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

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Abstract

A major regulatory event in April 2009, the so-called "CDS Big Bang," induces upfront fees for trading CDSs. This funding shock, combined with several other shocks that took place soon afterwards (the CDS Small Bang, central clearing, and Deutsche Bank's exit from the CDS market) offers a rich setup to not only quantify the negative market liquidity effect from funding shocks, but also examine the economic mechanism behind this effect. This funding shock also increases the absolute value of the CDS-bond basis, and the effect is stronger if arbitrageurs are the payers, rather than the receivers, of the upfront fees.

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1 Introduction

The effect of funding liquidity has been analyzed extensively in the theoretical literature, especially since the recent global finance crisis (e.g., Brunnermeier and Pedersen (2009), He and Krishnamurthy (2013), Brunnermeier and Sannikov (2014), among others). On the empirical side, a number of studies have examined the link between funding liquidity constraints and market liquidity (e.g., Coughenour and Saad (2004), Comerton-Forde et al. (2010), Hameed, Kang, and Viswanathan (2010), Garleanu and Pedersen (2011), Karolyi, Lee, and Van Dijk (2012)). These studies examine whether or not funding constraint has an adverse effect on market liquidity. As is clear in Brunnermeier and Pedersen (2009), funding liquidity, market liquidity, and asset prices are jointly determined in equilibrium, making it difficult to identify the effects of funding liquidity. However, for some issues, such as policy evaluations, it is crucial to isolate and quantify funding liquidity effects.

In this paper, we exploit a quasi-experiment not only to quantify the effects of funding liquidity, but also examine the economic mechanism behind the funding effects. On April 8th 2009, a collection of trading convention changes was introduced into the CDS market, which is commonly referred to as the "CDS Big Bang." One consequence of these rule changes was that they increased 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. Since the CDS Big Bang, however, the coupon rate is restricted to be either 100 basis points (bps) or 500 bps.

The intention of this change was to standardize CDS contracts to facilitate central clearing. However, this trading convention change also induced an upfront payment, whose size depends on the CDS spread level. Suppose, for example, a contract has a CDS spread of 150 bps. That is, the "breakeven" coupon rate is 150 bps—the contract is worth zero on the inception day if the coupon rate is set to be 150 bps. After the CDS Big Bang, however, the coupon rate can only be either 100 or 500 bps. Suppose the coupon rate is set to be 100 bps. Since this coupon rate is 50 bps less than the breakeven rate (which is 150 bps), the protection *buyer* needs to compensate the seller by paying an upfront fee that is the present value of 50 bps per year during the life of the CDS contract. Alternatively, suppose the coupon rate is set to be 500 bps. Since this coupon rate is 350 bps more than the breakeven rate (which is 150 bps), the protection *seller* needs to pay an upfront fee that is the present value of 350 bps per year during the life of the CDS contract.[1] In summary, the CDS Big Bang induces upfront fees. The size of the fee depends on the credit spread level: it is larger if the credit spread is “further away” from the coupon rate. This upfront fee and its dependence on the credit spread level allow us to identify the effects of these funding shocks through diff-in-diff analyses.

How large is this upfront fee in aggregate? In our sample, the average size of the upfront fee is 4.07% of the notional amount of the CDS contract. As illustrated in Section 3.2, even if we exclude all the upfront fees for off-setting positions, the aggregate upfront fee for new trades is still about 3.87 billion dollars per month. It is only natural to expect this funding shock to have sizeable effects on market liquidity and prices. Indeed, the liquidity effect from these funding shocks was anticipated by practitioners before the implementation of the CDS Big Bang.[2]

Our paper examines two main hypotheses about the effects from funding shocks. The first one is that, as suggested by Brunnermeier and Pedersen (2009), these funding shocks should reduce market liquidity. Specifically, the upfront funding cost should increase bid-ask spreads in the CDS market through two channels. First, the upfront fees reduce investors’ willingness to trade. On the one hand, the trader who pays the fee incurs the funding cost. On the other hand, as explained in detail in Section 2.1, the trader who receives the fee needs to post the received payment as collateral, which earns a return that is typically lower than his cost of funding. Hence, the fee reduces the total gain from trade. This impediment to trading reduces market activity, leading to higher bid-ask spreads. Second, the upfront fees increase the cost of market making

[1] Naturally, in practice, the coupon is typically chosen to minimize the upfront fee. Hence, in the above example of a contract with a CDS spread of 150 bps, the coupon rate is typically chosen to be 100 bps.

[2] For instance, J.P. Morgan Worldwide Securities Services predicted in *Credit Derivatives Standardization Initiatives 2009* that after the CDS Big Bang, liquidity is expected to increase more for CDS contracts whose spreads are closer to the fixed coupons (100 and 500 bps).

for dealers. Suppose a dealer takes two offsetting positions with two different customers. The dealer receives an upfront fee from one customer, but needs to pay a fee of a similar size to the other customer. Without central clearing, however, the dealer typically cannot net the two payments, i.e., he cannot use the received fee from one customer to pay the other customer. Instead, he has to post the received fee as collateral, and incur the funding cost to pay the other fee. Hence, the funding cost for upfront fees increases the dealer's cost of market making, leading to higher bid-ask spreads. Central clearing can mitigate this effect by partially addressing the netting issue.[3] Specifically, for centrally cleared transactions, the central counterparty clearing house (CCP) serves as the sole counterparty for all traders. Hence, the dealer can net the two offsetting upfront payments, if both positions are cleared at the same CCP.

The second hypothesis is that the upfront funding cost should increase the absolute value of CDS-bond basis.[4] This is because the upfront fees make arbitrage more costly, leading to a stronger violation of the law of one price, i.e., a larger absolute value of CDS-bond basis. Moreover, this effect should be stronger if basis arbitrageurs are the payers, rather than the receivers, of the upfront fees. That is, if basis arbitrageurs are the payers, the upfront fees would further reduce the efficacy of arbitrage activities in pushing CDS-bond basis towards zero.

As illustrated in the earlier example, the size of the upfront fee is determined by the distance between the CDS spread and the coupon rate (which can be either 100 bps or 500 bps). Moreover, the coupon rate is usually chosen to minimize the size of the upfront fee. Hence, we measure the size of the upfront fee by constructing a variable *DIS*, the minimum of the distances between the CDS spread and the two coupon rates. Note that, for CDS contracts with a given maturity, *DIS* reflects the size of the upfront fee only after the CDS Big Bang. Following Gârleanu and Pedersen (2011), we use the 3-month Libor-OIS spread, *LOIS*, as a proxy for the

[3] As noted in Duffie and Zhu (2011), central clearing cannot fully address this netting issue if there are multiple clearing houses. A practice known as rehypothecation may also alleviate this netting issue. It allows the receiver of collateral (usually a dealer) to use the collateral for his own purposes upon the permission of the payer of the collateral. Since the onset of the 2008 financial crisis, however, this practice has encountered difficulties. The Dodd-Frank Act put further restrictions on rehypothecation for derivatives.

[4] A 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 close to zero. A negative (positive) CDS-bond basis implies that the bond price is lower (higher) than what is implied by the CDS spread.

price of funding. Hence, we construct the upfront funding cost *F* as the product of *DIS* and *LOIS*. Note that, for CDS contracts of a given maturity, our measure *F* reflects the upfront funding cost only after the CDS Big Bang.

To quantify the effects of the funding shocks, we run a series of diff-in-diff regressions. Specifically, we regress five-year CDS bid-ask spreads on the interaction term $F \times BB$, where *BB* is a dummy variable that is 0 before the CDS Big Bang, and 1 afterwards. The coefficient of this interaction term is estimated to be 2.36 (t=6.08), suggesting that, consistent with our hypothesis, the upfront funding cost increases CDS bid-ask spreads. What is the economic magnitude of this effect? Let's take a CDS contract with a spread level of 300 bps as an example. Our estimate implies that, on average, the upfront funding cost increases the bid-ask spread by 1.51 bps. This is sizable given that our sample median and mean are 5.30 and 9.61 bps, respectively. Moreover, given the enormous size of the CDS market, this effect has considerable economic significance.

We conduct two placebo tests to further test our hypothesis. Specifically, we pick two fictitious dates for the CDS Big Bang: October 8, 2008 (6 months before the actual date) and October 8, 2009 (6 months after the actual date). Then, for each date, we rerun the above diff-in-diff tests using one year of data (from 6 months before to 6 months after the date). We expect the interaction coefficient to be insignificant for these two placebo tests, since the first test is based entirely on pre-Big-Bang data and the second on post-Big-Bang data. Indeed, the estimates of the interaction coefficient are -0.31 (t=1.49) and 0.32 (t=0.16) for these two placebo tests, respectively. In contrast, if we run the diff-in-diff test based on one year of data surrounding the actual date for the CDS Big Bang, the estimated interaction coefficient is 1.86 (t=6.95), similar to the estimate based on the overall sample, both in economic magnitude and statistical significance. These tests lend further support to our hypothesis that the funding costs induced by the CDS Big Bang increase CDS bid-ask spreads.

To account for potential confounding effects of unobserved shocks around the time of the CDS Big Bang, we conduct triple difference analysis using samples from both European and North American CDS markets. Since the CDS Big Bang applies only to North American CDS contracts, we can use European CDSs as a control group. Under the assumption that unobservable shocks have the same effects on the *sensitivity* of bid-ask spreads to *F* across the two CDS markets, our triple difference test can account for the confounding effects from those unobservable shocks and identify the effect from the CDS Big Bang. Specifically, we define a dummy variable *NA*, which is equal to 1 if the reference entity is a North American firm, and is 0 otherwise. We regress CDS bid-ask spread on the triple interaction term $F \times BB \times NA$, and find that the estimate of the triple interaction coefficient is 1.66 (t=2.61). That is, after controlling for the confounding effects around the CDS Big Bang, our evidence is still consistent with the hypothesis that the upfront fees increase the CDS bid-ask spreads. We also conduct similar placebo tests by repeating our triple difference analysis using fictitious dates for the CDS Big Bang. As expected, the triple interaction coefficients in those placebo tests become insignificant. These tests further support our hypothesis that it is the upfront funding cost induced by the CDS Big Bang that increases CDS bid-ask spreads.

As an independent test on an entirely new dataset, we repeat our analysis on the CDS Small Bang, a similar trading protocol change for CDS contracts on European reference entities on June 20, 2009, and find similar funding liquidity effects.

To shed light on the economic mechanism behind the funding effect, we examine its cross-sectional variations. Our evidence suggests that the funding effect is stronger for CDS contracts on smaller and riskier reference entities. This is consistent with the prediction in Brunnermeier and Pedersen (2009) that the funding effect is stronger for riskier and less liquid securities. Similarly, we also examine the funding effect on the term structure of CDS contracts. Our previous evidence has been based on 5-year CDS contracts, which are the most widely traded and most liquid. We also analyze the funding effect on CDS contracts with maturities ranging from 1 year to 10 years. Our evidence suggests that the upfront funding effect is mostly similar for contracts with other maturities, and appears to be stronger for contracts with longer maturities.

To further examine the economic mechanism behind the effect of the upfront funding cost, we analyze two important shocks in the CDS market. The first one is that Deutsche Bank, a major dealer in the single-name CDS market, decided to exit the market in late 2014 because "regulation had made the business less attractive".[5] This creates a major shock to the aggregate market making capacity in the CDS market. As shown in Brunnermeier and Pedersen (2009), the funding effect is stronger when traders' capital constraint is closer to being binding. Consistent with this prediction, our evidence suggests that bid-ask spreads become more sensitive to the upfront funding cost after Deutsche Bank's exit. Our estimate shows that due to Deutsche Bank's exit, the upfront funding cost on average increases the bid-ask spread by an additional 0.5 bps.

