Liquidity and Price Impacts of Financial Distress: Evidence from the Market for Defaulted Bonds*

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Abstract

This paper employs bond transaction data from 2002 and 2011 to investigate the trading activity and price dynamics of defaulted corporate bonds, aiming to shed light on the impact of financial distress on trading liquidity and market efficiency. We find that when new defaults generate supply shocks in the market for defaulted corporate bonds—an over-the-counter market that is commonly viewed as segmented - these defaulted bonds will experience more active trading, wider bid-ask spreads and a sudden drop in prices followed by price reversal in the weeks after default. Furthermore, 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, reflecting in part that broker-dealers' market-making capacities may be more constrained by their own financial stress during the crisis. Thus, this paper provides new evidence on the role of the financial health of intermediaries in aggravating the impact of corporate financial distress on market liquidity and price discovery.

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

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1 Introduction

Recent financial crises 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. The lack of efficient price discovery may result in prices deviating from fundamental values and thus magnify the original shocks to the financial market. Taken as a leading example, 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.

In this paper, we use the market for defaulted corporate bonds as a laboratory to quantify the loss in trading liquidity and the delays in discovering equilibrium prices due to financial distress. For a defaulted bond, there exists two layers of financial distress: one is the default event itself; another is the distress of the financial market where the defaulted bond is trading, such as funding shortage of the investors trading those bonds and the financial distress of dealers who make markets for those bonds. We start with the impacts of the default event and find those impacts are more significant when the market-wide financial distress is presenting.

Defaulted corporate bonds provide a unique setting for analyzing the impact of financial distress. 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 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 (Altman (1999), Lim (2012)). In a segmented market, new defaults, especially those at large quantities, could generate supply shocks for traded securities. Existing theories suggest that, to the extent that the supply of funds are not perfectly elastic, these shocks result in trading illiquidity and price pressures, leaving prices temporarily deviated from their neoclassical equilibrium. Duffie (2010) suggests that the impact of supply shocks can be measured by price reversals after the shocks. Initially, the price of securities may drop upon the supply shock. But as the supply of funds becomes more available, the price gradually comes back to a higher level and eventually reaches to the new equilibrium. In theory, the magnitude of the effects, or the extent of the price reversals, may be associated with the nature of shocks (such as size and duration) and the speed of capital moving from potential investors to the markets, the latter of which is influenced by factors such as trading search costs, funding costs, and the inventory risks of market makers.

We first use a standard event study approach to estimate abnormal bond returns and trading illiquidity around the time of default events for corporate bonds that defaulted over the period from 2002 to 2011. Our methodology is similar to those employed by Ellul et al. (2011), Bessembinder et al. (2009), and Ambrose et al. (2012). We use Moody's DRD database to identify the set of defaulted corporate bonds. We then retrieve the intraday transaction information of these bonds from the Trade Reporting and Compliance Engine (TRACE) system of the Financial Industry Regulatory Authority (FINRA). Our TRACE data are comprehensive in that they include corporate bond transactions for both publicly and non-publicly disseminated bonds as well as information on the identifications of dealers that intermediated the transactions. Thus, the data allow us to calculate estimated bid-ask spreads for each specific dealer and examine the importance of broker-dealer financial strength to trading liquidity and price discovery.

We find that the recent financial crisis has had a profound impact on the trading liquidity and post-default returns of defaulted bonds. Trading becomes more active around default time, but the estimated bid-ask spreads widens. On average, bid-ask spreads tripled around default during the 2008-2009 crisis and but only increased at most by 50% during other periods. Cumulative abnormal returns of a typical defaulted bond from ten weeks before default were about negative 50% during the crisis, compared with negative 20% for non-crisis periods. Price reversal patterns after default also vary over credit cycles. The degree of price reversal is much smaller in crisis periods than non-crisis period. Prices discovery also takes longer time for defaults in crisis. Hence, our analysis shows that general financial market conditions, or credit cycles, are important factors for determining trading liquidity and returns following a default. Our preliminary cross-sectional regressions for abnormal return and illiquidity indicates that part of the reasons for the impact of financial crisis are because broker-dealers—the market makers for these defaulted securities—also experienced significant financial distress during the 2008-2009 financial crisis.

Overall, our findings on the impact of financial distress on the liquidity and return of defaulted bonds are consistent with the hypotheses implied from slow-moving capital hypothesis like in Duffie (2010). During the downturns of credit cycles, such as 2002 and 2008-2009, a supply shock with more defaults worsened the trading liquidity of defaulted bonds and the initial impact faded in a few weeks after default. In terms of price discovery, we observe more significant price reversals following defaults during the 2008-2009 financial crisis. This finding is consistent with the slow-moving capital explanation for the market inefficiency. A special characteristic of the 2008-2009 financial crisis is that it contains some rare events of the failures of two major broker-dealers, Bear Stearns and Lehman Brothers, who happened to be big market makers in the corporate bond market. We find some preliminary support that the market share of Lehman Brothers in defaulted bonds is positively correlated with bigger loss of liquidity and larger price drop of those bonds. The severe loss of liquidity and the significant negative price drift for defaulted bonds in 2008-2009 may be partially due to the dysfunction of these financial intermediaries.

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, access to 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 bonds 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. Feldhutter (2012) and Das et al. (2012) do not distinguish defaulted bonds from nondefaulted bonds in their sample. The only study which we are aware of that utilizes TRACE data, focuses on the distressed bond market, and also addresses liquidity issue is provided by Jankowitsch et al. (2012), which uses a slightly different definition for defaults. But the purpose of Jankowitsch et al. (2012) is to estimate market-based recovery rates for distressed bonds. Liquidity is just one independent variable in their recovery rate regression. In contrast, we aim to quantify the impact of financial distress on liquidity and the dynamic price discovery process simultaneously. To our knowledge, our study is the first one that uses the defaulted bond market to empirically test the loss in market efficiency during financial crises.

The rest of the paper is organized as follows. Section 2 describes data and methodologies for measuring liquidity and abnormal returns. Section 3 presents our main empirical results from event studies to analyze abnormal returns, trading behavior, and liquidity in defaulted bond market. Section 4 concludes and discusses future work.

2 Data and Methodology

2.1 Data sources and sample description

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 novel 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 is more stable/realistic/reasonable and perhaps reflects more accurately the change of liquidity during financial distress compared with other liquidity measures used in previous studies. Dealer identity information also allows us to analyze the impact of dealers' financial strength to the liquidity and pricing of defaulted bonds traded by those dealers.

We pull the entire trading history from TRACE for each bond from July 2012 to December 2011, 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[1].We clean the data by removing canceled trades, erroneous entries, and trades with nonpositive prices or nonpositive volumes. TRACE-eligible bonds are merged with Moody's DRD data based on bond CUSIPs. The final sample contains more than 2,000 distinct defaulted bonds for over 500 distinct defaulted issuers during our sample period. Their total par value at default time sum to over $300 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 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. For indicating dealer's financial strength, we collect CDS spread data of major broker-dealer firms from Markit.

