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Andrada Bilan, Yalin Gündüz

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CDS Market Structure and Bond Spreads*

Andrada Bilan
Swiss National Bank

Yalin Gündüz
Deutsche Bundesbank

Abstract

We study the response of bond spreads to a liquidity supply shock in the credit default swap (CDS) market. Our identification strategy exploits the exogenous exit of a large dealer from the single-name CDS market as well as granular data on CDS transactions and bond portfolio holdings of German investors. Following the shock, CDS market liquidity declines and bond spreads increase, especially for the reference firms intermediated by the dealer. Individual portfolio data indicate hedging motives as a mechanism: as CDS insurance on their bond holdings becomes costlier, investors offload the bonds. Our results therefore show that frictions in derivative markets affect the underlying securities, which can raise firms' cost of capital.

Keywords: Credit default swaps, dealer markets, bonds markets, credit risk, Depository Trust and Clearing Corporation (DTCC).

JEL classification: G11, G18, G20, G28

*EMail: andrada.bilan@snb.ch, yalin.gunduz@bundesbank.de. We would like to thank Claire Celerier, Pierre Collin-Dufresne, Daniel Foos (editor), Miguel Ferreira, Itay Goldstein, Emanuel Mönch, Steven Ongena, Emil Siriwardane and Alexander Wagner for their insightful suggestions. We also greatly appreciate comments from participants at the Deutsche Bundesbank Research Seminar (Frankfurt, 2019) and the EFA Conference (August 2020).

1 Introduction

Does the credit default swap (CDS) market benefit bond market liquidity? This question has repeatedly raised interest in both academic and policy circles. In theory, CDS contracts serve to complete markets by offering new hedging opportunities to bond holders. Therefore, both liquidity and demand should increase in bond markets, allowing firms better access to debt.[1] Others argue, however, that the CDS market draws investors away from the bond market because it is more liquid and more homogeneous.[2] If CDSs and bonds are indeed substitutes, then bond market liquidity will decrease. Our paper uses a quasi-natural experiment to assess the role of CDS markets for bond markets, along with the implications for firms' cost of capital.

Our empirical laboratory is the universe of CDS transactions conducted by investors headquartered in Germany. We study the dynamics of the CDS market following the exogenous and complete closure of the single-name CDS trading desk at a large dealer bank. The closure was part of a strategy shift aimed at increasing regulatory capital for the global banking group.[3] We then measure whether there are spillover effects to bond markets from this change in the structure of the CDS market. To identify the mechanism through which these effects are transmitted across markets, we use a second, granular dataset: monthly portfolios of all German banks, at asset level. With the two datasets, we can investigate how investors allocate funds between bonds and CDSs. Access to both CDS transactions and portfolio holdings is facilitated for research by the Deutsche Bundesbank.

Data coverage allows us to exploit information on the global exposure of the withdrawing dealer to underlying reference entities. Our main treatment measure is based on the (ex ante) share of the dealer in CDS trade intermediation, at reference entity level. The research design is difference-in-differences. We compare the effects on prices and volumes of CDSs and bonds of reference entities intensely intermediated by the dealer with a control group of reference entities with lower dealer intermediation. While a growing number of papers have used CDS transaction data (Siriwardane, 2019; Eisfeldt, Herskovic, Rajan, and Siriwardane, 2018), we are the first to exploit a complete dealer desk closure in order to measure the effects on the bond yields of the underlying reference entities, as well as on the portfolios of retail investors.

The results reveal that, for the highly intermediated entities, the liquidity of the CDS market decreases in the aftermath of the dealer closure. Buyside investors

[1] These arguments are explained, for instance, in Oehmke and Zawadowski (2016) and Saretto and Tookes (2013).

[2] Das, Kalimipalli, and Nayak (2014) find that the advent of CDSs was largely detrimental to the efficiency of bond markets.

