
basis	-40.77	281.76	6,460	-1,113.26	720.71	1,926	-798.70	662.85	2,809
p(CDS)	748.21	439.11	6,460	2,801.74	2,378.70	1,926	2,168.42	2,799.52	2,809
p(Bond)	797.61	664.28	6,460	3,819.91	2,263.40	1,926	2,662.05	1,992.42	2,809
q(CDS, buy)	42.18	63.38	3,059	35.09	41.35	799	14.69	28.13	1,400
q(CDS, sell)	40.34	56.56	2,987	34.39	33.85	794	19.29	31.99	1,058
q(Bond, buy)	3.74	8.40	6,460	5.14	16.48	1,926	3.45	7.18	2,809
q(Bond, sell)	4.05	9.40	6,460	5.07	15.42	1,926	3.52	7.65	2,809

Table 2
Liquidity Provision by Dealers

This table provides the estimation results of the following regressions:

$$\Delta p(\text{Bond}, t) = c_1 + \beta_1(-q(\text{Bond}, t)) + \text{ctrls} + \varepsilon_{1t}$$
$$\Delta p(\text{CDS}, t) = c_2 + \beta_2 q(\text{CDS}, t) + \text{ctrls} + \varepsilon_{2t}$$
$$\Delta \text{basis}(t) = c_3 + \gamma_3 q(\text{CDS}, t) + \delta_3 q(\text{Bond}, t) + \text{ctrls} + \varepsilon_{3t}$$

where $p(\text{CDS}, t)$ and $p(\text{Bond}, t)$ are CDS and par-equivalent CDS spreads (PECS), respectively, and basis(t) is $p(\text{CDS}, t) - p(\text{Bond}, t)$. Changes in CDS, PECS, and basis are at the daily frequency and are winsorized at the 0.25% both at the top and bottom. The control variables *ctrls* include: the lagged basis, basis($t-1$); lagged changes in CDS and PECS; changes in VIX, VIX(t); changes in epo spread, *repo*, which is the difference between the 3-month general collateral repo rate and the T-bill rate; changes in overnight index swap (OIS) spreads, OIS, which is Libor minus OIS rates; and aggregate stock returns on primary dealers $\text{CP}^{\text{equity}}$. The sample sub-periods are: *Crisis 1* from July 2007 through Sep 14 2008, *Crisis 2* from Sep 15 2008 through February 2009, and *Crisis 3* from March 2009 through June 2009. The numbers in parentheses are standard errors clustered at the issuing firm level.

