Dealer Liquidity Provision and Price Discovery in Distressed Markets

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Abstract

This paper employs transaction data from 2002 and 2013 to investigate the trading activity and price discovery process of defaulted corporate bonds, aiming to provide empirical evidence on the relationship between financial intermediaries' strength, liquidity, and price discovery of distressed assets. We find that, following bond default, dealers indeed "lean against the wind" by absorbing large selling pressures from customers. They compensate this liquidity provision role by charging customers wider bid-ask spreads, mostly during the financial crisis period. Consistent with previous theoretical prediction, default results in a sharp drop in prices followed by price reversals. Liquidity is correlated with the magnitude of this price impact. In addition, we demonstrate such price impact is more significant during the financial crisis and for bonds traded by dealers with higher funding costs.

JEL Classifications: G01, G12, G14, G33
Key words: Broker-dealers, Bond liquidity, price discovery, OTC market, default, TRACE

1 Introduction

Assets traded over the counter often rely on broker-dealers to make the market. The ability and willingness of the broker-dealers to facilitate trades can impact transaction prices of these assets through search costs in matching buyers and sellers. As a result, asset prices may deviate from their neoclassical equilibria due to the search costs or "slow-moving capital" phenomenon ((Duffie, 2010)) amplified by the stress in financial intermediaries. In this paper, we use the market for defaulted corporate bonds as a laboratory to examine the role of dealers in providing liquidity to trading securities issued by distressed firms and how the financial health of these dealers influence the price discovery process of the distressed assets.

Defaulted bonds provide a unique setting for analyzing the impact of dealer liquidity provision on price discovery process. Defaulted bonds are generally traded in a relatively segmented over-the-counter (OTC) market where financial intermediaries play an important role in facilitating the trades. Traditional bond investors such as insurance companies and pension funds normally have risk restrictions to prevent them from holding defaulted bonds. As a result, the majority of investors in defaulted bonds are "vulture" funds or hedge funds focusing on distressed debt (e.g., Altman (1999), Lim (2015)). In this segmented market, new defaults, especially those at large quantities, generate supply shocks for traded securities. In theory, market makers' financial strength, capital capacity, and funding costs will affect the immediate price impact of these supply shocks as well as the process of digesting these shocks following default (e.g., Duffie (2010), Adrian and Shin (2010)). The availability of bond transaction data enables us to test this theory. Unlike delisted stocks, a large amount of corporate bonds continue to trade actively in the OTC market following bonds default (Jankowitsch et al. (2014)). Altman and Kuehne (2012) estimates that the market value of the defaulted and distressed debt[1] market is about $713.8 billion as of March 30, 2012.

Recent financial crises also highlighted the importance of efficient price discovery in the markets for distressed securities for the stability of the global financial system. An efficient price discovery is characterized by the fast adjustment of market prices to the new equilibrium with the arrival of new information. As an extreme example of the lack of efficient price discovery, BNP Paribas SA, France's biggest bank, halted withdrawals from three of its investment funds on August 9, 2007 because it couldn't "fairly" value their holdings after U.S. subprime mortgage losses roiled credit markets. The halt has been widely viewed to have fueled the meltdown of the financial markets during the outset of the crises.

[1] including non-defaulted but rated below CCC corporate bonds and distressed loans

Existing theory suggests that financial distress may affect securities trading and prices through two channels. The news of financial distress and associated trading may contain valuation information that results in permanent effect on equilibrium price and liquidity (e.g., Glosten and Milgrom (1985)). In addition, to the extent that the supply of funds are not perfectly elastic, these shocks may result in both trading illiquidity and "price pressures", leaving liquidity and prices deviating from their neoclassical equilibrium (e.g., Grossman and Miller (1988), Hendershott and Menkveld (2013)). Importantly, in contrast to the permanent effect, price pressures last only temporarily. Initially, securities prices drop and liquidity deteriorates upon the supply shock. But as the supply of funds becomes more available, prices and liquidity gradually recover and reach to the new equilibrium. Thus, this second channel generally exhibits liquidity and return reversals (Duffie, 2010). Despite this transitory nature, price pressures have important implications for the financial stability, especially during systemic events, because they may amplify the original shocks to the financial market.

We employ an event study approach to estimate both permanent and transitory impacts of defaults on trading liquidity and bond returns and then investigate the role of broker-dealers' financial strength in the price discovery process.[2] Our event study analysis builds on the methodologies previously utilized for the corporate bond markets (Bessembinder et al., 2009; Ellul et al., 2011; Ambrose et al., 2012; Feldhütter et al., 2014). For a sample of corporate bonds that defaulted from 2002 to 2013, we estimate abnormal bond returns and trading illiquidity around the time of default events. In doing so, we use the comprehensive data on intraday corporate bond transactions from the Trade Reporting and Compliance Engine (TRACE) system of the Financial Industry Regulatory Authority (FINRA). In particular, the data include trade information on both publicly disseminated and nondisseminated bonds as well as dealers' identifications.[3] We take advantage of these features to construct a dealer-specific "round-trip cost" to estimate trading liquidity of each specific bond and each specific dealer in order to link individual dealers' financial strength and the liquidity provision of this dealer to distressed assets through a cross-sectional analysis.

Our main results are summarized as follows. First, we find evidence that dealers indeed provide liquidity to this distressed market by absorbing a large amount of selling orders from customers around bond default, but that dealers with weak financial health provide less intermediation. During a short period around default events, we use reported directions of transactions in TRACE together with trading volumes to track down dealers' net position changes. We find that dealers

[2] The literature has a long tradition to use the event study approach to identify the permanent and transitory effects of trading. For example, one of the earliest study, Kraus and Stoll (1972), shows that prices overshoot in the event of a block trade in stocks. However, while there is a rich literature on stock liquidity and price behavior along this line, similar research on the corporate bond market is much sparser.

[3] This regulatory data is provided by FINRA to the Board of Governors of the Federal Reserve System under a data sharing agreement.

increase their inventories in defaulted bonds while customers unload those positions. Such liquidity provision exists even during the financial crisis. This finding is consistent with theoretical prediction by Weill (2007) and empirical evidence in Choi and Shachar (2013). Interestingly, we also find that dealers' liquidity provision tends to diminish within U.S. dealer firms after the crisis, perhaps due to more restrictive risk management practice or regulations, such as Volcker's Rule, that limits U.S. firms in proprietary trading. Linking dealers' financial health reflected by Credit Default Swaps (CDS) spreads to liquidity provision, we find that dealers with higher CDS spreads tend to balance positions on defaulted bonds more often and appear to be more reluctant to hold either long or short positions in defaulted bonds.

Second, the cost of liquidity provided by dealers, measured by our "round-trip cost" measure of bid-ask spreads extracted from transaction prices of two opposite-direction trades with the same dealer as the intermediary, varies over time and with the funding costs of dealers. It is generally expected that liquidity cost should increase around bond default since the credit quality of underlying assets deteriorates. However, we only observe significant increase in liquidity cost during the financial crisis of 2007-2009. If a bond defaults during the period of July 2007 to March 2009, on average, its abnormal round-trip cost increases by around 75 basis points during the week of default which doubles its average abnormal trading costs in five weeks around default. However, if a bond defaults outside of this financial crisis period, we only observe about 25 basis points increase in its abnormal trading costs during the default week compared with surrounding weeks and the general time-variation patterns in liquidity costs makes such difference an insignificant deviation from its means. All else being equal, a bond defaulted in crisis period would have 70 basis points higher in abnormal illiquidity measure than it would if the default happened in non-crisis periods. For the first time in the literature, our cross-sectional regression shows consistent results that dealers with higher funding costs, represented by wider CDS spreads, tend to charge customers with higher liquidity costs, measured by the "round-trip cost". For 10 basis points increase in dealers' CDS spreads, a defaulted bond traded between three weeks around default time will experience an increase of 2 to 3 basis points in the average "round-trip cost", our estimated bid-ask spreads borne by customers, after controlling for bond-specific characteristics, year fixed effects, and an average contemporary liquidity measure for high yield bonds. Dealers that profited from trading or holding the same bonds also charges less bid-ask spreads for the bonds during default time but this effect is small in magnitude.

Third, we examine the impact of trading liquidity on the price discovery process of defaulted bonds, using dealers CDS spreads as an instrument variable for trading liquidity. Consistent with prediction from slow-moving capital theory and previous findings in distressed assets, we document the existence of price reversals for corporate bonds following default. Furthermore, the immediate price impact and subsequent price reversal are more significant during the financial crisis and for bonds traded with larger liquidity costs by dealers with wider CDS spreads. Cumulative abnormal returns of a typical defaulted bond from ten weeks before default till default time reach about -30 percent during the crisis, compared with around -10 percent for non-crisis periods. In terms of the impact of liquidity cost to abnormal returns, one basis point increase in liquidity cost is on average accompanied by 2 to 3 basis points deterioration in the abnormal return around default time, cumulated from 10 weeks prior to default. Taking the difference between cumulative abnormal return in 10 to 15 weeks following default to it around the default time, we define a price reversal measure. The magnitude of this price reversal enlarges by about 10 basis points with one basis point increase in liquidity cost around the time of default. When we look at these impacts of liquidity cost quantitatively using dealers' CDS spreads as the instrumental variable, all these impacts becomes larger indicating that estimated liquidity costs from financial intermediations' health may have more profound impact to price discover process than observed (realized but may subject to endogeneity) measures of liquidity.

Overall, our findings on the impact of defaults on trading liquidity and bond returns are consistent with the hypotheses implied by the slow-moving capital hypothesis as in Duffie (2010). The greater deterioration in trading liquidity and bond return reversals observed during the 2007-2009 financial crisis reflects the significant strains experienced by major broker-dealers, including the failures of two major broker-dealers, Bear Stearns and Lehman Brothers, which accounted for a large share of making the corporate bond market.

This paper contributes to the fast-growing literature on the role of liquidity shocks and search frictions to asset pricing in the OTC markets by providing new empirical evidence on the interaction of selling pressure, strength of financial intermediaries, and capital mobility. Theoretical works that build our thoughts include Duffie et al. (2005), Duffie et al. (2007), Duffie and Strulovici (2012), He and Milbradt (2012), He and Krishnamurthy (2012), and Lagos et al. (2011). Our results are largely consistent with these works in that financial distress of financial intermediaries may magnify the shocks to the OTC markets.