[3] Reducing market-making saves capital. Market making requires large inventories of securities to be kept, making it very expensive in terms of leverage and capital requirements. In fact, market making is one of the investment banking activities with the lowest revenue returns on regulatory exposures: as capital requirements increase, the return on inventories decreases.

pay higher transaction costs and trade lower volumes in the aftermath of the exit. Our findings are thus consistent with models of slow-moving capital (Duffie, 2010; Duffie and Strulovici, 2012), which posit that capital does not necessarily flow quickly to market segments with profitable opportunities. Subsequently, we document significant spillover effects to bond markets. On average, bond yields increase slightly for reference firms highly intermediated by the dealer. Yields of higher-risk bonds increase more. Studying the individual portfolios of German non-dealer banks indicates hedging motives as a mechanism: as CDS insurance on their bond holdings becomes costlier, investors offload the bonds.

The first part of the empirical analysis is concerned with the CDS market response to the supply shock triggered by the dealer exit. Do other dealers step in, maintaining the same volumes of trading at existing prices, or does the CDS market move to a new equilibrium, where fewer liquidity providers possibly lead to lower traded volumes and higher prices?[4] To answer this question, we conduct an analysis on volumes and transaction prices.

For the volume analysis, we use the set of CDS transactions and study whether investors trade *less* notional in CDS references with relatively *higher* treatment intensity. The challenge when interpreting the volume results is to disentangle the supply of CDS liquidity from confounding trends at the level of investor demand. It could be that the withdrawal of the dealer coincides with a simultaneous decrease in investor demand for CDSs. We alleviate this concern by including detailed investor fixed effects in our regressions. Moreover, in robustness, we show that the CDS portfolios intermediated by German dealers have similar risk profiles to global dealer portfolios, suggesting that German and non-German dealers cater to similar investor demand.

However, crucial to our analysis is the effect on prices. The relevant price measure is the bid-ask spread that a dealer charges a buyside investor for a CDS contract on top of the "upfront fee", i.e. the cost of credit risk.[5] If the remaining dealers respond to the dealer exit by decreasing volumes and raising prices,[6] then we will observe an increase in dealer spreads, along with lower traded volumes. On the contrary, if the lower volumes are driven by weaker investor demand, dealer spreads could also decrease. Because our data include both the actual traded upfront payments and the corresponding upfront quotes from Markit, we can calculate an estimate of the dealer spreads. We measure the spread on a CDS trade as the discrepancy between the traded and quoted upfront fees *for contracts with the same characteristics traded on the same day.*[7] We then estimate difference-

[4]The CDS market is highly concentrated, with the five largest dealers supplying 75% of the liquidity in the single-names segment(Siriwardane, 2019).

[5]Most CDS contracts trade with standardized notionals, maturities, and fixed coupons. The buyer and the dealer exchange upfront fees at the start of the contract in order to compensate for the discrepancy between the fixed coupon, which reflects the regular protection payment, and the actual price of protection agreed upon at the time of entering the contract.

[6]This effect could be either because the remaining dealers engage in anticompetitive pricing or simply because they are only able to satisfy additional demand at increasing cost, possibly because of limited risk-bearing capacity

[7]Effectively, this means that we study changes in the half bid-ask spreads – calculated as the

in-differences models on these bid-ask spreads in our panel of CDS trades.

In the second part of the analysis, we investigate the response of the bond market to the CDS market shock. We collect all live bonds issued by firms with CDSs traded on them and study how bond yields vary with our measure of treatment intensity. The model employed is a monthly difference-in-differences panel on the logarithm of the yield, with bond and month fixed effects, as well as same-day macro indicators. We also study the interaction between our treatment measure and a linear function of the rating scores in order to see how the estimate varies with the riskiness of the bond. In the last crucial step, we add the detailed investor holdings to strengthen causality and shed light on the mechanism driving the results. We estimate models explaining the growth of holdings at the investor and bond levels. Here, we compare bonds that an investor was ex-ante long or short CDS protection with other bond holdings in the same investor's portfolio.

The estimations using CDS transactions reveal that German banks decrease their CDS traded volumes after the liquidity shock. The decrease is proportional to the dealer's market share: when treatment intensity increases by 10 pp, the same investor decreases CDS exposure to the treated entity by 13 pp more relative to its CDS exposure to the remaining reference entities. We also document an increase in the bid-ask spreads on the upfront CDS payments, confirming that this is indeed a shock to the supply of CDS liquidity. Specifically, the transaction costs on a round-trade CDS contract increase by 0.10 percentage point, which is equivalent to 7.4% of the total upfront fee. To trade standard CDS contracts of €5 million notional and with a five-year maturity, buyers have to pay €5,000 more upfront for transaction costs, on average.