	Crisis 1				Crisis 2				Crisis 3			
	Dependent Variables				Dependent Variables				Dependent Variables			
	$\Delta p(\text{Bond}, t)$	$\Delta p(\text{CDS}, t)$	$\Delta basis_t$	$\Delta basis_t$	$\Delta p(\text{Bond}, t)$	$\Delta p(\text{CDS}, t)$	$\Delta basis_t$	$\Delta basis_t$	$\Delta p(\text{Bond}, t)$	$\Delta p(\text{CDS}, t)$	$\Delta basis_t$	$\Delta basis_t$
q(Bond)	-2.43***		-2.58***	-2.07***	-6.26***		-5.95***	-6.09***	-3.26***		-2.91***	-2.67***
	(0.42)		(0.44)	(0.36)	(1.48)		(1.42)	(1.53)	(0.93)		(0.90)	(0.90)
q(CDS)		0.08		-0.39		-1.99		-1.70		-3.38***		1.22
		(0.21)		(0.55)		(1.70)		(1.42)		(0.63)		(1.59)
$basis_{t-1}$	0.03***	0.00	-0.03***	-0.05***	0.02**	0.01	-0.02***	-0.03***	0.02***	0.00	-0.02***	-0.03***
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta p(\text{CDS}, t-1)$	0.73***	0.22***	-0.54***	-0.42***	0.80***	0.16***	-0.62***	-0.66***	0.51***	0.18***	-0.38***	-0.35***
	(0.10)	(0.03)	(0.10)	(0.11)	(0.10)	(0.04)	(0.08)	(0.10)	(0.10)	(0.05)	(0.09)	(0.11)
$\Delta p(\text{Bond}, t-1)$	-0.16***	0.02***	0.17***	0.13***	-0.14***	0.02**	0.17***	0.18***	-0.14***	0.02***	0.17***	0.17***
	(0.03)	(0.01)	(0.02)	(0.03)	(0.03)	(0.01)	(0.03)	(0.03)	(0.02)	(0.01)	(0.02)	(0.02)
Δvix_t	0.14	0.88***	0.73**	0.64*	1.86***	1.81***	-0.02	0.06	-1.54***	-0.03	0.79	2.07***
	(0.34)	(0.31)	(0.35)	(0.37)	(0.61)	(0.34)	(0.37)	(0.43)	(0.56)	(0.32)	(0.61)	(0.61)
$\Delta repo_t$	2.20	2.92	1.88	3.84	-15.74	-16.39***	1.52	-3.43	29.07	74.73***	18.08	-1.41
	(3.57)	(2.24)	(2.81)	(2.62)	(12.26)	(5.01)	(11.71)	(14.75)	(38.82)	(18.41)	(28.14)	(24.56)
Δois_t	2.98	19.09***	12.35***	17.27***	53.67***	43.06***	-15.79	-3.66	128.96**	120.44***	-22.60	-17.30
	(4.04)	(2.27)	(3.84)	(4.66)	(11.52)	(9.07)	(13.23)	(16.14)	(61.88)	(32.62)	(65.09)	(49.44)
$ret_{dealer,t}$	-133.48***	-128.69***	31.55	-2.90	-14.49*	-0.21	22.92**	12.66	-162.56***	-190.19***	-17.13	7.46
	(35.30)	(17.07)	(25.91)	(21.92)	(7.81)	(4.29)	(10.13)	(8.40)	(32.81)	(18.93)	(24.15)	(28.49)
R^2	0.078	0.142	0.059	0.061	0.069	0.114	0.058	0.076	0.053	0.118	0.049	0.055
N	64,287	47,321	64,287	47,321	21,065	15,726	21,065	15,726	28,009	20,908	28,009	20,908

Table 3
Liquidity Provision by Dealers when Basis is Positive vs. Negative

This table provides the estimation results of the following regressions for the positive lagged basis (basis$(t-1) > 0$) and negative lagged basis cases (basis$(t-1) < 0$) separately:

$$\Delta \text{basis}(t) = c + \beta_1 q(\text{CDS}, \text{buy}, t) + \beta_2 q(\text{CDS}, \text{sell}, t) + \gamma_1 q(\text{Bond}, \text{buy}, t) + \gamma_2 q(\text{Bond}, \text{sell}, t) + \text{ctrls} + \varepsilon_t$$

where basis(t) is $p(\text{CDS}, t) - p(\text{Bond}, t)$ and $p(\text{CDS}, t)$ and $p(\text{Bond}, t)$ are CDS and par-equivalent CDS spreads (PECS), respectively. The buy and sell CDS volumes ($p(\text{CDS}, buy)$ and $p(\text{CDS}, sell)$) are defined as $q(\text{CDS}, \text{buy}, t) \equiv q(\text{CDS}, t)1_{q(\text{CDS},t)>=0}$ and $q(\text{CDS}, \text{sell}, t) \equiv q(\text{CDS}, t)1_{q(\text{CDS},t)<0}$. The buy and sell bond volumes are defined similarly: $q(\text{Bond}, \text{buy}, t) \equiv q(\text{Bond}, t)1_{q(\text{Bond},t)>=0}$ and $q(\text{Bond}, \text{sell}, t) \equiv q(\text{Bond}, t)1_{q(\text{Bond},t)<0}$. The control variables *ctrls* include: the lagged basis, basis$(t-1)$; lagged changes in CDS and PECS; changes in VIX, VIX(t); changes in repo spread, *repo*, which is the difference between 3-month general collateral repo rate and T-bill rate; changes in overnight index swap (OIS) spreads, OIS, which is Libor minus OIS rates; and aggregate stock returns on primary dealers $\text{CP}^{\text{equity}}$. The sample sub-periods are: *Crisis 1* from July 2007 to Sep 14 2008, *Crisis 2* from Sep 15 2008 to Feb 28, 2009, and *Crisis 3* from March 2009 to June 2009. The numbers in parentheses are standard errors clustered at the issuing firm level.

