Funding Liquidity Shocks in a Natural Experiment: Evidence from the CDS Big Bang*

Xinjie Wang

Yangru Wu

Hongjun Yan

Zhaodong (Ken) Zhong

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* All authors are from the Rutgers Business School. Please direct all correspondence to Hongjun Yan at hongjun.yan.2011@gmail.com. The latest version is at https://sites.google.com/site/hongjunyanhomepage/

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Abstract

The CDS Big Bang (the protocol changes for the CDS market in April 2009) increased the upfront funding requirements for trading CDS contracts, especially for those with credit spreads further away from 100 and 500 basis points. Exploiting this natural experiment, we document direct evidence that a higher funding requirement reduces market liquidity, increases the absolute value of the CDS-bond basis, and CDS spread volatility. Our evidence highlights an unintended consequence of the ongoing standardization of OTC markets—while its intention is to reduce systemic risk, standardization may significantly jeopardize market liquidity precisely during periods of financial distress.

1 Introduction

The literature has come a long way in understanding the role of funding liquidity (or capital constraint) in financial markets.[1] On the empirical side, however, existing evidence has mostly been indirect. This is perhaps because, as is clear in Brunnermeier and Pedersen (2009), funding liquidity, market liquidity and asset prices are interdependent with one another, making it difficult to identify the effect of funding liquidity. For some issues, however, it is crucial to isolate and quantify funding liquidity effects. For instance, the interaction between market liquidity and funding liquidity is considered to have played a key role in the recent financial crisis and the ensuing Great Recession (Brunnermeier and Pedersen (2009), Brunnermeier and Sannikov (2014)). To draw implications on the policy for funding requirement, it is important to isolate and quantify funding liquidity effects.

We exploit a natural experiment in order to identify the effects of funding liquidity. On April 8th 2009, a collection of trading convention changes in the CDS market took place, which is commonly referred to as the "CDS Big Bang." One important consequence is that it increases the initial funding requirement for trading North American single-name CDS contracts. Before the changes, a CDS contract was traded at a coupon rate that set the contract value to zero on the inception day, and hence no upfront payment was needed. After the CDS Big Bang, however, the coupon rate is restricted to be either 100 basis points or 500 basis points.

This trading convention change makes the upfront payment necessary and the size of the payment depends on the CDS spread level. Suppose, for example, a contract has a CDS spread of 400 basis points, i.e., the contract is worth zero on the inception day if the protection buyer pays a coupon rate of 400 basis points. However, after the CDS Big Bang, the coupon rate can only be either 100 or 500 basis points. Suppose the coupon rate is set to be 100 basis points. Since the protection buyer pays 300 basis points less than the fair coupon rate (i.e., 400 basis points), he needs to compensate the protection seller by paying an upfront fee that is the present value of 300 basis points per year. Similarly, if the coupon rate is set to be 500 basis points, since the protection buyer pays 100 basis points more than the fair coupon rate, the protection seller needs to pay an upfront fee that is the present value of 100 basis points per year. In sum, after the CDS

[1] See, for example, Gromb and Vayanos (2002), Brunnermeier and Pedersen (2009), He and Krishnamurthy (2013), Brunnermeier and Sannikov (2014).

Big Bang, an upfront payment is necessary unless the CDS spread happens to be 100 or 500 basis points. The size of the upfront payment depends on the credit spread level: it is larger if the credit spread is "further away" from 100 and 500 basis points. This upfront payment and its dependence on the credit spread level allow us to identify the effect of funding liquidity.

Intuitively, the upfront payment is an impediment to trading, and so reduces the market liquidity, leading to higher bid-ask spreads. Moreover, a higher funding cost makes arbitrage more costly, leading to a stronger violation of the law of one price. Hence, the upfront cost should be positively related to the absolute value of the CDS-bond basis. Finally, with the upfront payment, the market is less effective is absorbing temporary supply and demand shocks, leading to a higher CDS spread volatility.

Before any formal test of the above hypotheses, we first plot the change in bid-ask spread around the CDS Big Bang against the CDS spread. That is, for CDS contracts at each spread level, we compute the change in bid-ask spread as the post-Big-Bang average bid-ask spread minus the pre-Big-Bang average. We then plot this change in bid-ask spread against the CDS spread level. Under the hypothesis that the upfront payment reduces market liquidity, we should observe a W-shaped pattern, with the two low points at around 100 and 500 basis points. The reason is that, in the post-Big-Bang sample, for CDS contracts with spread levels at around 100 and 500 basis points, the upfront payments are smaller, and hence the market liquidity is better. Hence, the bid-ask spreads are smaller when the CDS spread is around 100 or 500 basis points. As shown in Panel A of Figure 1, there is indeed a W-shaped pattern, with the two low points at around 100 and 500 basis points. The plot also suggests that the effect of the upfront payment on the bid-ask spread is a few basis points, which is sizeable as the average bid-ask spread in our sample is around 10 basis points.

Similarly, our hypotheses imply that there is also a W-shaped pattern in the change in the absolute value of CDS-bond basis. When CDS spread levels are around 100 or 500 basis points, the CDS contracts are more liquid and arbitrage forces are more effective in reducing the violation of the law of one price, i.e., the absolute value of the CDS-bond basis should be smaller when the CDS spread is at around 100 or 500 basis points levels. Indeed, this is confirmed by Panel B in Figure 1. The two low points in the W-shaped pattern are also around 100 and 500 basis points.

To formally quantify these effects of upfront payments, we need to measure the cost of the upfront payment, which has two components: the size of the payment and the cost of each unit of the payment. We can separately measure both. After the CDS Big Bang, the size of the upfront payment can be constructed from CDS spread: for each CDS contract *i* on day *t*, we construct a variable, DIS_{it} as

$$DIS_{it} = \min(|S_{it} - 100|, |S_{it} - 500|), \tag{1}$$

where S_{it} is the CDS spread. That is, *DIS* is the minimum distance between the CDS spread and the two possible coupon rates, 100 and 500 basis points. Under the assumption that the coupon rate is usually chosen to be closer to the CDS spread,[2] the size of the upfront payment is approximately linear in *DIS*. The higher the *DIS*, the larger the upfront payment. We use the 3-month Libor-OIS spread to measure the cost of each unit of funding. Libor is the uncollateralized borrowing rate of large banks and the OIS rate (overnight indexed swap rate) is usually considered to be the risk free rate. Hence the spread represents the funding cost of institutional investors. Taken together the two components, we can measure the cost of the upfront payment as

$$Upfront\ Cost_{it} = DIS_{it} \times Libor\text{-}OIS\ Spread_t\ . \tag{2}$$

After the CDS Big Bang, $Upfront\ Cost$ measures the cost of the upfront payment. Before the CDS Big Bang, however, $Upfront\ Cost$ is not related to this cost, since no upfront payment was required then.

To quantify the effects of the upfront funding cost, we run a series of diff-in-diff analyses. First, we regress the CDS bid-ask spread on *Upfront Cost*, the coefficient of the interaction term *Upfront Cost* × *BB* measures the effect of upfront cost on the CDS bid-ask spread, where *BB* is a dummy variable that is 0 before the CDS Big Bang, and 1 afterwards. This coefficient is estimated to be 2.96 (t=6.73), suggesting that the upfront payment increases the CDS spread. For a CDS contract with a spread level of 300 basis points, at the average level of the *Libor-OIS spread* in our sample, 32 basis points, the upfront payment introduced by the CDS Big Bang

[2] Using a different dataset, we verify that this assumption has an accuracy rate of 92%.

increases the bid-ask spread by 1.5 basis points. This is a sizeable effect as the bid-ask spread in our sample has a mean of 9.6 basis points and median of 5.3 basis points.

We run similar panel regressions to quantify the effects of the upfront payments on the absolute value of CDS-bond basis and CDS spread volatility. Our estimates imply that, for a CDS contract with a spread level of 300 basis points, at the average level of *Libor-OIS spread* in our sample, the upfront payment increases the absolute value of the CDS-bond basis by 20 basis points, and increases the CDS spread volatility by 4 basis points. Both effects are sizeable relative to the sample averages.

These findings provide direct evidence on the effect of funding liquidity on market liquidity and asset prices. They also highlight an unintended consequence of the ongoing standardization of the CDS market. One of the main goals for standardization is to improve central clearing and reduce systemic risk. Our evidence, however, shows that these benefits don't come for free. The standardization (i.e., restricting the coupon rates to 100 and 500 basis points) induces an upfront payment, which reduces market liquidity and is an impediment to the arbitrage mechanism. During normal time, these effects, while sizeable, are perhaps not a concern. During periods of financial distress, however, these effects are substantially larger and should be considered carefully when evaluating the effect of standardization. For instance, during the peak of the financial crisis, the Libor-OIS spread is around 250 basis points, implying that the upfront payments increases the bid-ask spread by over 10 basis points, the absolute value of CDS-bond basis by 150 basis points, and increases the CDS spread volatility by 30 basis points. Moreover, some studies suggest that the funding costs were likely to be an order of magnitude higher than what the Libor-OIS spread suggests (Gârleanu and Pedersen (2011), Gorton and Metrick (2012)). Hence, the effects of upfront payment during financial distress is likely to be an order of magnitude larger. While its intention is to reduce systemic risk, standardization may significantly jeopardize market liquidity precisely during periods of financial distress.