The other major shock in the CDS market is central clearing. In December 2009, 8 months after the CDS Big Bang, ICE Clear Credit (ICECC) started to clear CDS trades. Over time, more CDS contracts became eligible for central clearing. By the end of our sample, October 2016, CDS contracts for 243 names had been centrally cleared at ICECC. As noted earlier, central clearing can facilitate netting and mitigate the upfront funding effect. We analyze this mechanism through diff-in-diff regressions. Consistent with this prediction, our estimates suggest that, on average, central clearing reduces the effect of the upfront funding cost on bid-ask spreads by around 0.5 bps.

To test our second hypothesis that upfront funding cost should increase the absolute value of CDS-bond basis, we regress the absolute value of CDS-bond basis on the interaction term $F \times BB$. The estimate of the interaction coefficient is 37.79 (t=4.10), suggesting that, also consistent with our hypothesis, a higher funding cost leads to a larger basis in absolute value. The implied economic magnitude is also significant. Let's take a CDS contract with a spread level of 300 basis points as an example. Our estimates imply that the average effect of the funding cost on the absolute value of the CDS-bond basis is around 24 bps. This effect becomes about twice as strong when basis arbitrageurs are expected to be the payers, rather than receivers, of the upfront fees. This evidence provides further support to our limit-to-arbitrage interpretation.

A common belief in the industry is that the CDS Big Bang helped to eliminate offsetting trades and facilitate same day matching and central clearing, and hence may reduce the systemic

[5] See, for example, *Deutsche Bank Exits Credit Swaps Trades on Most Companies*, Bloomberg November 17, 2014, https://www.bloomberg.com/news/articles/2014-11-17/deutsche-bank-exits-most-single-name-credit-default-swap-trading.

risk.[6] Our paper primarily focuses on the cross-sectional variation of the induced funding shocks, a less-recognized consequence of the CDS Big Bang. Our identification is from the cross-sectional, rather than time series, variation in funding shocks. We find that the standardization induces upfront payments, which reduce market liquidity and are an impediment to the arbitrage mechanism. It is natural to expect this funding effect to be stronger during periods of financial distress. Hence, our results highlight the importance of accounting for these funding effects when evaluating the tradeoff between standardization and upfront payments. When fewer coupon rates are allowed, CDS contracts are more standardized but upfront payments are larger. Interestingly, more standard coupons are adopted at the CDS Small Bang. Apparently, the motivation for this choice is to reduce the size of upfront fees.[7] Finally, our analysis offers some evidence that central clearing can help to partially alleviate the funding cost effect, suggesting the importance of implementing central clearing after the standardization of CDS contracts.

There is a large literature on the effects of funding liquidity and arbitrageurs' capital constraints. Important theoretical 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, funding liquidity effects have been analyzed in various contexts. 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. Karolyi, Lee, and Van Dijk (2012) find that the commonality in liquidity is greater in countries with and during times of high market volatility, especially after large market declines. 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 that the market liquidity of a stock decreases when its market maker

[6] See, for example, Markit technical note, *The CDS Big Bang: Understanding the Changes to the Global CDS Contract and North American Conventions*, March 13, 2009

[7] For example, a Markit technical report states: "[t]he main reason for the additional strikes is the idea that people have a preference to enter into trades near par…" and that "[t]he additional coupons allow for greater minimization of the upfront fees that will be exchanged."

holds large inventory or has suffered recent trading losses. Hameed, Kang, and Viswanathan (2010) find that negative market returns decrease stock liquidity. 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), Dick-Nielsen, Feldhutter, and Lando (2012)).[8]

These studies focus on whether or not the funding constraint has an adverse effect on market liquidity. The contribution of our paper is that our setup makes it possible to quantify the effects of funding liquidity, and examine the economic mechanism behind the funding effects. A better understanding of the underlying economic mechanism can not only deepen our understanding of the funding effects, it may also lead to specific policy implications. For instance, our evidence shows that part of the funding effect is due to the difficulty in netting the upfront fees. Hence, central clearing can address this issue and alleviate its adverse market liquidity effect, highlighting the importance of implementing central clearing after the standardization of CDS contracts.

The CDS Big Bang and Small Bang have been used to study liquidity spillover (Haas and Reynolds (2015), the empty credit hypothesis(Danis (2015)), and the effect on credit availability (Gunduz et al (2017)). 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), Shachar (2011), Chen, Cheng, and Wu (2013), and Loon and Zhong (2014). Augustin et al. (2016) provide a recent survey.

Finally, our paper is related to the analysis of standardization in the OTC derivative market. Oehmke and Zawadowski (2015, 2017) argue that one important role of the CDS market is to provide standardization to various bond markets of the reference entity. Augustin et al. (2016) argue that standardization fosters aggregation of information and price discovery. Chen et al. (2011) document the effects of the CDS Big Bang on the standardization of product and

[8] More generally, Adrian, Etula, and Muir (2014) and He, Kelly, and Manela (2017) find that the capital constraints of financial intermediaries can help to price cross-sectional asset returns. Mitchell, Pedersen, and Pulvino (2007) and Mitchell and Pulvino (2012) document cases where arbitrage capital appears slow in exploiting opportunities.

trading conventions. 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 analysis highlights the mechanism through which standardization induces upfront funding costs and reduces market liquidity.

2 A Quasi-Experiment: the CDS Big Bang

2.1 Institutional details

The "CDS Big Bang" refers to the trading convention changes in the CDS market on April 8, 2009. The changes that are relevant for our study are the fixed coupon and upfront payment for North American single-name CDS contracts. 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 was restricted to be either 100 bps or 500 bps. The purpose of this change is to standardize CDS contracts to facilitate central clearing and reduce systemic risk.

This standardization, however, induces upfront payments. Suppose, for example, a contract has a CDS spread of 150 bps. That is, the contract is worth zero on the inception day if the coupon rate is set to be 150 bps—the "breakeven" rate is 150 bps. After the CDS Big Bang, however, the coupon rate is restricted to be either 100 or 500 bps. Suppose the coupon rate is set at 100 bps. Since this is 50 bps lower than the breakeven rate (which is 150 bps), the protection *buyer* needs to compensate the seller by paying an upfront fee that is the present value of 50 bps per year during the life of the CDS contract. Suppose now that the coupon rate is set to be 500 bps. Since this coupon rate is 350 bps higher than the breakeven rate (which is 150 bps), the protection *seller* needs to pay an upfront fee that is the present value of 350 bps per year during the life of the CDS contract.

Note that, in practice, the funding cost induced by these upfront payments is in addition to the funding cost for the margins for CDS trades. The details for the margin requirements for CDS trades are described in Duffie, Scheicher, and Vuillemey (2015). For a trade between a dealer and a customer, for example, an initial margin is required at the inception for the customer but not the dealer (although proposed regulatory reforms will also require dealers to post initial margins for inter-dealer trades). Moreover, variation margins are posted by both parties, and adjusted over time according to their collateral agreement when the mark-to-market value of the CDS contract changes. After the CDS Big Bang, on the inception day of a trade, a trader pays the upfront fee and its counterparty typically posts the received fee as the variation margin. This upfront payment is an extra funding requirement in addition to the initial margin.[9]

In summary, the CDS Big Bang induces upfront fees. The size of the fee depends on the CDS spread level: it is larger if the CDS spread is "further away" from the coupon rate. This upfront fee and its dependence on the CDS spread level allow us to identify the effect of these funding shocks.

2.2 Upfront funding cost and market liquidity

Hypothesis 1: The upfront funding cost increases the CDS bid-ask spread.

As shown in Brunnermeier and Pedersen (2009), funding liquidity shocks reduce market liquidity. Intuitively, the upfront funding shock induced by the CDS Big Bang is an impediment to trading, and so reduces the market liquidity, leading to higher bid-ask spreads. Specifically, the upfront payment can affect the bid-ask spreads through two channels. First, the upfront fees reduce investors' *willingness to trade*.[10] As in Gârleanu and Pedersen (2011) and Shen, Yan, and Zhang (2014), capital-constrained investors are reluctant to trade assets that are capital intensive. For investors, the benefit from receiving the upfront fee is typically smaller than the cost of paying it. The trader who receives the upfront fee has to post it as collateral, and so earns a return that is typically lower than his cost of funding. Hence, the upfront payment reduces market activities, making it difficult for dealers to make market and leading to higher bid-ask spreads.

[9] For more details on the funding requirement changes induced by the CDS Big Bang, see, e.g., *The Bond-CDS Funding Basis* (JP Morgan September 2009).

[10] In principle, one can avoid upfront payments by trading the two contracts at the same time. For instance, if the CDS spread is 300 bps, one can take half position in the 100-coupon contract and half position in the 500-coupon one, so that the upfront payments of the two contracts cancel out each other. This is similar to the process known as "portfolio re-couponing", which modifies legacy CDS positions into 100 and 500 fixed coupon positions. However, this strategy is usually infeasible, since many contracts have only one coupon traded. For those with dual coupons, liquidity is typically concentrated in one contract, making it expensive to trade the less liquid one.

Second, the upfront fees increase the *cost of market making* for dealers, because they have to incur extra funding costs when they take offsetting positions. Suppose a dealer sells a protection on a reference entity to investor A, and, to offset this exposure, buys a protection on the same reference entity from investor B. In this case, the dealer needs to pay an upfront fee for one position, and receives an upfront fee of similar size for the other. Suppose, then, the dealer receives an upfront fee from A, and pays an upfront fee to B. Although these two offsetting payments are similar in size, the dealer cannot net them without central clearing. Specifically, for the trade between the dealer and A, the mark-to-the-market value of the CDS contract for investor A is the size of the upfront fee. Hence, the dealer needs to post the fee from A as collateral for this trade.[11] On the other hand, the dealer has to finance the upfront fee for the trade with investor B. As formulated in Andersen, Duffie, and Song (2016), funding the upfront payments is costly to dealers, leading to higher bid-ask spreads.

The above discussion makes it evident that central clearing can alleviate the effect of the upfront funding cost by partially addressing this netting issue. Specifically, for centrally cleared transactions, a CCP serves as the sole counterparty for all parties. This allows a higher degree of netting benefits across trades. For instance, in our earlier example where the dealer has two offsetting positions with investors A and B, if both positions are cleared at the same CCP, the dealer now effectively has two offsetting positions with the same counterparty, namely the CCP. Hence, the dealer can net the two offsetting upfront fees. However, despite the push from the Dodd-Frank Act, central clearing for single-name CDSs is still not mandatory. At the end of our main sample, only 14% of the contracts had adopted central clearing. Moreover, as noted in Duffie and Zhu (2011), central clearing is unlikely to fully address this netting issue if, for instance, there are multiple central clearing houses. Finally, central clearing cannot eliminate the

[11] If there is a collateral agreement between two parties of a trade, the party who receives an upfront fee is not entitled to retain the payment, but must post the payment as collateral to the payer. According to the 2009 ISDA margin survey, 66 percent of net credit exposure of OTC derivatives is covered by collateral. Collateral is usually held either by dealers' internal custody service or by a third agent upon the request of the counterparty. In either case, once the upfront fee is transferred to a custody account, neither party can use the payment for their own purposes. In other words, collateral agreements freeze upfront fees for both parties. After the inception of a trade, additional collateral may be called or released when the mark-to-market value of the trade changes. The collateral from the upfront fee is gradually released over time when the trade approaches maturity. For more details on collateral requirements in practice, see *The Standard Credit Support Annex*, ISDA, 2011.

effect from the willingness-to-trade channel. Hence, even if central clearing is mandatory for all CDS contracts and there is a single central clearing house for the entire market, it still cannot eliminate the effect of the upfront funding cost on market liquidity.