	Crisis 1		Crisis 2		Crisis 3	
	$basis_{t-1} > 0$	$basis_{t-1} < 0$	$basis_{t-1} > 0$	$basis_{t-1} < 0$	$basis_{t-1} > 0$	$basis_{t-1} < 0$
q(Bond,buy)	-5.56***	-2.81***	-4.19*	-12.09***	-0.12	-6.58***
	(0.96)	(0.52)	(2.48)	(2.83)	(0.79)	(1.94)
q(Bond,sell)	-0.75	-0.54	-0.31	-4.74**	-0.79	-5.86**
	(0.55)	(0.37)	(0.98)	(2.37)	(0.70)	(2.28)
q(CDS,buy)	-2.88*	0.06	-7.41***	1.04	2.99	0.09
	(1.73)	(0.91)	(1.56)	(2.21)	(3.62)	(1.68)
q(CDS,sell)	0.94	0.94*	-3.42	-2.40	-17.01**	5.41*
	(0.64)	(0.50)	(4.57)	(2.15)	(8.59)	(2.85)
$basis_{t-1}$	-0.06***	-0.05***	-0.01	-0.04***	-0.05***	-0.03***
	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)	(0.00)
$\Delta p(\text{CDS}, t-1)$	-0.31***	-0.50***	-0.52**	-0.70***	0.07	-0.50***
	(0.08)	(0.16)	(0.22)	(0.09)	(0.19)	(0.09)
$\Delta p(\text{Bond}, t-1)$	0.24***	0.10***	0.14	0.19***	0.31***	0.16***
	(0.03)	(0.04)	(0.10)	(0.03)	(0.03)	(0.02)
Δvix_t	1.50***	-0.20	0.50	-0.05	3.65***	1.96***
	(0.54)	(0.44)	(0.48)	(0.46)	(1.28)	(0.69)
$\Delta repo_t$	6.72*	0.17	-8.32	-1.52	52.03	-19.94
	(3.57)	(5.00)	(9.55)	(18.51)	(57.31)	(24.78)
Δois_t	23.91***	14.10**	29.93	-18.88	125.38***	-78.96
	(5.67)	(7.11)	(21.92)	(14.19)	(44.14)	(52.90)
$ret_{dealer,t}$	31.70	-35.27*	-17.01**	18.44**	-32.95	42.29
	(33.98)	(19.07)	(7.14)	(8.48)	(78.62)	(39.77)
R^2	0.079	0.057	0.064	0.080	0.114	0.059
N	19,842	27,479	3,095	12,631	6,158	14,750

Table 4
Liquidity Provision when basis is large

This table provides the estimation results of the following regressions for the positive lagged basis (basis$(t-1) > 0$) and negative lagged basis cases (basis$(t-1) < 0$) separately:

$$\begin{aligned}\Delta\text{basis}(t) &= \beta_1 q(\text{CDS},\text{buy},t) + \beta_2 q(\text{CDS},\text{buy},t)\cdot|\text{basis}(t-1)| + \beta_3 q(\text{CDS},\text{sell},t) + \beta_4 q(\text{CDS},\text{sell},t)\cdot|\text{basis}(t-1)| \\ &+ \gamma_1 q(\text{Bond},\text{buy},t) + \gamma_2 q(\text{Bond},\text{buy},t)\cdot|\text{basis}(t-1)| + \gamma_3 q(\text{Bond},\text{sell},t) + \gamma_4 q(\text{Bond},\text{sell},t)\cdot|\text{basis}(t-1)| \\ &+ c + \varepsilon_t\end{aligned}$$