The cost of upfront payment, $Upfront\ Cost$, has two components, the size of the payment *DIS* and the cost of funding *Libor-OIS spread*. We separately analyze them and find that both components contribute significantly to the effects described above. Moreover, we also repeat our analysis for various subsamples. For example, we repeat our analysis for the subsample of one year before the CDS Big Bang to one year after, and obtain similar results. We also divide our sample according to firm size. Our main results remain similar for both large and small firms, and the results are stronger in the small firm subsample.

Our paper contributes to the large and growing literature on the effects of funding liquidity or arbitrageurs' capital constraint. There has been an extensive theoretical literature. Important contributions include Grossman and Miller (1988), Shleifer and Vishny (1997), Basak and Croitoru (2000), Xiong (2001), Kyle and Xiong (2001), Gromb and Vayanos (2002), Brunnermeier and Pedersen (2009), He and Krishnamurthy (2013), Brunnermeier and Sannikov (2014), among others. On the empirical side, the evidence has mostly been indirect. For example, Chordia, Sarkar, and Subrahmanyam (2005) document that the common factors in the shocks to stock and bond market liquidity appear correlated with money flows. Coughenour and Saad (2004) find that the liquidity of stocks handled by the same specialist firm display excess co-movement. Comerton-Forde et al. (2010) find evidence that the market liquidity of a stock decreases when its market maker holds large inventory or has suffered recent trading losses. Mitchell, Pedersen and Pulvino (2007) and Mitchell and Pulvino (2012) provide evidence of slow-moving arbitrage capital. Several studies use major market events as exogenous shocks to the funding condition of financial intermediaries to examine their effects on market liquidity (e.g., Acharya, Schaefer, and Zhang (2015), Aragon and Strahan (2012)). Our paper adds to this literature by using the CDS Big Bang as a natural experiment to provide direct evidence on the effect of funding liquidity on market liquidity and asset prices. The CDS Big Bang has also been exploited to analyze the liquidity spillover by Haas and Reynolds (2015), and test the empty credit hypothesis by Danis (2015).

Our paper is related to the literature on the CDS-bond basis, which attributes the basis to margin requirements (Gârleanu and Pedersen (2011), Mitchell and Pulvino (2012), Shen, Yan, and Zhang (2014)), and liquidity (Nashikkar, Subrahmanyam, and Mahanti (2011), Bai and Collin-Dufresne (2013)). Our evidence shows that that the CDS-bond basis is also determined by the upfront funding cost. More broadly, our paper adds to the large literature on the liquidity in the CDS market. See, for example, Longstaff, Mithal, and Neis (2005), Tang and Yan (2007), Bongaerts, De Jong, and Driessen (2011), Qiu and Yu (2012), Chen, Cheng, and Wu (2013), Loon and Zhong (2014). Augustin et al. (2016) provide a recent survey.

Finally, our paper is related to the analysis of the product standardization in the OTC derivative market. Standardization fosters aggregation of information and price discovery (e.g. Augustin et al. (2016)). Chen et al. (2011) document the effects of the CDS Big Bang on the standardization of product and trading convention. Oehmke and Zawadowski (2013) argue that the role of the CDS market is to provide standardization and liquidity as an alternative to the bond market. Despite many benefits of standardization, derivatives end-users face higher costs because they are less likely to find a product that exactly matches their needs (e.g. Stulz (2010) and Duffie, Li, and Lubke (2010)). Our results highlight that product standardization may jeopardize market liquidity during financial distress.

The rest of the paper is organized as follows. Section 2 describes the CDS Big Bang and develops testable hypotheses. Section 3 describes our data. Section 4 presents our main empirical analysis, and Section 5 concludes the paper.

2 A Natural Experiment: the CDS Big Bang

On April 8 2009, a collection of trading convention changes in the CDS market took place, which is commonly referred to as the "CDS Big Bang." The one change that is relevant for our study is the fixed coupon and upfront payment for North American single-name CDS contracts.[3] Before the changes, a single-name CDS contract was traded at a coupon rate that set the contract value to zero on the inception day, and hence no upfront payment was needed. After the CDS Big Bang, however, the coupon rate is restricted to be either 100 basis points or 500 basis points. The purpose of this convention change is to standardize CDS contracts and facilitate central clearing. However, this restriction on the coupon rate induces upfront payments.

Suppose, for example, a CDS contract has a spread of 400 basis points, that is, the contract is worth zero on the inception day if the protection buyer pays a coupon rate of 400 basis points. However, after the CDS Big Bang, the coupon rate can only be either 100 or 500 basis points. Suppose the coupon rate is set to be 100 basis points. Since the protection buyer pays 300 basis points less than the fair coupon rate (i.e., 400 basis points), he needs to compensate the protection seller by paying an upfront payment that is the present value of 300

[3] For more details on the convention changes, see Markit technical note "The CDS Big Bang: Understanding the Changes to the Global CDS Contract and North American Conventions" March 13, 2009.

basis points per year. Similarly, if the coupon rate is set to be 500 basis points, since the protection buyer pays 100 basis points more than the fair coupon rate, the protection seller needs to pay an upfront payment that is the present value of 100 basis points per year. In sum, after the CDS Big Bang, upfront payments are necessary unless the CDS spread happens to be 100 or 500 basis points. The size of the upfront payment depends on the credit spread level: it is larger if the credit spread is "further away" from 100 and 500 basis points. This upfront payment and its dependence on the credit spread level allow us to identify the effect of funding liquidity.

2.1 Hypothesis

Intuitively, the upfront payment is an impediment to trading, and so reduces the market liquidity, leading to higher bid-ask spreads. More specifically, the upfront payment for trading CDS contracts can affect their bid-ask spreads in two ways. First, if CDS dealers are required to make upfront payments, the funding costs associated with the upfront payments would be reflected in the bid-ask spreads. Second, if financially constrained traders are reluctant to take on capital-intensive positions, dealers would find it more difficult to offset their inventories, and hence increase the bid-ask spread. Moreover, a higher upfront payment cost makes arbitrage more costly and so less effective in enforcing the law of one price. Note that the CDS-bond basis measures the degree of the violation of the no-arbitrage relation between a CDS and its underlying bond. A higher absolute value of the CDS-bond basis implies a stronger violation of the law of one price. Hence, the CDS-bond basis is positively related to the cost of the upfront payment. Finally, with the upfront payment, the market is less effective is absorbing temporary supply and demand shocks. Therefore, the CDS spread is more volatile if the cost of the upfront payment is higher. The above intuition leads to the following hypotheses.

Hypotheses: The CDS bid-ask spread, the absolute value of the CDS-bond basis, and CDS spread volatility are all increasing in the cost of the upfront payment.

The CDS Big Bang offers a nice opportunity to test these hypotheses. It not only introduces upfront payments, but also creates cross-sectional variations in the size of the upfront payments. The size of the payment is larger if the CDS spread is "further away" from the coupon rate (which is either 100 or 500 basis points). This allows us to identify the effects of the upfront funding requirement through diff-in-diff analysis.

3 Data

We obtain daily bid and ask quotes for 5-year CDS contracts on North American companies from two sources. Our main analysis is based on the data from Credit Market Analysis Ltd. (CMA) via Datastream, and we will refer to it as the "CMA sample." It covers 634 North American companies from January 2004 to October 2010.[4] Hence, this sample period includes about 5 years before and 1.5 years after the CDS Big Bang. Our second dataset is from Markit Group Ltd., and we will refer to it as the "Markit sample." It covers 521 North American companies (out of which 319 are also in our CMA sample) from April 1, 2010 to May 30, 2014. Hence, our Markit sample only covers the post-Big-Bang period. Nevertheless, it is still a nice complement to our CMA sample, because it not only covers a longer post-crisis period, but also includes some important variables that are not in the CMA sample, which will be discussed later.

We apply the following filters to the CDS bid and ask quotes to both samples. We removed the observation if the bid quote is greater than or equal to the ask quote, or if the quote is indicated as "derived" rather than "observed." We also removed the observations if the mid-point of bid and ask quotes is greater than 750 basis points.[5] After applying these filters, the CMA and Markit samples consist of 929,217 and 420,501 daily observations, respectively.

Panels A and B of Table 1 report the summary statistics in the CMA sample and the Markit sample, respectively. Each variable is pooled over time and across firms. We winsorize all unbounded variables at the 1% and 99% level. Our main market liquidity measure is the quoted bid-ask spread computed as the difference between ask and bid quotes. Panel A shows that the mean and median of the bid-ask spread in the CMA sample are 9.61 and 5.30 basis points, respectively. They are slightly higher in the Markit sample in Panel B, where the mean and median are 11.74 and 10.00 basis points.

The CDS-bond basis is the CDS spread minus the credit spread of the bond issued by the reference entity. The law of one price implies that in a frictionless market, the CDS-bond basis should be zero. A negative (positive) CDS-bond basis implies that the bond price is lower

[4] CMA stopped providing data through Datastream after October 2010.