2.3 Upfront funding cost and CDS-bond basis

Hypothesis 2: The upfront funding cost increases the absolute value of CDS-bond basis, and this effect is stronger if basis arbitrageurs are the payers, rather than receivers, of the upfront fees.

As we argue in Hypothesis 1, the upfront funding cost reduces market liquidity. Naturally, this makes arbitrage costlier, leading to a stronger violation of the law of one price. Note that a CDS-bond basis is essentially 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 close to zero. A negative (positive) CDS-bond basis implies that the bond price is lower (higher) than what is implied by the CDS spread. A higher absolute value of the CDS-bond basis implies a stronger violation of the law of one price. Hence, the upfront funding cost increases the absolute value of the CDS-bond basis. Moreover, if the basis arbitrageur's strategy is such that he is the payer (rather than the receiver) of the upfront fee, the funding cost will further reduce his incentive to trade, leading to a higher absolute value of CDS-bond basis. That is, the effect of the upfront funding cost on the absolute value of CDS-bond basis is stronger if basis arbitrageurs are the payers, rather than receivers, of the upfront fees.

3 Data and Measurement

3.1 Data description

We obtain daily bid and ask quotes for 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, which we will refer to as the "CMA sample." We will focus on 5-year CDS contracts since they are the most liquid and most widely-traded contracts. It covers 634 companies from January 1, 2004 to September 30, 2010.[12] Hence, this sample covers about five years before and 1.5 years after the CDS Big Bang. Our second CDS data source is the Liquidity report from the CDS Pricing Data of Markit Group Ltd., and we will refer to it as the "Markit sample." Its 5-year CDS contracts cover 765 North American companies (out of which 319 are also in our CMA sample) from April 1, 2010 to October 19, 2016. That is, the Markit sample only covers the post-Big-Bang period. Nevertheless, it is a useful complement to our CMA data.

We apply the following filters on the CDS bid and ask quotes to both samples. We remove observations where the bid quote is greater than or equal to the ask quote, or the quote is indicated as "derived" rather than "observed." To improve the identification of the funding effect, we also remove the observations if the mid-point of bid and ask quotes is greater than 750 bps.[13] After applying these filters, the CMA and Markit samples consist of 633,977 (620 firms) and 659,618 (728 firms) daily observations, respectively.

Table 1 reports the summary statistics. Each variable is pooled over time and across firms. Panel A shows that the mean and median of the bid-ask spread in the CMA sample are 9.61 and 5.30 bps, respectively. They are slightly higher in the Markit sample in Panel B, where the mean and median are 12.39 and 10.00 bps, respectively.

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 construct CDS-bond basis. In our CMA sample, the mean and median of CDS-bond basis is -22.47 and -1.63 bps, respectively, while in the Markit sample, the mean and median are -17.75 and -13.92 bps.

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 bps, respectively, in our CMA sample, and are 155 and 102 bps in our Markit sample. For

[12] From October 1, 2010, CMA data are not available without a separate license.

[13] This is because before the CDS Big Bang, some CDS contracts on distressed firms were already traded with a fixed coupon of 500 bps and upfront payments (*The CDS Big Bang: Understanding the Changes to the Global CDS Contract and North American Conventions*, Markit 2009). The cutoff of 750 bps is equivalent to excluding firms with a credit rating below CCC. This filter removes about 5.5% of total observations in the CMA sample and 5% in the Markit sample. Our results are robust if the cutoff is chosen to be 1000 bps.

each CDS contract, on each day, we compute two volatility measures. *CDS volatility (level)* is the standard deviation of daily CDS levels during the previous two weeks. Its mean and median are 6.74 and 2.85 bps for the CMA sample, and 5.09 and 2.17 bps in the Markit sample. *CDS volatility (change)* is the standard deviation of daily CDS spread changes during the previous two weeks. Its mean and median are 4.88 and 2.36 bps for the CMA sample, and 3.29 and 1.50 bps in the Markit sample.

As control variables, we obtain daily close values of the CBOE volatility index from Datastream, reference entities' stock returns, trading volume, and bid-ask spreads from CRSP, assets and liabilities from Compustat, transaction prices of bonds issued by the reference entities from TRACE, and bond characteristics from Mergent Fixed Income Securities Database (FISD). We construct two bond market liquidity measures. The first is the 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 day, r_i and v_i are the percentage price change and the dollar volume of the ith trade, respectively. If a firm has multiple bonds, we aggregate the Amihud measures of all bonds issued by the same firm (identified by its 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. After merging with firm-level control variables, our CMA sample covers 459 firms and consists of 354,670 observations and our Markit sample covers 361 firms and has 333,401 observations.

3.2 Measuring the upfront funding cost

The upfront funding cost has two components: the upfront fee size and the funding cost of each unit of payment. We can separately measure both. As illustrated in earlier examples, after the CDS Big Bang, the size of the upfront fee is determined by the distance between the CDS spread and the coupon rate. In our CMA sample, we cannot directly observe the upfront fee size or coupon rate, 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 to convert the coupon rate and the upfront fee into a CDS spread.[14] We can infer the coupon rate (i.e., 100 or 500 bps) since it is usually chosen to be closer to the CDS spread.[15] Hence, for each CDS contract *i* on day *t*, we construct a variable DIS_{it}

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

where S_{it} is the CDS spread. That is, *DIS* is the minimum distance between the CDS spread and the two possible coupon rates. As discussed in Section 2.1, for a given maturity of CDS contracts, *DIS* can be used as a measure of the upfront fee size. After the CDS Big Bang, for CDS contracts with the same maturity, the size of the upfront fee is approximately linear in *DIS*.[16] The higher the *DIS*, the larger the upfront fee.

To measure the price of funding, we follow Gârleanu and Pedersen (2011) and 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 rate of large banks and the OIS rate is often considered the risk-free rate. Hence, this spread is a proxy for the price of funding for large institutional investors. From Bloomberg, we obtain daily close values of Libor-OIS spreads, which have significant variations in our sample period, ranging from less than 5 bps to over 250 bps during the recent financial crisis.

The upfront funding cost can be measured as

$$F_{it} = DIS_{it} \times LOIS_t , \tag{2}$$

where $LOIS_t$ is the 3-month Libor-OIS spread on day *t*. Therefore, *F* reflects the upfront funding cost for CDS *i* on day *t*, but only for the post-CDS-Big-Bang sample.

Finally, in our Markit sample, we can directly observe the size of the upfront fee. As shown in Panel B, the average upfront fee size, *Fee*, is 4.07% of the notional amount of the CDS contract.

[14] The ISDA CDS Standard Model is used to convert coupon rate and upfront fee into the CDS spread. The details of the model are available from http://www.cdsmodel.com/cdsmodel/.

[15] For example, according to our Markit sample, where the coupon rate is directly observable, the "primary coupon rate" is chosen to be the one that is closer to the CDS spread for about 92% of the observations.

[16] The nonlinearity is caused by the possibility of default of the reference entity, but the effect is minor for our sample, where the credit spread is below 750 bps. The advantage of this distance-based measure is that it is simple and transparent. Nevertheless, as a robustness analysis, we use the ISDA Standard CDS Model to directly estimate the fee. The results based on this alternative measure, reported in Section 6, remain very similar.

How large is the aggregate funding liquidity shock? According to the DTCC TIW report, the gross notional value of single-name CDS trades executed between April and December 2009 is about $10 trillion. According to the estimate in Duffie, Scheicher, and Vuillemey (2015), the ratio between net and gross notional amounts is 7.6%. Hence, the aggregate net notional amount of single-name CDS trades during this period is $0.76 trillion. Even if we exclude the upfront fees for all off-setting positions, the aggregate monthly upfront fee for these new trades is still 3.87 billion dollars (=0.76 trillion × 4.07% / 8). It is only natural to expect this funding requirement to have a sizeable effect on market liquidity and prices.

3.3 Arbitrageurs' positions

To determine if basis arbitrageurs need to pay or receive the upfront fee, let's first consider the case where the CDS-bond basis is negative, i.e., the CDS spread is lower than the reference entity's corporate bond spread. In this case, a basis arbitrageur's position is long in both the CDS and the underlying corporate bond. Is the arbitrageur the payer or the receiver of the upfront fee? As discussed in Section 2.1, this depends on the CDS spread and the coupon rate. Since the coupon rate is mostly chosen to minimize its distance to the CDS spread, we can infer that the coupon rate is 100 bps if the CDS spread is lower than 300 bps, and is 500 bps otherwise. Hence, the explanation in Section 2.1 implies that basis arbitrageurs pay the upfront fee if the CDS spread is between 100 and 300 bps, or is higher than 500 bps, and they receive the fee otherwise. Let the dummy variable Pay_{it} be 1 if basis arbitrageurs pay the upfront fee, and 0 otherwise. The above discussion implies that when the CDS-bond basis is negative, we have

$$Pay_{it} = \begin{cases} 1, & if\ 100 < S_{it} \leq 300, or\ S_{it} > 500 \\ 0, & otherwise. \end{cases} \tag{3}$$

Similarly, when the CDS-bond basis is positive, a basis arbitrageur's position is short in both the CDS and its underlying corporate bond, and so we have

$$Pay_{it} = \begin{cases} 1, & if\ 300 < S_{it} \leq 500, or\ S_{it} < 100 \\ 0, & otherwise. \end{cases} \tag{4}$$

Our Hypothesis 2 implies that the upfront funding effect is stronger if $Pay_{it} = 1$.

4 The funding cost effects on bid-ask spreads

4.1 Univariate analysis

We first examine the effect by plotting the bid-ask spread against the CDS spread. Since the upfront funding cost induced by the CDS Big Bang is smaller for contracts with CDS spreads closer to 100 or 500 bps, Hypothesis 1 implies that, in the cross-section, the bid-ask spread increase caused by the upfront funding cost is smaller for contracts with CDS spreads closer to 100 or 500 bps.[17] Hence, if we plot the change in bid-ask spread around the CDS Big Bang against the CDS spread, we should observe a W-shaped pattern with the two low points at around 100 and 500 bps.

We obtain our CMA sample for the two years around the CDS Big Bang, i.e., from April 8, 2008 to April 8, 2010. First, we normalize the bid-ask spreads based on a firm-fixed-effect model and focus on the residuals. That is, we run a panel regression $Y_{i,t} = u_i + \epsilon_{i,t}$, where $Y_{i,t}$ is the bid-ask spread for the CDS contract i on day t, u_i is a constant that captures the firm-fixed effects, and $\epsilon_{i,t}$ is the residual.

Then, we divide CDS contracts into 30 groups by their CDS spreads. Specifically, we divide the interval [0,750] equally into 30 subintervals. For each day, we sort CDS contracts into 30 groups based on which subinterval the CDS spreads fall into. For each group, we compute the bid-ask spread change around the CDS Big Bang as the post-Big-Bang average of the normalized bid-ask spread minus the pre-Big-Bang average. We then plot this change in average bid-ask spread against the CDS spread level. As shown in Panel A of Figure 1, there is indeed a W-shaped pattern and the two low points are at around 100 and 500 bps. The effect of the upfront fee on bid-ask spread is several bps, which is sizeable given that the median bid-ask spread in our sample is around 5 bps.

[17] Note that this prediction is about the cross-sectional pattern, and does not depend on whether the overall market liquidity effect from the CDS Big Bang is positive or negative.