where basis(t) is $p(\text{CDS},t) - p(\text{Bond},t)$ and $p(\text{CDS},t)$ and $p(\text{Bond},t)$ are CDS and par-equivalent CDS spreads (PECS), respectively. The buy and sell CDS volumes ($p(\text{CDS}, buy)$ and $p(\text{CDS}, sell)$) are defined as $q(\text{CDS},\text{buy},t) \equiv q(\text{CDS},t)1_{q(\text{CDS},t)>=0}$ and $q(\text{CDS},\text{sell},t) \equiv q(\text{CDS},t)1_{q(\text{CDS},t)<0}$. The buy and sell bond volumes are defined similarly: $q(\text{Bond},\text{buy},t) \equiv q(\text{Bond},t)1_{q(\text{Bond},t)>=0}$ and $q(\text{Bond},\text{sell},t) \equiv q(\text{Bond},t)1_{q(\text{Bond},t)<0}$. The control variables *ctrls* include: the lagged basis, basis$(t-1)$; lagged changes in CDS and PECS; changes in VIX, VIX(t); changes in repo spread, *repo*, which is the difference between the 3-month general collateral repo rate and the T-bill rate; changes in overnight index swap (OIS) spreads, OIS, which is Libor minus OIS rates; and aggregate stock returns on primary dealers $\text{CP}^{\text{equity}}$. The coefficient estimates for the control variables are not reported here to save space. The sample sub-periods are: *Crisis 1* from July 2007 through Sep 14 2008, *Crisis 2* from Sep 15 2008 through Feb 28, 2009, and *Crisis 3* from March 2009 through June 2009. The numbers in parentheses are standard errors clustered at the issuing firm level.

	Crisis 1		Crisis 2		Crisis 3	
	$basis_{t-1} > 0$	$basis_{t-1} < 0$	$basis_{t-1} > 0$	$basis_{t-1} < 0$	$basis_{t-1} > 0$	$basis_{t-1} < 0$
q(Bond,buy)	-2.46***	-5.06***	-11.14**	-7.28***	-4.98**	0.99
	(0.89)	(0.61)	(5.06)	(2.68)	(2.06)	(1.58)
q(Bond,buy)$\|basis_{t-1}\|$	-46.21***	19.35***	13.59**	-8.92***	6.67***	-14.20***
	(11.05)	(4.46)	(6.62)	(2.92)	(2.26)	(3.48)
q(Bond,sell)	0.71*	0.35	-1.76	-0.46	0.94	10.52***
	(0.41)	(0.67)	(3.95)	(1.85)	(0.93)	(3.60)
q(Bond,sell)$\|basis_{t-1}\|$	-25.90***	-8.13	3.02	-6.22**	-2.79***	-34.63***
	(7.75)	(5.97)	(6.26)	(2.73)	(0.87)	(10.64)
q(CDS,buy)	-0.44	-1.27	-7.79*	-12.99***	3.03	-4.69
	(0.73)	(1.02)	(4.34)	(4.98)	(6.33)	(5.32)
q(CDS,buy)$\|basis_{t-1}\|$	-25.09	12.88	1.60	35.33**	1.59	6.34
	(17.68)	(13.65)	(11.59)	(14.87)	(10.70)	(7.86)
q(CDS,sell)	0.82	0.21	5.14	3.19	9.19	5.20
	(0.76)	(0.74)	(13.58)	(2.18)	(6.13)	(5.99)
q(CDS,sell)$\|basis_{t-1}\|$	-0.76	7.32	-32.25	-9.47***	-53.51**	1.37
	(13.45)	(5.70)	(41.55)	(3.03)	(26.57)	(7.83)
R^2	0.085	0.066	0.065	0.090	0.118	0.081
N	19,842	27,479	3,095	12,631	6,158	14,750

Table 5
Liquidity Demand by Insurance Company

This table provides the estimation results of the following regressions for the positive lagged basis (basis$(t-1) > 0$) and negative lagged basis cases (basis$(t-1) < 0$) separately:

$$\begin{aligned}\Delta\text{basis}(t) &= c + \beta_1 q(\text{CDS}, \text{buy}, t) + \beta_2 q(\text{CDS}, \text{sell}, t) \\ &\quad + \gamma_1 q(\text{Bond}, \text{buy}, t) + \gamma_2 q(\text{CDS}, \text{sell}, t) + \text{ctrls} + \varepsilon_t\end{aligned}$$