[5] Even before the Big Bang, some CDS contracts on distressed firms were already traded with a fixed coupon of 500 basis points and upfront payments (The CDS Big Bang: Understanding the Changes to the Global CDS Contract and North American Conventions, Markit 2009; Mitchell and Pulvino (2012)). The cutoff of 750 basis points is equivalent to excluding firms with a credit rating below CCC.

(higher) than what is implied by the CDS spread. Following previous studies (e.g., Elizalde, Doctor, and Saltuk (2009) Nashikkar, Subrahmanyam, and Mahanti (2011); Bai and Collin-Dufresne (2013); Choi and Shachar (2014)), we adopt the par equivalent CDS methodology to measure CDS-bond basis. The details of this methodology are summarized in the Appendix. In our CMA sample, the mean and median of CDS-bond basis is -22.47 and -1.63 basis points, respectively, while in Markit sample, the mean and median are -14.25 and -10.74 basis points.

The credit ratings of the reference entities in our sample are mostly between A and B, according to S&P long-term issuer credit ratings. The mean and median CDS spread are 137 and 71 basis points, respectively, in our CMA sample, and are 165 and 113 basis points in our Markit sample. For each CDS contract, on each day, we compute the "CDS volatility" as the standard deviation of daily CDS spreads during the previous two weeks. The mean and median of the CDS volatility are 9.86 and 4.24 basis points for the CMA sample, and 7.82 and 3.83 basis points in the Markit sample.

As control variables, we obtain daily close values of the CBOE volatility index (VIX) from Datastream, stock returns, trading volume, and bid-ask spreads from CRSP, transaction prices of bonds issued by the reference entities from TRACE, bond characteristics from Mergent Fixed Income Securities Database (FISD). We construct two bond market liquidity measures. The first is Amihud (2002) measure, defined as $1/N \sum_{i=1}^{N} |r_i|/v_i$, where N is the number of trades within a given date, r_i and v_i are the percentage price change and the dollar volume of ith trade respectively. Since there may exist more than one bond on a given date for a firm in TRACE, we aggregate the Amihud measures of all bonds issued by the same firm (identified by 6-digit CUSIP number) by averaging their daily values. The second measure is the trading volume aggregated across daily trading volumes of all bonds issued by the same firm.

3.1 Measure the Cost of Upfront Payment

The cost of the upfront payment has two components: the size of the payment and the cost of each unit of the payment. We can separately measure both. In our CMA sample, we cannot observe the upfront payment or coupon rate directly, but can infer them from the CDS spread. After the CDS Big Bang, when broker-dealers provide their quotes to CMA, they follow a standard procedure convert the coupon rate and the upfront payment into a CDS spread.[6] Our CMA sample reports the CDS spread but not the coupon rate or upfront payment. However, we can easily infer the coupon rate (i.e., 100 or 500 basis points) since it is usually chosen to be closer to the CDS spread.[7]

As explained in Section 2, the size of the upfront payment is determined by the distance between the CDS spread and the coupon rate. Hence, the size of the upfront payment for CDS contract *i* on day *t*, can be measured by DIS_{it} in equation (1), which is the minimum distance between the CDS spread to 100 or 500 basis points. After the CDS Big Bang, the size of the upfront payment is approximately linear in *DIS*. The higher the *DIS*, the larger the upfront payment. For the pre-Big-Bang sample, however, *DIS* is not related to the upfront payment, since no upfront payment is required.

To measure the cost of each unit of upfront payment, we follow Gârleanu and Pedersen (2011) to use the 3-month Libor-OIS spread, which is the 3-month Libor rate minus the 3-month overnight indexed swap (OIS) rate. The Libor rate is the uncollateralized borrowing cost of large banks and the OIS rate is considered the risk free rate. Hence the spread represents the funding cost of institutional investors. We obtain daily close values of Libor-OIS spreads from Bloomberg. It has significant variations in our sample period, ranging from less than 5 basis points to over 250 basis points during the recent financial crisis.

Taken together, we can measure the cost of the upfront payment as the product of *DIS* and the Libor-OIS spread, as $Upfront\ Cost_{it}$ in equation (2). After the CDS Big Bang, $Upfront\ Cost$ measures the cost of the upfront payment. Before the CDS Big Bang, however, $Upfront\ Cost$ is not related to this cost, since no upfront payment was required then.

In our Markit sample, we can directly observe the size of the upfront payment. As shown in Panel B, the average upfront payment is 3.58% of the notional amount of the CDS contract. Hence, we can use the upfront fee to replace *DIS* in compute the *Upfront Cost*.

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[6] They use the ISDA CDS Standard Model to convert coupon rate and upfront payment into CDS spread. The details of the model are available from http://www.cdsmodel.com/cdsmodel/.

[7] According to our Markit sample, for around 92% of the observations, the "primary coupon rate" is chosen to be the one that is closer to the CDS spread.

4 Analysis

Before formally testing the hypothesis in Section 2.1, we first examine if the effects are visible from plotting the observations. Specifically, we divide our observations in the CMA sample into equally-spaced groups by CDS spreads. For each group, we compute the change in average bid-ask spread as the post-Big-Bang average bid-ask spread minus the pre-Big-Bang average bid-ask spread. We then plot this change in average bid-ask spread against the CDS spread level. Under the hypothesis that the upfront payment reduces market liquidity, we should observe a W-shaped pattern, with the two low points at around 100 and 500 basis points. This is because that, in the post-Big-Bang sample, for CDS contracts with spread levels at around 100 and 500 basis points, the upfront payments are smaller, and hence the market liquidity is better, i.e., the bid-ask spreads are smaller. As shown in Panel A of Figure 1, there is indeed a W-shaped pattern and, as predicted, the two low points are at around 100 and 500 basis points. The plot also suggests that the effect of the upfront payment on the bid-ask spread is a few basis points, which is sizeable as the average bid-ask spread in our sample is around 10 basis points.

We then conduct a similar calculation for the absolute value of the CDS-bond basis and plot the change in the absolute value of the CDS-bond basis against the CDS spread in Panel B. Our hypotheses imply that there should also be a W-shaped pattern. When spread levels are around 100 or 500 basis points, the CDS contracts are more liquid and arbitrage forces are more effective in reducing the violation of the law of one price. Therefore, the absolute value of the CDS-bond bases should be smaller at around 100 or 500 basis points levels. Indeed, this is confirmed by Panel B in Figure 1. The two low points in the W-shaped pattern are also around 100 and 500 basis points. The implied magnitude of the effect is around 30 basis points.

4.1 Diff-in-diff tests of the effect of the cost of upfront payment

To formally test the hypotheses, we first run a panel regression of bid-ask spread on *Upfront Cost*. According to our hypothesis, the funding liquidity effect implies that the bid-ask spread is *more* positively correlated with the *Upfront Cost* in the post-Big-Bang sample than in the pre-Big-Bang one. Note that the bid-ask spread can potentially be correlated *Upfront Cost* in the pre-Big-Bang sample. For example, the CDS market may be more liquid for certain spread levels perhaps due to higher trading activities for those contracts. Hence, the bid-ask spread is correlated with *DIS*, and so is correlated with *Upfront Cost*. The essence of our hypothesis is that after the Big Bang, the bid-ask spread becomes *more* correlated with *Upfront Cost*, which can be tested using a diff-in-diff analysis.

Let *BB* be the dummy variable that is 0 before the CDS Big Bang and 1 otherwise. Our interest is the coefficient of the interaction term *BB* × *Upfront Cost*, which identifies the effect of the upfront payment, the diff-in-diff effect on the bid-ask spread. Our hypothesis implies that the coefficient for this interaction term is positive.

The regression results are reported in Table 2. In the first column, the specification includes a firm fixed effect, but no time fixed effect. The coefficient for the interaction term is 2.759, with a *t*-statistic of 6.726. It implies that after the CDS Big Bang, the upfront funding requirement increases the bid-ask spread. For a CDS contract with a spread of 300 basis point, for example, this diff-in-diff estimate implies that when the Libor-OIS spread is 32 basis points (our sample mean), the upfront payment increases bid-ask spread of this CDS contract by 1.8 basis points. This is sizeable as the mean and median of the bid-ask spread in our sample is 9.6 and 5.3 basis points, respectively. The regression in the second column includes both a firm fixed effect and a year-quarter fixed effect, and the results remain similar. The coefficient for the interaction term is 2.34 (*t*=6.19). It implies that, for a CDS contract with a spread of 300 basis point, when the Libor-OIS spread is 32 basis points (our sample mean), the upfront payment increases bid-ask spread of this CDS contract by 1.5 basis points.

We conduct similar diff-in-diff test of the hypothesis on the CDS-bond basis. Specifically, we regress the absolute value of the CDS-bond basis on *Upfront Cost*. The coefficient of the interaction term *BB* × *Upfront Cost* measures the effect of the funding requirement on the absolute value of the CDS-bond basis. As shown in column 3, in the specification with a firm fixed effect but without a time fixed effect, this coefficient for the interaction term is 36.51 (*t*=3.67), suggesting that, consistent with our hypothesis, a higher funding cost leads to a larger basis in absolute value, i.e., a stronger violation of the law of one price. For a CDS with a spread of 300 basis points, this estimate implies that when the Libor-OIS spread is 32 basis points (our sample mean), the upfront payment increases the absolute value of the CDS-bond basis by 23 basis points. Column 4 reports the estimates from the regression with both firm fixed effects and year-quarter fixed effect, and the results remain very similar. The coefficient for the interaction term is 31.02 (*t*=3.40), suggesting that, for a CDS with a spread of 300 basis points, with a Libor-

OIS spread of 32 basis points (our sample mean), the upfront payment increases the absolute value of the CDS-bond basis by 20 basis points.