To study the liquidity and price impacts of defaults over credit cycles, we divide our 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, 2009; and the post-crisis period, from April 1, 2009 to December 31, 2011.[2]

Table 1 shows annual bond-issuer counts in our defaulted bond sample. On average, for each year, there are around 960 defaulted bonds from about 380 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

[1]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.

[2]There is no unanimous agreement on the beginning date of the subprime crisis. On June 21, 2007, two Bear Stearns subprime hedge funds collapsed, and on August 1, 2007, shareholders of Bear Stearns brought a lawsuit against Bear Stearns in connection with this hedge fund collapse. Subsequently, the subprime crisis spread to the broader financial markets. So one opinion is that the subprime crisis started in August 2007. Here we took a middle ground by assuming the crisis started in July. As for the end of the crisis, on March 9, 2009, the S&P500 reached its nearly 13-year closing low at 676.53 and has subsequently recovered. So we picked March 31, 2009 as the ending date for the crisis period. We also varied the starting and ending dates by a month or so and reached similar conclusions.

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 two outstanding bonds on average, while in the 2008-2009 period, there are on average close to six bonds per defaulted issuer.[3]

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 crisis took forms other than bankruptcy, although all nonbankruptcy defaults may end up with bankruptcy at some later times.

2.2 Estimating liquidity and returns of defaulted bonds

We have explored several commonly-used liquidity measures in our analysis of the liquidity effect of bond defaults, including the Amihud measure (Amihud (2002)), the Roll measure (Roll (1984)), and the Imputed Roundtrip (IRT) cost measure, as laid out in Dick-Nielsen et al. (2012). TRACE data with dealer identification number enables us to calculate more accurate "roundtrip" cost than previous studies. Different from IRT cost in Dick-Nielsen et al. (2012), we construct the roundtrip cost in the following way.

First, we match trades within the same day for the same dealer, same bond, and same trade size. That is to say, for each trade in which a customer sells a bond to a dealer, we try to find the next trade in which the same dealer unloads the bond with the same amount to another customer within the same day. If we find such a pair[4], we estimate the bid-ask spread that the dealer charges to the customers as the difference between the pair of buy-sell prices, normalized by the average of two prices. We name this illiquidity measure as the

[3] 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.

[4] On the other hand, a dealer could first sell a bond to a customer and buy it back from another customer. We get those pairs too.

"exact roundtrip markup" (RM), denoted as λ.

$$\lambda = 2\frac{P_{ask} - P_{bid}}{P_{ask} + P_{bid}}, \tag{1}$$

For each bond, daily RM is calculated as the median of all the available dealer-specific λ. Weekly RM is the simple average of daily RMs during the week.

We also report results using the effective bid-ask spread measure estimated using the Roll (1984) model, because the Roll measure has been employed widely in the studies on bond trading liquidity (e.g., Bao et al. (2011)). However, due to the special trading behavior of defaulted bonds, key assumptions in Roll model such as market efficiency may not be satisfied, so we think RMs, whenever available, could be a more accurate measure of illiquidity for our data. We decided that the Amihud measure does not fit our data mainly because observations of defaulted bond trading are very sparse. Detailed discussions on various liquidity measures including their correlations and statistics for our data will be added to Appendix (to be completed).

The weekly Roll measure of illiquidity is the simple average of daily Roll measure $\gamma_{i,t}$, estimated by

$$\gamma_{i,t} = 2\sqrt{-\mathrm{COV}(\Delta lnP_{i,t}^{s+1}, \Delta lnP_{i,t}^{s})}, \tag{2}$$

where $P_{i,t}^{s}$ is the price of sth transaction for bond i in day t and $\Delta lnP_{i,t}^{s+1} = lnP_{i,t}^{s+1} - lnP_{i,t}^{s}$.

In addition to these, 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 all trading prices for that 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

$$R_{it} = \frac{P_{it} - P_{i,t-1}}{P_{i,t-1}} \tag{3}$$

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

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

$$\mathrm{ER}_{it} = R_{it} - R_t^{rf}, \tag{4}$$

where R_t^{rf} is the weekly return of the Barclays 5-year Treasury Index.

2.3 Estimating abnormal returns and abnormal illiquidity using an event study approach

We follow an event-study approach to examine abnormal returns and abnormal illiquidity in order to control for the movement of the broader financial market. Since it is questionable that if default event is exogenous to the market value of bonds and bond trading is very sparse relatively to equity market, the standard market-model approach for estimating these abnormal measures may not add accuracy to our analysis. So we employ a more straightforward "simple method" to define abnormal returns (AR) and abnormal illiquidity around default events, which is just to take difference between defaulted bond sample and non-defaulted high-yield bond sample. We also tested a standard "market-model method" relying on linear regression results within the estimation window for robustness check. We lay out both methods in this section.

With the simple method, AR of a defaulted bond i in week t is defined as the difference between the weekly return of this defaulted bond, R_{it}, and the weekly return of Barclays U.S. Corporate High-yield Index R_t^{HY}.[5]

$$\mathrm{AR}_{it} = R_{it} - R_t^{HY}. \tag{5}$$

Cumulative abnormal return (CAR) is the cumulative sum of AR_{it}.

Similarly, abnormal illiquidity is measured by estimated abnormal bid-ask spread (ABA), coming either from Roll measure or "exact roundtrip" cost measure RM. the market illiquidity index is the weighted median of bid-ask spreads of all nondefaulted high yield bonds constructed using our TRACE sample with trading volume as the weights.[6]

With the market-model method, we define the estimation window as the period from 50 weeks to 10 weeks before the the default week, i.e., $t \in [-50, -10]$. For the return analysis,

[5] All returns of Barclays indices are downloaded from DataStream.

[6] A bond is included in the high yield bond index if it is rated as speculative grade by at least one rating agency and if it does not default in the next two years.

we first estimate the following regression for the estimation window:

$$\text{ER}_{it} = \alpha_i + \beta_i \times (R_t^{HY} - R_t^{rf}) + \epsilon_t, \tag{6}$$

We then use the estimated coefficients to predict the "normal" excess returns, $\hat{\text{ER}}_{it}$, over the event window, $t \geq -10$. AR_{it} is simply the difference between ER_{it} and $\hat{\text{ER}}_{it}$. With the estimated AR_{it}, the cumulative abnormal returns (CAR) are the running sum of AR_{it}. The standard errors of all estimated statistics are estimated using the standard method (see, for example, Campbell et al. (1997)).

We use the same method to estimate ABA, using high yield illiquidity index stated above. In the market model, ABA will be the difference between the estimated bid-ask spread and the "normal" bid-ask spread predicted by the regression model.