where basis(t) is $p(\text{CDS}, t) - p(\text{Bond}, t)$, where $p(\text{CDS}, t)$ and $p(\text{Bond}, t)$ are CDS and par-equivalent CDS spreads (PECS), respectively. The buy and sell CDS volumes by insurance companies ($p(\text{CDS}, buy)$ and $p(\text{CDS}, sell)$) are defined as $q(\text{CDS}, \text{buy}, t) \equiv q(\text{CDS}, t)1_{q(\text{CDS},t)>=0}$ and $q(\text{CDS}, \text{sell}, t) \equiv q(\text{CDS}, t)1_{q(\text{CDS},t)<0}$. The buy and sell bond volumes are defined similarly: $q(\text{Bond}, \text{buy}, t) \equiv q(\text{Bond}, t)1_{q(\text{Bond},t)>=0}$ and $q(\text{Bond}, \text{sell}, t) \equiv q(\text{Bond}, t)1_{q(\text{Bond},t)<0}$. The control variables *ctrls* include: the lagged basis, basis$(t-1)$; lagged changes in CDS and PECS; changes in VIX, VIX(t); changes in repo spread, *repo*, which is the difference between 3-month general collateral repo rate and T-bill rate; changes in overnight index swap (OIS) spreads, OIS, which is Libor minus OIS rates; and aggregate stock returns on primary dealers $\text{CP}^{\text{equity}}$. The coefficients of the control variables are not reported here to save space. The sample sub-periods are: *Crisis 1* from July 2007 to Sep 14 2008, *Crisis 2* from Sep 15 2008 to Feb 28, 2009, and *Crisis 3* from March 2009 to June 2009. The numbers in parentheses are standard errors clustered at the issuing firm level.

	Crisis 1		Crisis 2		Crisis 3	
	$basis_{t-1} > 0$	$basis_{t-1} < 0$	$basis_{t-1} > 0$	$basis_{t-1} < 0$	$basis_{t-1} > 0$	$basis_{t-1} < 0$
q(Bond,buy)	-2.98	-0.40	-5.78*	2.39	0.92	0.40
	(2.52)	(0.48)	(3.49)	(4.83)	(1.35)	(1.43)
q(Bond,sell)	4.09***	5.90***	-4.58	8.93	8.31*	0.04
	(0.90)	(1.61)	(6.08)	(7.98)	(4.50)	(5.53)
q(CDS,buy)	1.37	3.22	-1.96	1.21	0.75	-3.62
	(1.20)	(4.02)	(3.48)	(1.58)	(2.88)	(5.24)
q(CDS,sell)	-1.67	-2.85	60.51	0.81	35.64*	7.25
	(1.57)	(2.20)	(39.37)	(4.62)	(20.96)	(4.70)
R^2	0.171	0.271	0.082	0.191	0.135	0.053
N	1,891	2,884	323	1,153	683	1,469

Table 6
Returns of Corporate Bonds with Available CDS vs. Unavailable CDS After Lehman Brothers' Collapse

This table provides the regression results for the following model:

$$\text{Ret}(t) \quad = \quad c_1 + \beta_1 \text{CDS}^{\text{exists}} + \beta_2 \text{basis(Aug)Mat5Y(Aug)} + \text{Controls} + \varepsilon_t$$

where Ret(t) is the monthly corporate bond returns constructed from TRACE using the last available daily price within a week from the end of the month, $\text{CDS}^{\text{exists}}$ is an indicator variable that takes the value of one if the bond has a CDS contract available in Markit prior to September 2009 and zero otherwise, basis(Aug) is the CDS-bond basis at the end of August 2008, and Mat5Y(Aug) is an indicator variable that takes the value of one if the maturity of the bond at the end of August 2008 is between 4.5 and 5.5 years and zero otherwise. The control variables $ctrls$ include: time to maturity of bonds, TTM; changes in VIX, ΔVix; changes in the repo spread, $\Delta repo$, the difference between the 3-month general collateral repo rate and the T-bill rate; two illiquidity measures, $ILLIQ1$ by Amihud (2010) and $ILLIQ2$ by Bao et al. (2011); market leverage; equity returns of the issuers of the bonds, $Ret(EQ)$; and changes in monthly stock volatility estimated using daily stock returns, Δvol. We also include rating dummies (AAA, AA+, AA, ...). The numbers in parenthesis are standard errors clustered at the issuing firm level. The sample period is September 2008 from December 2008.