Finally, we test the effect of the upfront payment on the CDS spread volatility. Columns 5 and 6 report the estimates of the regressions of CDS spread volatility on *Upfront Cost*. In both specifications, the estimates of the coefficient for the interaction term are around 6, with t-statistics above 4. These results are consistent with our hypothesis that the initial funding requirement makes the market less effective in absorbing supply and demand shocks, leading to higher volatility. For a CDS with a spread of 300 basis points, this estimate implies that when the Libor-OIS spread is 32 basis points (our sample mean), the upfront payment increases the absolute value of the CDS-bond basis by around 4 basis points. In comparison, the mean the median of the CDS spread volatility is 9.86, 4.24 basis points, respectively.

4.2 Separate identification

Our evidence so far shows that the cost of the upfront payment affects market liquidity and prices in the CDS market. As is clear in equation (2), the cost of upfront payment has two components, the size of the payment *DIS* and the funding cost *Libor-OIS spread*. In this section, we separate the two components in our analysis, and test if both components have contribute to the effects documented in the previous section.

Specifically, we first rerun the regressions in the previous section, using *DIS* to replace *Upfront Cost*. Hence, the effect of the upfront payments is only identified through the effect of the variation in the size of the upfront payment. As shown in the first two columns in Table 3, the estimate of the coefficient for the interaction term *BB* × *DIS* is 1.18 (t=5.79) for the specification without a year-quarter fixed effects, and is 0.71 (t=3.67) for the specification with a year-quarter fixed effect. These results suggest that after the CDS Big Bang, the bid-ask spread becomes *more* sensitive to *DIS*, the distance between the CDS spread and the coupon rate (100 or 500 basis points). These two estimates imply that for a CDS contract with a spread of 300 basis points, the upfront payment increases the bid-ask spread by 1.4 to 2.3 basis points, comparable to the implications in the previous section.

We then also include the interaction term with *Libor-OIS spread* to test if the above *DIS* effect is stronger when the cost of funding is higher. As shown in columns 3 and 4, the coefficient estimates for the triple interaction term *BB* × *DIS* × *Libor-OIS spread* are both positive. For the specification with both firm fixed effect and year-quarter fixed effect, the coefficient is 1.08, with a *t*-statistic of 2.11. Consistent with our hypothesis, the evidence suggests that when the funding cost is higher, the bid-ask spread is more sensitive to the size of the upfront payment.

We run similar regressions for the absolute value of CDS-bond basis and CDS spread volatility, and report the results in Panels B and C. The results show that the evidence is weaker for the payment size *DIS*. As shown in the first two columns of the two panels, although the sign of the interaction terms *BB* × *DIS* is consistent with our hypotheses, only one estimate is statistically significant. Combined with the identification from the funding cost, our evidence becomes much stronger statistically. In the last two columns of the two panels, the coefficients for the interaction term *BB* × *DIS* × *Libor-OIS spread* are highly significant for all specifications.

Our evidence suggests that both size of the upfront payment *DIS* and the funding cost *Libor-OIS spread* contribute to the effects of the funding cost in the previous section.

4.3 Unintended consequence

These findings have important implications on the ongoing standardization of the OTC market. One of the main goals for standardization is to reduce systemic risk by reducing the counterparty risk and facilitating central clearing. Our evidence, however, shows that these benefits don't come for free. The standardization (i.e., restricting the coupon rates to 100 and 500 basis points) necessarily induces upfront payments. Our evidence shows that upfront payments reduce market liquidity and impediments to the arbitrage mechanism. During normal times, these effects, while sizeable, are perhaps not concerning, especially if there is significant benefit from improved central clearing. During periods of financial distress, however, these effects are substantially larger and should be considered carefully when evaluating the effect of standardization. For instance, during the peak of the financial crisis, the Libor-OIS spread was around 250 basis points. Our estimates suggest that the upfront payments increases the bid-ask spread by over 10 basis points, the absolute value of CDS-bond basis by 150 basis points, and increases the CDS spread volatility by 30 basis points. Moreover, some studies suggest that the funding costs were likely to be an order of magnitude higher than what the Libor-OIS spread suggests. For example, Gârleanu and Pedersen (2011) estimate that the shadow cost of capital is around 10%, Gorton and Metrick (2012) demonstrate that many markets simply shut down during the recent global financial crisis. Hence, the effect from the upfront funding is likely to be an order of magnitude larger.

Therefore, the standardization may exacerbate, rather than improve, market liquidity in periods of financial distress. That is, while the main purposes of standardization is to reduce systemic risk, our evidence suggests that standardization may significantly jeopardize market liquidity precisely during periods of financial distress. This unintended consequence deserves careful consideration for the policy for standardization.

Essentially, there is a tradeoff between standardization and the upfront payment. When fewer coupon rates are allowed, CDS contracts become more standardized but the upfront payments become larger. To the extent the upfront payments can significantly jeopardize market liquidity during financial distress, it should be considered when deciding on the optimal level of standardization.

4.4 Robustness Analysis

We explore the robustness of our previous results by analyzing various subsamples. First, we repeat our analysis for the period of April 2008 to April 2010, i.e., one year before to after the CDS Big Bang. The results, reported in Panel A of Table 4, remain similar to those for the overall sample. Consistent with our hypotheses, the coefficients for the interaction term *BB* × *Upfront Cost* are all significantly positive, suggesting that the cost of upfront payment increases the bid-ask spread, the absolute value of the CDS-bond basis, and the CDS spread volatility. Perhaps due to the smaller sample size, the statistical significance for the coefficients in the regressions for ABS(Basis), reported in columns 3 and 4, is somewhat weaker.

Next, we divide our sample into two subsamples according to firm size. Specifically, we identify the median of the reference entities' asset value in our entire sample, and then, on each day, we classify the reference entities into large and small firms according to their asset values relative to the median. We then re-run the regressions on both subsample, and the results are reported in Panels B and C. Our main results remain similar for both subsamples. Interestingly, the results in the small firm subsample are stronger. For example, the coefficients for the interaction term *Upfron cost* × *BB* are larger both in their economic magnitude and in statistical significance for all six regressions. This comparison suggests that the funding liquidity effects are stronger when the CDS market is smaller and less liquid.

Finally, we conduct our analysis on the Markit sample. The drawback of this sample is that it only covers the post-Big-Bang period, and hence we cannot conduct the diff-in-diff tests. However, the advantage of this dataset is that both the size of the upfront payment and the coupon rate are directly observable. This allows us to verify the important assumption for the variable *DIS* that the coupon rate is usually chosen to be the one that is closer to the CDS spread. Indeed, in our Markit sample, the "primary coupon rate" is chosen to be the one that is closer to the CDS spread for around 92% of the observations. We also run the regressions in Table 2 on the Markit sample, without the interaction term, and the results are reported in Table 5. In all specifications, the coefficients for *Upfront Cost* is significantly positive, which is consistent with our hypotheses that the upfront payment increases the bid-ask spread, the absolute value of the CDS-bond basis, as well as the CDS spread volatility.

5 Conclusion

The CDS Big Bang is a major step forward towards the standardization of the CDS market. We exploit this historic event to provide direct evidence on the effects of funding liquidity. Using a large sample of North American corporate CDS contracts, we find that the cost of the upfront payment increases the CDS bid-ask spread, the absolute value of the CDS-bond basis, and CDS spread volatility. Our findings have important implications for the policy on the standardization of the OTC markets. One of the main purposes of standardization is to reduce systemic risk. However, our evidence suggests that standardization may significantly jeopardize market liquidity precisely during periods of financial distress. This unintended consequence deserves careful consideration for the policy for standardization.

Appendix: Par-Equivalent CDS Methodology

In this section, we describe the Par-Equivalent CDS methodology developed by J.P. Morgan to calculate the CDS-bond basis. Under this methodology, the bond spread is the shift over the term structure of CDS spreads. The present value of discounted risky cash flows of a bond is matched to its market price by applying a parallel shift to the term structure of default probabilities implied from CDS spreads. The shifted default probabilities are then transformed to a set of new CDS spreads, referred to as *PECDS*.

To price a bond, we start from bootstrapping default probabilities from the term structure of CDS spreads using a fixed recovery rate R of 40%.[8] The present value of the bond is given by

$$\text{bond PV} = C\sum_{i=1}^{N} DF(t_i)\cdot SP(t_i)\cdot \Delta t_i + 100\cdot DF(t_N)\cdot SP(t_N) + 100\cdot R\sum_{i=1}^{N} DF(t_i)\cdot \Delta DP(t_i)$$

where C is the bond coupon, $DF(t_i)$ and $SP(t_i)$ are the discount factor and the survival probability at time t_i respectively, Δt_i is the time interval between two coupon dates, 100 is the face value of the bond and $\Delta DP(t_i)$ is the default probability between t_{i-1} and t_i. We apply a parallel shift over the term structure of default probabilities until the bond present value is equal to the market price of the bond. The shifted default probabilities, denoted as $SP^*(t_i)$, are then transformed to a set of new CDS spreads by

$$PECDS = \frac{(1-R)\sum_{i=1}^{N}\Delta DP(t_i)\cdot DF(t_i)}{\sum_{i=1}^{N} DF(t_i)\cdot SP(t_i)\cdot \Delta t_i + \sum_{i=1}^{N} DF(t_i)\cdot \Delta DP(t_i)\cdot \frac{\Delta t_i}{2}}$$

[8] The term structure consists of 1Y, 2Y, 3Y, 4Y, 5Y, 7Y and 10Y maturities. 40% is the standard value of recovery rate for senior unsecured debt.