Empirical studies on defaulted bond trading are still emerging. Early works such as Hradsky and Long (1989) and Eberhart and Sweeney (1992) suffer from the lack of transaction-level data. As a result, they only focus on monthly performance of these bonds without addressing the liquidity effect. Recent empirical studies focusing on bond trading liquidity tend to ignore the defaulted bond market. For example, Bao et al. (2011) examine the time variation and cross-sectional variation of liquidity in corporate bond trading, but their sample consists of only investment-grade bonds. Feldhütter (2012) and Das et al. (2014) do not distinguish defaulted bonds from non-defaulted bonds in their sample. A couple of latest studies utilize TRACE data to examine the distressed bond market include Jankowitsch et al. (2014), which focuses on recovery rates, and Feldhütter et al. (2014), which focuses on the effects of stronger creditor control rights on bond prices as issuers come closer to default. Both papers estimate liquidity around the deterioration in issuer credit quality and use liquidity as an independent variable in their analysis. In contrast to their papers, we run regressions with liquidity losses as dependent variables and aim to explain time-varying liquidity losses around default events with financial intermediations' financial strength. Also related to our studies include recent event studies on the fire sale effects in the corporate bond market (Ellul et al., 2011; Ambrose et al., 2012). We believe our marginal contribution to these empirical literature lies in our most comprehensive transaction-level trading data that enable us to quantify the impact of defaults on both liquidity and the dynamic price discovery process as well as to distinguish the varying roles of different broker-dealers' in providing liquidity in this distressed market. We limit our scope to rely primarily on the asset price movements and other trading observations in bond market, hence leave out discussions on the impacts of capital structure change over default. (See Gertner and Scharfstetin (1991), Helwege (1999), and Ivashina et al. (2013) for a rich literature on the link between capital structure and the cost of financial distress.)

The rest of the paper is organized as follows. Section 2 describes data and methodologies for measuring liquidity and abnormal returns. Section 3 describes dealers' participation in the defaulted bond market in terms of the quantity of liquidity provision and market structure. Section 4 presents our empirical results from event studies to analyze abnormal returns, liquidity costs, and trading activities in defaulted bond market. Section 4 presents empirical results from cross-sectional regressions that aim to find the impact of dealers' financial health on the liquidity and price impacts of default. Section 6 concludes and discusses future work.

2 Data and Liquidity Measure

2.1 Data Sources

We construct a dataset on defaulted bond trading mainly based on two databases: Moody's DRD data and FINRA's TRACE data. Moody's DRD database is used to identify defaults for corporate bonds. For each defaulted bond, we retrieve default date, default type, default amount, resolution date, and resolution type from this database. When a bond identified by a unique CUSIP has multiple default incidents, we keep only the first default event within the two-year time span.

TRACE data provide transaction-level bond trading information since July 2002. It is the most prevailing database for bond trading analysis and it covers 99% of bond trading executed in the OTC secondary markets. We are allowed to get access to the more comprehensive version of the TRACE data which distinguishes our study from the majority of previous studies using TRACE data in three major aspects: first, our data contains transactions that were not publicly disseminated before 2005 while TRACE was still in its experimenting phases; second, we have exact trading size for each transaction in contrast to other studies using truncated trade sizes for large trades; third and the most important aspect is that we have dealer identifier information for each transaction in TRACE. This allows us to calculate a unique bond liquidity measure based on the price difference charged by the same dealer to buyers and sellers of the same bond. We find this liquidity measure requires less restrictive assumptions on market efficiency and may reflect real transaction costs more accurately. The change of liquidity during financial distress is less dramatic using this liquidity measure compared with other liquidity measures used in previous studies, so we believe our results on liquidity dynamics during financial crisis are less likely to be contaminated by the measurement errors. Dealer identity information also allows us to examine dealers' participation in the distressed debt trading at a more granular levels and link individual dealer's financial strengths to the liquidity and price discovery of the bonds that these dealers are trading. Thus, dealer information enables us to analyze the impact of financial intermediaries to the transmission of financial distress through trading in OTC market[4].

We pull the entire trading history from TRACE for each bond from July 2002 to December 2013, including transaction time, trade price, trading volume, and trading parties in terms of if the trade happens between a customer and a dealer or between two dealers. For dealers participating in the trade, we observe their four-letter Electronic Blue Sheets (EBS) ID and whether the dealer records the trade to their proprietary trading book or "agency" book. When the transaction happens between two dealers and both dealers report the trade, we keep only the sell-side report to avoid duplicates[5].We clean the data by removing canceled trades, erroneous entries, and trades with non-positive prices or non-positive volumes. TRACE-eligible bonds are merged with Moody's DRD data based on bond CUSIPs. The final sample contains about 2,700 distinct defaulted bonds for about 650 distinct defaulted issuers during our sample period. Their total par value at default time sum to over $500 billion US dollars.

For these defaulted bonds, we use Mergent Fixed Income Securities Database (FISD) to obtain bond characteristics such as par amount outstanding, seniority, the date of issuance, maturity date, coupon, coupon frequency, option features (put, call, sink fund, convertible, pay-in-kind, etc.), and

[4]The MPID information of dealers' identification is provided by FINRA to the Board of Governors of the Federal Reserve System under a data sharing agreement.

[5]In principle, both dealers should report the trade to TRACE, but after trying to match the trades with the same amount and close reporting time, we find there are indeed some trades with only one side report. We keep those entries since there is no duplicate.

rating history. We supplement the cases that FISD does not contain using Moody's DRD data. We also use the Compustat quarterly and annual database to retrieve issuers' financial fundamentals that are associated with firms' credit risk and degree of information transparency and tested some cross-sectional hypotheses with these variables. For indicating dealer's financial strength, we collect CDS spread data of major broker-dealer firms from Markit.

2.2 Sample Description

Table 1 shows annual bond-issuer counts in our defaulted bond sample. On average, for each year, there are around 700 defaulted bonds from about 200 issuers available for trade. The last two columns of the table show the number of bonds and issuers who newly defaulted in each year. Not surprisingly, new defaults peak in 2008-2009. Notably, because of defaults by some large firms in 2008 - in particular, Lehman Brothers and Washington Mutual - the increase in the number of bonds defaulted in the 2008-2009 period is greater than the increase in the number of issuers defaulted. Comparing the two default-intensive periods in the sample, 2008-2009 vs. 2002-2003, we can see the period of 2008-2009 not only has more defaults, but also has more defaults concentrated to a group of issuers, with Lehman alone having 570 different bonds outstanding at the time of its bankruptcy filing. In the 2002-2003 period, each defaulted issuer has about three outstanding bonds on average, while in the 2008-2009 period, there are on average more than seven bonds per defaulted issuer.[6]

The distribution of default type of the defaults occurring during the 2008-2009 financial crisis also differs from the 2002-2003 episode. We group all defaults into six broad categories: Chapter 11 filing, Chapter 7 filing, distressed exchange, prepackaged Chapter 11 filing, receivership, and "missed payments" (which includes missed interest/principal payments and all other default types). Table 2 shows the total number of defaulted bonds and defaulted issuers by default type in the whole sample period. Chapter 11, distressed exchange, and missed payments are the three main default types. Figure 1 shows that many defaulted issuers with filings in 2009 took the form of distressed exchange instead of filing for outright bankruptcies. There are also more cases of pre-packaged Chapter 11 filings in 2009 relative to previous years. The number of issuers filing for Chapter 11 bankruptcy does not differ much from 2002-2003 to 2008-2009. The majority of the defaults in the 2008-2009 period took forms other than bankruptcy, although non-bankruptcy defaults may end up with bankruptcy at some later times.

[6]If excluding Lehman, there are just over three bonds per defaulted issuer in the 2008-2009 period, which is still higher than the 2002-2003 level.

2.3 Measurements of Liquidity and Returns

We have explored several commonly-used liquidity measures for bond trading, including the Amihud measure (Amihud (2002)), the Roll measure (Roll (1984)), and the Imputed Round-Trip (IRT) Cost measure, as laid out in Dick-Nielsen et al. (2012). Since defaulted bonds are expected to have volatile price movements around default time, all these liquidity measures tend to be large by definition since they all proxy illiquidity with the degree of transaction price changes without linking transactions to the same trading counterparties. (See Firewald et al. (2013) for definitions and information set requirements of these measures.) Fortunately, as in Goldstein et al. (2007) and Firewald et al. (2013), our data set has the ability to link traded prices and volumes to individual dealers, so we construct a liquidity measure based on round-trip transactions with respect to the same dealer. We call this liquidity measure as "round-trip cost" (RTC), which is similar to the DRT (dealer round-trip) liquidity measure in Goldstein et al. (2007). It is essentially the bid-ask spread charged by a dealer implied from TRACE reported prices of buy and sell transactions intermediated by this dealer. In details, RTC is constructed in the following way:

For each bond in our sample, we search for matched trading pairs within the same day for the same dealer and the same trading volume at the opposite trading sides, taking only dealer to customer trades into consideration. That is, for each trade in which a customer sells (buys) a bond to a dealer, we search for another trade in which the same dealer sells (buys) the bond with the same amount to another customer within the same day. In cases that there are multiple trades that match the original trade, we select the trade with the closest transaction time. For each pair of trades that we find, we estimate the effective bid-ask spread that the dealer charges to the customers as the price difference between the price by which dealer sells the position to a customer (i.e. "ask" price) and the price by which dealer buys the position from a customer ("bid" price), normalized by the average of these two prices. Formally, we define this "round-trip cost" (RTC) for each pair of trades as:

$$RTC = \frac{p_{ask} - p_{bid}}{(p_{ask} + p_{bid})/2}, \tag{1}$$

where p_{ask} is the reported price of a transaction when a dealer sells the bond to a customer, and p_{bid} is the reported price when a dealer buys the bond from a customer.

For each bond - dealer combination, daily RTC is the average of the RTCs of all pairs of trades we could identify. Weekly RTC is the average of daily RTCs during the week. We also take averages across dealers to get bond-level RTCs [7]. Larger RTC indicates worse liquidity, or equivalently, larger transaction cost for trading the bond.

[7] Normally we take simple averages unless otherwise noted. Weighted averages using trading volume as weights have been calculated but turn out to be highly correlated with simple averages and our results do not change much if we use weighted averages.

Although this liquidity measure is still exposed to the risk of mixing liquidity effects with pricing effects during volatile price movements since we still need to assume that the difference between bid and ask prices charged by the same dealer in the consecutive transactions is not affected by the fundamental market price movements in the same period, the risk is considerably lower compared to other liquidity measures that are based on price and volume information alone. In principle, bid-ask price differential charged by the same dealer within a short period of time is a close proxy to the transaction cost that a dealer would charge to customers if buyers and sellers asked the dealer to intermediate the trades at the same time. This dealer-specific liquidity measure also enables us to investigate the variation in liquidity provision across different dealers, for example, whether dealers' own financial strengths impact liquidity in the distressed bond market.

In addition to RTC, we have also examined other liquidity proxies not driven by transaction prices including a simple count of the number of trades and turnover, which is defined as total trading volume over the week divided by the par amount of the bond outstanding.

In estimating trading returns of defaulted bonds, daily prices are first constructed based on the "trade-weighted price, all trades" approach recommended by Bessembinder et al. (2009). In this approach, daily price is the weighted average of prices of all customer-to-dealer transactions for each bond during the day, using trade size as the weights. Weekly price is estimated as the last available daily price in the week. Let $p_{i,t}$ be the weekly price of bond i in week t, then the weekly trading return, R_{it}, is defined as

$$R_{it} = \frac{p_{it} - p_{i,t-1}}{p_{i,t-1}} \tag{2}$$

Since most defaulted bonds are changing hands without interest payments, accrued interest is not included in the return calculation.

The excess return of a defaulted bond i in week t, ER_{it}, is then defined as:

$$\text{ER}_{it} = R_{it} - R_t^f, \tag{3}$$

where R_t^f is the weekly return of the Barclays 5-year Treasury Index.