	Bond Return			
CDS^{exist}	-0.02***		-0.03**	-0.03*
	(0.01)		(0.01)	(0.02)
$basis_{Aug}Mat_{Aug}$		1.60***	1.58*	-0.18
		(0.73)	(0.81)	(0.69)
TTM			0.00	-0.00
			(0.00)	(0.00)
ΔVix_t			-0.00***	-0.00***
			(0.00)	(0.00)
$\Delta repo_t$			-0.06***	-0.04***
			(0.02)	(0.01)
$ILLIQ1_{t-1}$			0.35	0.15
			(0.27)	(0.18)
$ILLIQ1_{t-2}$			0.01***	0.00*
			(0.00)	(0.00)
$MktLev_{t-1}$				0.00***
				(0.00)
$Ret(EQ, t)$				0.10***
				(0.03)
$MktLev_{t-1} \cdot Ret(EQ, t)$				-0.00
				(0.00)
Δvol_t				-0.29***
				(0.10)
R^2	0.103	0.101	0.354	0.558
N	1,960	1,933	1,466	1,120
Rating Dummy	Yes	Yes	Yes	Yes

Table 7
Returns of Corporate Bonds with Available CDS vs. Unavailable CDS After Lehman Brothers' Collapse: Month-by-Month

This table provides the regression results for the following model for each month from August 2008 to December of 2008:

$$\text{Ret}(t) \quad = \quad c_1 + \beta_1 \text{CDS}^{\text{exists}} + \beta_2 \text{basis(Aug)Mat5Y(Aug)} + \varepsilon_t$$

where Ret(t) is the monthly corporate bond returns constructed from TRACE, $\text{CDS}^{\text{exists}}$ is an indicator variable that takes the value of one if the bond has a CDS contract available in Markit prior to September 2009 and zero otherwise, basis(Aug) is the CDS-bond basis at the end of August 2008, and Mat5Y(Aug) is an indicator variable that takes the value of one if the maturity of the bond at the end of August 2008 is between 4.5 and 5.5 years and zero otherwise. We include rating dummies (AAA, AA+, AA, ...). The numbers in parenthesis are standard errors clustered at the issuing firm level.

	Bond Return						
	Aug	Sep	Oct	Nov	Dec	Jan	Feb
CDS^{exist}	-0.00	-0.08***	-0.01	-0.00	-0.00	0.00	-0.02**
	(0.00)	(0.03)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
$basis_{Aug}Mat_{Aug}$	-0.30**	4.63***	-3.30*	0.66	-0.42	-7.55	0.86
	(0.14)	(1.75)	(1.89)	(0.76)	(1.38)	(4.60)	(1.29)
R^2	0.096	0.221	0.382	0.377	0.054	0.126	0.139
N	567	503	539	529	362	453	635
Rating Dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes

A Measuring the Bond-CDS Basis

The bond-CDS basis, which measures the credit risk pricing discrepancy between the two markets, is the difference between a CDS spread and a bond spread with the same maturity. While calculating CDS spread minus bond spread might seem as a simple difference calculation, bringing two different instruments to be comparable is a more intricate task in practice than what it may appear. CDS is already readily available at a spread form[9] and a full term-structure is observable. Bond spreads, on the other hand, are a theoretical measure that needs to be backed out from a unique bond price. In this appendix we review two common spread measures for fixed-rate corporate bond, Z-Spread and Par Equivalent CDS Spread (PECS), and we then explain why we choose to use the latter as the benchmark specification in this paper.