Strictly speaking, the CDS-bond basis measures the difference in credit spreads between a CDS contract and the underlying bond. The spread of a CDS contract can be observed in the CDS market on a daily basis. The credit spread of a bond is not directly observed in the bond markets and needs to be implied from a bond price based on certain assumptions. As shown by Duffie (1999), the CDS spread on a reference firm is equivalent to the credit spread of a floating-rate bond issued by the same firm. Thus ideally we should use a float-rating bond to compute the bond credit spread. However, a majority of corporate bonds were issued with fixed-rate coupons. Duffie and Liu (2001) show that the spread of a fixed-rate bond is, in general, not equal to that of a floating-rate bond. A simple use of the credit spread of fixed-rate bond would lead to a biased CDS-bond basis. We adopt the par equivalent CDS (PECDS) methodology described in Elizalde, Doctor, and Saltuk (2009) (see Appendix B). This methodology has been used in previous empirical studies (Nashikkar, Subrahmanyam, and Mahanti (2011); Bai and Collin-Dufresne (2013); Choi and Shachar (2014)).

Moreover, a firm typically has many bonds outstanding with different maturities. In practice, it is very difficult to identify underlying bonds for CDS contracts across a large number of firms over a long period of time. Following Bai and Collin-Dufresne (2013), we restrict our sample to fixed-rate corporate bonds with maturity between 3 and 7.5 years. In calculating bond credit spreads, we utilize all qualified bonds and use simple linear regression of PECDS on bond maturity. We define the CDS-bond basis for a firm i at time t as the difference between the 5Y CDS spread and estimated 5Y PECDS spread.

$$basis_{it} = CDS_{it}(5Y) - PECDS_{it}(5Y)$$

References

Acharya, Viral V., Stephen M. Schaefer, and Yili Zhang, 2015, Liquidity Risk and Correlation Risk: A Clinical Study of the General Motors and Ford Downgrade of 2005, *Quarterly Journal of Finance* 5, 1–51.

Amihud, Yakov, 2002, Illiquidity and stock returns: Cross-section and time-series effects, *Journal of Financial Markets* 5, 31–56.

Aragon, George O., and Philip E. Strahan, 2012, Hedge funds as liquidity providers: Evidence from the Lehman bankruptcy, *Journal of Financial Economics* 103, 570–587.

Augustin, Patrick, Marti G. Subrahmanyam, Dragon Yongjun Tang, and Sarah Qian Wang, 2016, Credit Default Swaps: Past, Present, and Future, *Annual Review of Financial Economics*, forthcoming

Bai, Jennie, and Pierre Collin-Dufresne, 2013, The CDS-Bond Basis, *Working paper*.

Basak, Suleyman and Benjamin Croitoru, 2000, Equilbrium Mispricing in a Capital Market with Portfolio Constraints, *Review of Financial Studies* 13, 715-748.

Blanco, Roberto, Simon Brennan, and Ian W. Marsh, 2005, An Empirical Analysis of the Dynamic Relation between Investment-Grade Bonds and Credit Default Swaps, *Journal of Finance* 60, 2255–2281.

Bongaerts, Dion, Frank De Jong, and Joost Driessen, 2011, Derivative Pricing with Liquidity Risk: Theory and Evidence from the Credit Default Swap Market, *Journal of Finance* 66, 203–240.

Brunnermeier, Markus K., and Lasse Heje Pedersen, 2009, Market liquidity and funding liquidity, *Review of Financial Studies* 22, 2201–2238.

Chen, Kathryn, Michael Fleming, John Jackson, Ada Li, and Asani Sarkar, 2011, An analysis of CDS transactions: implications for public reporting, *Staff report 517. Federal Reserve Bank of New York, NY.*

Chen, Ren-Raw, Xiaolin Cheng, and Liuren Wu, 2013, Dynamic Interactions Between Interest-Rate and Credit Risk: Theory and Evidence on the Credit Default Swap Term Structure, *Review of Finance* 17, 403–441.

Choi, Jaewon, and Or Shachar, 2014, Did Liquidity Providers Become Liquidity Seekers? Evidence from the CDS-Bond Basis During the 2008 Financial Crisis, *Working paper*.

Chordia, Tarun, Asani Sarkar, and Avanidhar Subrahmanyam, 2005, An Empirical Analysis of Stock and Bond Market Liquidity, *Review of Financial Studies* 18, 85–129.

Comerton-Forde, Carole, Terrence Hendershott, Charles M. Jones, Pamela C. Moulton, and Mark S. Seasholes, 2010, Time Variation in Liquidity: The Role of Market-Maker Inventories and Revenues, *Journal of Finance* 65, 295–331.

Coughenour, Jay F., and Mohsen M. Saad, 2004, Common market makers and commonality in liquidity, *Journal of Financial Economics* 73, 37–69.

Danis, Andras, 2015, Do Empty Creditors Matter? Evidence from Distressed Exchange Offers, *Working paper*.

Das, Sanjiv, Madhu Kalimipalli, and Subhankar Nayak, 2014, Did CDS trading improve the market for corporate bonds, *Journal of Financial Economics* 111, 495–525.

Duffie, Darrell, Ada Li, and Theo Lubke, 2010, Policy Perspectives on OTC Derivatives Market Infrastructure, *Federal Reserve Bank of New York Staff Reports*.

Elizalde, Abel, Saul Doctor, and Yasemin Saltuk, 2009, Bond-CDS Basis Handbook, (J. P. Morgan Credit Derivatives Research).

Gârleanu, Nicolae, and Lasse Heje Pedersen, 2011, Margin-based asset pricing and deviations from the law of one price, *Review of Financial Studies* 24, 1980–2022.

Gorton, Gary and Andrew Metrick, 2012, Securitized banking and the run on repo, *Journal of Financial Economics* 104, 425–451.

Gromb, Denis, and Dimitri Vayanos, 2002, Equilibrium and welfare in markets with financially constrained arbitrageurs, *Journal of Financial Economics* 66, 361–407.

Grossman, Sanford J, and Merton H Miller, 1988, Liquidity and Market Structure, *The Journal of Finance* 43, 617–633.

Haas, Marlene, and Julia Reynolds, 2015, Illiquidity Contagion and Information Spillover from CDS to Equity Markets, *Working paper*.

He, Zhiguo, and Arvind Krishnamurthy, 2013, Intermediary asset pricing, *American Economic Review* 103, 732–770.

Kyle, Albert and Wei Xiong, 2001, Contagion as a Wealth Effect, *Journal of Finance* 56, 1401-1440.

Longstaff, Francis A., Sanjay Mithal, and Eric Neis, 2005, Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit, *The Journal of Finance* 60, 2213–2253.

Loon, Yee Cheng, and Zhaodong Ken Zhong, 2014, The impact of central clearing on counterparty risk, liquidity, and trading: Evidence from the credit default swap market, *Journal of Financial Economics* 112, 91–115.

Mitchell, Mark, Lasse Pedersen, and Todd Pulvino, 2007, Slow Moving Capital, *American Economic Review, Papers and Proceedings* 97, 215–220.

Mitchell, Mark, and Todd Pulvino, 2012, Arbitrage crashes and the speed of capital, *Journal of Financial Economics* 104, 469–490.

Nashikkar, Amrut, Marti G Subrahmanyam, and Sriketan Mahanti, 2011, Liquidity and Arbitrage in the Market for Credit Risk, *Journal of Financial and Quantitative Analysis* 46, 627–656.

Oehmke, Martin, and Adam Zawadowski, 2013, The Anatomy of the CDS Market, *Working Paper*.

Qiu, Jiaping, and Fan Yu, 2012, Endogenous liquidity in credit derivatives, *Journal of Financial Economics* 103, 611–631.

Shen, Ji, Hongjun Yan, and Jinfan Zhang, 2014, Collateral-Motivated Financial Innovation, *Review of Financial Studies* 27, 2961–2997.

Shleifer, Andrei, and Robert Vishny, 1997, The Limits of Arbitrage, *Journal of Finance* 52, 35–55.

Stulz, Rene M, 2010, Credit Default Swaps and the Credit Crisis, *Journal of Economic Perspectives* 24, 73–92.

Tang, Dragon Yongjun, and Hong Yan, 2007, Liquidity and credit default swap spreads, *Working paper, University of Hong Kong.*

Xiong, Wei, 2001, Convergence Trading with Wealth Effects: An Amplification Mechanism in Financial Markets, *Journal of Financial Economics* 62, 247-292.

Table 1. Summary Statistics.