3 Market for Defaulted Bonds and Dealers' Liquidity Provision

One concern in empirical study of defaulted bond trading is that bonds may not trade much after default. But after comparing frequencies of trading in defaulted bonds with non-defaulted high-yield bonds, we find that defaulted bonds may trade more frequently than people had thought.

Figure 2 provides a calendar time view on the sample means of the weekly number of trades per bond in the defaulted bond population and in the non-defaulted high-yield bond population. Those two lines are surprisingly close to each other with some short periods of even more defaulted-bond trading than non-defaulted high-yield bonds. On average, over the period from 2002 to 2013, an average non-defaulted high-yield bond trades about three times per week, while a defaulted bond trades about twice per week. Unlike equity market where stocks mostly get delisted immediately after bankruptcy filings, a defaulted bond could continue to be traded just as all the other bonds in the OTC market. Such market structure enables us to track down the changes in liquidity, returns and market participates for bond trading continuously over default event time.

Did broker-dealers provide liquidity for defaulted bonds? In spite of lacking initial inventory information for either customers or dealers, we could still measure the change in inventory of defaulted bonds for dealers from tracking down their position change over some fixed time periods around default time. Figure 3 shows the change in dealers' aggregate holdings of defaulted bonds as a percentage of bonds' total offering amount between one hundred calendar day before the default date and one hundred calendar day after the default date. Changes in customers' holdings would be just the mirror image of this graph since customers' net sell position should equal dealers' net buy position during the same period. The position change is plotted for defaults in three sub-periods. We can see customers aggressively reduced holdings of defaulted bonds around default time and those positions have been absorbed by dealers. So dealers as a whole indeed provide liquidity to this distressed market, as predicted in Weill (2007). Although with falling prices and higher bid-ask spreads, dealers employ smaller amount of capital than what would be needed to take into the same amount of bonds at pre-default price levels. When customers move back to buy these bonds after default, dealers could sell the positions that they cumulated around default time for a profit as prices normally reverse upward.

Furthermore, we check which kind of dealers tend to provide more liquidity to the defaulted bond market. One of our hypotheses is that dealers with weaker financial health or higher funding costs should hold fewer positions in defaulted bond market. Another is that during the crisis when broker dealers also experience financial distress, there may be fewer dealers who are willing to provide liquidity. To test these hypotheses, we calculate the position change of each dealer during the short period around default time in defaulted bonds and divide dealers into three different groups according to their net positions in defaulted bonds: net buyers, net sellers, and zero-balance dealers. [8] The net buyers contribute more to liquidity provision in terms of holding longer net

[8] We aggregate dealers' position in all defaulted bonds using trading shares. For example, if one dealer traded only two defaulted bonds in the default week - bond A and bond B, and if he bought 100 shares of bond A and sold 80 shares of bond B, this dealer is a net buyer for defaulted bonds. In majority of the cases, the net position is based on the same bond.

long positions. We look at how the composition of these groups change over credit cycles around default week. Table 3 summarizes our preliminary findings.

The first three columns in Table 3 aggregate dealer positions from one week before default week to one week after default week. The last three columns aggregate positions only during the default week. The sample here covers all dealers with valid CDS spreads and all defaulted bonds during the period. [9] These are considered to be the most stressful period for defaulted bonds since selling pressure is likely to be most severe during these weeks. First, we observe that the number of unique dealers participating in defaulted bond trading around default week decreases from pre-crisis period to post-crisis period, so does the shares of net buy and percentage of net buy respect to total offering amount. But when the market experienced big supply shock during the financial crisis, number of net buyers in dealers group actually increased compared with non-crisis periods. Similarly, number of net sellers decreased during crisis too. Hence, we find evidence that dealers indeed provided liquidity during financial crisis.

When we look at the market structure of dealer participation, we find concentration ratio in net buyers is quite high. Top three dealers in net buyers group hold 70-98% total shares of net long positions of defaulted bonds in the whole dealer community. Number of dealers who hold more than 99% aggregated net long positions is less than nine. So most of the net long positions (or liquidity provision in terms of “leaning against wind") are absorbed by a few large broker-dealer houses. The concentration during financial crisis becomes weaker during the crisis, but stronger after crisis. Interestingly, after crisis, there is a significant change in the composition of net buyers in dealer group - there are fewer US dealers among big net buyers. More foreign-headquartered firms move to the top list of providing liquidity to defaulted bonds. This might be related to the Volcker Rule that restrict US banks in proprietary trading.

We use the CDS spread of a dealer as a proxy for the financial health and funding cost of the dealer. A regression analysis does not find CDS spread will have any significant impact on whether a dealer will turn out to be a net buyer. But if we take average on CDS spreads for dealers belonging to each group, we find some variance in CDS spread across dealer groups. As shown in the last three rows of Table 3, dealers in zero-balance group tend to have highest average CDS spreads. These might be the dealers who can only provide trading liquidity by serving as middle-men between two customers and are not willing to take inventory risk and hold longer-term positions in defaulted bonds. They tend to be small firms. Dealers in net-buy group have lower average CDS spreads than dealers in net-sell group before crisis but the comparison has mixed result for during and after crisis periods. Given the large concentration ratio in these two

[9] We use Markit data for CDS spreads and retrieve them for the parent company of dealers. At default week, dealers with CDS spreads operate about 60% of the trading volume on average.

groups, the result could be driven by idiosyncratic variation in CDS market for individual firms.

4 Price Reversal and Liquidity Costs around Default

4.1 Cumulative Abnormal Returns around Default

Following event study literature on price dynamics of bond market such as in Ambrose et al. (2012) and Ellul et al. (2011), we examine the cumulative abnormal return (CAR) dynamics around default time. CAR is defined as individual defaulted bond's weekly return in excess of the weekly return of Barclays U.S. Corporate High-yield Index R_t^{HY}[10]. We focus our study on Chapter 11 filings and payment defaults and stay away from distressed exchanges in the following analysis, because the announcement of distressed exchanges often changed the value of defaulted bonds instantly to an offered level or halting the trading of the original bonds [11]. We also conduct several data cleaning steps and remove bonds if they have been traded less than 30 times in the full sample[12].

There are around $1,240$ bonds and 400 unique issuers that have been traded over time in our sample. On average, each defaulted bond has about $1,700$ trades. Among them, the largest default is Lehman Brothers in terms of both default amount and number of bonds involved. So we single out bonds issued by Lehman Brothers as a case study and track down how CAR changes for these bonds after Lehman filed bankruptcy on September 15, 2008. Figure 4 plots CARs of five most actively traded senior bonds issued by Lehman starting from one year before default. Panel (a) plots the CARs for each bond separately and Panel (b) shows the mean and median CARs across these bonds.

Two interesting observations emerge from these plots. First, the CARs were lowest in the short period after default and significantly reversed the trend in about 15 to 20 weeks after default and ended up at a much higher level than their levels right after default. In other words, we do observe significant price reversals for this big default event. Second, it takes a long time for CARs to

[10]Since default event may not be exogenous to the market value of bonds and bond trading is very sparse relatively to equity market, the market-model approach for estimating CAR in equity market may not be suitable to defaulted bond market. Unlike in Ellul et al. (2011), many defaulted issuers do not have equities traded after default so we cannot employ the market model used there. To minimize distortions in results coming from definition of abnormal returns, we employ a straightforward "simple method" to define abnormal returns as well as abnormal illiquidity around default events, which is just to take difference between defaulted bond sample and non-defaulted high-yield bond sample, in order to control for the movement of the broader financial market. All returns of Barclays indices are downloaded from DataStream.

[11]If the issue goes through distressed exchange first but the issuer files bankruptcy after a while, the case is included in our sample with default marked at the bankruptcy filing date. There are very few cases of other types of defaults, such as pre-packaged Chapter 11, so we ignore them as well to keep our sample relatively homogenous in terms of default type.

[12]Other data cleaning steps include: remove trades with non-positive price or suspiciously high or low price, or at exact par price after default time.

finally stabilize at a low-volatile level, ranging from approximately 25 weeks for three bonds and 50 weeks for the other two bonds. Such long time to the equilibrium recovery rate may be due to the uncertainty of a court restructuring plan, or may be due to the slow speed that capital moves to these distressed assets [13].

For the other bonds in our sample, we also observe similar CAR patterns, although the degree of CAR drop at the default time and consequent price reversals is not as extreme as in Lehman's case. We plot the median and mean values of CARs across bonds in our sample excluding Lehman Brothers' bonds along the event time line in Figure 5, starting from 10 weeks prior to default week and ending at the 10th week after default. As in Ellul et al. (2011), we only take into account CARs if there was a valid trade during the week when taking averages. Since not all the bonds have trades during each week along the event time line, we also report the number of bonds counted in for the average CARs. The clear V-shaped CAR curve with the dip at the default time shows significant price reversal in defaulted bond trading in Table 4. Generally speaking, an average defaulted bond lost more than 10% cumulatively from 10 weeks before default to default time relatively to high-yield bond index. Interestingly, such loss reversed right after default week and may even give buyers of defaulted bonds positive return in five weeks after default. Around ten weeks after default, the negative CAR seems to have largely recovered and stabilized to the 10-week pre-default levels[14].

Hence, for the overall sample, we observe significant loss in returns around default time and price reversal after default. This indicates that first, default still generates significant downward price pressure to the defaulted bonds within short periods before default. Since bond prices should already incorporate the probability of default, the quick and large drop in prices for defaulted bonds may be largely due to liquidity crunch rather than changes in the prediction of default probability. Second, positive price reversals after default implies that there might be some inefficiency in moving capital quickly to defaulted bond market to absorb the supply shock and adjust the prices to their new equilibria.

More interestingly, when we investigate CAR dynamics over different calendar time periods, we find that defaults happened during 2008-2009 crisis have much deeper drop in CARs at default time and slower price reversal following default. Hence, the broad market distress aggravates financial distresses encountered by individual firms. To explore this credit cycle effect, we divide sample period into three subperiods based on the recent subprime mortgage crisis: the pre-crisis period, defined as July 1, 2002 to June 30, 2007; the crisis period, characterized by the subprime credit crisis and the bankruptcy of Lehman Brothers, spanning from July 1, 2007 to March 31,

[13] We checked that the volatility of High-yield index returns is not the driven force of CAR dynamics.

[14] We use simple averages of CARs here. We checked this result does not vary much while we use offering amount as the weights to get weighted averages.

2009; and the post-crisis period, from April 1, 2009 to December 31, 2013. We find that during the 2008-2009 financial crisis periods, even when we exclude Lehman Brothers from our sample, the loss of CAR is much more severe than other subperiods and the subsequent price reversal after default is more volatile and major recovery does not appear within 10 weeks after default[15].

Figure 6 compares the median CAR of defaults in three subperiods without Lehman Brothers. During the crisis, CAR drops more than 20% within the default week, while in other periods, weekly drop in CAR around default week is less than 5%. Price reversal in crisis period also appears most dramatically although the statistical significance merits more investigation as shown in Table 5.

These patterns suggest that abnormal return of distressed assets during financial crisis is much worse than it in normal times and price discovery may takes longer than usual times. Next, we check if there also exist differences in trading liquidity and dealer behaviors during the crisis over other time periods.