3 Empirical Results

3.1 Cumulative abnormal returns around default time

We start empirical analysis by asking if there exit price reversals following default time. Price reversals are defined as positive cumulative abnormal returns (CAR) in weeks after default. We use simple method to estimate CAR and constrain our sample by imposing the following restrictions: a bond is included only if there are at least one valid weekly return before ten weeks pre its default time, at least one valid return after ten weeks post default time, at least one valid return in the four weeks before default and in the four weeks after default, and at least twelve valid returns from ten weeks before default and ten weeks after default. Such selection criteria is similar in spirit to the approach in Ellul et al. (2011) and aims to keep sample size relatively stable over event time line. [7] On top of these restrictions, we also remove distressed exchange type due to some problem in deciding their default dates and Lehman, CIT defaults due to their big size. For defaults that happened after June 2011, we manually cleaned data to remove bonds that have too few trades after default time but keep the bonds with short trading history if the default happened too late in our sample period. We call this sample as "constant sample".

There are around 250 bonds that trade over time in our defaulted bond sample after this sample selection. We plot the median and mean values of CARs across these bonds

[7] Since most of bonds trade more frequently around default time, it is hard to avoid sample selection problem while showing simple summary of statistics - a standard event study approach. We are going to explore more advanced econometrics treatment, such as generalized Tobit model to estimate probability of having a trade and the determinants of CARs in the future.

along the time line of twenty weeks around default week in Figure 2, normalizing CARs at the tenth week prior to default. The V-shaped CAR curve shows clearly that there is a significant negative abnormal return around the default time and price reversal exists after default. Starting from ten weeks before default, bond return drops continuously and reaches its lowest point around default time. The loss in median CAR is about 20% in the ten weeks before default. CAR changes direction immediately following the default time. In the first five weeks after default, median CAR recovers about 6% and in ten weeks after default and it generates about 15% positive returns after default. The main portion of the V-shaped mean CAR curve is statistically significant, as shown in Table 3.

Such price dynamic patterns indicate that first, lots of the defaults are not fully anticipated, or in other words, default still generates surprise to the market despite the fact that bond price should already incorporate the probability of default. Second, as we were looking for, there exist price reversals after default, which implies that there is tentative lack of market efficiency that results in over-shooting and under-pricing for defaulted bonds around default time.

More interestingly, the degree of price reversal differs by crisis periods. Figure 3 shows that defaults during the 2008-2009 financial crisis have more significant price reversal patterns than defaults before the crisis. CAR could drop by 50% since ten weeks before default, compared with a less than 20% drop for defaults happening in pre-crisis period and post-crisis period. Price reversal after default is also larger for crisis period than pre-crisis period. Significant positive return for defaults in post-crisis period may be driven by some unique default experience. This graph shows strong evidence that price discovery for distressed assets such as defaulted bonds in distressed financial environment such as financial crisis is different from it in normal times.

We also examine cross-sectional determinants of CARs in order to show the impact of financial crisis still exists after controlling for some standard bond characteristics and default types. First, we estimate the magnitude of price reversals using a simple linear regression model with time fixed effects along the event time line, as in Equation 7.

$$CAR_i(0,t) = \alpha_t + \beta_0 \mathbb{1}\{crisis\} + \beta' \mathbf{X_{it}} + \epsilon_{it} \tag{7}$$

Dependent variable in this regression is CAR for bond i in window $(0,t)$ where 0 stands for event (default) week. $\mathbb{1}\{crisis\}$ is an indicator variable for the subperiod of defaults which will reflect either in-crisis defaults and post-crisis defaults. X_{it} include all the other independent variables which may or may not depend on week t. To control for bond-specific characteristics, we include standard variables in the literature of empirical corporate bond trading:

- Senior: takes value as 1 if the bond is a senior secured bond. Zero otherwise.
- Bond size: log of the initial offering amount of the bond.
- Age: log of the age of the bond.
- Finance: takes value as 1 if the issuer belongs to financial sector. Zero otherwise.
- Default barrier: defined as a combination of long term and short term debt as a percentage of total assets of issuers before default following KMV's formula and Jankowitsch et al. (2012).

We also include a couple of variables specifically about defaulted bonds:

- Ch11: default type. Takes value as 1 if the default type is a Chapter 11 filing. Zero otherwise.
- Resolution: takes value as 1 if the final resolution type of the default is recorded as a liquidation. Zero otherwise.

For trading-related information, we include total weekly trading volume and Roll measure of illiquidity in the previous period, and indicator variable Dissem which is 1 if the transaction information is disseminated to the public in TRACE and hence reflects information transparency in trading. Besides these, we use CAR(-10,0) to control for bond-specific CAR movements not captured by other bond-specific variables.

Panel regression results using "constant sample" are shown in Table 4. The result of equation (1) which uses indicator variable of in-crisis default shows that after controlling for other variables, CARs are still higher for defaults that happened in the crisis period for all the weeks after default. This result is pretty robust across all the sample selections and other control variables that we experimented. The coefficient estimates of other control variables seem to have reasonable signs. In particular, more positive price reversals after default tend to happen for larger bonds, bonds with lower levels of pre-default debt, in non-financial sector and those who avoid liquidation as final resolution type. If a bond's transaction is disseminated in TRACE, i.e., there is better information transparency for this bond, returns tend to be higher. This is consistent with views in the literature of bond market transparency. If previous Roll measure is higher, which reflects larger price dispersion before current trade and/or larger degree of illiquidity, abnormal return is lower. Note CAR is negatively correlated to trading volume. This might indicate that although there are significant positive abnormal return after defaults, investors may not be able to take advantage of those return opportunities if they could not find counterparties to conduct the trade, or if they do not have desire or funding to trade.

To summarize findings in this section, we have found evidence of price reversal for defaulted bonds following default and the degree of price reversal is larger for bonds defaulted in financial crisis compared with defaults in pre-crisis period. This suggests that price takes longer to go back to its new equilibrium for distressed debt during distressed period. Next, we are interested in understanding what causes price discovery particularly inefficient during financial crisis for defaulted bonds, focusing on the trading behavior of defaulted bonds and dealers' role in providing liquidity.

3.2 Trading behavior of defaulted bonds

First we observe from TRACE data that trading activity picks up around default time. It is well-known that corporate bond trading is infrequent in OTC market, but defaulted bonds may trade more frequently than people had thought. Figure 4 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 nondefaulted high-yield bond population. Those two lines are surprisingly close to each other with some short periods of more defaulted-bond trading than nondefaulted high-yield bonds. On average, over the period from 2002 to 2011, an average nondefaulted high-yield bond trades about three times per week, while a defaulted bond trads about twice per week.

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. This "fire-sale" phenomenon should 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 for most of the defaulted bonds, "fire-sale" force outperforms bargain hunters in a relatively long period after default and such imbalance is more severe during financial crisis.

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. CAR dynamics around default time will be consistent with the hypothesis that customer selling order outnumbers customer buying order around default time. When the price reversal happens after default, we should observe the selling pressure to ease off. The imbalance between customer selling orders and customer buying orders should also be bigger during financial crisis than during other time periods. These hypotheses are confirmed with simple means of number of trades in Figure 5 and Figure 6.