Panel A provides summary statistics of our CMA sample, which contains daily bid and ask quotes for 5-year CDS contracts from Credit Market Analysis Ltd. (CMA) via Datastream. It covers 634 North American companies from January 2004 to October 2010. Panel B provides summary statistics of our Markit sample, which contains daily bid and ask quotes for 5-year CDS contracts from Markit Group Ltd., on 521 North American companies from April 1, 2010 to May 31, 2014. *Bid-ask spread* is the difference between bid and ask quotes. *CDS spread* is midpoint of bid and ask quotes. *CDS volatility* is 2 week rolling standard deviations of daily *CDS spread*. All other variables have the same sample period as the CDS data. *VIX* is the daily close values of the CBOE volatility index, and is from Datastream. Stock returns, trading volume, and bid-ask spreads from CRSP, corporate bond prices are from TRACE. *CDS-bond basis* is calculated from the CDS spread and corporate bond price based on the Par-Equivalent CDS Methodology in the Appendix. *ABS(Basis)* is the absolute value of *CDS-bond basis*. *Log(stock volume)* is the logarithm of daily stock trading volume from CRSP. *Libor-OIS spread* is the difference between 3 month Libor rate and 3 month Overnight Indexed Swap rate, and is from Bloomberg. *Upfront fee* is the size of the upfront payment expressed in percentage of the notional value. *Stock bid-ask spread* is the daily bid-ask spread of the reference entity, *Log(bond volume)* is the logarithm of the daily bond trading volume of the reference entity, *Log(bond Amihud)* is the logarithm of the Amihud measure of the reference entity's bond. *DIS* is defined in equation (1) and *Upfront cost* is defined in equation (2).

Panel A: CMA sample (January 2004 to October 2010)

Variable	N	Mean	Std Dev	1st Pctl	50th Pctl	99th Pctl
Bid-ask spread	633,977	9.61	8.28	2.00	5.30	40.00
CDS-bond basis	278,446	-22.47	95.42	-380.65	-1.63	172.69
ABS(Basis)	278,446	54.43	81.53	0.34	24.40	385.69
CDS volatility	633,977	9.86	16.94	0.32	4.24	73.75
CDS spread	633,977	136.69	152.80	9.00	71.20	681.22
DIS	633,977	0.67	0.45	0.02	0.62	1.98
VIX	633,977	20.44	10.54	10.23	17.18	63.92
Libor-OIS spread	633,975	0.3232	0.4547	0.0515	0.1063	2.5343
Log(stock volume)	541,845	14.70	1.40	10.64	14.70	17.82
Stock bid-ask spread	542,578	0.00	0.00	0.00	0.00	0.01
Log(bond volume)	393,615	15.01	2.14	9.62	15.43	18.84
Log(bond Amihud)	393,615	-15.52	2.22	-22.43	-14.92	-12.00

Panel B: Markit sample (April 1, 2010 to May 31, 2014)

Variable	N	Mean	Std Dev	1st Pctl	50th Pctl	99th Pctl
Bid-ask spread	400,129	11.74	8.04	4.17	10.00	41.70
CDS-bond basis	257,954	-14.25	63.55	-229.42	-10.74	161.81
ABS(Basis)	257,954	41.27	50.38	0.45	26.31	243.41
CDS volatility	400,143	7.82	13.47	0.23	3.83	54.30
CDS spread	400,124	165.28	149.34	17.91	112.95	677.12
Upfront fee	400,215	3.58	3.53	0.06	2.53	16.75
Contracts count	348,312	1933.86	1197.46	353.00	1691.00	6423.00
CDS trading volume	295,138	123.00	178.98	1.05	66.30	854.00
VIX	400,215	19.21	6.45	11.98	17.31	41.08
Libor-OIS spread	400,215	0.21	0.10	0.08	0.16	0.49
Log(stock volume)	357,831	14.8704	1.4587	9.6989	14.9072	18.1058
Stock bid-ask spread	358,094	0.00	0.00	0.00	0.00	0.00
Log(bond volume)	308,896	14.95	2.10	9.68	15.29	18.97
Log(bond Amihud)	308,896	-8.69	1.71	-14.48	-8.35	-5.66

Table 2. The effects of the Upfront Payment Cost

The regressions are based on the CMA sample (January 2004 to October 2010). *BB* is a dummy variable that equals 1 if date is later than April 8, 2009, 0 otherwise. All other variables are defined in Table 1. Interaction terms between *BB* and other variables are not reported in the table. Numbers in parentheses are *t*-statistics based on standard errors that are clustered by firm and are corrected for heteroscedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Dependent variable	Bid-ask spread	Bid-ask spread	ABS(Basis)	ABS(Basis)	CDS Volatility	CDS Volatility
Upfront cost	0.549***	0.668***	-7.302*	-6.833*	1.996***	1.805***
	(5.167)	(6.144)	(-1.961)	(-1.786)	(6.422)	(5.930)
Upfront cost X BB	2.759***	2.340***	36.51***	31.02***	6.486***	6.086***
	(6.726)	(6.188)	(3.674)	(3.404)	(4.933)	(4.786)
BB	-5.719***	-3.625***	-6.526	-87.47***	-14.07***	-2.683
	(-3.871)	(-2.587)	(-0.233)	(-3.274)	(-2.798)	(-0.546)
Libor-OIS spread	-0.414***	0.170	2.202	-0.400	1.246***	1.363***
	(-3.163)	(1.217)	(0.623)	(-0.118)	(3.293)	(2.939)
CDS spread	0.0329***	0.0311***	0.119***	0.0993***	0.0689***	0.0723***
	(32.24)	(29.45)	(6.399)	(4.499)	(36.01)	(35.70)
Log(stock volume)	-0.111*	0.163***	-4.528***	-1.594	1.422***	1.514***
	(-1.815)	(2.901)	(-3.537)	(-1.254)	(7.263)	(7.900)
Log(bond volume)	0.00145	-0.0303**	-1.037***	-1.635***	0.159***	0.155***
	(0.114)	(-2.493)	(-3.410)	(-5.469)	(6.054)	(6.188)
Log(bond Amihud)	0.0185*	0.00587	0.822***	0.435*	0.00525	0.0412**
	(1.782)	(0.591)	(3.210)	(1.730)	(0.268)	(2.266)
Stock bid-ask spread	47.36***	31.12**	1,171***	1,332***	186.8***	71.17**
	(3.133)	(2.319)	(2.689)	(3.184)	(5.373)	(2.020)
VIX	0.0958***	0.0343***	3.094***	0.737***	0.0270	0.0910***
	(12.39)	(7.375)	(13.46)	(9.097)	(1.495)	(6.606)
Observations	356,848	356,848	236,112	236,112	356,848	356,848
R-squared	0.674	0.698	0.494	0.536	0.543	0.568
Number of firms	461	461	406	406	461	461
Firm FE	YES	YES	YES	YES	YES	YES
Year-Quarter FE	NO	YES	NO	YES	NO	YES

Table 3. Payment Size vs. Funding Cost

This table is based on the CMA sample (January 2004 to October 2010). *BB* is a dummy variable that equals 1 if date is later than April 8, 2009, 0 otherwise. All other variables are defined in Table 1. Interaction terms between *BB* and other variables are not reported in the table. Numbers in parentheses are *t*-statistics based on standard errors that are clustered by firm and are corrected for heteroscedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: Dependent variable: *Bid-ask spread* (basis points)

VARIABLES	(1) Bid-ask spread	(2) Bid-ask spread	(3) Bid-ask spread	(4) Bid-ask spread
DIS	0.442***	0.612***	0.123	0.294*
	(3.658)	(5.040)	(0.705)	(1.754)
BB	-6.308***	-3.731***	-6.160***	-3.698***
	(-4.261)	(-2.680)	(-4.161)	(-2.628)
BB X DIS	1.177***	0.708***	1.174***	0.576**
	(5.786)	(3.672)	(4.201)	(2.159)
Libor-OIS spread	-0.0335	0.637***	-0.351**	0.310*
	(-0.303)	(5.747)	(-2.247)	(1.926)
DIS X Libor-OIS spread			0.464***	0.467***
			(2.997)	(3.097)
BB X DIS X Libor-OIS spread			0.655	1.076**
			(1.215)	(2.109)
CDS spread	0.0331***	0.0312***	0.0328***	0.0309***
	(32.78)	(29.93)	(32.30)	(29.32)
Log(stock volume)	-0.123**	0.160***	-0.112*	0.163***
	(-2.000)	(2.853)	(-1.827)	(2.919)
Log(bond volume)	0.00281	-0.0283**	0.00216	-0.0287**
	(0.220)	(-2.291)	(0.170)	(-2.349)
Log(bond Amihud)	0.0174*	0.00506	0.0185*	0.00579
	(1.661)	(0.504)	(1.778)	(0.583)
Stock bid-ask spread	47.58***	30.68**	47.17***	30.80**
	(3.159)	(2.286)	(3.121)	(2.288)
VIX	0.0957***	0.0352***	0.0959***	0.0348***
	(12.38)	(7.654)	(12.42)	(7.507)
Observations	356,848	356,848	356,848	356,848
R-squared	0.675	0.698	0.675	0.698
Number of firms	461	461	461	461
Firm FE	YES	YES	YES	YES
Year-Quarter FE	NO	YES	NO	YES