4.2 Diff-in-diff and placebo tests

Hypothesis 1 implies that, due to the upfront funding cost, the CDS bid-ask spread is *more* positively correlated with F in the post-Big-Bang sample than in the pre-Big-Bang one. Note that the CDS bid-ask spread can potentially be correlated with F even in the pre-Big-Bang sample. For example, the CDS market may be more liquid for certain credit spread levels, perhaps due to higher trading activities for those contracts. Furthermore, F is the product of the upfront payment and Libor-OIS spread which is correlated with the bid-ask spread. Hence, the CDS bid-ask spread could be correlated with F. The essence of our Hypothesis 1 is that after the CDS Big Bang, due to the upfront funding cost, the CDS bid-ask spread becomes *more* correlated with F, which can be tested using a diff-in-diff analysis.

To test this implication, we first run two panel regressions of CDS bid-ask spread on F, one for the pre-Big-Bang sample and one for the post-Big-Bang one. All our regressions include firm-fixed effects and monthly time-fixed effects.[18] The results are reported in Panel A of Table 2. As shown in the first two columns, the coefficient of F is 0.59 (t=5.46) in the pre-Big-Bang sample, and it increases substantially to 2.89 (t=7.92) in the post-Big-Bang sample. The difference between these two coefficients identifies the funding effect from the CDS Big Bang. This is formally estimated in the regression in the third column, which is based on the entire sample, and includes the interaction term $BB \times F$, where BB is a dummy variable that is 0 before the CDS Big Bang and 1 afterwards. The estimate of the interaction coefficient is 2.36 (t=6.08). This is consistent with Hypothesis 1 that the upfront funding cost induced by the CDS Big Bang increases the bid-ask spread. For a CDS contract with a spread of 300 bps, for example, this estimate implies that when the Libor-OIS spread is 32 bps (our sample mean), the upfront funding cost increases the bid-ask spread of this CDS contract by 1.51 bps. This is sizeable, as the mean and median of the bid-ask spreads in our sample are 9.6 and 5.3 bps, respectively.

[18] Perhaps due to the global financial crisis and the new regulations afterwards (e.g., capital requirements in Basel III and the Volcker rule), the aggregate notion value of the CDS market decreases from over $60 trillion in 2007 to about $30 trillion at the end of 2010. Our identification strategy relies on cross-sectional variations in upfront fees. Hence, it is important to include time-fixed effects to control for those unobservable aggregate shocks. As robustness checks, we also repeat our analysis using quarterly and weekly time-fixed effects. The results remain very similar.

To further test Hypothesis 1, we conduct placebo tests by using fictitious dates for the CDS Big Bang and repeat the above diff-in-diff test. Specifically, we set two fictitious dates for the CDS Big Bang: October 8, 2008 (6 months before the actual date) and October 8, 2009 (6 months after the actual date). We then rerun the above diff-in-diff tests using one year of data around the two dates. In the first test, the sample is from April 9, 2008 to April 8, 2009. Since this entire sample period is before the policy change, we expect the interaction coefficient to be insignificant. Similarly, since the entire sample period in the second test (from April 9, 2008 to April 8, 2009) is after the policy change, we expect the interaction coefficient to be insignificant as well. Indeed, as shown in the first two columns of Panel B of Table 2, the estimates of the interaction coefficient are -0.31 (t=1.49) and 0.32 (t=0.16) for the two placebo tests. As a contrast, we also repeat our analysis using one year of data around the actual date for the CDS Big Bang. As shown in the third column, in sharp contrast to the two placebo tests, the interaction coefficient is 1.86 (t=6.95). These tests lend further support to our hypothesis that the funding cost induced by the CDS Big Bang increases bid-ask spreads.

4.3 European CDSs as a control group

To account for potential confounding effects of unobserved shocks around the CDS Big Bang, we conduct triple difference analysis using samples from both European and North American CDS markets. Since the CDS Big Bang applies only to North American CDS contracts, we can use European CDSs as a control group. Under the assumption that unobservable shocks have the same effects on the *sensitivity* of bid-ask spreads to F across the two CDS markets, our triple difference test can account for the confounding effects of those unobservable shocks and identify the effect from the CDS Big bang.

From Datastream, we obtain daily bid-ask spreads for single-name CDSs on European firms from April 1, 2004 to Sep 30, 2010, the same sample period as our main CMA sample. We apply the same filters as in Section 3.1, and obtain a sample of CDS contracts on 401 European firms and 420,775 contract-day observations.

For our main triple difference analysis, we choose the sample period as from January 25th to June 19th 2009. The end date is chosen because, on June 20, 2009, similar policy changes took place for European CDS contracts. This is commonly referred to as the "CDS Small Bang." We will see, in Section 4.6, that the CDS Small Bang has a similar effect on the upfront funding cost and market liquidity. To avoid this confounding effect from the CDS Small Bang, we end our sample on the day before it was implemented. The starting date of this sample (January 25th, 2009) is chosen so that the pre- and post-Big-Bang samples have the same length (about two months). During the second half of this period (April 8th to June 19th), the CDS Big Bang has been adopted for North American CDS contracts while the CDS Small Bang has not yet been implemented for European CDS contracts. This window of opportunity allows us to examine the effect from the CDS Big Bang, using European CDS contracts as a control.

We define a dummy variable *NA*, which is equal to 1 if the reference entity is a North American firm, otherwise 0. We regress CDS bid-ask spread on the triple interaction term $F \times BB \times NA$, and the results are reported in Table 3. In column 1, the coefficient for the triple interaction term is 1.66 (t=2.61), suggesting that after the CDS Big Bang, bid-ask spreads become more sensitive to the upfront funding costs for North American CDS contracts, after controlling for the effect in the European sample. Moreover, the economic magnitude of this coefficient is comparable to the estimates in Table 2.

As in the previous section, we also conduct placebo tests to further test our hypothesis. Specifically, we pick two fictitious dates for the CDS Big Bang. Then, for each date, we repeat the above triple difference analysis using the sample from two months before the chosen date to two months after. In the second column, the chosen fictitious date is February 8, 2009. Hence, the entire sample period for this regression (from December 8, 2008 to April 7, 2009) is before the CDS Big Bang. Therefore, we expect the coefficient for the interaction term $F \times BB \times NA$ to be insignificant. Indeed, as shown in column 2, the estimate of this coefficient is 0.08 (t=0.15). Similarly, for the placebo test in column 3, the chosen fictitious date is August 20, 2009, so that the entire sample for this regression is after both the CDS Big Bang and the CDS Small Bang. Hence, the triple interaction coefficient is also expected to be insignificant. Consistent with this conjecture, as shown in column 3, the estimate of this triple interaction coefficient is 0.95 (t=0.81). These tests further support our interpretation that it is the upfront funding cost induced by the CDS Big Bang that increases CDS bid-ask spreads.

4.4 Cross-sectional variation

We now examine the cross-sectional variation of the funding liquidity effect. Brunnermeier and Pedersen (2009) show that the funding effect is stronger for riskier and less liquid securities. In our context, to the extent that CDS contracts with smaller reference entities and lower credit ratings are less liquid and riskier, this prediction implies that the funding effect should be stronger for CDS contracts on smaller and riskier reference entities. To test this prediction, we construct a dummy variable *Small*, which is 1 if the reference entity's asset value is below the median, and 0 otherwise. Similarly, we define a dummy variable *Speculative*, which is 1 if the reference entity's credit rating is below BBB, and 0 otherwise.

We then rerun the diff-in-diff regression in Table 2 with an additional term $BB \times F \times Small$, and report the results in Table 4. As shown in the first column, the coefficient of this term is 1.34 (t=2.63), suggesting that the funding effect is stronger for CDS contracts on smaller entities. Note that the coefficient for $BB \times F$ is 1.64 (t=3.44), implying that the funding effect for CDS contracts on smaller reference entities is around 80% (≈1.34/1.64) stronger. Similarly, in the second column, the coefficient for $BB \times F \times Speculative$ is 1.33 (t=2.02) and the coefficient for $BB \times F$ is 1.91 (t=4.58), implying that the funding effect for CDS contracts on entities with speculative ratings is around 70% (≈1.33/1.91) stronger. Overall, our evidence is consistent with the prediction in Brunnermeier and Pedersen (2009) that the funding effect is stronger for riskier or less liquid securities.

4.5 Term structure of CDS spreads

In this subsection, we analyze CDS contracts with different maturities to provide further insights on the effect of the upfront funding cost on market liquidity. Specifically, we collect data of 1-year, 3-year, 7-year and 10-year CDS contracts from Datastream, and apply the same filters as those in Section 3.1. We then repeat our diff-in-diff analysis for each maturity, and the results are summarized in Table 5. The first column reports the results based on 1-year CDS contracts. Perhaps due to the small sample size (there are only 34 reference entities), the interaction coefficient is statistically insignificantly different from zero. The second column reports the results based on 3-year CDS contracts. The coefficient of the interaction term $BB\times F$ is 2.67 (t=1.84), which is close to the estimate based on 5-year contracts in column 3 of Panel A of Table 2. The results of similar regressions based on 7-year and 10-year contracts are reported in columns 3 and 4. The coefficient of the interaction term $BB\times F$ is 3.92 (t=2.82) and 4.16 (t=2.16), respectively. In summary, our evidence suggests that the upfront funding effect is similar for contracts with other maturities, and appears to be stronger for contracts with longer maturities.

4.6 CDS Small Bang

As noted in Section 4.3, on June 20, 2009, about two months after the CDS Big Bang, similar trading protocol changes took place for European CDS contracts. This is commonly referred to as the “CDS Small Bang.” Since the CDS Small Bang, the coupons for European single-name corporate CDS contracts have been restricted to be 25, 100, 500, and 1000 bps.[19] This event offers a chance for an additional test of our hypothesis in an entirely new sample.

We define a time dummy variable SB that equals 1 after June 20 2009, otherwise 0. The construction of the upfront funding cost F is similar to that in (2), with two adjustments. The first is that DIS is now the minimum distance of the CDS spread to the four standard coupons, 25, 100, 500, and 1000. The second adjustment is that the price of funding is now measured by the 3-month *Euro Libor-OIS spread*, the 3-month Euro Libor rate minus the 3-month Euro OIS rate.

We run the same diff-in-diff regressions as those in Panel A of Table 2 on this new sample. The results are presented in Table 6. In the first column, the coefficient for the interaction term $F\times SB$ is 3.32 (t=2.90). This is again consistent with our hypothesis that the upfront funding cost increases CDS bid-ask spreads. In the second column, we add stock bid-ask spread and trading volume as control variables and results remain similar. The interaction

[19] For more details, see Markit technical note, *CDS Small Bang: Understanding the Global Contract and European Convention Changes*, July 20, 2009. Two more coupons, 300 and 750 bps, have been implemented to allow more flexibility in recouponing legacy trades.

coefficient is 3.39 (t=3.18). These results, based on an entirely different dataset, lend further support to our hypothesis that the upfront funding cost increases CDS bid-ask spreads.

4.7 Deutsche Bank Exit

In late 2014, Deutsche Bank, a major CDS dealer, decided to exit the single-name CDS market because "regulation had made the business less attractive", creating a major shock to the aggregate market making capacity in this market. We exploit this shock to test the economic mechanism of the funding effect. As shown in Brunnermeier and Pedersen (2009), the funding effect is stronger when traders are closer to hitting their capital constraints. The exit of Deutsche Bank reduces dealers' aggregate market-making capacity and thus traders are closer to their funding constraints. Hence, we expect that the funding effect should be stronger after the exit of Deutsche Bank. It is worth noting that this event is after the sample period of our CMA sample, which is from 2004 to 2010. Hence, this event offers yet another independent opportunity to test our hypothesis.