Lastly, we find that the effects spill over to bond yields and bond holdings. A 10 pp increase in treatment intensity raises bond yields by 6 basis points on average. Individual portfolio data indicate hedging motives as a mechanism: as CDS insurance on their bond holdings becomes costlier, German banks offload the bonds, especially if they had previously relied on CDS protection for hedging. The effects are strongest in the riskiest buckets, from lower-medium investment grade to speculative and below. That CDS contracts improve bond market liquidity through the hedging channel has already been proposed by Oehmke and Zawadowski (2016) and Saretto and Tookes (2013). Ours is the first study that provides causal evidence for this channel.[8]

We contribute to the literature in three ways. First, we add to recent studies

difference between the traded bid or ask upfront (depending on the direction of the contract) and the quoted upfront mid. The advantage of using this pricing measure is that it is robust to intra-day changes in publicly available information on the reference entity and also to changes in the composition of contract types across the period of analysis.

[8] Sambalaibat (2018) proposes an additional channel through which the CDS market increases the liquidity of the bond market. In her model, the possibility of trading CDSs attracts additional investors that use both CDS and bond markets to long credit risk, hence generating positive spillovers for bond market liquidity. Czech (2020) provides empirical evidence for this additional channel.

on the *role of CDS markets*. We provide evidence of a positive function of CDS markets in terms of reducing bond spreads and subsequently firms' cost of capital. In this sense, we confirm the descriptive findings in Oehmke and Zawadowski (2016) that suggest that investors use the CDS market for hedging – with CDS and bond volumes increasing proportionately. Gündüz, Ongena, Tumer-Alkan, and Yu (2017) and Saretto and Tookes (2013) also document the positive role of CDSs. Gündüz et al. (2017) show that, following an improvement in liquidity in the European CDS market as a result of the Small Bang protocol, German banks increased their credit exposures to firms. Saretto and Tookes (2013) show that lenders appear more willing to extend credit to firms with traded CDS and that this behaviour is more pronounced in the presence of capital constraints. In their earlier work, Ashcraft and Santos (2009) compared firms with and without CDS trading and found no effect on bond or loan spreads for the average firm. Most of the remaining literature focuses on the harmful effects of CDSs. Subrahmanyam, Tang, and Wang (2014) find that, after the inception of CDS trading, the probabilities of credit rating downgrades or of bankruptcy increase substantially. They argue that this is due to the effect of "empty creditors" or disinterested lenders that retain control rights but not the economic exposures to the underlying firms. In the same spirit, Amiram, Beaver, Landsman, and Zhao (2017) show that the onset of CDS trading on a firm's debt increases the share of loans retained by the loan syndicate lead arrangers in order to reinforce their commitment to monitoring.

Second, we extend previous research on the *structure and externalities of OTC markets*. Biais (1993) provides the workhorse theoretical model to compare opaque and exchange markets. Pagano and Röell (1996), De Frutos and Manzano (2002), Duffie, Gârleanu, and Pedersen (2005), and Yin (2005) use this framework to introduce imperfections due to adverse selection, generalized risk aversion, and search frictions. More recent literature has shown that these characteristics of the OTC markets result in core-periphery networks in which most of the trading is intermediated by a few dealers (Atkeson, Eisfeldt, and Weill, 2015; Babus and Kondor, 2018; Li and Schürhoff, 2019). In this context, it becomes crucial to understand how changes in the number of liquidity suppliers impact the functioning of the OTC market.

Di Maggio, Kermani, and Song (2017) find that, following the collapse of a dealer in bond markets, intermediation chains between buyers and sellers lengthen significantly, resulting in higher costs for clients looking for liquidity. Similarly, Eisfeldt et al. (2018) find that the failure of a CDS dealer with large risk-bearing capacity increases spreads by 40%. Siriwardane (2019) shows that capital fluctuations of large CDS dealers affect the prices of CDSs. Unlike Di Maggio et al. (2017) and Eisfeldt et al. (2018), we study the impact of a liquidity shock driven by a reduction in the number of dealers in the CDS market, how it affects equilibrium traded prices and volumes, as well as its spillover effects. The implications are likely different, since the increase in spreads we document is driven purely by a negative shock to liquidity supply and not by contagion or counterparty risk considerations.