Figure 5 plots the average number of trades across defaulted bonds in the whole "constant 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. As expected, there are more trades in which customers sell bonds to dealers. Customer sell trades also increase more and earlier than customer buy trades before default time. It is interesting to notice that customer buy trades continue to decrease after default although CAR turns direction.[8] Does this mean positive price reversal of defaulted bonds is only captured by a small set of investors who has higher risk tolerance or it is largely driven by inter-dealer trades?

There can be two types of inter-dealer trades: one with which dealers trade their own positions for inventory management or speculation purposes, and another where dealers search for trading counterparties to facilitate trading orders initiated by customers. It is hard to distinguish them with available data, since one inter-dealer trades could involve two dealers belonging to these two different types. But in general, market liquidity improves with more inter-dealer trades since with more advanced trading tools, inter-dealer trades could move positions faster and generate more price information to the market.

From Figure 5, 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

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

(especially for those who need to sell) and this results into larger bid-ask spreads and lower prices.

For the subsample of defaults during the financial crisis, as shown in Figure 6, 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. Inter-dealer trades as a percentage of order imbalance (defined as the difference between customer sell trades and customer buy trades) decreases by about 25% at default week from non-crisis period to crisis period. So suppose all the customer sell orders that could not be cleared by a customer buy order at aggregate level need to rely on dealers to find them another dealer on the other side, there will be less chance to do so during the crisis period. Nevertheless, the number of inter-dealer trades does not decrease significantly at default time in crisis period. This shows dealers indeed provide liquidity during distressed period for distressed debts. But demand for liquidity is higher too, so naturally, the price of liquidity - transaction costs or bid-ask spread - should increase during financial distress. We will analyze the change in liquidity, or bid-ask spreads, in the following section.

3.3 Loss in liquidity due to default and the determinants of illiquidity

Going along with more active trading, trading costs of defaulted bonds, measured by estimated bid-ask spreads, rise sharply as a bond is close to default and then reverse significantly after default. Figure 8 shows along the weeks from default time, a typical defaulted bond experiences an increasing abnormal bid-ask spread (ABA) before default time and a decreasing spread after default. [9] The ABAs estimated by both the Roll measure and roundtrip markup show similar patterns. Median abnormal RM peaks at around 85 basis points at the default time, rising from about 55 basis points ten weeks before default. Median abnormal Roll measure peaks at around 2% at default, rising more sharply than measured by roundtrip markups. This might be because Roll measure has higher chance to be contaminated by the price volatility. Abnormal illiquidity seems to drop quickly after default but remains at some higher level than the pre-default period. Trading activity drops quickly after default too,

[9] This plot is based on a sample larger than "constant sample" with a less restrictive selection criteria: a bond is included only if there are at least 12 traded weeks in the estimation window (50 to 10 weeks prior to default), at least one traded week within four weeks prior to and at default, and at least one traded week within four weeks after default. This is the sample we used in previous version and we checked the qualitative conclusions on illiquidity around default does not depend on which sample we use.

reflected by the decreasing number of cusips that have a valid Roll measure or RM. [10]

To examine the impact of the financial crisis on the loss of liquidity in the defaulted bond market, we divide the sample into various periods and plot the median ABA by roundtrip markup in Figure 9. We can see the sharp increase in illiquidity is much more severe during the 2008-2009 financial crisis. Median abnormal roundtrip markup shoots up by about three times from around ten weeks before default to the default time if that default happens during the crisis period (July 2007 to March 2009). In contrast, ABA only increases about 50% around default time for the pre-crisis period and there is no significant increase in ABA around default during the post-crisis period. Illiquidity measured by the Roll measure confirms the 2008-2009 crisis has profound impact on defaulted bond liquidity too, as shown in Figure 10.

What makes the 2008-2009 financial crisis particularly harmful for trading liquidity of defaulted bonds? There are many factors, such as supply shock triggered by large defaults, difficulty of capital raising for hedge fund investors, or panic in market that prevents investors to enter this high risk market. Besides these, one special feature of the 2008-2009 financial crisis is the distress of big broker-dealer firms highlighted by the collapses of Lehman Brothers and Bear Stearns. These dealing firms, especially Lehman, used to be the main players in corporate bond OTC market. As stated in Duffie (2010), the distress of financial intermediations could be an important reason for capital to move slowly to the underpriced assets and temporary loss of efficiency for price discovery in the OTC market. Next, we will use cross-sectional regression to examine the impact of dealers' financial strength to the liquidity of defaulted bonds.

Using the dealer identification numbers of our TRACE data and mapping them with the parent dealer firm's CDS spreads, we can proxy what are the relative financial strengths of dealers who dominant trading of a particular bond. Our hypothesis is that if the CDS spreads of major dealers of a bond are higher, than the liquidity of this bond reflected in bid-ask spreads should be worse. Since dealer's financial strength matters more in financial distress period, we should observe such correlation more likely during the financial crisis period rather than other periods. As a preliminary test, we run simple linear regression with the following specification on the "constant sample":

[10] Mean of ABA, and pure bid-ask spread without substracting the high-yield market illiquidity index shows the same pattern of movement around default time. Mean values are statistically significant within 20 weeks around default time. The market-model based ABAs do not show significant increase in illiquidity around default time though, mainly because sample size for fitting a valid market model is very small due to the sparse data of liquidity measures.

$$Illiquidity_{it} = \alpha + \beta_0(CDS_t, \mathbb{1}\{crisis\}) + \beta'\mathbf{X_{it}} + \epsilon_{it}, \tag{8}$$

where CDS_t is defined as the market share weighted mean of CDS spreads (in log term) of the top three dealers of a particular bond in week t 90 days before its default. Top three dealers are identified by the total trading volume of the bond in 90 days before default. We calculate weekly mean of CDS spreads from Markit daily data. Dependent variable is the illiquidity measure, which is either Roundtrip Markup or Abnormal Bid-Ask spread, starting from the default week till the tenth week after default. We expect pre-default dealer's CDS spread is positively correlated with after-default illiquidity, because if major market makers of the distressed bonds are enduring some financial stress themselves, they may withdraw from trading those bonds when default happens, leaving investors to seek for new trading partners to complete trades after default thus suffering from higher transaction costs and slower trading speed.

Besides CDS spreads, we also consider two other two variables that may affect trading liquidity through dealers' participation:

- Customer trade pct: percentage of customer trades over all trades (including customer-to-dealer and dealer-to-dealer trades), within three months before default.
- log(HHI): log of the Herfindahl index for dealers participating in dealer-to-customer trades for each defaulted bond, calculated from trades within three months before default. This reflects dealer concentration in trading the bond. Higher HHI shows the bond is traded by fewer dealers and we expect such high concentration make the trading liquidity is more vulnerable to default and dealers own distress.

Other control variables are similar to CAR regression in the previous section, such as bond's seniority, size, age, sector, default type, and TRACE dissemination status. Regression results with various specifications are show in Table 5.