Deutsche Bank's exit from the CDS market has been a gradual process. Although Deutsche Bank's exit was reported in the media in November 2014, the bank reportedly sold a portfolio of CDSs with a notional value of nearly $250 billion, which is "around 5–10% of a large dealer's total CDS book," to Citibank in September 2014.[20] Hence, we analyze a wide range of time as the event time. Specifically, we define a time dummy variable, *DB*, which is equal to 1 after the exit event and 0 otherwise. For robustness, we consider 3 different event times, September 15, 2014, December 15, 2014, and March 15, 2015.

Our hypothesis implies that after the exit, CDS market liquidity becomes more sensitive to the upfront funding cost. To test this hypothesis, we construct the funding cost in our Markit sample as $FC_{i,t} = Fee_{i,t} \times LOIS_t$, where $Fee_{i,t}$ is the upfront fee of CDS contract i on day t. We then regress the bid-ask spread on the interaction term $FC \times DB$, and the results are reported in Table 7. As shown in the first column, where the exit event time is set to be September 15,

[20] See the report by Risk.net at https://www.risk.net/derivatives/credit-derivatives/2388970/citi-buys-250bn-deutsche-bank-single-name-cds-portfolio.

2014, the interaction coefficient is 0.59 (t=2.41). This is consistent with our hypothesis that the Deutsche Bank exit from the market reduces the aggregate market making capital, and hence the market liquidity becomes more sensitive to the upfront funding cost. In our sample, the average of FC is 0.81 bps, hence our estimate implies that, on average, the Deutsche Bank exit increases the bid-ask spread by 0.48 bps (=0.81× 0.59). Our results are not sensitive to the choice of the exit time. For example, the second and third columns report the regression results when the exit time is set to December 15, 2014 and March 15, 2015, respectively. In both specifications, the interaction coefficient is similar in both economic magnitude and statistical significance.

4.8 Central clearing

Central clearing is one of the main reasons for the standardization of CDS contracts. With central clearing, CDS traders only face a single counterparty: the CCP. Hence, if a CDS trader has multiple positions with the same CCP, he can effectively net his positions. This netting benefit can be large for CDS dealers, since they often have significant offsetting positions. Hence, central clearing can mitigate the upfront funding effect. This economic mechanism is analyzed in the current section.

We obtain the initial dates for central clearing for the CDS contracts in our sample from the website of ICE Clear Credit (ICECC).[21] ICECC started to clear CDS trades in December 2009, which is 8 months after the CDS Big Bang. At the end date of our sample, central clearing for single-name CDSs was still not mandatory, and was only available for a limited number of reference entities. Our CMA sample, which ends in September 2010, has very limited coverage of central clearing. Only less than 3% of the sample is affected by central clearing. Not surprisingly, when repeating our analysis in Table 2 by excluding those observations, we obtain almost identical results. For brevity, these results are not presented in the paper.

Our Markit sample has better coverage of central clearing. At the end of our Markit sample, October 2016, there are 765 single-name corporate CDS contracts, out of which 243 have initiated central clearing. To analyze the influence of central clearing on the upfront

[21] https://www.theice.com/clear_credit.jhtml

funding effect, we define a dummy variable $Clear_{i,t}$, which is equal to 1 if a CDS contract *i* is centrally cleared at date *t*, 0 otherwise. The effect of central clearing can be estimated by diff-in-diff tests. Specifically, we regress *Bid-ask spread* on the interaction term *FC*×*Clear* and report the results in Table 8. In the first column, the estimate of the interaction term coefficient is -0.43 (*t*=2.16). This implies that, consistent with our hypothesis, our evidence suggests that central clearing mitigates the negative effect of the upfront funding cost on bid-ask spreads.[22]

We note that one should interpret this result with caution because CDS contracts are, of course, not randomly selected for central clearing. One potential concern is that a contract's probability of being selected for central clearing somehow depends on the *sensitivity* of its market liquidity with respect to the upfront funding cost.

To partially address this concern, we create a subsample in which all the CDS contracts initiated central clearing during our sample period. That is, we exclude contracts that started central clearing before our sample starts, and those that still have not started central clearing at the end of our sample. This subsample covers CDS contracts on 108 firms. By focusing on this subsample where all contracts are selected at some point in time, we only need to be concerned that the *timing* of the selection depends on the *sensitivity* of market liquidity with respect to the upfront funding cost. This helps to alleviate some concern about the selection issue.

We run the same regression on this subsample, and report the results in the second column. It shows that the effect remains very similar, and the interaction coefficient is -0.57 (*t*=2.34). The economic effect is also quantitatively significant. For example, the average of *FC* is 0.81 bps in our sample period. Hence, our estimate implies that, on average, due to the improvement in netting, central clearing reduces the bid-ask spread by 0.46 bps (=0.81 × 0.59).

[22] Our goal is to test how and if central clearing influences the effect from funding liquidity shocks, which is identified from the diff-in-diff regression. To evaluate the overall effect of central clearing on market liquidity (which may or may not be driven by the funding liquidity effect), we run this regression without interaction terms. The coefficient for the dummy variable *Clear* is -0.78 (*t*=3.05), suggesting that central clearing reduces bid-ask spreads. This is consistent with the evidence in the literature, e.g., Loon and Zhong (2014). For brevity, the regression results without interaction terms are not presented in the paper.

5 The funding cost effects on CDS-bond basis and volatility

To quantify the effect of the upfront funding cost on CDS-bond basis, we first construct a plot similar to Panel A in Figure 1. Specifically, we plot the change in the absolute value of the CDS-bond basis against the CDS spread in Panel B. Our Hypothesis 2 implies that there should also be a W-shaped pattern. After the CDS Big Bang, when spread levels are around 100 or 500 bps, CDS contracts are relatively 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 basis should be smaller at around 100 or 500 bps. This is confirmed by the W shape in our plot. The two low points in the W-shaped pattern are also at around 100 and 500 bps.

To formally test Hypothesis 2, we run a diff-in-diff regression similar to that in Table 2. Specifically, we regress *ABS(basis)*, the absolute value of the CDS-bond basis, on the interaction term $BB \times F$. As shown in column 1 in Panel A of Table 9, the coefficient for the interaction term is 37.79 (t=4.10), suggesting that, consistent with Hypothesis 2, a higher upfront funding cost leads to a larger basis in absolute value, i.e., a stronger violation of the law of one price. This estimate implies that, for a CDS with a spread of 300 bps, when the Libor-OIS spread is 32 bps, the upfront funding cost increases the absolute value of the CDS-bond basis by about 24 bps. As a comparison, the mean and median of the absolute value of the CDS-bond basis in our sample are 54 and 24 bps, respectively.

We further test our hypothesis by regressing *ABS(basis)* on the triple interaction term $BB \times F \times Pay$. As shown in the second column, the coefficient for this triple interaction term is 21.71 (t=1.94). This is consistent with our hypothesis that the upfront funding cost effect on *ABS(basis)* is stronger if basis arbitrageurs are the payers, rather than receivers, of the upfront fees. Note that the coefficient for $BB \times F$ is 26.92 ($t=2.59$), comparable to the coefficient for the triple interaction term. This implies that when the basis arbitrageurs need to pay the upfront fee, the effect of the upfront funding cost on *ABS(basis)* is more than twice as strong as when arbitrageurs receive the upfront fee.

Finally, as a corollary to Hypothesis 1, the upfront funding shocks should also increase the CDS spread volatility, since a less liquid market is less effective in absorbing temporary supply and demand shocks. We test this prediction by regressing the CDS spread volatility on the interaction term $BB \times F$. The results are reported in Panel B. In the two specifications, where the CDS volatility is estimated based on spread levels and changes, respectively, the estimates of the coefficient for the interaction term are highly significant, with *t*-statistics well over 4. Consistent with the prediction, the upfront funding cost leads to higher volatility.

6 Robustness analysis

In our previous analysis, the upfront fee is measured by *DIS*, the distance between the coupon rate and the CDS spread since, for contracts with a given maturity, the fee is approximately linear in this distance. In this section, we follow the ISDA CDS standard model to convert the distance between the coupon rate and the CDS spread into the upfront fee.[23] Specifically, using our main CMA sample, we calculate the two possible upfront fees for the two coupon rates (100 bps and 500 bps) and choose the smaller one as our estimated upfront fee, *EFee*. The upfront funding cost is then measured as $EFC = LOIS \times EFee$. We then repeat our earlier diff-in-diff analyses using our estimated upfront funding cost. The results, reported in Table 10, are very similar to those in our earlier analysis. For example, in the first column, the interaction term $BB \times EFC$ is 0.52 (t=5.57). This is consistent with the evidence in Table 2 that the upfront funding cost increases the bid-ask spread. Similarly, the evidence in columns 2 to 4 is consistent with that in Table 9. The upfront funding cost increases the absolute value of the CDS-bond basis and the CDS spread volatility. In fact, since *EFee* is mostly proportional to our earlier upfront fee measure *DIS*, the interaction coefficients in Table 10 are roughly proportional to those in Tables 2 and 9.

[23] We use the function "JpmcdsCdsoneUpfrontCharge" to compute the upfront fee from the CDS spread, coupon rate, and the term structure of the LIBOR rates. Details of this function and the model can be found at http://www.cdsmodel.com/cdsmodel/.

In the previous analysis, we use the Amihud measure for bond liquidity because TRACE provides reliable and comprehensive bond transaction data, but doesn't provide bid and ask prices. Nevertheless, we collect bond bid and ask prices from Bloomberg and use the bid-ask spread as a liquidity control for bonds. As shown in Table 11, our main results remain very similar when we include bond bid-ask spreads as a control variable.

7 Policy Implications

What is the overall effect of the CDS Big bang? It is believed that this policy change helps to facilitate central clearing and hence may reduce systemic risk.[24] A formal assessment of these benefits is outside the scope of this paper. So far, we have primarily focused on the funding liquidity effect, a less-recognized consequence of the CDS Big Bang. We find that the standardization induces upfront payments, which reduce market liquidity and are an impediment to the arbitrage mechanism. It is natural to expect this funding effect to be stronger during periods of financial distress. Hence, our results highlight the importance of accounting for the funding effects for the overall evaluation of the policy for standardization.

The overall market liquidity effect can be decomposed into two components: the upfront funding effect and other effects arising from the policy change such as the benefits of standardization. For example, it is believed that the standardization from the CDS Big Bang helps to improve market liquidity by eliminating offsetting trades and facilitating same day matching and central clearing. One can estimate the two components by removing the time-fixed effects in our main regression in Table 2. The upfront funding effect is captured by the coefficient of $F \times BB$, and other effects are captured by the coefficient of BB. The estimates based on a long sample are likely to be contaminated by confounding effects, making inference difficult. To minimize confounding effects, we focus on short time windows around the CDS Big Bang and the regression results are reported in Table 12.

[24] See, for example, Markit technical note, *The CDS Big Bang: Understanding the Changes to the Global CDS Contract and North American Conventions*, March 13, 2009.

In the first column, the regression is based on the sample from 3 months before the CDS Big Bang to 3 months after. The estimate of the coefficient of BB is -0.62 (t=3.17). This is consistent with notion that the standardization from the CDS Big Bang improves market liquidity. Moreover, as in our earlier regressions, the coefficient of $F \times BB$ is significantly positive, suggesting that the upfront funding cost decreases market liquidity. Similarly, the regression in the third column, which is based on the sample from 6 months before the CDS Big Bang to 6 months after, also shows that the upfront funding effect decreases market liquidity but other effects improve market liquidity.