A.1 Z-Spread Methodology

The Z-spread is the parallel shift, z, to the risk-free curve which gives the market value of the risky corporate bond. The price of a risk-free bond is equal to the present value of the cash flows, including the bond coupons plus the notional amount paid back at maturity. The price of a risky corporate bond is lower than the price of a risk-free bond as we might not receive all cash flows in case the firm does not survive. Hence, to equate the price of a risky corporate bond to the present value of the expected cash flows of the risk-free bond we need to move the risk-free discount curve by a constant amount z. So, the Z-spread is given as follows:

$$\text{Bond's Dirty Price} \quad = \quad \sum_{n=1}^{N} \frac{\frac{C}{f}}{\left(1+\frac{r(0,t_n)+z}{f}\right)^n} + \frac{1}{\left(1+\frac{r(0,t_N)+z}{f}\right)^N} \qquad \text{(A.1)}$$

[9]HY reference entities often are traded on an upfront basis but they can be converted to a running spread

where C is the coupon, and $r(0,t_n)$ is the discretely compounded zero rate, determined from the discount factor to time t_n, $Z(0,t_n)$:

$$Z(0,t_n) \quad = \quad \frac{1}{\left(1+\dfrac{r(0,t_n)}{f}\right)^n} \,.$$

The basis will then be calculated as (CDS Spread $-\, z$). If the bond's maturity is exactly that of a quoted CDS spread, then it is clear which CDS spread to use for the basis calculation. If not, the choice is either to compare it with the CDS of closest maturity or to interpolated CDS spread for the bond maturity. While the latter gives a more accurate idea of the spread differential, it has the disadvantage that it is not an actual tradable security. Another choice that needs to be made is how to measure the bond spread using the unique price of that bond so it will be comparable with the whole curve of CDS spreads. In the course of converting bond's spread conversion, we also need to decide which risk-free rate to use, and which recovery rate to assume.

A.2 Par-Equivalent CDS Spread Methodology

The PECS, proposed by J.P. Morgan back in 2005, uses the market price of a bond to calculate a spread based on implied default probabilities. These default probabilities can then be transformed into an implied CDS spread, which is referred to as PECS. In other words, the PECS is the shift in the term structure of CDS spreads in order to match the price of the bond.

To get the PECS, we start with bootstrapping the default probabilities from the full CDS curve traded in the market. Then, we take as inputs the derived term-structure of default probabilities and assume some recovery rate (in this paper, we use a fixed recovery rate assumption at 40% as well as Markit's reported recovery assumption), and we calculate a CDS-implied bond price as follows:

$$\text{Bond Price} \quad = \quad C\sum_{n=1}^{N}(t_n - t_{n-1})PS(t_n)Z(0,t_n) + PS(t_N)Z(0,t_N) + R\sum_{n=1}^{N}PD(t_{n-1},t_n)Z(0,t_n)$$

where C is the bond coupon; $(t_n - t_{n-1})$ is the length of time period n in years; $PS(t_n)$ is the probability of survival to time t_n at time t_0; $PD(t_n)$ is the probability of default at time t_n at time t_0; $Z(0, t_n)$ is the risk-free discount factor to time t_n; and, R is the recovery rate upon default assumed for pricing CDS contracts referencing the same firm.

The resulting CDS-implied bond price is going to differ from the traded dirty price of the bond. So, we apply a parallel shift to those default probabilities, while maintaining the recovery rate assumption, until we match to the market price of the bond. Given these bond-implied survival probabilities, we convert them back into a CDS spread using the usual CDS pricing equation:

$$S(N) = \frac{(1-R)\sum_{n=1}^{N} PD(t_n)DF(t_n)}{\sum_{n=1}^{N}(t_n - t_{n-1})PS(t_n)DF(t_n) + \text{Accrued Interest}} \tag{A.2}$$

The resulted spread, $S(N)$, is the PECS, and the basis is CDS Spread $-$ PECS. Note that unlike the Z-spread, which is one number, the PECS is an entire curve and we therefore able to calculate the basis at any maturity.

As it emerges from the calculations described above, the Z-spread accounts for the maturity of the bond and the term-structure of interest rates, while the PECS accounts for the assumed recovery rate and the term structure of default probabilities derived from the CDS market. The former measure implicitly assumes a flat term-structure of credit spreads and does not take into account the term-structure of default probabilities. Taking as given that the price of credit risk is less biased in the CDS market, the fact that the PECS takes advantage of the entire information encapsulated in the CDS curve adds value and is a key reason for why this measure is preferable.