In the first equation of Table 5, we only include the indicator variable for crisis period. Result shows illiquidity is worse for defaults happened in the crisis. In equation (2), we add dealer's CDS spread as a control variable. We expect marginal effect of the crisis dummy is smaller if dealers CDS spread could capture part of the difference between crisis period and non-crisis period. This is exactly what we observe from the result. Crisis dummy is not statistically significant any more. Equation (3) includes interaction term of crisis dummy and dealer CDS spread, which turns to be statistically significant, indicating dealer's own financial distress could harm the liquidity of bond trading after bond default and this negative impact on liquidity is mostly significant during the financial crisis. Such relationship also holds when we change roundtrip markup into abnormal bid-ask spreads as in equation (4). Thus, we find evidence in defaulted bond market that financial intermediation's own financial distress could contribute to the trading illiquidity of distressed securities and magnify the shocks to the financial market.

The other two independent variables about dealer participation do not show statistical significance although the coefficient signs are consistent with our expectation: when customer trade percentage is low, or in other words, inter-dealer trade percentage is high, illiquidity measures become smaller, reflecting more active inter-dealer trading improves liquidity; when dealer concentration is high, liquidity is worse since dealers may have more bargaining power to charge higher bid-ask spreads. Other control variables showing significant impact on liquidity include the dissemination indicator, bond seniority, and bond age. other things equal, senior bonds, bonds issued closer to default date, and bonds disseminated in TRACE have lower transaction costs or bid-ask spread after default. In particular, information transparency improves liquidity from the result on dissemination indicator.

Overall, the results highlight the significant impact of the crisis on the trading liquidity or transaction costs in the market for the defaulted corporate bonds, which may be a source of market inefficiency reflected in price reversals from our CAR analysis. The impact of crisis may be partly due to the fact that the crisis hits particularly hard the broker-dealers—the market makers in defaulted bond market and hurt risk appetite for all market participants, which causes persistent illiquidity in trading.

4 Summary and Discussions

Defaulted corporate bonds are commonly 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 deteriorations in trading costs and deviations of prices from their neoclassical equilibriums. Using a comprehensive transactions data on corporate bonds, we show empirical evidence that such effects indeed exist and more interestingly, 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. In general, defaults trigger more active trading, wider bid-ask spreads, and lower abnormal returns. On average, estimated bid-ask spreads tripled around default during the 2008-2009 crisis, but only increased at most by 50% during other periods. Cumulative abnormal returns of a typical defaulted bond from ten weeks before default was about negative 50% during the crisis, compared with negative 20% for non-crisis periods. Price reversal patterns after default also varies over credit cycles, with faster and bigger reversal during non-crisis periods and slower and partial price recovery during crisis period. We find preliminary evidence that dealer's financial strengths measured by the CDS spreads of major dealers for a specific bond is positively correlated to the liquidity of defaulted bonds. Our results are consistent with the recent theoretical work on the liquidity and price discovery in the OTC markets in that financial distress of financial intermediaries may magnify the shocks to these markets.

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Table 1: Defaulted Bond Sample

This table shows the numbers of bonds and issuers in our sample by each year. The first two columns show the count for all the bonds that have defaulted by the end of each year. The last two columns show the count 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)	724	379	184	65
2003	842	451	130	75
2004	844	465	78	40
2005	901	441	166	34
2006	846	414	30	20
2007	662	346	26	17
2008	1261	340	743	73
2009	1535	363	605	164
2010	1088	324	55	35
2011	944	274	62	27
Total			2079	550

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 issuers who defaulted.

Default Type	N. of Bonds	Bonds Percent	N. of Issuers	Issuers Percent
Chapter 11	983	47.28	154	27.90
Chapter 7	3	0.14	3	0.54
Distressed exchange	599	28.81	138	25.00
Missed payment	376	18.09	211	38.22
Prepackaged Chapter 11	90	4.33	40	7.25
Receivership	28	1.35	6	1.09
Total	2079	100	552	100

Table 3: CAR Statistics of Defaulted Bonds around Default Time

This table lists some statistics of CARs along the event calendar for the defaulted bonds in our full sample period of 2002-2011 computed from the simple model. Both median CAR and mean CAR provide clear evidence on large negative returns around default time and significant price reversals after default. *t*-statistics is for the mean CAR and shows majorities of the mean CARs along event calendar are statistically significant. Weeks are the number of weeks from default week. Number of bonds is the number of defaulted bonds with observed weekly returns for each week along the event calendar. It shows the sample size for the cross-sectional statistics.

Weeks	Median CAR	Mean CAR	t-stat for Mean CAR	Number of bonds
-9	-1.29	-1.72	-1.98	254
-8	-2.72	-4.03	-3.52	262
-7	-3.06	-4.54	-3.43	262
-6	-5.25	-7.81	-5.18	266
-5	-8.29	-13.27	-6.77	273
-4	-8.27	-13.42	-6.48	269
-3	-9.47	-14.72	-5.95	269
-2	-15.31	-21.92	-8.80	265
-1	-17.15	-25.68	-9.21	250
0	-21.36	-26.51	-8.78	263
1	-18.62	-24.71	-7.28	262
2	-16.10	-22.58	-6.62	274
3	-18.38	-22.90	-6.82	264
4	-17.92	-25.83	-6.49	253
5	-15.06	-21.53	-5.46	258
6	-15.77	-21.64	-4.99	246
7	-16.15	-21.44	-5.11	250
8	-7.76	-16.50	-3.94	243
9	-10.64	-18.28	-4.26	243
10	-5.34	-12.38	-3.01	246

Table 4: Determinants of Price Reversal: CAR at $t \in (0, t)$

This table reports coefficient estimates of panel CAR regression for CARs after default using "constant sample". Dependent variable is CAR for bond i in window $(0, t)$ for $t = 1$ to 10 (weeks after default). Fixed effects on t is included in the regression but estimates are omitted from this table. First two columns are estimation results from equation (1) with indicator variable for defaults having happened in financial crisis period (July, 2007 to March, 2009). Last two columns are estimation results from equation (2) with indicator variable for defaults having happened after financial crisis period (April, 2009 to December, 2011). Regression results show that price reversals are stronger for defaults that happened in the crisis period and after crisis period even after controlling for other variables affecting CARs.
Significance levels: (*) = 10%, (**) = 5%, (***) = 1%

	(1)		(2)	
Parameter	Coefficients	P-value	Coefficients	P-value
CAR(-10,0)	0.178***	<.0001	0.164***	<.0001
Trading Volume	-0.043***	0.0024	-0.044***	0.0023
in_crisis	12.783***	< 0.0001		
post_crisis			8.063***	0.0067
lag_Roll	-0.066**	0.0149	-0.066**	0.0141
Ch11	0.732	0.7365	0.625	0.7747
Bond size	5.236***	0.0009	5.253***	0.001
Resolution	-11.064	0.1054	-12.633*	0.0656
Age	-2.012	0.167	-2.974**	0.0392
Senior	-24.999***	<.0001	-24.69***	<.0001
Dissem	18.798***	<.0001	19.455***	<.0001
finance	-30.051***	<.0001	-20.074***	<.0001
default barrier***	-0.542	<.0001	-0.541***	<.0001
N	1500		1500	
R Squared	0.15		0.17	