4.2 Liquidity Costs around Default

Empirical literature on liquidity in bond market consistently demonstrates that liquidity deteriorates when bonds bear higher credit risks. As an extreme case, defaulted bonds are expected to have worst liquidity among all traded bonds. When we measure the (il)liquidity by transaction costs, i.e., the effective bid-ask spreads estimated by round-trip cost (RTC), we do observe that liquidity rapidly deteriorates around default time. But similar to price reversals, liquidity loss also appears most severe during the financial crisis. To examine the dynamics of liquidity change over default, we focus on the abnormal illiquidity which is measured by estimated abnormal RTC - the difference between RTC of a defaulted bond and the weighted median of RTCs of all non-defaulted high yield bonds constructed using our TRACE sample with trading volume as the weights.

Figure 7 shows along the weeks from default time, a typical defaulted bond experiences a jump in liquidity cost measured by abnormal RTC during the default week. Both the mean and median plots show that the abnormal RTC increases around 30% at the default week compared with weeks away from default, with around 0.5% to 1% of the transaction price as the “normal" level of abnormal RTC for a typical defaulted bond[16].

When we divide the sample into three periods as in the CAR analysis, we can see the loss

[15]We have tracked CARs for longer periods after default and found that starting from 11th week after default, the average CAR for defaulted bonds shows a more consistent and significant upward trend. However, number of bonds traded after 10 weeks post default decreased significantly, so the recovery trend may be due to some selection bias.

[16]Not shown in the paper, round-trip costs without adjustment of market index show the same pattern. Subtracting RTC for high-yield bond index only seem to mark the original RTC for individual defaulted bond down by a small constant (around 0.2% of transaction price) over default time.

in liquidity around default time is only significant during the crisis period, as shown in Figure 8. During crisis, default increases median abnormal RTC of defaulted bonds by around 70% while there is no significant patterns of changes in abnormal RTC for defaults in other periods.

Connecting these findings with the different price reversal patterns of defaulted bonds in crisis period, it seems to suggest that significant loss in liquidity could be one reason that loss in CAR is more severe and price reversals take much longer time for in-crisis defaults, which is consistent with the theory that price reversals are associated with slow-moving capital with elevated search costs.

On the other hand, higher transaction costs do not necessarily accompany inactive trading. In fact, we observe more active trading around default time. As shown in Figure 9, all types of trading activities pick up before default, peak at the default week, and decline sharply after two weeks post default. Figure 9 plots the average number of trades per bond in our sample for the three types of trades: dealer-to-dealer, customer buy from dealers, and customer sell to dealers, along the event time line [17]

Default may spur trading for two reasons: first, conventional bond investors, such as pension funds and insurance companies, may be forced to sell a defaulted bond if they are not allowed to hold any defaulted bonds. Forced sale may be also triggered when defaulted bonds are used as collateral and their diminishing value causes margin calls. Such "fire-sale" phenomenon is likely to be the driving force behind the negative CAR around default time. Second, vulture funds, hedge funds specialized in distressed debt investment, or proprietary trading desks in big investment firms may see buying opportunities following defaults. Such bargaining incentives could also attract investors to initiate trades on defaulted bonds. If there were sufficient number of buyers who can move capital quickly to defaulted bond market and if whenever they want to purchase a defaulted bond, they could quickly find dealers to complete the trade with minimal transaction cost, we should not observe continuing price reversal in weeks after default or delay in price discovery process. Our CAR analysis in the previous section suggests that this is not the case. For majority of the defaulted bonds, buyers do not seem to emerge quick enough to absorb the supply shock of defaulted bonds. By examining data on trading counterparties in this section, we can provide evidence that "fire-sale" force seems to outperform bargain hunters in a relatively long period after default and such imbalance is more severe during financial crisis

Consistent with CAR pattern, there are more trades in which customers sell bonds to dealers around default time. Customer-sell trades also increase more and earlier than customer-buy trades before default time. It is interesting to notice that number of customer-buy trades per bond continue

[17] TRACE data is able to distinguish if a trade happens between two dealers or between a customer and a dealer. For a customer-to-dealer trade, we can further identify if the customer is selling bonds to a dealer or buying from a dealer.

to decrease after default although CAR turns direction.[18] In the next section, we also look at the holding position change of customers and dealers in order to examine the selling pressure of defaulted bonds more closely.

For the subsample of defaults during the financial crisis, as shown in Figure 10, there are bigger imbalance between customer sell trades and customer buy trades. Customer sell trades increase more sharply before default, indicating more unanticipated defaults or investor panic. Customer buy trades increase very little around default time, in contrast to the bigger increase in the full sample.

From Figure 9, it seems that inter-dealer trades as a percentage of total number of trades decreases gradually when a bond approaching default and that share increases in post-default trading. During ten to six weeks prior to default, when customer sell interests and customer buy interests are more balanced, there are also larger percentage of inter-dealer trades. It is reasonable since in a balanced market, dealers are more willing to take position according to a customer‘s order and then go to search for another dealer to clear the position. However, around default time, dealers may be only willing to take positions if they can cancel them internally and let the customer to bear more search costs. Thus, searching for trading counterparties become a slower process for customers who need to trade around default time (especially for those who need to sell) and this results into larger bid-ask spreads and lower prices[19].

5 Impact of Dealer's Funding Costs on Liquidity and Price Discovery around Bond Default

In this section, we explore cross-sectional regression analysis on the variation of liquidity losses and CAR dynamics across defaulted bonds, focusing on the impact of broker-dealers' own funding costs to the market of defaulted bonds. Briefly, we explore the following empirical strategy:

First, using dealer-specific liquidity measure RTC, we estimate the effect of variables describing dealers' financial health and funding costs, such as dealers' CDS spreads, dealers' affiliation with banks, and dealer's profitability, on liquidity in a panel regression for weekly trading statistics, controlling for bond characteristics and market liquidity index. Our null hypothesis is that

[18]Plots using trading volume (not shown here) also show very similar patterns.

[19]Number of interdealer trades increase significantly around default time. Rule NASD IM 2440-1 and NASD IM 2440-2 once set up the guidance for markup cap that broker and dealers could charge to be 5%, but for high yield bonds and distressed debt, the sale to QIB(qualified institutional buyer, such as another dealer) is exempt from this rule. It is possible that one dealer prefers to sell positions to another dealer instead of a customer to avoid this markup cap, hence boost the number of interdealer trades, but since this rule is only a "guidance" and the mark-up should be based on "reasonable market price", which is hard to determine for defaulted bonds, such motivation of interdealer trades may not be an important factor for large number of interdealer trades.

financial distress experienced by broker-dealers should be associated with wider bid-ask spreads they charge to customers while trading defaulted bonds. If we could identify such relationship, we would like to investigate further how such effects enter the price discovery process of defaulted bonds, namely, if the liquidity cost measured by expected RTC based on the information about dealers' financial health affects the drop of price at default time and the degree of price reversals following default for various bonds as a cross-sectional analysis. So second step is to estimate the impact of liquidity costs on CARs and price reversals using dealer characteristics as instrumental variables for liquidity measure. This section describes our empirical results and variables used for this regression analysis are listed in Appendix.

5.1 Impact of Dealers' Financial Health on the Liquidity of Defaulted Bonds

Theoretical work on the liquidity and price discovery in the OTC markets, such as Duffie (2010), suggests that while facing a supply shock, the speed of capital moving from potential investors to the markets may be influenced by factors such as trading search costs, funding costs, and the inventory risks of market makers. In this section, we first check if liquidity cost of trading bonds around their default time is related to the financial health of broker-dealers who facilitate the trades.

We use a dealer's CDS spread as a major proxy for the funding cost of a broker-dealer. Our hypothesis is that dealers' CDS spreads should have negative relationship with liquidity, namely, dealers with wider CDS spreads will charge customers wider bid-ask spreads. When a dealer is a public firm, we can also find its financial statement variables such as total asset value and profitability. We retrieve these data at quarterly frequency from SNL Financial database. Table 6 reports the regression results based on panel data with weekly bond-dealer level observations from three weeks before default week to three weeks after default week. We include year fixed-effect according to default year to control for the impact of credit cycles including the presence of financial crisis. After selecting relevant variables representing dealer's financial health and also bond characteristics, we find that the liquidity cost around default time measured by RTC is significantly and positively correlated with dealer's CDS spreads. This result is pretty robust regardless other control variables included in the regression. Financial statement variables such as total asset value of dealers and Return on Equity do not seem to have significant impact on the trading liquidity costs. However, when a dealer is affiliated with a bank holding company, this tends to benefit the liquidity provision to the defaulted bonds. Following Comerton-Forde et al. (2010) which measures the impact of dealers' financial health to equity trading liquidity, we also construct dealer's trading revenue on a specific bond and find that dealers tend to charge higher bid-ask spread following a low revenue from trading the bond in the previous week, although this effect is small in magnitude.

Our result also shows that the liquidity costs vary by bond type. Consistent with previous literature, we find that bonds with larger issuing amount and higher seniority level tend to have lower liquidity costs. Lehman bonds are included in the regression and not surprisingly, those bonds bear much higher liquidity costs around default.

5.2 Impact of Liquidity on Abnormal Returns at Default

To examine the cross-sectional variations of abnormal returns at default, we run regressions for bond-level CARs at default week cumulated from 10 weeks prior to default. RTC at default week is the key independent variable of interest and we expect that higher RTC is associated with lower CAR at default. To get bond-level liquidity measure and dealer characteristics variables, we take weighted average of dealer-specific variables using trading volume as the weights. Since liquidity and price are simultaneously determined from trades and are only observable for realized trades, we apply two-stage least squares estimation method using dealer CDS spreads as the instrumental variable for liquidity measure RTC, given the panel regression results in the previous section. We report both OLS and two-stage least square regression results in Table 7 Panel A with first-stage result in Panel B, with two model specifications distinguished by inclusion of bond characteristics as control variables.

It is clear from first stage regression results that liquidity measure at bond level is still significantly related with dealer CDS spreads. Also it is noted that the dummy variable indicating whether default happens during financial crisis does not significantly impact liquidity, at the presence of dealer CDS spreads. In the 2SLS result, liquidity estimated with dealer CDS spreads has a larger impact to abnormal returns at default compared with the impact observed liquidity from OLS result. This suggests that the impact of liquidity to the price reaction of default shock may be even stronger than we can observe from realized trades, since with the loss of liquidity, some orders may not go through. This result also provides empirical evidence that the distress of financial intermediations such as broker dealers could result into large price impacts on distressed debt that are trading in the OTC markets hence rely heavily on these financial intermediations.

5.3 Impact of Liquidity on Price Reversals after Default

Last, we examine cross-sectional variations in price reversals, focusing on the impact of liquidity cost around default time to subsequent price reversals after default. We measure price reversals around 10 to 15 weeks after default, since we observe fast declining of trading activities and stabilizing prices around that time for defaulted bonds. As the dependent variable of regression analysis, we define price reversal as the difference between the maximum of CARs from 10 to 15 weeks after default and the minimum of CARs in three weeks around default time, where CAR is cumulated from 10 weeks prior to default. Formally,

$$\texttt{Price Reversal for bond } i = \max_{t \in [10,15]} CAR_{i,t} - \min_{t \in [-1,1]} CAR_{i,t}.$$

Table 8 reports the results of regressing price reversals on average RTC from three weeks before default to three weeks after default and other control variables with both an OLS model and a two-stage least squares specification using dealer CDS spreads as the instrument variable. Similar to results in the previous section, when we bring in dealer CDS spread as an instrument for the liquidity measure, the impact of liquidity to price reversal is largely enforced. Such impact is in general significant across different model specifications with different control variables except for in the last model where we put crisis dummy and market liquidity index together. Overall, these results are consistent with our hypothesis that when liquidity cost is higher around default time, subsequent price reversal is stronger, indicating a larger degree of market friction at the time of bond default.