As our third contribution, we add to the recent literature that has studied the *effects of regulation on market making*. Duffie (2012) argues that regulatory provisions that penalise risk taking in dealer inventories can lead to substantial decreases in the quality and quantity of market making, as well as to the exit of some dealers. This could increase trading costs for investors, reduce the resilience of markets, lower the quality of information revealed through securities prices, and drive up the cost of capital for corporations and governments. A few early papers found that anticipating post-crisis regulations had no negative effect on dealer liquidity (Trebbi and Xiao, 2017; Bessembinder, Jacobsen, Maxwell, and Venkataraman, 2018; Anderson and Stulz, 2017). However, Bao, OHara, and Zhou (2018) show that liquidity provision in US bonds decreased following the implementation of the Volker Rule and, in particular, around bond downgrades. Adrian, Boyarchenko, and Shachar (2017) find that, prior to the financial crisis, bonds traded by more levered institutions and institutions with investment bank-like characteristics were more liquid, and that this relationship reverses after the financial crisis. We add to this literature by showing that, when regulatory provisions affect the liquidity of derivative markets, there can be spillovers to underlying securities as well as real effects.

The remainder of the paper is organized as follows. Section 2 introduces the design of our research, first by discussing the institutional and theoretical aspects of the CDS market. Section 3 explains our CDS and bond datasets. Section 4 analyses the response of the CDS market to the reduction in the number of dealers, in particular by studying whether the market converges to a new equilibrium. Section 5 turns to the bond market and the analysis of real effects. This section begins with the analysis on bond yields and subsequently it studies whether investors rebalance their bond portfolios in response to the CDS shock. Finally, Section 6 concludes.

2 The CDS Market: The Setting of the Research Background

2.1 Institutional and Theoretical Aspects

A credit default swap is a financial derivative that is used to transfer the credit risk of a certain underlying reference entity. It is typically traded for reasons including hedging, credit risk speculation or arbitrage, and it is in zero net supply by the nature of its construction. The underlying reference entity, whose credit risk is transferred, can be a firm or a sovereign (in which case it is referred to as a "single-name CDS") or an index of securities (a "multi-name CDS"). In a typical CDS contract, a CDS protection buyer purchases credit insurance from a CDS protection seller on a standardized amount with a preset maturity date (at one of the four IMM dates) in exchange for a fixed coupon, generally for 100 or 500 bps. At the transaction date, the buyer and the seller exchange the upfront payment, which is the net present value of the difference between the market coupon and the fixed coupon of the contract. Therefore, all variation in traded CDS prices is contained within the upfront payments.

Even though outstanding CDS notionals have declined since the financial crisis, the product is still highly traded. At the end of December 2013, before the start of our period of interest, there were US$11 trillion worth of single-name CDSs outstanding, and close to US$9 trillion worth of multi-name CDSs.[9] This is almost as much as the outstanding volume of the bond market, which amounted to US$23 trillion at the end of the same year. CDSs are typically traded on the OTC market, which is naturally opaque with high search frictions and this makes them prone to concentrated market structures. Moreover, the costs of operating in an OTC market are high because dealers typically hold large inventories. This implies that the barriers to entry are also high, in particular for smaller firms. Search frictions and barriers to entry can sustain prices that are above competitive levels.

Search frictions are mainly understood as the direct costs investors must incur in order to find a dealer who is willing to trade. In addition, there are also indirect costs stemming from the fact that dealer quotes are fleeting. Buyside investors need to decide on the spot whether to enter the trade at the quoted price a dealer offers them or otherwise they incur the risk of being offered a worse price. This prevents investors from fully researching their outside options. It is through these two mechanisms that the existence of search frictions leads to bid-ask spreads that are higher than the competitive level (Duffie et al., 2005).

Barriers to entry imply that it is difficult for external firms to challenge the incumbents, typically due to institutional features. Barriers to entry support concentrated market structures and reinforce the possibility of earning monopolistic rents. In fact, Siriwardane (2019) shows that, in the single-name CDS market, 75% of the liquidity supply is in the hands of five dealers.