Panel B: Dependent variable: *ABS(basis)* (basis points)

DIS	3.647	3.940	17.28***	16.83***
	(1.243)	(1.256)	(5.545)	(5.359)
BB	-7.523	-90.99***	1.596	-75.23***
	(-0.266)	(-3.400)	(0.0568)	(-2.819)
BB X DIS	7.774*	2.153	-11.74**	-19.16***
	(1.654)	(0.471)	(-2.153)	(-3.414)
Libor-OIS spread	-2.219	-5.199**	11.10***	7.551**
	(-0.922)	(-2.165)	(2.876)	(2.152)
DIS X Libor-OIS spread			-19.37***	-18.40***
			(-4.519)	(-4.372)
BB X DIS X Libor-OIS spread			39.30***	46.47***
			(3.267)	(3.839)
CDS spread	0.101***	0.0789***	0.112***	0.0900***
	(5.351)	(3.492)	(5.890)	(3.972)
Log(stock volume)	-4.165***	-1.411	-4.607***	-1.569
	(-3.240)	(-1.115)	(-3.681)	(-1.268)
Log(bond volume)	-0.952***	-1.547***	-0.933***	-1.535***
	(-3.162)	(-5.236)	(-3.183)	(-5.331)
Log(bond Amihud)	0.852***	0.447*	0.783***	0.396
	(3.306)	(1.766)	(3.127)	(1.609)
Stock bid-ask spread	1,134***	1,327***	1,151***	1,321***
	(2.619)	(3.215)	(2.638)	(3.161)
VIX	3.133***	0.750***	3.110***	0.760***
	(13.72)	(9.321)	(13.59)	(9.455)
Constant	82.67***	85.09***	79.22***	79.01***
	(4.517)	(4.725)	(4.389)	(4.454)
Observations	236,112	236,112	236,112	236,112
R-squared	0.493	0.535	0.497	0.539
Number of ticker_num	406	406	406	406
Firm FE	YES	YES	YES	YES
Year-Quarter FE	NO	YES	NO	YES

Panel C: Dependent variable: *CDS volatility* (basis points)

DIS	1.334***	1.194***	-0.0764	-0.0707
	(4.568)	(4.132)	(-0.207)	(-0.196)
BB	-15.53***	-3.205	-13.90***	-2.416
	(-3.071)	(-0.652)	(-2.716)	(-0.483)
BB X DIS	0.832	0.592	-0.470	-0.946
	(1.627)	(1.169)	(-0.627)	(-1.234)
Libor-OIS spread	2.610***	2.627***	1.207***	1.329***
	(7.477)	(6.181)	(3.032)	(2.811)
DIS X Libor-OIS spread			2.049***	1.853***
			(5.096)	(4.806)
BB X DIS X Libor-OIS spread			7.357***	7.750***
			(3.866)	(4.058)
CDS spread	0.0700***	0.0734***	0.0690***	0.0723***
	(36.74)	(36.35)	(35.75)	(35.17)
Log(stock volume)	1.376***	1.500***	1.423***	1.514***
	(7.015)	(7.816)	(7.287)	(7.888)
Log(bond volume)	0.161***	0.156***	0.158***	0.154***
	(6.159)	(6.249)	(6.066)	(6.190)
Log(bond Amihud)	0.000538	0.0384**	0.00526	0.0412**
	(0.0274)	(2.092)	(0.269)	(2.266)
Stock bid-ask spread	188.7***	70.75**	186.9***	71.25**
	(5.339)	(1.972)	(5.377)	(2.021)
VIX	0.0259	0.0928***	0.0269	0.0909***
	(1.434)	(6.717)	(1.489)	(6.559)
Constant	-23.42***	-25.52***	-22.62***	-24.37***
	(-8.164)	(-8.992)	(-7.796)	(-8.463)
Observations	356,848	356,848	356,848	356,848
R-squared	0.540	0.565	0.543	0.568
Number of firms	461	461	461	461
Firm FE	YES	YES	YES	YES
Year-Quarter FE	NO	YES	NO	YES

Table 4. Subsample analysis

This table is based on the CMA sample (January 2004 to October 2010). *BB* is a dummy variable that equals 1 if date is later than April 8, 2009, 0 otherwise. All other variables are defined in Table 1. Panel A is based on the sample from April 2008 to April 2010. Panel B is based on observations with total asset above the median. Panel B is based on observations with total asset below the median. Interaction terms between *BB* and other variables are not reported in the table. Numbers in parentheses are *t*-statistics based on standard errors that are clustered by firm and are corrected for heteroscedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A: 1 year before and after the Big Bang

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Bid-ask spread	Bid-ask spread	ABS(Basis)	ABS(Basis)	CDS Volatility	CDS Volatility
Upfront cost	0.430***	0.486***	-3.525	-1.835	2.172***	2.045***
	(4.686)	(5.399)	(-1.194)	(-0.613)	(6.993)	(6.967)
Upfront cost X BB	2.137***	2.169***	19.61*	18.13*	6.071***	6.306***
	(5.384)	(6.123)	(1.962)	(1.860)	(4.203)	(4.586)
BB	-8.009***	-6.764***	-139.3***	-193.5***	-35.75***	-16.50***
	(-4.394)	(-3.996)	(-3.526)	(-4.719)	(-5.569)	(-2.720)
Libor-OIS spread	-0.495***	0.367**	-5.563	-3.350	3.858***	3.564***
	(-3.070)	(2.360)	(-1.397)	(-1.044)	(8.362)	(6.606)
CDS spread	0.0347***	0.0327***	0.0160	-0.0461	0.0671***	0.0707***
	(30.20)	(26.77)	(0.495)	(-1.347)	(22.06)	(23.17)
Log(stock volume)	-0.167*	-0.0632	-10.82***	-7.068***	-1.085***	-0.156
	(-1.893)	(-0.749)	(-4.317)	(-2.801)	(-3.318)	(-0.502)
Log(bond volume)	0.0693***	-0.00277	2.026***	1.096**	0.241***	0.125***
	(4.585)	(-0.198)	(4.129)	(2.355)	(4.903)	(2.814)
Log(bond Amihud)	0.0682***	0.0258*	1.793***	0.794*	-0.125***	-0.0900**
	(4.543)	(1.780)	(3.934)	(1.806)	(-2.703)	(-2.052)
Stock bid-ask spread	59.28***	66.16***	1,958***	2,538***	173.4***	114.9**
	(4.030)	(4.493)	(3.498)	(4.655)	(3.575)	(2.414)
VIX	0.0814***	0.00165	3.585***	1.155***	0.0265	0.0495***
	(11.05)	(0.367)	(13.47)	(10.69)	(1.493)	(3.003)
Observations	122,240	122,240	86,187	86,187	122,240	122,240
R-squared	0.670	0.694	0.484	0.512	0.439	0.459
Number of firms	398	398	330	330	398	398
Firm FE	YES	YES	YES	YES	YES	YES
Year-Quarter FE	NO	YES	NO	YES	NO	YES

Panel B: Large firms

Dependent variable	(1) Bid-ask spread	(2) Bid-ask spread	(3) ABS(Basis)	(4) ABS(Basis)	(5) CDS Volatility	(6) CDS Volatility
Upfront cost	0.579***	0.682***	-11.58**	-10.23**	2.360***	2.116***
	(3.965)	(4.324)	(-2.463)	(-2.118)	(5.572)	(4.921)
Upfront cost X BB	2.179***	1.985***	19.81	18.36	4.522**	4.492**
	(3.747)	(3.475)	(1.547)	(1.497)	(2.174)	(2.249)
BB	1.085	2.977	22.63	-9.032	-9.845	0.0232
	(0.535)	(1.623)	(0.515)	(-0.212)	(-1.234)	(0.00299)
Libor-OIS spread	-0.0535	0.485**	12.66***	7.604**	2.049***	2.585***
	(-0.330)	(2.486)	(3.402)	(2.037)	(4.155)	(4.424)
CDS spread	0.0337***	0.0324***	0.136***	0.111***	0.0768***	0.0805***
	(23.65)	(21.48)	(5.005)	(3.444)	(26.78)	(27.41)
Log(stock volume)	0.0253	0.244***	-4.292**	-0.918	1.479***	1.476***
	(0.308)	(3.347)	(-2.501)	(-0.512)	(5.355)	(5.386)
Log(bond volume)	0.00215	-0.0252*	-0.502	-0.953***	0.0860**	0.0843**
	(0.139)	(-1.745)	(-1.380)	(-2.768)	(2.314)	(2.314)
Log(bond Amihud)	0.0362**	0.0250*	1.115***	0.843**	-0.00620	0.0484*
	(2.535)	(1.816)	(2.997)	(2.400)	(-0.208)	(1.680)
Stock bid-ask spread	21.34	19.45	1,975**	2,103***	148.3***	54.01
	(0.955)	(0.947)	(2.560)	(2.758)	(2.795)	(1.011)
VIX	0.0698***	0.0251***	2.152***	0.616***	-0.0169	0.0703***
	(7.451)	(4.987)	(8.513)	(6.090)	(-0.724)	(4.247)
Observations	192,973	192,973	138,612	138,612	192,973	192,973
R-squared	0.740	0.755	0.475	0.505	0.612	0.631
Number of firms	237	237	200	200	237	237
Firm FE	YES	YES	YES	YES	YES	YES
Year-Quarter FE	NO	YES	NO	YES	NO	YES