6 Summary and Discussions

Defaulted corporate bonds are generally traded in a segmented OTC market. In such an environment, new defaults may generate supply shocks for traded securities in this market. Theories predict that these supply shocks may result in temporary deterioration in trading liquidity and deviations of prices from their neoclassical equilibriums. Using comprehensive data on intraday transactions of corporate bonds, we show that defaults trigger more active trading, wider bid-ask spreads, lower abnormal returns, and subsequent price reversals after default. More interestingly, we provide empirical evidence that broker-dealers' funding costs are positively correlated with the liquidity cost charged to defaulted bond investors. Dealers provide liquidity to distressed debt by absorbing selling pressures around bond default, or "leaning against wind", even during the financial crisis. However, the loss in liquidity and downward price pressures are more severe for the defaults that occurred during the 2008-2009 financial crisis than defaults in other periods. Overall, our results are consistent with the recent theoretical work on the liquidity and price discovery in the OTC markets in that financial intermediaries' financial strengths and funding costs are important drivers for market friction or elevation of search costs in price discovery process.

Appendix: Variables Used for Regression Analysis

Definitions of variables used in regression analysis:

- **RTC**: Dealer-specific round-trip cost in basis points, proportional to bond price.
- **dealer CDS**: 5-year CDS spreads in basis points for dealers from Markit.
- **have_dealer_cds**: dummy variable that equals one if the dealer has CDS spreads available from Markit.
- **haveCDS** $\times$ **dealer CDS**: interaction term of **have_dealer_cds** and **dealer CDS**.
- **dealer profit**: dealer's revenue from holding and trading the specific bond in the previous week, including mark-to-market profit (or loss) from inventory and the returns from round-trip trading of the bond , calculated as the gross trading revenue measure in Comerton-Forde et al. (2010), equation (3).
- **log assets**: log of dealer's total assets from SNL Financial quarterly financial statements.
- **ROE**: dealer's Return on Equity calculated as EBITA divided by book value of equity from SNL Financial quarterly financial statements.
- **is_private**: dummy variable that equals one if dealer is a private company hence does not have financial statement data.
- **public_size**: interaction term of public dummy variable and dealer's total assets, equal to (1-**is_private**) times **log assets**.
- **is_bank**: dummy variable that equals one if dealer is affiliated with a bank holding company.
- **in_crisis**: dummy variable that equals one if default happened between July 2007 and March 2009.
- **bond_size**: natural logarithm of bond offering amount which is in millions of US dollars.
- **is_seniorsecured**: dummy variable that equals one if a bond belongs to senior and secured class.
- **is_seniorunsecured**: dummy variable that equals one if a bond is senior but not collateralized.
- **maturity**: Time-to-Maturity of a bond in years.
- **lehman**: dummy variable that equals one if a bond has Lehman Brothers as the issuer.
- **preweekprice**: end-of-week price of the bond in the past week.
- **HY RTC**: weighted-average RTC of High Yield bonds.
- **predefault liquidity**: average RTC of the bond from 50 weeks to 15 weeks before default time.

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Table 1: Defaulted Bond Sample

This table shows the numbers of bonds (i.e., issues) and issuers in our sample by each year. The first two columns show the counts for all the TRACE-eligible bonds that have defaulted and still in default status by the end of each year with defaults identified by Moody's DRD database. The last two columns show the counts for bonds whose default dates fell within each year.

	Defaulted Bonds by Year-end		New Defaults in Each Year	
Year	N. of Bonds	N. of Issuers	N. of Bonds	N. of Issuers
2002(2nd half)	795	351	403	126
2003	669	298	147	80
2004	587	237	218	43
2005	584	183	191	34
2006	397	143	43	20
2007	298	119	25	17
2008	935	125	841	58
2009	1411	231	581	150
2010	942	188	64	38
2011	787	157	69	30
2012	716	159	61	32
2013	198	123	41	27
Total			2684	655

Table 2: Default Type Distribution

This table shows the type distribution of defaults in our sample. The first columns count the number of distinct bonds(issues) that defaulted in our sample period. The last two columns count the number of distinct defaulted issuers.

Default Type	N. of Bonds	Bond Percent	N. of Issuers	Issuer Percent
Chapter 11	1591	59.3	266	40.5
Chapter 7	6	0.2	4	0.6
Distressed exchange	638	23.8	158	24.1
Missed payment	310	11.5	178	27.1
Prepackaged Chapter 11	96	3.6	40	6.1
Receivership	43	1.6	10	1.5
Total	2684	100	656	100

Table 3: Dealer Participation in Defaulted Bonds

This table presents some summary statistics that reflect dealers' trading activities in defaulted bonds around time of bond default. The first three columns aggregate dealer positions from one week before default week to one week after default week. The last three columns aggregate positions only during the default week. The sample is based on the "constant sample" for bonds and dealers who trade those bonds with a valid CDS spreads. Three subperiods are defined as before: During Crisis - July 2007 to March 2009, Before Crisis - June 2002 to June 2007, and After Crisis - April 2009 to December 2013.

	Weeks Around Default $t \in [-1, +1]$			At Default Week $t = 0$		
	Before Crisis	During Crisis	After Crisis	Before Crisis	During Crisis	After Crisis
Number of Dealers	64	59	48	64	58	47
Number of Net Buyers	15	21	11	12	16	8
(percentage of total)	(23%)	(36%)	(23%)	(19%)	(28%)	(17%)
Number of Net Sellers	33	11	9	27	10	9
(percentage of total)	(52%)	(19%)	(19%)	(42%)	(17%)	(19%)
Number of Zero-balance Dealers	16	27	28	25	32	30
(percentage of total)	(25%)	(46%)	(58%)	(39%)	(55%)	(64%)
Market Structure:						
Top 3 Net Buyers' Market Shares	95%	70%	84%	91%	77%	98%
Number of Dealers Who Shared 99% Buys	7	9	6	8	8	4
Number of US Dealers among above	4	5	2	5	4	0
Scale of Dealer Participation:						
Total Defaulted Bonds Offering Amount ($mil at par)	155,124	203,887	147,782	153,495	203,603	146,632
Net Buy by all Dealers ($mil at par)	4,615	3,202	607	745	2,020	73
Net Buy as a % of Total Offering	2.97%	1.57%	0.41%	0.49%	0.99%	0.05%
Cash Dealers Paid for Net Buy ($1000)	$ (2,798,723)	$ (830,019)	$ (233,448)	$ (664,983)	$ (395,112)	$ (121,240)
Dearlers' Average CDS Spreads (bps)						
Net Buyers	31	288	166	34	276	139
Net Sellers	36	329	158	37	262	172
Zero-balance Dealers	60	348	196	55	304	236

Table 4: CAR Statistics of Defaulted Bonds around Default Time

This table presents statistics of CARs along the event time for the defaulted bonds in our cleaned sample excluding Lehman Brothers. CAR, shown in percentage, is estimated as cumulative abnormal return from 10 weeks before default week with abnormal return defined by simple method, i.e., the difference between Excess Return of defaulted bonds and Excess Return of Barclays High Yield Bond index. Weeks show the number of weeks from default week. Median and means are taken across defaulted bonds that have been traded at each time spot without any weighting scheme and the number of bonds is shown in the last column. *t*-statistics is for the mean CAR.

Weeks	Median CAR	Mean CAR	t-stat for Mean CAR	Number of bonds
-9	-1.38	-2.04	-2.28	416
-8	-1.69	-2.14	-2.01	424
-7	-1.22	-2.42	-1.90	417
-6	-3.07	-4.02	-2.80	425
-5	-5.04	-4.95	-3.08	417
-4	-4.02	-5.22	-3.09	434
-3	-1.01	-4.88	-2.73	444
-2	-4.13	-6.49	-3.26	427
-1	-10.26	-9.50	-4.64	434
0	-9.40	-11.56	-5.55	504
1	-3.73	-4.08	-1.83	459
2	-4.14	-2.68	-1.16	426
3	-4.43	-1.87	-0.80	417
4	-2.06	-1.82	-0.76	401
5	0.08	1.84	0.76	428
6	0.68	2.00	0.84	409
7	0.00	1.08	0.46	414
8	0.17	1.47	0.59	410
9	-1.81	-1.62	-0.66	387
10	0.53	4.10	1.66	402

Table 5: CAR Statistics over Credit Cycles

This table presents statistics for CARs during three periods: “In Crisis" period (July 2007 to March 2009), “Before" crisis period (June 2002 to June 2007), and “After" crisis period (April 2009 to December 2013). CAR is estimated using simple method along the event time for the defaulted bonds in our cleaned sample excluding Lehman Brothers, shown in percentage. Median and means are taken across N defaulted bonds that have been traded at each time spot without any weighting scheme. *t*-statistics is for the mean CAR.

	In Crisis				Before				After			
Weeks	Median CAR	Mean CAR	t-stat	N	Median CAR	Mean CAR	t-stat	N	Median CAR	Mean CAR	t-stat	N
-9	-7.99	-8.95	-3.33	67	-0.78	-0.61	-0.53	227	-1.20	-0.92	-0.59	122
-8	-7.09	-6.81	-2.12	68	-0.94	-1.48	-1.28	243	-1.53	-0.72	-0.30	113
-7	-5.90	-10.01	-2.53	67	-0.22	-1.55	-1.14	239	-0.69	0.31	0.11	111
-6	-12.39	-11.31	-2.62	68	-2.34	-3.33	-1.92	245	-2.77	-1.10	-0.38	112
-5	-17.72	-16.93	-3.70	69	-3.83	-1.17	-0.55	233	-4.37	-5.43	-2.08	115
-4	-18.15	-17.69	-3.12	68	-0.83	-2.34	-1.13	246	-4.30	-4.06	-1.42	120
-3	-9.82	-8.78	-1.49	66	0.00	-4.10	-1.95	271	-3.44	-4.45	-1.21	107
-2	-28.49	-19.16	-3.05	63	-1.01	-1.39	-0.60	259	-10.54	-11.47	-2.77	105
-1	-23.90	-18.90	-3.04	60	-9.72	-7.30	-2.94	271	-3.98	-9.82	-2.29	103
0	-47.03	-32.48	-4.92	68	-6.69	-7.06	-2.93	311	-7.96	-11.37	-2.55	125
1	2.87	-1.02	-0.13	50	-3.84	-3.24	-1.24	293	-6.46	-7.53	-1.58	116
2	3.06	-0.40	-0.05	51	-4.41	-0.77	-0.28	268	-3.56	-8.56	-1.78	107
3	4.72	0.20	0.02	54	-6.16	-2.64	-0.97	261	-3.67	-0.99	-0.20	102
4	13.15	4.98	0.51	42	-5.25	-2.32	-0.82	253	-2.40	-3.34	-0.70	106
5	1.29	-3.51	-0.41	53	0.00	3.24	1.16	274	0.05	0.83	0.16	101
6	14.45	9.27	1.13	50	-2.48	0.27	0.10	258	2.57	2.85	0.53	101
7	3.13	0.12	0.01	50	0.00	0.07	0.03	274	-0.91	4.66	0.79	90
8	9.14	12.12	1.27	46	0.06	0.90	0.33	272	-1.24	-2.19	-0.38	92
9	-13.46	-6.58	-0.67	48	-1.56	0.57	0.22	260	-0.71	-5.80	-1.03	79
10	12.95	11.01	0.98	45	0.00	2.61	0.99	272	4.64	5.23	0.95	85