Recent literature suggests that, in OTC markets, dealers can extract and maintain bid-ask spreads above competitive levels. Indeed, Green, Hollifield, and Schürhoff (2006) note that dealers in the municipal bond market exercise substantial market power. In the corporate bond market, Di Maggio et al. (2017) find that, when dealers trade with clients, they charge a mark-up that is 50 basis points higher than when they trade with other dealers. For the CDS market, Eisfeldt et al. (2018) find that credit spreads of dealer-to-dealer trades are nearly 6% lower than those of dealer-to-customer trades.

2.2 Research Design

In this type of market structure with a finite number of suppliers, any single dealer's supply is likely to impact market clearing prices. Moreover, in response to a reduction in the number of suppliers, the remaining dealers could act strategically

[9]BIS Statistics: https://www.bis.org/publ/qtrpdf

when deciding on the equilibrium quantity supplied and the bid-ask spreads they offer. This means that, in addition to accounting for information about asset fundamentals and investor demand, traded prices are fixed as a best response to the supply of other dealers. At the new market equilibrium, this could result in lower traded volumes and higher rents. Theoretical models have formalized this intuition: Bernhardt, Dvoracek, Hughson, and Werner (2004) show that imperfect competition leads to higher transaction costs for retail trades in dealer markets. They also offer empirical evidence to show that this was indeed the case for equities on the London Stock Exchange when it functioned as a dealer market. Foucault, Pagano, and Roell (2013) show in a simple game-theoretic framework that, in opaque markets with a finite numbers of dealers, the players act strategically in order to earn monopolistic rents – the lower the number of dealers, the higher the rents. Finally, in these types of markets, relationship trading tends to be important. In fact, Hendershott, Li, Livdan, and Schürhoff (2020) study insurer trading patterns in corporate bonds and find that 30% of the insurers trade with a single dealer.

Therefore, a reduction in the number of suppliers of single-name CDS market liquidity could increase the difficulty of trading CDSs through three channels. First, even in the absence of oligopolistic dynamics, it implies a decrease in the overall risk-bearing capacity of the CDS liquidity suppliers. Since increasing inventories is costly, absorbing the additional demand that comes from the dealer's clients is going to take time. It is likely that the remaining dealers would only accept increasing their inventories if clients were willing to pay higher prices. Second, the remaining dealers are likely to respond strategically to reductions in the number of suppliers. By reducing the quantity they offer, they could profit from the higher concentration and increase markups. Third, the destruction of long-term dealer-customer relationships would have a negative impact on the investors who are forced to switch dealers. These three channels explain why changes in the number of liquidity suppliers could have an impact on prices and volumes, at least in the short to medium term. In the paper, we test the null hypothesis of no effect – perfect capital markets – versus the alternative hypothesis – institutional frictions generate an impact on prices and liquidity.

2.2.1 Trading Costs of Dealers

In recent years, increases in the capital requirements of bank-affiliated dealers have drained liquidity from over-the-counter markets, especially for products that occupy a lot of space on dealer balance sheets, such as bonds, swaps, repos and foreign exchange contracts. Dealers have reduced their market-making inventories and are offering less liquid two-way markets for asset classes whose capital requirements have increased significantly. For example, under the US supplementary leverage ratio rule for the largest US broker-dealers, every US$100 million of additional assets requires an additional US$5 million of capital, regardless of the risk of the assets. This means that intermediating safe assets requires a lot of capital relative to the tiny risk involved.

In general, dealers best respond to higher capital requirements by increasing bid-ask spreads for positions that require a lot of regulatory capital relative to their risk. In fact, there is now evidence that this is indeed the case in practice. Duffie (2017) argues that, since the imposition of the supplementary leverage ratio rule, bid-ask spreads in the US Treasury repo market have increased from around 3 basis points to more than 16 bps. Siriwardane (2019) shows that a US$1 billion reduction in dealer capital leads to an increase of 3 bps in CDS spreads. A second response of the dealers to these regulations has been to use financial engineering or new intermediation methodologies to economise the use of balance sheet space. These methods include clearing and compression, which allow dealers to buy and sell positions in net terms and only report the capital on the net amount outstanding.