Table 5: Determinants of Illiquidity

This table reports coefficient estimates of illiquidity regression for markups and abnormal bid-ask spread after default using "constant sample". In first three columns or equations (1) to (3), dependent variable is roundtrip markups for bond i at $t = 1$ to 10 (weeks after default). Coefficient estimates are reported in the table with standard errors in parenthesis adjusted with clustering by issuers. Equation (1) has indicator variable for defaults in financial crisis period (July, 2007 to March, 2009). Equation (2) adds dealer CDS spreads variable. Equation (3) include interactions between dealer CDS spreads and crisis indicator. Last column, equation (4) changes dependent variable into abnormal bid-ask spreads measured by roundtrip method, with interaction term of dealer CDS spreads and crisis indicator. Regression results show that dealers' financial strength pre-default is positively correlated with the trading liquidity of defaulted bonds and this relationship is stronger during financial crisis.
Significance levels: (*) = 10%, (**) = 5%, (***) = 1%

Parameter	1	2	3	4
Intercept	−0.356	−0.362	−0.332	−0.252
	(0.792)	(0.805)	(0.792)	(0.780)
in_crisis	0.229 (**)	0.116		
	(0.100)	(0.110)		
CDS		0.089		
		(0.071)		
CDS*in_crisis			0.044 (**)	0.037 (*)
			(0.019)	(0.019)
Markup($t-1$)	0.277 (***)	0.272 (***)	0.277 (***)	
	(0.044)	(0.045)	(0.044)	
ABA($t-1$)				0.282 (***)
				(0.045)
Ch11	0.058	0.077	0.057	0.038
	(0.095)	(0.097)	(0.095)	(0.095)
Finance	−0.081	−0.090	−0.079	−0.053
	(0.116)	(0.118)	(0.117)	(0.115)
Senior	−0.256 (***)	−0.280 (***)	−0.254 (***)	−0.222 (**)
	(0.088)	(0.089)	(0.088)	(0.089)
Is_dissem	−0.177 (*)	−0.205 (**)	−0.178 (*)	−0.197 (**)
	(0.093)	(0.100)	(0.093)	(0.093)
Bond age	0.202 (***)	0.195 (***)	0.202 (***)	0.215 (***)
	(0.070)	(0.071)	(0.070)	(0.071)
Bond size	0.024	−0.002	0.023	0.030
	(0.072)	(0.083)	(0.072)	(0.071)
Customer trade pct	−0.036	−0.100	−0.036	−0.050
	(0.181)	(0.183)	(0.181)	(0.179)
log_HHI	0.104	0.092	0.102	0.085
	(0.072)	(0.073)	(0.072)	(0.071)
N	1050	1050	1050	1042
R Squared	0.140	0.143	0.141	0.141

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, 2011). Vertical axis shows the number of issuers who defaulted during each year with any of the four major types of default: Chapter 11 filing, missed payment, prepackaged Chapter 11, and distressed exchange.

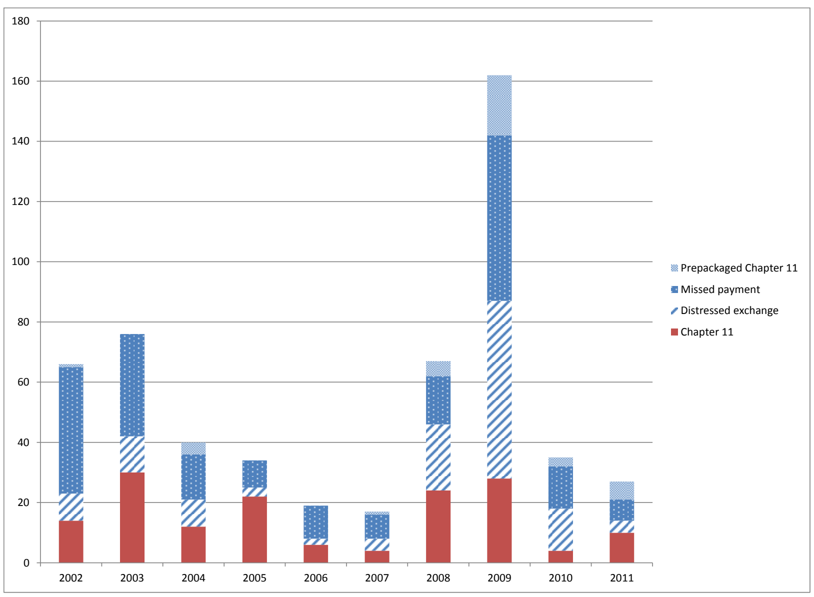

Figure 2: Average Weekly CAR around Default

This figure plots the median and mean values of CARs across defaulted in weeks from default for "constant sample". CAR is estimated by simple method, starting 10 weeks before default. CAR = Excess return of defaulted bonds - Excess return of Barclays High Yield Bond index. Black solid line: median of CAR; Red dotted line: mean of CAR.

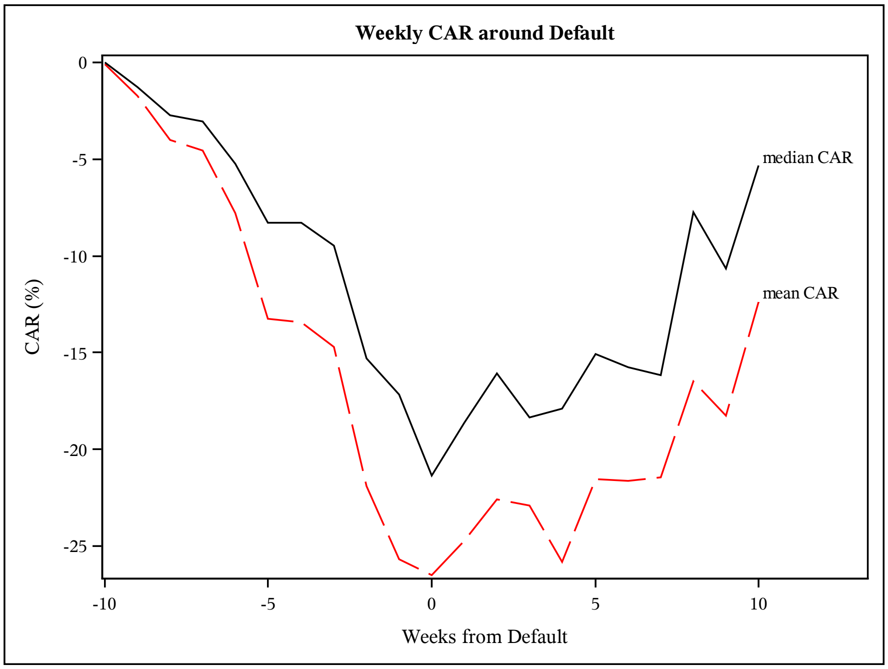

Figure 3: CAR over the Credit Cycle

This figure shows median CAR 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 2011). CAR is estimated using simple method on "constant sample".