Table 6: Determinants of Liquidity Cost around Default

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Dependent variable:	RTC										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dealer market variable											
dealer CDS	–	0.32***	–	–	–	–	–	0.19***	–	0.26***	–
		(5.46)						(2.61)		(2.58)	
have_dealer_cds	–	–	-10.91**	–	–	–	–	–	-15.05***		-17.66***
			(-2.24)						(-2.85)		(-2.80)
haveCDS * dealer CDS	–	–	0.18***	–	–	–	–	–	0.17***		0.19***
			(4.59)						(4.38)		(3.66)
dealer_profit	–	–	–	-0.01***	–	–	–	-0.02***	–	-0.01***	–
				(-11.70)				(-8.27)		(-5.01)	
Dealer financials											
log_assets	–	–	–	–	-0.96	–	–	-9.77	–	-9.46	–
					(-0.70)			(-1.37)		(-1.00)	
ROE	–	–	–	–	12.32	–	–	-4.13	–	-21.60	–
					(1.54)			(-0.31)		(-1.17)	
is_private	–	–	–	–	–	-22.83	–	–	-13.89		-91.07***
						(-1.24)			(-0.68)		(-2.76)
public_size	–	–	–	–	–	-0.63	–	–	-0.07		-3.87**
						(-0.67)			(-0.06)		(-2.25)
is_bank	–	–	–	–	–	–	-8.77**	-11.26	-10.40**	18.05	6.00
							(-2.36)	(-0.73)	(-2.46)	(0.90)	(1.16)
Bond characteristics											
bond_size	-4.92***	-6.39*	-6.07***	-5.79***	-12.21***	-5.43***	-4.27**	-11.85**	-5.81***	-7.25	-3.19
	(-2.95)	(-1.83)	(-3.59)	(-2.95)	(-3.80)	(-3.15)	(-2.53)	(-2.31)	(-3.36)	(-1.25)	(-1.04)
maturity	-0.56*	-0.97**	-0.59**	-0.76**	-0.91**	-0.57**	-0.53*	-0.75	-0.55*	-0.09	-0.73*
	(-1.96)	(-2.45)	(-2.05)	(-2.28)	(-2.20)	(-1.97)	(-1.85)	(-1.38)	(-1.91)	(-0.12)	(-1.92)
is_seniorsecured	-39.71***	-35.39***	-39.94***	-28.60***	-29.95**	-40.59***	-39.58***	-9.48	-40.52***	11.33	-18.01*
	(-5.30)	(-2.60)	(-5.35)	(-3.73)	(-2.43)	(-5.43)	(-5.28)	(-0.61)	(-5.42)	(0.52)	(-1.86)
is_seniorunsecured	-39.64***	-50.10***	-39.40***	-33.78***	-34.41***	-40.29***	-39.26***	-14.41	-39.57***	-10.62	-34.47***
	(-6.95)	(-5.00)	(-6.90)	(-5.57)	(-3.80)	(-7.08)	(-6.87)	(-1.26)	(-6.94)	(-0.66)	(-4.50)
lehman	44.61***	85.71***	43.02***	56.01***	83.02***	43.71***	45.62***	54.16***	42.87***	-13.90	34.13*
	(3.98)	(4.55)	(3.86)	(4.24)	(5.31)	(3.89)	(4.06)	(2.61)	(3.83)	(-0.62)	(1.65)
prevweekprice	-1.41***	-1.49***	-1.40***	-1.50***	-1.54***	-1.41***	-1.41***	-1.24***	-1.40***	-1.23***	-1.39***
	(-15.81)	(-10.25)	(-15.76)	(-15.52)	(-10.94)	(-15.84)	(-15.79)	(-6.49)	(-15.75)	(-5.12)	(-11.43)
HY_RTC	0.58*	0.28	0.45	-0.30	1.30**	0.57*	0.58*	0.63	0.44	-0.41	0.37
	(1.82)	(0.60)	(1.42)	(-0.86)	(2.56)	(1.79)	(1.82)	(1.03)	(1.39)	(-0.48)	(0.89)
predefault liquidity	–	–	–	–	–	–	–	–	–	0.32***	0.41***
										(4.38)	(12.26)
Constant	278.30***	293.06***	294.03***	285.42***	372.94***	302.10***	272.77***	485.33***	302.70***	410.53**	296.56***
	(12.33)	(6.60)	(12.89)	(11.04)	(8.87)	(11.35)	(12.03)	(3.34)	(10.57)	(2.26)	(6.39)
Year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	6,969	2,762	6,969	5,130	2,901	6,969	6,969	1,290	6,969	759	3,401
Adjusted R-squared	0.095	0.119	0.099	0.133	0.108	0.096	0.096	0.167	0.101	0.210	0.201

Table 7: Panel A. Abnormal return in default week and liquidity cost of trading: OLS vs. 2SLS using dealer CDS as instrument.

Dependent variable:	CAR(-10,0)			
	(1)	(1)	(2)	(2)
	OLS	2SLS	OLS	2SLS
RTC	-0.0355***	-0.384***	-0.0238**	-0.231**
	(-3.051)	(-3.103)	(-2.010)	(-1.990)
bond_size	–	–	-1.067	-5.087
			(-0.443)	(-1.199)
is_seniorsecured	–	–	16.35*	-3.533
			(1.679)	(-0.234)
is_seniorunsecured	–	–	-3.327	-9.886
			(-0.357)	(-0.932)
lehman	–	–	-26.70***	-30.22**
			(-3.871)	(-2.214)
in_crisis	–	–	-36.21***	-22.86*
			(-4.751)	(-1.796)
HY RTC	–	–	0.488***	0.818***
			(2.712)	(2.757)
Constant	-22.95***	27.12	-11.99	66.48
	(-10.01)	(1.540)	(-0.417)	(1.084)
Observations	550	550	541	541
Adjusted R-squared	0.016	–	0.179	–

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Panel B. First-stage results

Dependent variable:	RTC	
	(1)	(2)
Instrument:		
dealer CDS	0.286***	0.279***
	(3.894)	(2.903)
bond_size	–	-21.11*
		(-1.866)
is_seniorsecured	–	-119.5***
		(-3.320)
is_seniorunsecured	–	-34.87
		(-1.432)
lehman	–	-27.13
		(-0.745)
in crisis	–	32.39
		(1.224)
HY RTC	–	1.102
		(1.547)
Constant	120.8***	400.8***
	(12.64)	(2.860)
Observations	550	541
F Statistic	15.16	8.43
p-value	0.000	0.000

Table 8: Panel A: Price Reversal after default and liquidity cost around default.

Dependent variable:	Price reversal							
	(1)	(1)	(2)	(2)	(3)	(3)	(4)	(4)
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
RTC	0.114***	0.222**	0.108***	0.266**	0.0894***	0.378**	0.0844***	0.214
	(4.855)	(2.176)	(4.263)	(2.093)	(3.468)	(2.105)	(4.137)	(1.144)
bond_size			-0.823	1.416	-3.359	3.792	-4.183	-0.830
			(-0.237)	(0.363)	(-0.919)	(0.646)	(-1.336)	(-0.143)
is_seniorsecured			-19.19*	-16.12*	-17.78*	-14.08	-18.02*	-16.32
			(-1.837)	(-1.708)	(-1.766)	(-1.077)	(-1.743)	(-1.476)
is_seniorunsecured			-4.820	-6.857	-8.192	-7.816	-8.180	-8.015
			(-0.584)	(-0.837)	(-0.992)	(-0.891)	(-1.162)	(-1.090)
lehman			-42.91***	-40.61***	-21.02**	-29.56**	-38.63***	-39.06***
			(-3.762)	(-3.145)	(-2.415)	(-2.422)	(-3.582)	(-3.467)
in crisis			25.98***	17.37			21.37***	17.27*
			(3.035)	(1.507)			(2.858)	(1.767)
HY RTC					1.206***	-0.0561	1.075***	0.536
					(4.120)	(-0.0658)	(3.793)	(0.648)
Constant	39.43***	22.29	53.93	3.799	65.71	-38.70	76.62**	27.88
	(9.627)	(1.405)	(1.272)	(0.0658)	(1.536)	(-0.488)	(2.047)	(0.348)
Observations	376	376	367	367	367	367	367	367
Adjusted R-squared	0.080		0.121		0.135		0.152	

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Panel B. First Stage result for 2SLS

Dependent variable:	RTC			
	(1)	(2)	(3)	(4)
Instrument:				
dealer CDS	0.281***	0.318***	0.219***	0.201**
	(4.130)	(3.395)	(2.701)	(2.167)
bond_size		-18.32**	-27.39***	-27.45***
		(-2.271)	(-3.441)	(-3.445)
is_seniorsecured		-36.88	-25.71	-24.77
		(-1.317)	(-0.954)	(-0.914)
is_seniorunsecured		6.354	-4.389	-4.139
		(0.340)	(-0.242)	(-0.228)
lehman		-28.79	-2.967	-7.302
		(-0.997)	(-0.116)	(-0.259)
in crisis		14.30		8.305
		(0.629)		(0.378)
HY RTC			3.795***	3.781***
			(5.320)	(5.287)
Constant	130.8***	355.6***	394.3***	395.3***
	(13.93)	(3.636)	(4.172)	(4.176)
Observations	376	367	367	367
F-stat	17.06	11.53	7.3	4.7

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Number of Defaulted Issuers by Default Type and Default Year

This figure shows the distribution of defaulted issuers by default type over years in our sample (July, 2002 to December, 2013). Vertical axis shows the number of issuers who defaulted during each year with any of the six types of default (distribution listed in order from bottom to top of each column/year): Chapter 11 filing (ch11), distressed exchange (dtex), missed payment (mspm), prepackaged Chapter 11 (pk11), receivership (rcvr), and Chapter 7 filing (ch7).