Hence, the overall market liquidity effect from the CDS Big Bang is the tradeoff between two opposite effects, and can be estimated by removing the interaction term. The regression in the second column is based on the sample from 3 months before to 3 months after the CDS Big Bang. The coefficient of BB is 0.34 (t=2.08), suggesting that the upfront funding cost effect dominates. However, in the regression in the fourth column, which is based on the sample from 6 months before to 6 months after the CDS Big Bang, the coefficient is -0.72 (t=4.78), suggesting that other effects dominate. Our evidence on the overall effect is mixed. However, what is clear is that the overall effect is determined by the tradeoff between two opposite forces. Specifically, there is a tradeoff between standardization and upfront payments: when fewer coupon rates are allowed, CDS contracts are more standardized but the upfront payments are larger. Interestingly, as noted in Section 4, more standard coupons are adopted for European CDS contracts after the CDS Small Bang. Apparently, according to a Markit technical report, the motivation for this choice of less standardization is to reduce the size of upfront fees.[25]

Finally, our analysis offers some evidence that central clearing can help to partially alleviate the funding cost effect, suggesting the importance of implementing central clearing after the standardization of CDS contracts (i.e., the CDS Big Bang for North American contracts and the CDS Small Bang for European contracts).

[25] Markit technical report, "*CDS Small Bang: Understanding the Global Contract and European Convention Changes*," July 20, 2009.

8 Conclusion

As a step towards understanding the overall effects of the CDS Big Bang on the market, we exploit this historical event to provide economic insights on the effects of funding liquidity. We find that the upfront funding cost induced by the CDS Big Bang increases the CDS bid-ask spread. This effect is stronger for CDSs with smaller or riskier reference entities. The upfront funding cost also increases the absolute value of the CDS-bond basis, especially when basis arbitrageurs are the payers, rather than receivers, of the upfront fees. Our evidence also suggests that central clearing can partially address this funding issue, highlighting the importance of implementing central clearing after standardizing CDS coupons.

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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 1, 2004 to September 30, 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 765 North American companies from April 1, 2010 to October 19, 2016. *Bid-ask spread* is the difference between bid and ask quotes on CDS spreads, denominated in bps. *CDS-bond basis* is the CDS spread minus the bond yield spread of the reference entity, in bps. *ABS(basis)* is the absolute value of *CDS-bond basis*. *CDS volatility (level)* is the two-week rolling standard deviation of CDS spreads. *CDS volatility (change)* is the two-week rolling standard deviation of changes in CDS spreads. *S* is the midpoint of bid and ask quotes of CDS spreads, in bps. *DIS* is defined in equation (1). *LOIS* is the 3-month Libor rate minus the 3-month Overnight Indexed Swap rate, denoted in percentage, and is from Datastream. *VIX* is the daily close value of the CBOE volatility index expressed in percentage, and is from Datastream. We use VIX' to denote the orthogonalized VIX; the residual from regressing VIX on LOIS. *Fee* is the size of the upfront payment, expressed in percentage of the notional value. *Leverage* is the ratio of total liability to total asset. *Stock volatility* is the two-week rolling standard deviation of stock returns. *Log(stock volume)* is the logarithm of the daily stock trading volume, in number of shares, of the reference entity. *Stock bid-ask spread* is the ask price minus the bid price divided by the midpoint of the bid and ask prices of the stock price of the reference entity, denoted in bps. Both *Stock volume* and *Stock bid-ask spread* are from CRSP. *Log(bond volume)* is the logarithm of the daily trading volume (denominated in dollars in face value) of the reference entity's bonds, according to TRACE. *Log(bond Amihud)* is the logarithm of the Amihud (2002) measure calculated for the reference entity's bonds.

Panel A: CMA sample (January 1, 2004 to September 30, 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 (level)	633,977	6.74	12.39	0.17	2.85	52.36
CDS volatility (change)	633,868	4.88	9.58	0.21	2.36	33.39
S	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
LOIS	633,975	0.32	0.45	0.05	0.11	2.53
VIX	633,977	20.44	10.54	10.23	17.18	63.92
Leverage	579,937	0.67	0.18	0.32	0.66	1.12
Stock volatility	543,649	0.02	0.02	0.00	0.02	0.08
Log(stock volume)	541,845	14.70	1.40	10.64	14.70	17.82
Stock bid-ask spread	542,578	9.97	22.55	0.00	5.43	79.09
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 Oct 19, 2016)

Variable	N	Mean	Std Dev	1st Pctl	50th Pctl	99th Pctl
Bid-ask spread	659,618	12.39	9.36	4.00	10.00	47.17
CDS-bond basis	360,729	-17.75	61.58	-226.73	-13.92	154.09
ABS(basis)	360,729	41.09	49.18	0.45	26.84	241.05
CDS volatility (level)	659,618	5.09	8.97	0.09	2.17	40.22
CDS volatility (change)	658,904	3.29	5.61	0.08	1.50	24.03
S	659,618	154.52	145.48	15.33	101.99	675.73
Fee	659,618	4.07	4.15	0.06	2.76	19.08
LOIS	659,618	0.20	0.09	0.09	0.16	0.49
VIX	657,810	18.09	6.00	11.36	16.37	39.76
Leverage	422,882	0.68	0.18	0.36	0.65	1.29
Stock volatility	425,902	0.02	0.01	0.00	0.01	0.05
Log(stock volume)	425,382	14.71	1.41	9.62	14.78	17.60
Stock bid-ask spread	425,904	4.27	8.51	0.54	2.68	25.27
Log(bond volume)	416,762	14.90	2.16	9.39	15.29	18.83
Log(bond Amihud)	407,582	-15.61	1.71	-21.39	-15.28	-12.52

Table 2. The Effects of the Upfront Funding Cost

Panel A reports the effects of the upfront funding cost *F*, which is defined in (2), on *Bid-ask spread* based on the CMA sample (January 1, 2004 to September 30, 2010). The dependent variable is *Bid-ask spread*. *BB* is a dummy variable that is 1 if the date is later than April 8, 2009, and 0 otherwise. All other variables are defined in Table 1. Interaction terms between *BB* and control variables are not reported in the table. Panel B reports results from placebo tests. Columns (1) and (2) are based on regressions with fictitious dates for the CDS Big Bang, October 8, 2008 and October 8, 2009, respectively, while column (3) is based on the actual date. In both panels, firm-fixed effects and monthly time-fixed effects are included in all regressions. 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: Upfront funding cost and market liquidity

	(1) Pre-BB sample	(2) Post-BB sample	(3) Overall sample
F	0.59***	2.89***	0.62***
	(5.46)	(7.92)	(5.90)
F × *BB*			2.36***
			(6.08)
BB			-2.15
			(-1.58)
S	0.03***	0.03***	0.03***
	(29.16)	(20.29)	(29.90)
Leverage	-2.71**	0.19	-1.96**
	(-2.42)	(0.06)	(-2.13)
Stock volatility	15.82***	23.54***	17.30***
	(4.41)	(5.21)	(4.81)
Log(stock volume)	0.08	0.04	0.02
	(1.44)	(0.61)	(0.35)
Log(bond volume)	-0.02*	-0.03**	-0.02*
	(-1.91)	(-2.14)	(-1.76)
Log(bond Amihud)	0.01	-0.04***	0.01
	(0.95)	(-2.70)	(0.93)
Stock bid-ask spread	0.00*	0.00	0.00
	(1.74)	(0.28)	(1.40)
LOIS	0.47***	0.55	0.45***
	(3.17)	(1.42)	(3.10)
VIX'	0.01	-0.00	0.01
	(1.49)	(-0.73)	(1.60)
Observations	252,449	102,221	354,670
R-squared	0.675	0.572	0.684
Number of firms	450	387	459

Panel B: Placebo tests

	(1)	(2)	(3)
	Placebo test 1	Placebo test 2	Baseline test
Event date	10/08/2008	10/08/2009	04/08/2009
Sample period	4/8/2008–4/7/2009	4/8/2009–4/7/2010	10/8/2008–10/7/2009
F	0.70***	2.56***	0.26***
	(3.66)	(7.31)	(2.96)
F × BB	-0.31	0.32	1.86***
	(-1.49)	(0.16)	(6.95)
BB	1.30***	-0.72***	-0.65***
	(2.99)	(-4.23)	(-3.09)
S	0.03***	0.03***	0.03***
	(24.23)	(25.53)	(21.65)
Leverage	-6.59***	0.56	-0.30
	(-3.19)	(0.16)	(-0.12)
Stock volatility	7.12**	21.22***	1.34
	(2.22)	(4.46)	(0.46)
Log(stock volume)	0.05	0.11	0.26***
	(0.61)	(1.52)	(2.80)
Log(bond volume)	-0.01	-0.02*	-0.03
	(-0.88)	(-1.70)	(-1.57)
Log(bond Amihud)	0.02	-0.02*	-0.01
	(1.18)	(-1.66)	(-0.72)
Stock bid-ask spread	0.00***	0.00	-0.00
	(3.41)	(0.84)	(-0.34)
LOIS	0.53***	-0.42	-0.20
	(3.33)	(-0.89)	(-0.96)
VIX'	-0.02***	-0.06***	-0.04***
	(-4.32)	(-8.09)	(-6.90)
Observations	54,284	66,767	57,727
R-squared	0.695	0.604	0.514
Number of firms	376	375	369

Table 3. North American vs. European firms

This table reports the effects of the upfront funding cost *F*, which is defined in (2), on *Bid-ask spread* using a combined sample of CDSs on North American and European firms. The North American sample is from our CMA sample, and the European Sample is from Datastream. The dependent variable is *Bid-ask spread*. BB is a dummy variable that is 1 if the date is later than April 8, 2009, and 0 otherwise. *NA* is a dummy variable, which is equal to 1 if an observation is for a North American firm, and 0 otherwise. *Euro Libor-OIS spread* is the spread between 3 month Euro Libor rate and 3 month Euro OIS rate. *VSTOXX* is EURO STOXX 50 volatility index. Column (1) is based on the actual date for the CDS Big Bang, while columns (2) and (3) are based on two fictitious dates for the event, 2/8/2009 and 8/20/2009, respectively. All other variables are defined in Table 1. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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.

	(1)	(2)	(3)
	Baseline test	Placebo test 1	Placebo test 2
Event date	04/08/2009	02/08/2009	08/20/2009
Sample period	1/25/2009–6/19/2009	12/8/2008–4/7/2009	6/20/2009–10/20/2009
F	0.78***	0.94***	2.57***
	(3.14)	(4.26)	(4.08)
F × BB	0.45	-0.20	-0.43
	(0.92)	(-0.44)	(-0.42)
F × BB × NA	1.66***	0.05	0.61
	(2.61)	(0.10)	(0.52)
BB × NA	0.27	2.10***	1.17***
	(0.97)	(6.81)	(4.56)
BB	-0.30	-1.23***	-0.74***
	(-1.23)	(-4.84)	(-3.20)
S	0.02***	0.03***	0.02***
	(14.54)	(15.62)	(7.72)
VSTOXX	-0.03***	-0.10***	-0.02
	(-2.97)	(-9.96)	(-1.10)
VIX’	0.01	-0.02***	0.01
	(1.63)	(-2.65)	(0.32)
Euro Libor-OIS spread	-0.69	4.23***	-1.61**
	(-1.60)	(8.48)	(-2.01)
LOIS	4.43***	0.24	4.55***
	(9.06)	(1.03)	(4.14)
Observations	58,043	43,883	54,770
R-squared	0.246	0.246	0.229
Number of firms	731	672	753

Table 4. Cross-sectional variation

This table reports the cross-sectional variation of the effects of the upfront funding cost *F*, which is defined in (2), on *Bid-ask spread* based on the CMA sample (January 1, 2004 to September 30, 2010). The dependent variable is *Bid-ask spread*. *BB* is a dummy variable that is 1 if the date is later than April 8, 2009, and 0 otherwise. *Small* is a dummy variable that is 1 if the reference entity's asset is below the median, and 0 otherwise. *Speculative* is a dummy variable that is 1 if the reference entity's credit rating is below BBB, and 0 otherwise. All other variables are defined in Tables 1. The interaction terms between *BB* and control variables are not reported in the table. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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.