Market making in CDSs has indeed been affected by the same trends. One particularity of the single-name segment, however, is the fact that clearing has been very slow to penetrate this market. According to BIS statistics, at the end of December 2013, less than 20% of single-name CDSs had been subject to clearing. In the absence of clearing, dealers cannot net their CDS positions and the leverage amount is applied on the entire market-making inventory. As a result, single-name CDSs are particularly costly for dealers to intermediate in terms of capital regulation.

2.2.2 Exogenous Supply Shock

In order to generate quasi-experimental variation in the supply of CDS market liquidity at reference entity level, we exploit a reduction in the number of dealers which occurs for reasons unrelated both to the underlying risk of the reference entities and to investor demand. This specific event can be viewed as a shock to CDS market liquidity that affects reference entities heterogeneously. On 13 November 2014, one major dealer headquartered in Germany announces its decision to exit market making in single-name CDSs. This decision is part of a broader shift in strategy aimed at achieving higher capital savings. Consistent with a supply shock, we show that this decision is driven neither by investor trends nor by the riskiness of the underlying reference entities. As a main explanatory variable, the empirical analysis uses the ex ante intensity of trading in a specific CDS reference entity by the exiting dealer. We do this in a series of difference-in-difference analyses where the treatment intensity varies in the cross-section of firms. In order to take into account the possibility of any leaked information prior to the announcement, the analysis employs 1 October 2014 as a threshold separating the pre-treatment from the post-treatment period.[10]

[10] We note, however, that a dealer has all the incentives to avoid prematurely revealing its intentions to leave a market in order to prevent becoming exposed to predatory trading (Barbon, Di Maggio, Franzoni, and Landier, 2019).

2.2.3 Constructing the Heterogeneous Treatment Variable

The main explanatory variable employed in the analysis captures the intensity of treatment by means of the share of CDS notional intermediated by the exiting dealer, at reference entity level. For this, we combine the information in the individual position data with the gross notional information provided by the Depository Trust and Clearing Corporation (DTCC), and we calculate the average market share of the dealer for each of the 1,000 CDS-traded reference entities covered by our sample. To ensure the stability of the measure, we use the average market share over the three years prior to the dealer's decision to exit.

Therefore, for each of the top 1,000 reference entities for which we have information, this ratio is as follows:

$$TreatmentIntensity_f = \frac{DealerGrossNotional_f}{TotalGrossNotional_f}$$

With this measure, we first investigate the impact of the CDS supply shock on the liquidity offered to German buyside investors across reference entities treated heterogeneously. Subsequently, we study how bond yields respond to the treatment measure in the population of bonds issued by firms with traded CDSs.

3 Data

3.1 CDS Dataset Construction

The analysis of the CDS market equilibrium relies on CDS transaction and position data from the Depository Trust and Clearing Corporation (DTCC). In its supervisory role, the Bundesbank collects granular OTC market transaction and position data for all monetary and financial institutions based in Germany from the Trade Information Warehouse (TIW) of the DTCC.[11] These include all trades – the flow – and all CDS positions – the stock – if at least one trading counterparty is a German bank or, alternatively, if the reference entity on which the CDS is traded is headquartered in Germany. For the purpose of this analysis, we work with the former dataset: the trades and holdings of German banks.

The CDS position or stock data are crucial for calculating the measure of treatment intensity that is used to investigate the effect of the supply shock. These data contain weekly CDS gross sell and buy notional volumes outstanding, by reference entity, party, and counterparty to the trade. It includes the complete

[11] Gehde-Trapp, Gündüz, and Nasev (2015) mention that "*the DTCC estimates that its coverage of* [the TIW database on] *credit derivatives amounts to 95% of single-name CDS in terms of the number of contracts, and 99% of single-name CDS with respect to notional amounts*".

positions of the exiting dealer, which we aggregate across the counterparty, dealer and reference entity levels. We then calculate the average market shares of the dealer by reference entity, by combining these data with the global aggregated volumes that the DTCC provides to subscribers on the top 1,000 CDS-traded reference entitites. This latter dataset is the one used by Oehmke and Zawadowski (2016).