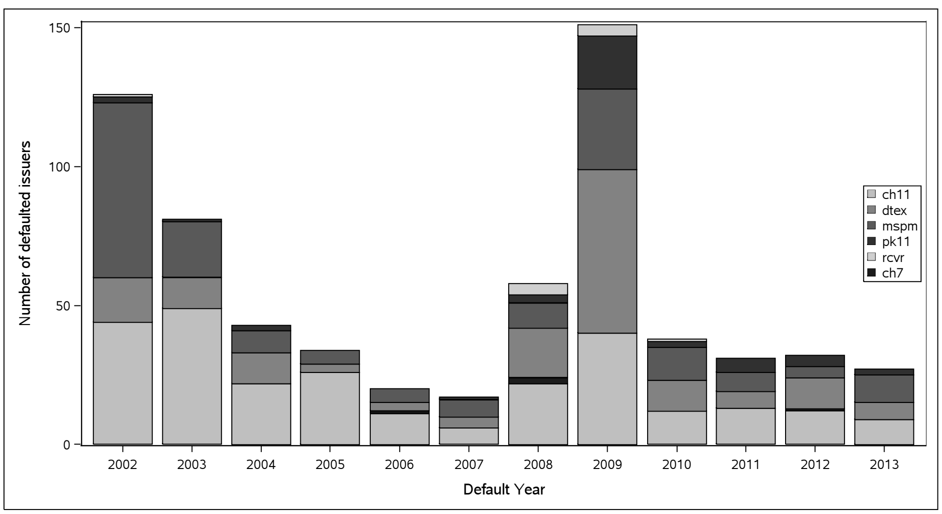


Figure 2: Average Number of Trades per Bond over Time

This figure plots the sample means of the weekly number of trades per bond in the defaulted bond population (red line) and in the non-defaulted high-yield bond population (blue line). On average, over the period from 2002 to 2013, a non-defaulted high-yield bond trades about three times per week, while a defaulted bond trades about twice per week. As an asset class, during most of the time along calendar time, non-defaulted high-yield bonds trade more frequently than defaulted bonds, but defaulted bonds trade more frequently than other type of bonds around default time.

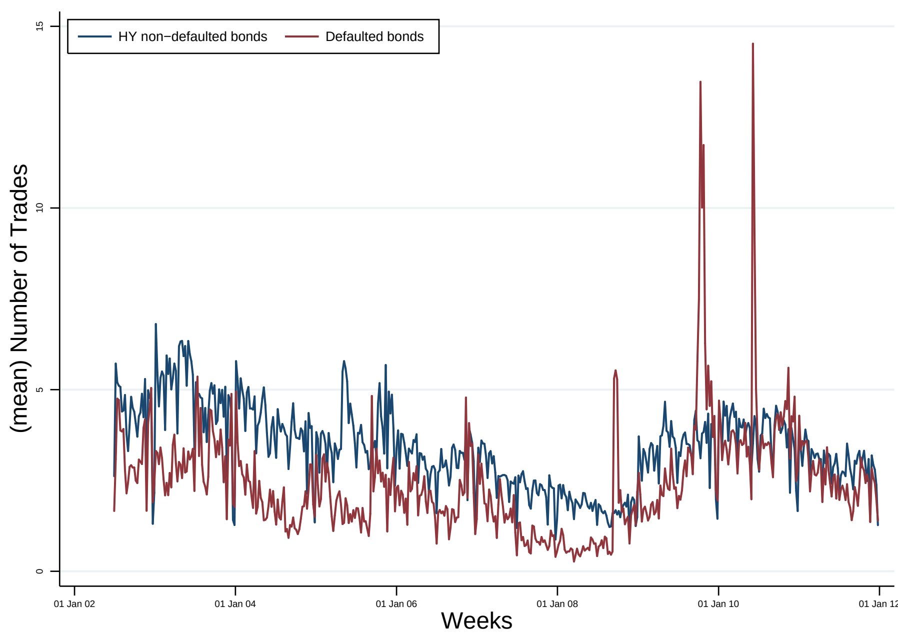


Figure 3: Dealers as a Net Buyer around Default

This figure shows the change in aggregate dealers' holdings of defaulted bonds for Chapter 11 filings and payment defaults excluding Lehman, as a percentage of the total offering amount in two hundred days around default time. Cumulated position changes of dealers increased sharply around default time, indicating dealers absorbed selling positions from customers. Time horizon is shown in days around default day. The average is taken across defaulted bonds in the three subsample periods: crisis period (Bonds defaulted during July 2007 to March 2009, blue solid line), pre-crisis period (June 2002 to June 2007, green dash-dotted line), and post-crisis period (April 2009 to December 2013, dashed line).

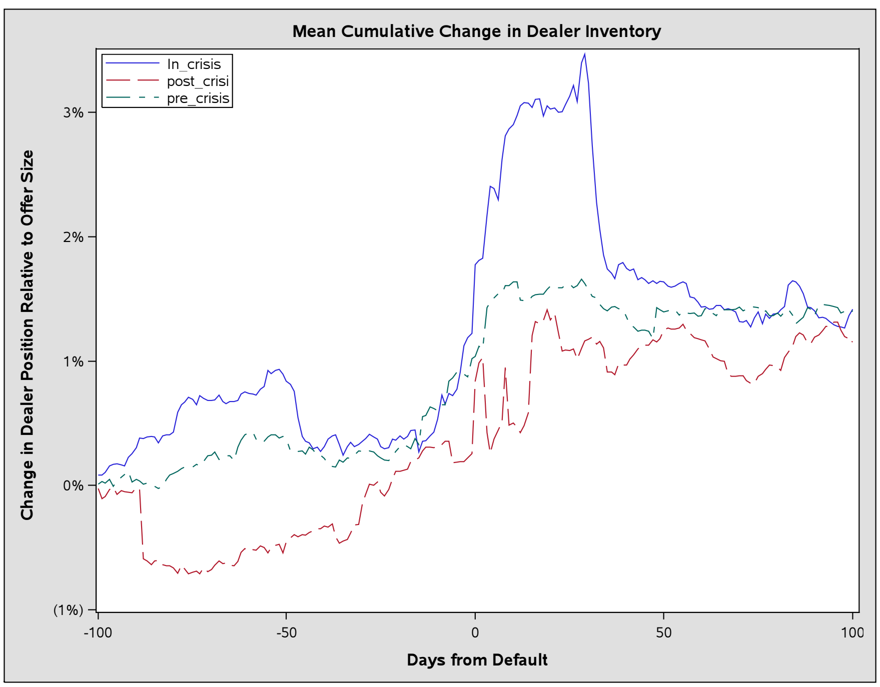
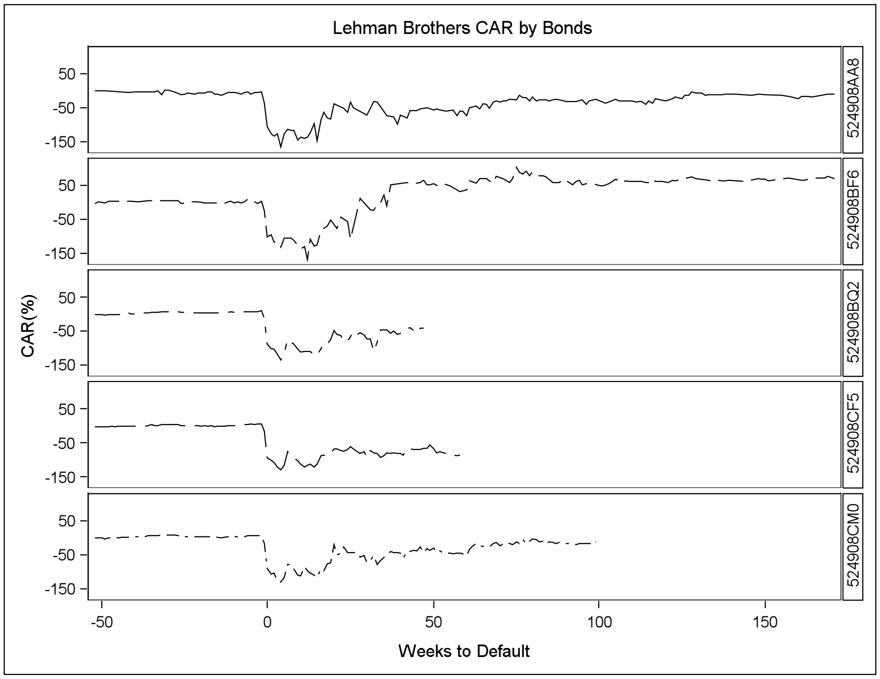


Figure 4: Example: CAR of Lehman Brothers Bonds

This figure plots the weekly CAR for five most actively-traded senior bonds issued by Lehman Brothers. Panel a shows the CAR for each bond. Panel b shows the unweighted mean and median CARs across these bonds. CAR is cumulated from one year before Lehman filed bankruptcy on September 15, 2008 where abnormal return is defined as the difference between the Excess Return of defaulted bonds and the Excess Return of Barclays High Yield Bond index.

(a) CAR of five Lehman bonds



(b) Unweighted average CAR

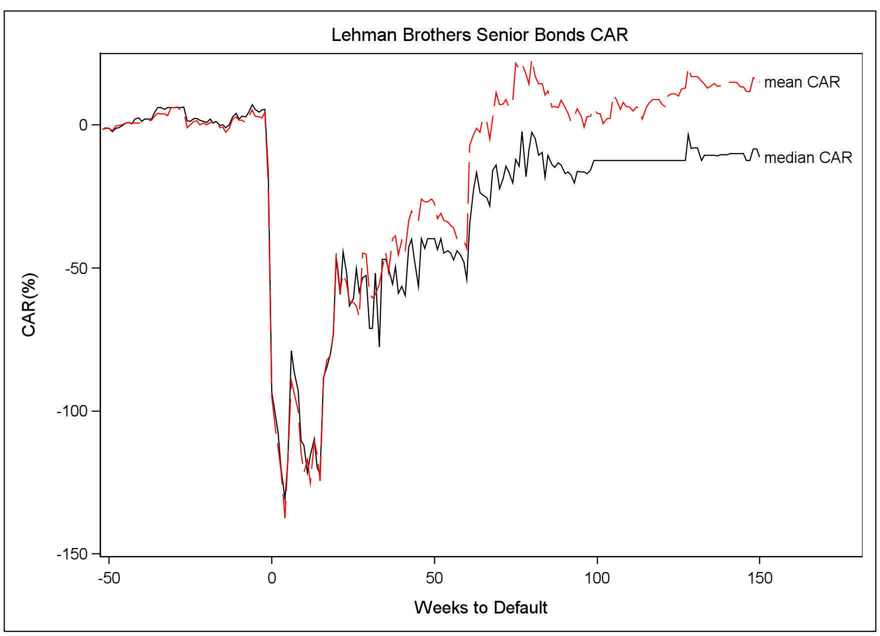


Figure 5: Weekly CAR around Default

This figure plots the median and mean values of CARs across defaulted bonds in weeks from default for Chapter 11 filings and payment defaults excluding Lehman Brothers. CAR is estimated starting 10 weeks before default with the following formula: CAR = Excess return of defaulted bonds - Excess return of Barclays High Yield Bond index. Left vertical scale: CAR in percentage. Black solid line: median of CAR; Red dotted line: mean of CAR. Right vertical scale: N - number of bonds included in the average calculation at each event time.