	(1) Firm size	(2) Rating
F	0.72***	0.77***
	(4.87)	(6.59)
F × *BB*	1.64***	1.91***
	(3.44)	(4.58)
BB	-1.30	-1.98
	(-0.90)	(-1.43)
F × *BB* × *Small*	1.34***	
	(2.63)	
F × *BB* × *Speculative*		1.33**
		(2.02)
S	0.03***	0.03***
	(30.18)	(29.85)
Leverage	-1.92**	-1.98**
	(-2.08)	(-2.13)
Stock volatility	16.61***	16.76***
	(4.58)	(4.65)
Log(stock volume)	0.03	0.01
	(0.50)	(0.26)
Log(bond volume)	-0.02	-0.02*
	(-1.61)	(-1.80)
Log(bond Amihud)	0.01	0.01
	(0.97)	(0.70)
Stock bid-ask spread	0.00	0.00
	(1.38)	(1.48)
LOIS	0.44***	0.43***
	(3.03)	(2.96)
VIX'	0.01	0.01
	(1.63)	(1.46)
Observations	354,670	354,670
R-squared	0.685	0.685
Number of firms	459	459

Table 5. Contracts with Different Maturities

This table reports the effects of the upfront funding cost *F*, which is defined in (2), on *Bid-ask spread* for CDS contracts with different maturities based on the CMA sample (January 1, 2004 to September 30, 2010). The dependent variable is *Bid-ask spread*. *BB* is a dummy variable that is 1 if the date is later than April 8, 2009, and 0 otherwise. All other variables are defined in Tables 1. The interaction terms between *BB* and control variables are not reported in the table. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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.

	(1)	(2)	(3)	(4)
Maturity	1 Year	3 Year	7 Year	10 Year
F	3.66***	-0.80	1.63***	2.25***
	(3.72)	(-1.36)	(4.94)	(5.47)
F × *BB*	-2.96	2.67*	3.92***	4.16**
	(-0.54)	(1.84)	(2.82)	(2.16)
BB	34.78	6.77*	-3.37	-3.80
	(1.58)	(1.74)	(-1.44)	(-1.41)
S	0.07***	0.04***	0.03***	0.02***
	(13.11)	(17.02)	(18.29)	(16.99)
Leverage	8.62	-0.11	1.15	1.22
	(1.21)	(-0.07)	(0.99)	(0.81)
Stock volatility	39.66*	28.63***	30.58***	33.16***
	(1.89)	(4.04)	(5.46)	(5.25)
Log(stock volume)	0.63	-0.00	-0.14*	-0.18*
	(0.99)	(-0.03)	(-1.76)	(-1.77)
Log(bond volume)	0.34**	0.01	-0.03*	-0.01
	(2.66)	(0.50)	(-1.77)	(-0.73)
Log(bond Amihud)	0.04	0.00	-0.02*	-0.02
	(0.27)	(0.25)	(-1.81)	(-1.04)
Stock bid-ask spread	-0.01	0.00	0.00	0.00
	(-0.79)	(1.24)	(0.88)	(0.35)
LOIS	0.01	1.15	0.07	-1.29**
	(0.00)	(1.11)	(0.13)	(-2.13)
VIX'	-0.05	-0.03**	0.01	0.01
	(-0.48)	(-2.01)	(0.63)	(0.75)
Observations	10,346	86,402	103,535	77,649
R-squared	0.692	0.688	0.689	0.620
Number of firms	34	274	300	261

Table 6. CDS Small Bang

This table reports the effects of the upfront funding cost *F*, which is defined in Section 4.6, on *Bid-ask spread* using a sample of CDS on European firms from April 1, 2004 to September 30, 2010. The dependent variable is *Bid-ask spread*. *SB* is a dummy variable which is equal to 1 if date is later than June 20, 2009, and 0 otherwise. *Euro Libor-OIS spread* is the spread between 3 month Euro Libor rate and 3 month Euro OIS rate. *VSTOXX* is EURO STOXX 50 volatility index. All other variables are defined in Table 1. Interaction terms between *SB* and control variables are not reported in the table. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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.

	(1)	(2)
F	1.56***	1.18***
	(5.24)	(3.86)
F × *SB*	3.32***	3.39***
	(2.90)	(3.18)
SB	0.23	-5.44***
	(0.50)	(-4.02)
S	0.04***	0.05***
	(23.19)	(24.53)
Stock bid-ask spread		15.30***
		(10.24)
Log(Stock volume)		0.11
		(1.22)
VSTOXX	0.04***	0.03***
	(8.82)	(6.83)
Euro Libor-OIS spread	0.80***	0.95***
	(3.81)	(4.32)
Observations	420,775	259,294
R-squared	0.683	0.759
Number of firms	401	286

Table 7. Deutsche Bank's Exit from the CDS Market

This table reports estimates of the difference-in-difference regressions using the event of Deutsche Bank's exit from the single-name CDS market based on the Markit sample (April 1, 2010 to Oct 19, 2016). The dependent variable is the *Bid-ask spread*. *DB* is a dummy variable that is 1 if the date is after Deutsche Bank exits the single-name CDS market, and 0 otherwise. The exit date is chosen to be September 15, 2014, December 15, 2014, and March 15, 2014, in columns 1 through 3, respectively. All other variables are defined in Table 1. Interaction terms between *DB* and control variables are not reported in the table. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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.

	(1)	(2)	(3)
Exit date	9/15/2014	12/15/2014	3/15/2015
FC	0.54***	0.54***	0.56***
	(4.93)	(4.96)	(5.16)
FC × *DB*	0.59**	0.58**	0.51**
	(2.41)	(2.37)	(2.18)
DB	5.60**	6.35**	6.67**
	(1.99)	(2.01)	(1.97)
S	0.04***	0.04***	0.04***
	(33.88)	(34.35)	(34.40)
Leverage	-2.16	-2.20	-2.36*
	(-1.56)	(-1.61)	(-1.79)
Stock volatility	4.60	6.88	8.85*
	(0.87)	(1.36)	(1.79)
Log(stock volume)	0.29***	0.30***	0.29***
	(3.50)	(3.72)	(3.72)
Log(bond volume)	-0.00	-0.01	-0.01
	(-0.25)	(-0.38)	(-0.47)
Log(bond Amihud)	0.03*	0.03**	0.04**
	(1.82)	(2.01)	(2.26)
Stock bid-ask spread	-0.03	-0.03	-0.03
	(-1.04)	(-0.94)	(-0.95)
LOIS	3.37***	3.43***	3.41***
	(5.56)	(5.71)	(5.74)
VIX'	0.02***	0.02***	0.02***
	(5.63)	(6.08)	(5.91)
Observations	333,401	333,401	333,401
R-squared	0.646	0.645	0.643
Number of firms	361	361	361

Table 8. Central clearing

This table reports the effects of the upfront funding cost *FC* on *Bid-ask spread* based on the Markit sample (from April 1, 2010 to Oct 19, 2016). The dependent variable is the *Bid-ask spread*. $Clear_{i,t}$ is a dummy variable, which is equal to 1 if a CDS contract *i* is centrally cleared at date *t*, 0 otherwise. All other variables are defined in Table 1. Interaction terms between *DB* and control variables are not reported in the table. The first column is based on the overall sample. The second column is based on the CDS contracts that initiated central clearing during the sample period. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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.

	(1) Overall sample	(2) Cleared sample
FC	0.66***	0.83***
	(4.82)	(4.41)
FC × *Clear*	-0.43**	-0.57**
	(-2.16)	(-2.34)
Clear	-0.40	0.49*
	(-1.61)	(1.97)
S	0.04***	0.04***
	(34.00)	(26.96)
Leverage	-2.47*	-2.68*
	(-1.81)	(-1.69)
Stock volatility	6.93	4.25
	(1.39)	(0.67)
Log(stock volume)	0.28***	0.23
	(3.60)	(1.50)
Log(bond volume)	-0.00	-0.04*
	(-0.12)	(-1.77)
Log(bond Amihud)	0.04**	-0.00
	(2.20)	(-0.03)
Stock bid-ask spread	-0.03	-0.06
	(-0.89)	(-1.32)
LOIS	3.40***	3.57***
	(5.74)	(3.81)
VIX'	0.03***	0.04***
	(6.35)	(5.39)
DB	5.89*	7.56
	(1.88)	(1.60)
FC × *DB*	0.71***	0.73*
	(2.94)	(1.89)
Observations	333,401	142,690
R-squared	0.647	0.673
Number of firms	361	108

Table 9. CDS-Bond Basis and CDS Volatility

This table reports the effects of the upfront funding cost *F*, which is defined in (2), on the absolute value of CDS-bond basis and CDS volatility, based on the CMA sample (January 1, 2004 to September 30, 2010). *BB* is a dummy variable that is 1 if the date is later than April 8, 2009, and 0 otherwise. The dependent variable is *ABS(basis)* in Panel A, and *CDS volatility (level)* and *CDS volatility (change)* in Panel B. *Pay* is defined in (3) and (4). All other variables are defined in Table 1. The interaction terms between control variables and *BB* and *Pay* are not reported in the table. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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 *ABS(basis)*

	(1)	(2)
F	-6.38*	-8.22**
	(-1.76)	(-2.20)
F × *BB*	37.79***	26.92***
	(4.10)	(2.59)
BB	8.37	26.86
	(0.27)	(0.77)
F × *BB* × *Pay*		21.71*
		(1.94)
Pay		-16.96
		(-1.01)
BB × *Pay*		-63.24*
		(-1.66)
F × *Pay*		2.81
		(0.79)
S	0.05**	0.04**
	(2.26)	(2.05)
Leverage	26.28	21.24
	(1.14)	(0.93)
Stock volatility	123.79	215.97**
	(1.34)	(2.50)
Log(stock volume)	-1.02	-1.80
	(-0.71)	(-1.15)
Log(bond volume)	-1.28***	-1.53***
	(-3.61)	(-3.50)
Log(bond Amihud)	1.01***	0.97***
	(3.29)	(2.90)
Stock bid-ask spread	0.14***	0.11**
	(3.17)	(2.50)
LOIS	21.60***	23.20***
	(5.96)	(5.89)
VIX'	0.66***	0.34**
	(7.22)	(2.06)
Observations	234,692	234,692
R-squared	0.476	0.481
Number of firms	405	405