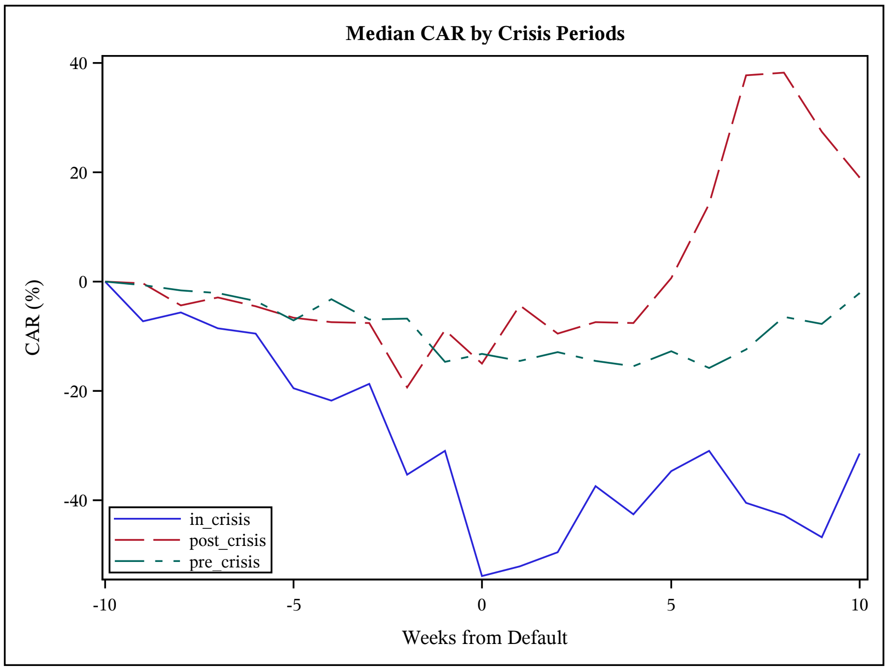

Figure 4: Average Number of Trades per Bond over Time

This figure plots the sample means of the weekly number of trades per bond in the defaulted bond population (red line) and in the nondefaulted high-yield bond population (blue line). On average, over the period from 2002 to 2011, an average nondefaulted high-yield bond trades about three times per week, while a defaulted bond trads about twice per week As an asset class, during most of the time along calendar time, nondefaulted high-yield bonds trade more frequently than defaulted bonds, but defaulted bonds trade more frequently than other type of bonds around their default time.

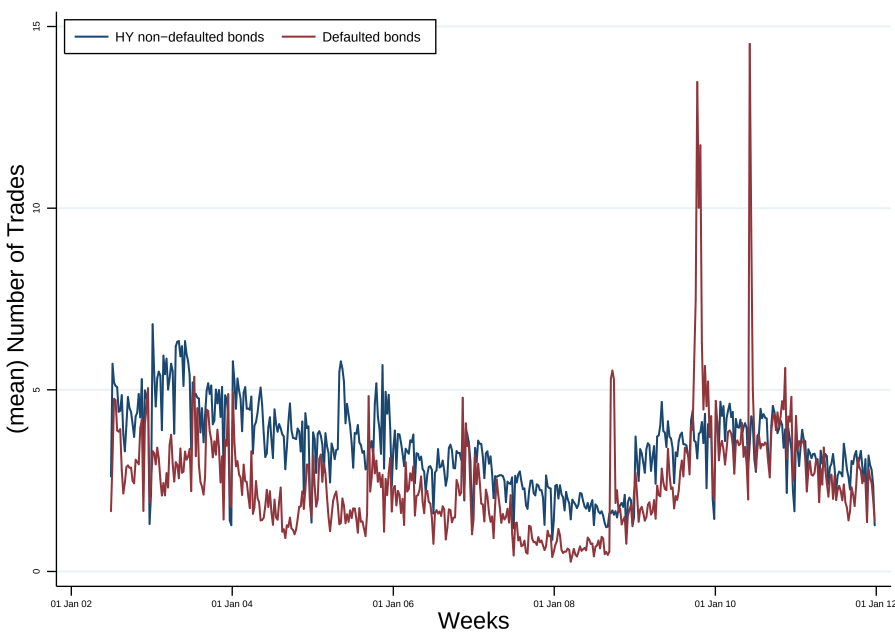

Figure 5: Number of Trades around Default (whole sample period)

This figure plots the average number of trades across defaulted bonds in the whole “constant 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.

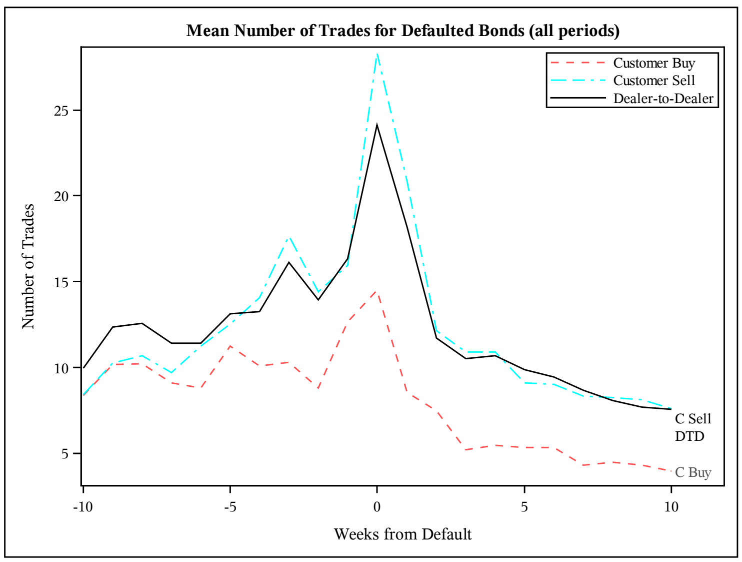

Figure 6: Number of Trades around Default (in Crisis)

This figure plots the average number of trades across defaulted bonds in the "constant sample", only for defaults that happened during the crisis (July 2007 to December 2011), 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.