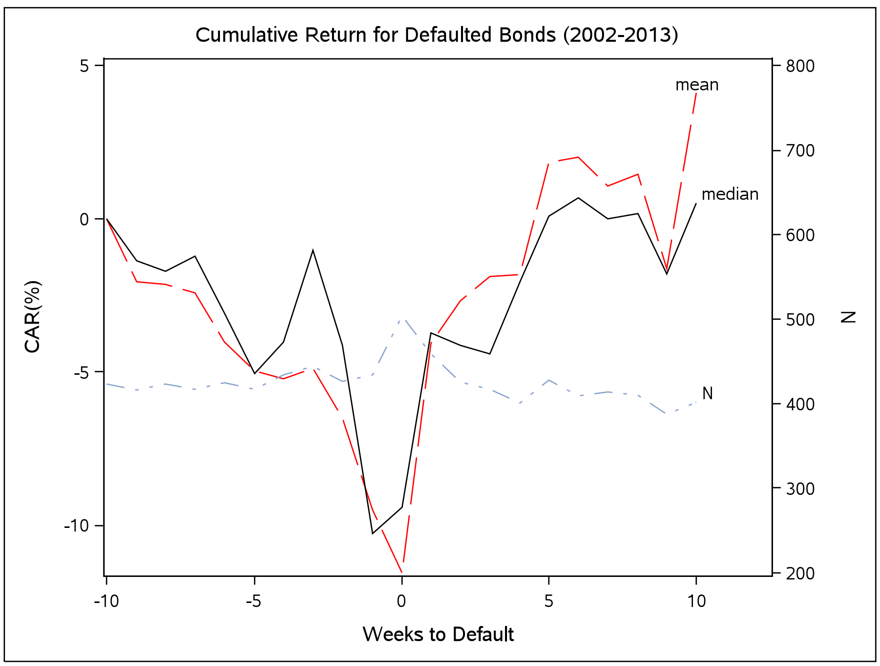


Figure 6: CAR over the Credit Cycle

This figure shows median CAR estimated for defaulted bonds by three periods: crisis period (July 2007 to March 2009), pre-crisis period (June 2002 to June 2007), and post-crisis period (April 2009 to December 2013). CARs are estimated in the same way as in Figure 5: CAR = Excess return of defaulted bonds - Excess return of Barclays High Yield Bond index, cumulated from 10 weeks before default and for defaulted bonds with Chapter 11 filings and payment defaults excluding Lehman Brothers. Solid line: crisis period; Dash line: post-crisis period; Dash-dotted line: pre-crisis period.

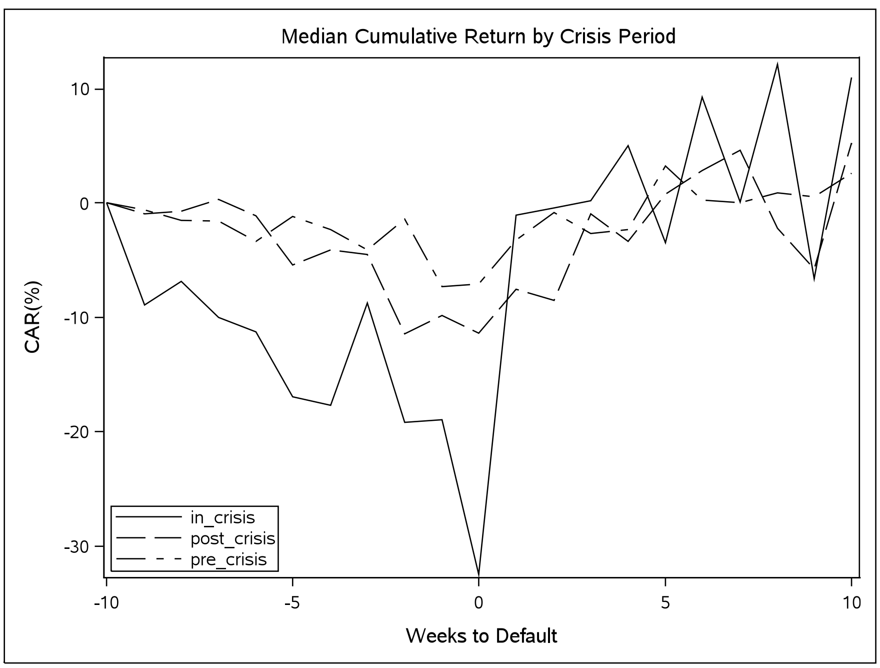


Figure 7: Abnormal Bid-Ask Spreads around Defaults

This figure shows the unweighted mean and median of abnormal Round-Trip Costs (RTC) across defaulted bonds in our sample in weeks from default. Abnormal RTC is defined as the round-trip cost of a defaulted bond minus the weighted median of round-trip costs of all non-defaulted high yield bonds traded in the same week in TRACE data with trading volume as the weights. Defaulted bonds in this sample consist of only Chapter 11 filings and payment defaults excluding Lehman Brothers. Left vertical scale: Abnormal RTC as a percentage of price. Black solid line: median of Abnormal RTC across defaulted bonds; Red dotted line: mean of Abnormal RTC. Right vertical scale: N - sample size, number of bonds with valid RTC data that are included in the calculation at each event time.

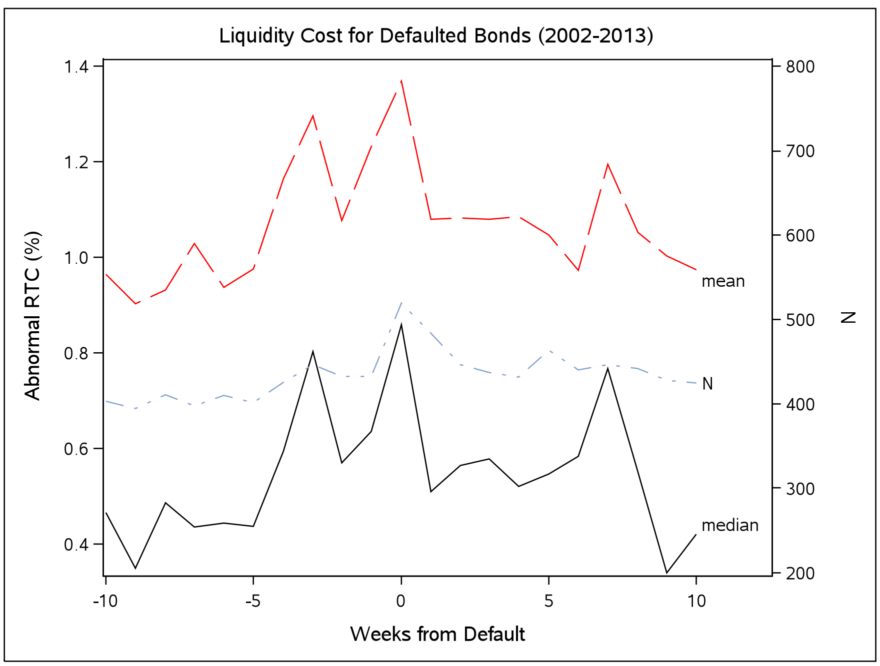


Figure 8: Abnormal Bid-ask Spread over Credit Cycles

This figure shows the median of defaulted bonds' abnormal Round-Trip Costs around default time by three periods: crisis period (July 2007 to March 2009), pre-crisis period (June 2002 to June 2007), and post-crisis period (April 2009 to December 2013). Abnormal Round-Trip Cost is estimated by RTCs using simple difference between defaulted bonds and High-yield bond index. Sample of defaulted bonds consist of Chapter 11 filings and payment defaults excluding Lehman Brothers bonds.

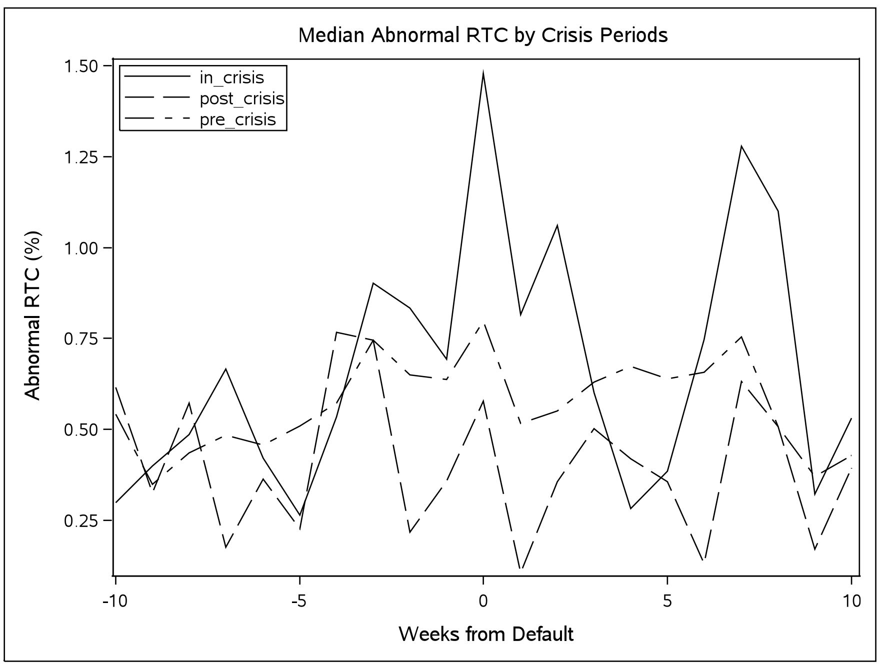


Figure 9: Number of Trades around Default (whole sample period)

This figure plots the average number of trades across defaulted bonds in our sample for the three types of trades: dealer-to-dealer, customer buy, and customer sell, along the event time line. All types of trading activities pick up before default, peak at the default week, and decline sharply after two weeks post default, with customer sell trades outnumber customer buy trades. Percentage of inter-dealer trades decline around default time.

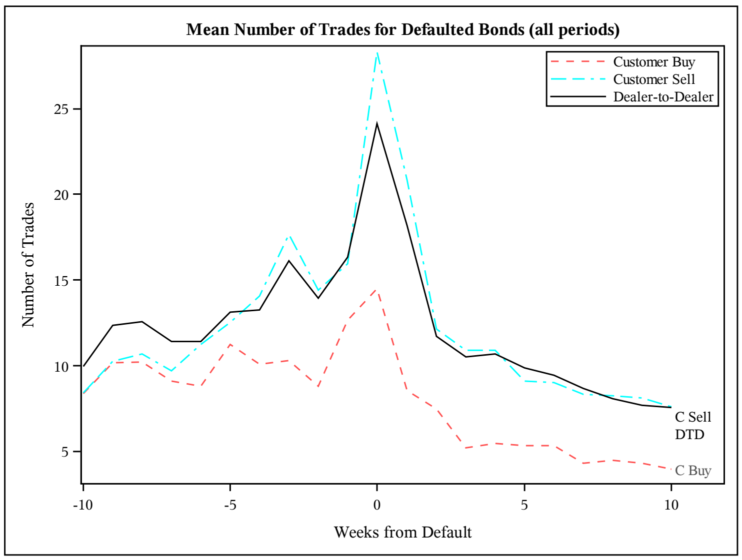


Figure 10: Number of Trades around Default (in Crisis)

This figure plots the average number of trades across defaulted bonds in our sample, only for defaults that happened during the crisis (July 2007 to March 2009), distinguished by three types of trades: dealer-to-dealer, customer buy, and customer sell. Compared with out-of-crisis defaults, there are bigger imbalance between customer sell trades and customer buy trades. Customer sell trades increased more sharply before default, indicating more unanticipated defaults or investor panic. Inter-dealer trades become more dominant for trading after default.