Panel C: Small firms

Dependent variable	(1) Bid-ask spread	(2) Bid-ask spread	(3) ABS(Basis)	(4) ABS(Basis)	(5) CDS Volatility	(6) CDS Volatility
Upfront cost	0.527***	0.659***	-8.280	-8.788	1.500***	1.330***
	(3.578)	(4.612)	(-1.469)	(-1.506)	(3.417)	(3.301)
Upfront cost X BB	3.357***	2.552***	43.18***	29.05**	8.470***	7.605***
	(5.666)	(4.918)	(3.134)	(2.364)	(5.387)	(4.794)
BB	-9.024***	-6.944***	43.39	-125.2***	-19.08***	-7.403
	(-3.941)	(-3.436)	(1.085)	(-3.603)	(-3.165)	(-1.299)
Libor-OIS spread	-0.925***	-0.296*	-8.075	-9.707	0.144	-0.374
	(-4.823)	(-1.764)	(-1.296)	(-1.622)	(0.258)	(-0.544)
CDS spread	0.0320***	0.0295***	0.0924***	0.0820***	0.0620***	0.0652***
	(24.27)	(22.02)	(3.659)	(2.720)	(25.95)	(25.01)
Log(stock volume)	-0.326***	-0.00263	-4.113**	-1.818	1.150***	1.352***
	(-3.850)	(-0.0364)	(-2.522)	(-1.223)	(5.714)	(7.143)
Log(bond volume)	0.00906	-0.0312**	-0.763*	-1.457***	0.194***	0.185***
	(0.579)	(-2.109)	(-1.896)	(-3.924)	(5.523)	(6.022)
Log(bond Amihud)	0.0102	-0.00732	0.707**	0.150	0.0204	0.0408*
	(0.776)	(-0.597)	(2.381)	(0.539)	(0.810)	(1.824)
Stock bid-ask spread	72.38***	34.15**	682.5**	876.8***	178.8***	33.12
	(4.384)	(2.367)	(2.130)	(2.715)	(4.498)	(0.909)
VIX	0.128***	0.0477***	4.590***	0.894***	0.0865***	0.127***
	(11.09)	(5.911)	(12.39)	(6.526)	(3.363)	(5.495)
Observations	163,875	163,875	97,500	97,500	163,875	163,875
R-squared	0.611	0.648	0.530	0.597	0.459	0.496
Number of firms	309	309	271	271	309	309
Firm FE	YES	YES	YES	YES	YES	YES
Year-Quarter FE	NO	YES	NO	YES	NO	YES

Table 5. The effect of the upfront payment cost in Markit sample

The regressions are based on the Markit sample (April 2010 to May 2014). All variables are defined in Table 1. Numbers in parentheses are *t*-statistics based on standard errors that are clustered by firm and are corrected for heteroscedasticity. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

VARIABLES	(1) Bid-ask spread	(2) Bid-ask spread	(3) ABS(Basis)	(4) ABS(Basis)	(5) CDS volatility	(6) CDS volatility
Upfront cost	0.828***	0.718***	4.434**	4.808**	1.532***	1.421***
	(8.392)	(7.342)	(1.992)	(2.132)	(8.180)	(7.376)
CDS spread	0.0363***	0.0364***	0.135***	0.129***	0.0519***	0.0529***
	(36.10)	(34.11)	(4.863)	(4.457)	(26.97)	(26.66)
Log(stock volume)	-0.0563	0.0522	0.262	0.251	0.782***	0.884***
	(-1.068)	(0.972)	(0.353)	(0.330)	(7.172)	(8.143)
Log(bond volume)	-0.0200*	-0.0275***	-0.944***	-0.899***	0.165***	0.154***
	(-1.844)	(-2.744)	(-4.963)	(-4.772)	(7.861)	(7.811)
Log(bond Amihud)	-0.00566	0.00990	0.176	0.128	0.0383**	0.0328**
	(-0.485)	(0.918)	(0.898)	(0.653)	(2.396)	(2.152)
Stock bid-ask spread	-548.0***	-370.8*	2,132	940.0	-790.4**	-722.3*
	(-3.021)	(-1.771)	(0.695)	(0.301)	(-2.248)	(-1.949)
VIX	0.0240***	0.0789***	-0.0319	-0.158**	0.189***	0.212***
	(3.172)	(15.26)	(-0.256)	(-2.178)	(14.28)	(16.05)
Libor-OIS spread	3.625***	1.905***	13.68	5.878	-2.511***	0.197
	(8.298)	(4.009)	(1.600)	(0.728)	(-3.592)	(0.191)
Observations	285,249	285,249	221,860	221,860	285,311	285,311
R-squared	0.581	0.618	0.118	0.126	0.351	0.367
Number of firms	414	414	364	364	414	414
Firm FE	YES	YES	YES	YES	YES	YES
Year-Quarter FE	NO	YES	NO	YES	NO	YES

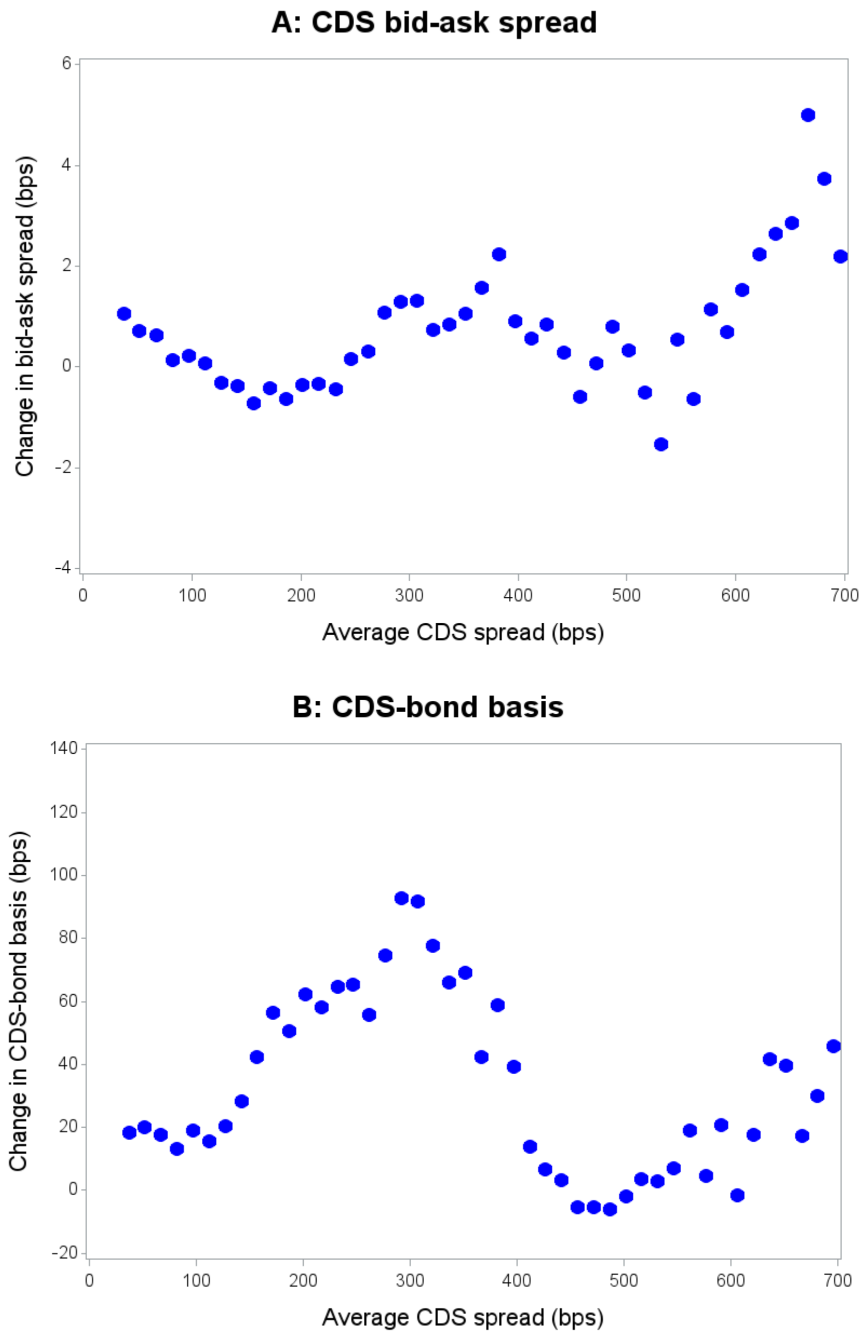

Figure 1: Change in bid-ask spread and CDS-bond basis around the CDS Big Bang

Both plots are based on our CMA sample (January 2004-September 2010). We divide our observations into equally-spaced groups by CDS spreads. For each group, we compute the average bid-ask spread and average CDS-bond basis for the pre- and post-Big Bang subsamples. We then plot the change in the average bid-ask spread across the two subsamples against the average CDS spread in Panel A, and plot the change in the absolute value of the average CDS-bond basis across the two subsamples against the average CDS spread in Panel B.