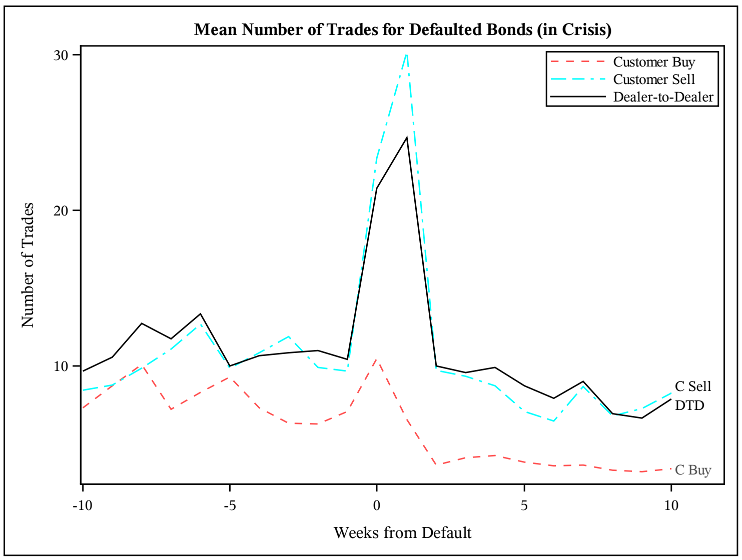

Figure 7: Number of Trades around Default (out of Crisis)

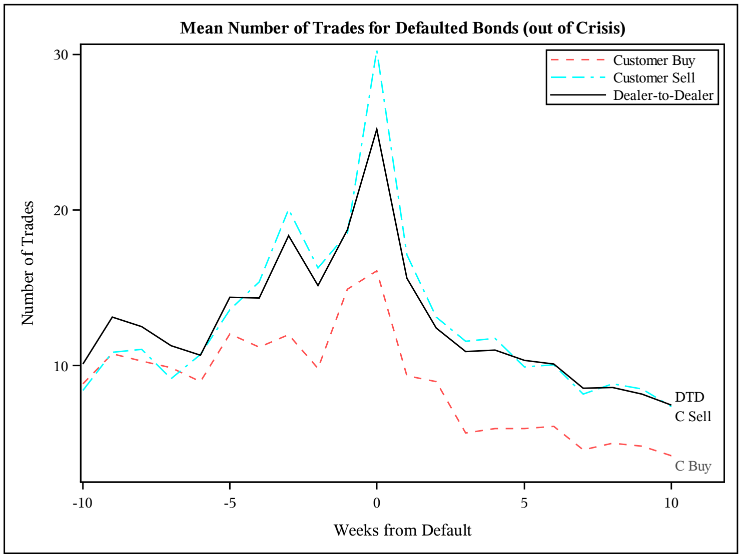

Figure 8: Abnormal Bid-Ask Spreads around Defaults

This figure shows the median abnormal bid-ask spreads along the weeks from default time. Abnormal bid-ask spread is defined by simple method, i.e., the difference between defaulted bond's bid-ask spread and the bid-ask spread of a high-yield bond index. Redline: median abnormal bid-ask spread estimated by Roll measure, left vertical axis; Black line: median abnormal bid-ask spread estimated by exact round-trip markup, left vertical axis; Blue line: number of bonds with valid Roll measure, right vertical axis; Green line: number of bonds with valid markup, right vertical axis.

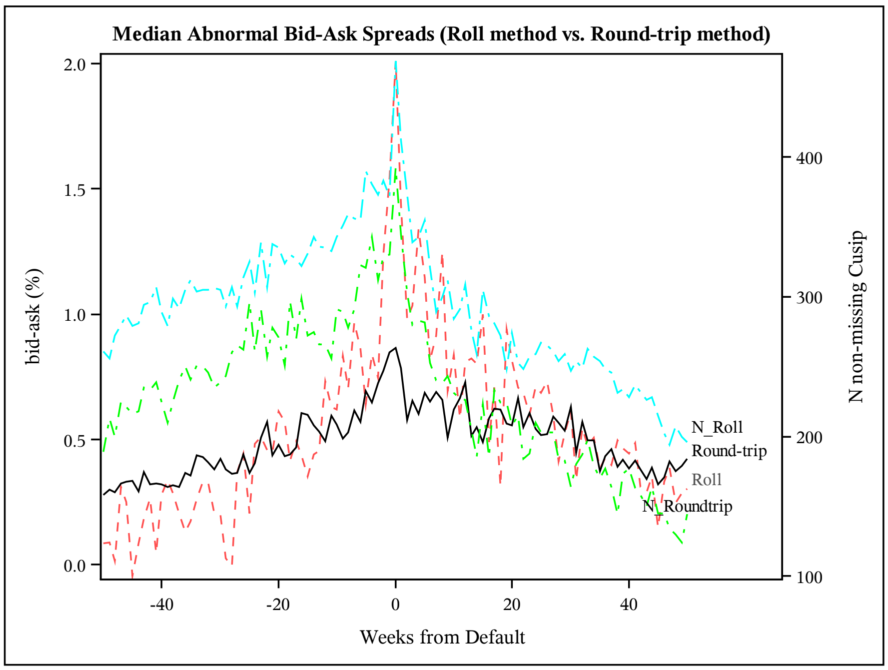

Figure 9: Abnormal Roundtrip Markup in Different Periods

This figure shows median abnormal bid-ask spread 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 2011). Abnormal bid-ask spread is estimated by round-trip markups using simple method.

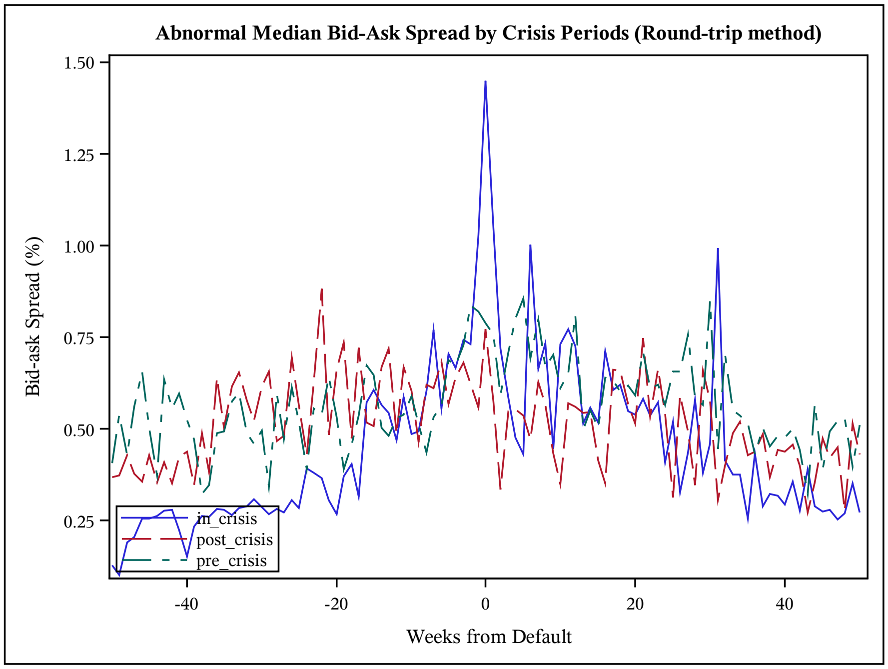

Figure 10: Roll Measure for Defaults in Different Periods

This figure shows median abnormal bid-ask spread 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 2011). Abnormal bid-ask spread is estimated by Roll measure using simple method.