Panel B: Dependent variable *CDS volatility*

	(1) *CDS volatility (level)*	(2) *CDS volatility (change)*
F	0.93***	0.30***
	(5.74)	(3.18)
F × BB	2.92***	2.12***
	(4.31)	(5.77)
BB	-1.83	-0.47
	(-1.32)	(-0.56)
S	0.04***	0.03***
	(39.36)	(39.92)
Leverage	-1.74**	-1.01*
	(-1.99)	(-1.77)
Stock volatility	108.85***	84.57***
	(14.78)	(17.44)
Log(stock volume)	0.60***	0.24***
	(7.97)	(4.97)
Log(bond volume)	0.13***	0.07***
	(8.69)	(7.69)
Log(bond Amihud)	0.03***	0.02**
	(2.90)	(2.22)
Stock bid-ask spread	0.00	0.00
	(1.50)	(0.77)
LOIS	1.66***	1.22***
	(5.87)	(7.31)
VIX'	0.03***	0.03***
	(3.13)	(6.33)
Observations	354,670	354,651
R-squared	0.536	0.596
Number of firms	459	459

Table 10. Robustness Analysis: the ISDA CDS Standard Model

This table reports estimates of the regressions based on estimated upfront funding cost. *EFC* is the estimated upfront funding cost based on the upfront fees that are converted from CDS spreads using the ISDA CDS standard model. The dependent variable is *Bid-ask spread, ABS(basis), CDS volatility (level)* and *CDS volatility (change)*, in columns 1 through 4, respectively. *BB* is a dummy variable that is 1 if the date is later than April 8, 2009, and 0 otherwise. All other variables are defined in Table 1. The interaction terms between control variables and *BB* are not reported in the table. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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) *Abs(basis)*	(3) *CDS volatility (level)*	(3) *CDS volatility (change)*
EFC	0.16***	-1.33	0.25***	0.09***
	(6.15)	(-1.49)	(6.36)	(3.73)
EFC × *BB*	0.52***	9.89***	0.75***	0.51***
	(5.57)	(4.25)	(4.79)	(5.80)
BB	-2.07	-20.93	-3.02**	-0.80
	(-1.59)	(-0.68)	(-2.14)	(-0.96)
LOIS	0.39***	17.61***	1.15***	1.07***
	(2.74)	(4.87)	(4.31)	(6.67)
S	0.03***	0.04**	0.04***	0.03***
	(30.16)	(2.00)	(39.49)	(40.05)
Leverage	-1.89**	20.28	-1.59*	-0.99*
	(-2.05)	(0.87)	(-1.88)	(-1.77)
Stock volatility	17.27***	218.92**	115.70***	86.97***
	(5.32)	(2.49)	(18.72)	(21.29)
Log(stock volume)	0.02	-1.23	0.60***	0.24***
	(0.37)	(-0.85)	(7.92)	(4.94)
Log(bond volume)	-0.02*	-1.20***	0.13***	0.07***
	(-1.81)	(-3.38)	(8.68)	(7.64)
Log(bond Amihud)	0.01	1.06***	0.03***	0.02**
	(0.84)	(3.54)	(2.83)	(2.20)
Stock bid-ask spread	0.00	0.14***	0.00	0.00
	(1.43)	(3.12)	(1.53)	(0.73)
VIX’	0.00	0.45***	-0.00	0.03***
	(1.12)	(5.68)	(-0.36)	(6.12)
Observations	354,670	234,692	354,670	354,651
R-squared	0.684	0.474	0.536	0.596
Number of firms	459	405	459	459

Table 11. Robustness Analysis: Bond bid-ask spread

This table reports estimates of the regressions based on estimated upfront funding cost *F*, which is defined in (2). The dependent variable is *Bid-ask spread*, *ABS(basis)*, *CDS volatility (level)* and *CDS volatility (change)*, in columns 1 through 4, respectively. *BB* is a dummy variable that is 1 if the date is later than April 8, 2009, and 0 otherwise. *Bond bid-ask spread* is the ask price minus the bid price of the bond price of the reference entity, denoted in dollar. All other variables are defined in Table 1 in the paper. The interaction terms between control variables and *BB* are not reported in the table. Firm-fixed effects and monthly time-fixed effects are included in all regressions. 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) *Abs(basis)*	(3) *CDS volatility (level)*	(4) *CDS volatility (change)*
F	0.73***	-6.97*	1.00***	0.33***
	(5.99)	(-1.74)	(5.19)	(2.84)
F X BB	2.26***	46.04***	2.38***	1.97***
	(4.97)	(4.16)	(2.90)	(4.53)
BB	-2.05	67.76**	-2.02	-1.18
	(-1.53)	(2.33)	(-1.32)	(-1.35)
S	0.03***	0.08***	0.04***	0.03***
	(26.23)	(3.14)	(33.69)	(32.62)
Leverage	-1.38	6.33	-1.67*	-0.96
	(-1.53)	(0.27)	(-1.68)	(-1.53)
Stock volatility	16.52***	44.31	100.10***	78.29***
	(4.84)	(0.47)	(13.58)	(16.56)
Log(stock volume)	-0.03	0.64	0.65***	0.27***
	(-0.52)	(0.47)	(7.88)	(5.33)
Log(bond volume)	-0.02	-1.58***	0.13***	0.07***
	(-1.34)	(-4.71)	(7.96)	(7.04)
Bond bid-ask spread	-0.40**	-13.13***	0.56**	0.33*
	(-2.24)	(-2.60)	(2.11)	(1.75)
Stock bid-ask spread	0.00**	0.11***	0.00	0.00
	(2.32)	(2.98)	(0.14)	(0.08)
Libor-OIS spread	0.49***	21.77***	1.52***	1.19***
	(3.00)	(5.95)	(5.05)	(6.76)
VIX	0.01***	0.64***	0.03***	0.03***
	(3.04)	(6.57)	(3.16)	(5.34)
Observations	268,879	197,130	268,879	268,867
R-squared	0.674	0.470	0.528	0.591
Number of firms	372	344	372	372

Table 12. Overall effect of the CDS Big Bang on bid-ask spreads

This table reports the overall effects of the Big Bang on bid-ask spreads based on subsamples of the CMA sample. The sample period for columns (1) and (2) is from 3 months before to 3 months after the CDS Big Bang. The sample period for columns (3) and (4) is from 6 months before to 6 months after the CDS Big Bang. The dependent variable is *Bid-ask spread*. The upfront funding cost *F* is defined in (2). *BB* is a dummy variable that is 1 if the date is later than April 8, 2009, and 0 otherwise. All other variables are defined in Table 1. In columns (1) and (3), the interaction terms between *BB* and control variables are not reported in the table. Firm-fixed effects are included in all regressions. 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.

	(1) 3 Months	(2) 3 Months	(3) 6 Months	(4) 6 Months
BB	-0.62***	0.34**	-2.14***	-0.72***
	(-3.17)	(2.08)	(-11.60)	(-4.78)
F × BB	1.35***		2.93***	
	(4.82)		(11.43)	
F	0.17		0.17*	
	(0.87)		(1.95)	
CDS spread	0.02***	0.02***	0.03***	0.03***
	(14.74)	(15.02)	(24.02)	(26.31)
Leverage	0.07	0.45	1.79	3.16
	(0.01)	(0.10)	(0.70)	(1.17)
Returns	0.78	2.01	0.70	3.27
	(0.19)	(0.47)	(0.24)	(1.10)
Log(stock volume)	0.36***	0.40***	0.26***	0.41***
	(3.36)	(3.55)	(2.70)	(3.94)
Log(bond volume)	0.01	0.02	-0.01	0.00
	(0.69)	(0.76)	(-0.80)	(0.00)
Log(bond Amihud)	0.01	0.01	0.00	0.02
	(0.64)	(0.69)	(0.34)	(1.35)
Stock bid-ask spread	0.00	-0.00	0.00	0.00
	(0.03)	(-0.31)	(0.50)	(0.11)
Libor-OIS spread	2.01***	3.18***	-0.14	0.30**
	(5.49)	(9.46)	(-1.00)	(2.45)
VIX'	0.01	0.02*	-0.03***	-0.02***
	(1.37)	(1.89)	(-5.04)	(-3.62)
Observations	29,079	29,079	57,727	57,727
R-squared	0.344	0.336	0.499	0.479
Number of firms	344	344	369	369

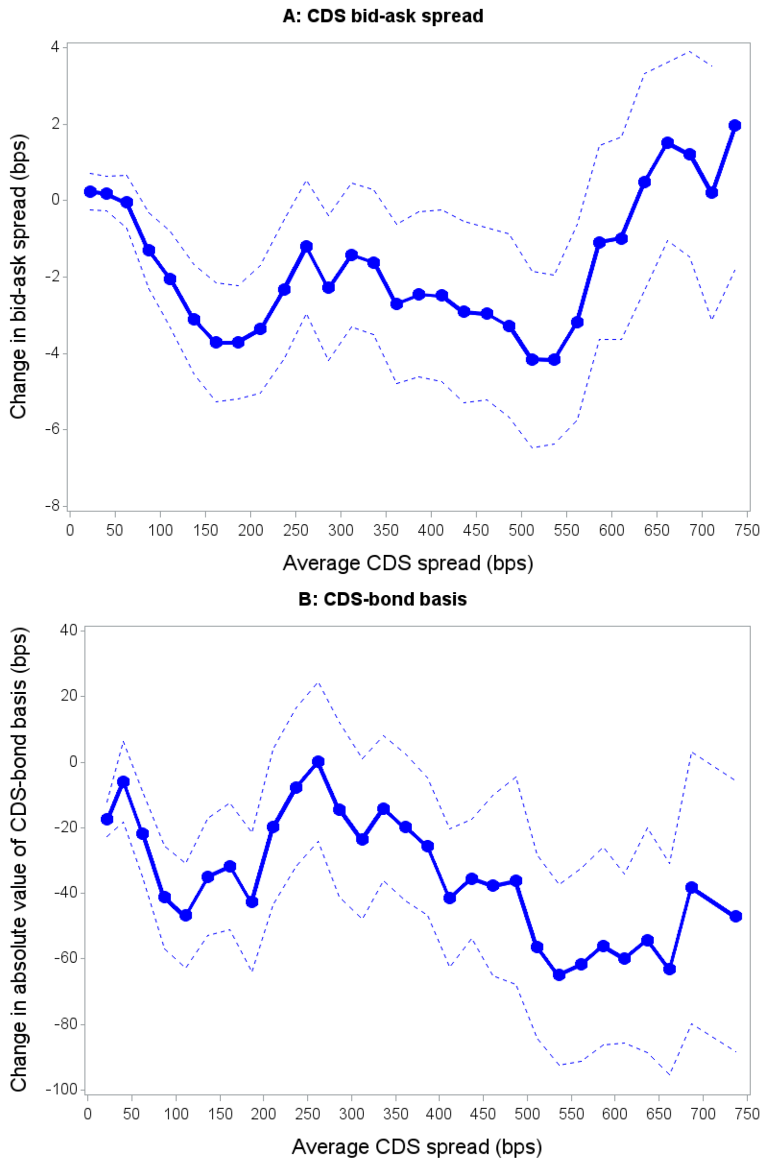

Figure 1: Change in bid-ask spread and CDS-bond basis around the CDS Big Bang

This figure is based on our CMA sample from April 8, 2008 to April 8, 2010. We first normalize our main variables based on a firm-fixed-effect model. Specifically, in Panel A, we run a panel regression $Y_{i,t} = u_i + \epsilon_{i,t}$, where $Y_{i,t}$ is the bid-ask spread for the CDS contract i at date t, u_i is a constant that captures the firm-fixed effects, and $\epsilon_{i,t}$ is the residual. Then, we divide CDS contracts into 30 groups by CDS spread. For each group, we compute the bid-ask spread change as the post-Big-Bang average residual minus the pre-Big-Bang average. Panel A plots the bid-ask spread changes against the average CDS spreads. The figure in Panel B is constructed similarly, with the absolute value of CDS-bond basis replacing the bid-ask spread. Dotted lines are 2-standard deviation confidence intervals.