To measure the price and volume effects on buyside investors, we use the CDS transaction or flow dataset. We apply the following cleaning procedures: From the overall dataset, we first select transactions that represent risk taking (these are new trades, assignments of existing trades to third counterparties, and trade terminations). Since we investigate the effects on final customers, which are the buyside investors in this market, we extract dealer-to-buyside (D2B) transactions and exclude the inter-dealer (D2D) market. There are two main reasons why we are interested in the D2B market. First, final investors are the main consumers in this market and any price or volume effects are likely to negatively impact their welfare. Second, while we can measure the effects on German investors as a whole, we observe only the segment of the inter-dealer market for which German dealers are a counterparty. Therefore, our sample is complete for the purpose of our analysis, since it includes all the buyside trades of German investors excluding those realised by the exiting dealer. Over the period from January 2012 to May 2015, we have 843,645 buyside entries.

Next, we select standardized contracts, which are contracts that follow the definitions set in the Big Bang and Small Bang protocols. Standard contracts are fairly homogeneous – they trade under fixed legal definitions with preset maturities, amounts, and fixed protection coupons of typically 100 bps or 500 bps. Because the coupons are fixed, the prices of these contracts are exchanged upfront. This fee amounts to the discounted value of the difference between the market value of the coupon and the fixed rate. When the seller of CDS protection estimates the value of the protection coupon to be higher than the market value, the protection buyer makes an upfront payment to the protection seller. Conversely, when the dealer estimates that the fixed coupon is too high a price for protection, the CDS protection buyer receives an upfront payment from the seller. Therefore, all price variation is comprised within the upfront spread.

We identify new standard trades following these three steps: (1) we keep new trades and assignments reported by the new party entering the trade, and we thus exclude trade terminations (44% of the sample), and assignments reported by the party exiting the trade (12% of the sample); (2) we only keep the new trades and assignments for which there is information on the upfront spreads (we drop 22% of the sample); and (3) we keep only contracts for which the ISDA definition matrix includes the term "Standard" (we drop 0.5% of the sample). Finally, in order to merge with the treatment measure calculated based on the position data, we only keep trades conducted on the top 1,000 CDS-traded reference entities (with this point, we exclude an additional 14% of the sample).

Our extended period of analysis thus spans from January 2012 to June 2015, and it covers 118,411 buyside-to-dealer transactions whereby which the buyside party is a German bank and the counterparty is a German or international dealer. The dataset contains relevant contract and reference entity characteristics including traded notionals, prices, the direction of the trades (buy or sell), the currency of the trade, its maturity, the identity of the trading parties as well as the sector, type and identity of the reference entity.

Most of the empirical analysis is focused on the period from January 2014 to June 2015.[12] Over this period, we collected 47,923 trades entered into by 43 banks on 780 reference entities. This is the final dataset that we use in the volume analysis. For the price analysis, we augment the dataset by adding the Markit upfront quotes to each trade, and we match these on both trade-day and contract characteristics. We thus collect matching upfront quotes for 17,544 trades.

Table 1 presents summary statistics on the main characteristics of the CDS trades, measured in the pre-period. Close to half of the transactions concern non-financial firms, while the remaining half is comprised of financial institutions and sovereigns. 52% of the trades are to buy CDS protection, while 48% are to sell protection. The average maturity of the traded contract is around 5 years, and the average amount traded is close to €5 million. The average upfront spread paid on a contract is 1.34% of gross notional, of which 0.04% are the transaction costs, or half of the bid-ask spread.

Table 1. Summary Statistics: CDS Transactions

	N	Mean	SD	P10	P50	P90
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
CDS Volume Analysis						
Notional (EUR mn)	47,923	4.95	6.87	0.38	3.63	10.50
Fixed rate	47,923	2.07	1.75	1	1	5
Buyside trade indicator	47,923	0.52	0.49	0	1	1
Maturity (in years)	47,923	4.27	1.78	2	5	5
Rating score	47,923	10.62	5.06	5	9	19
CDS Price Analysis						
Half spread (in %)	17,544	0.04	0.05	0.00	0.01	0.11
Distribution by sector of CDS holdings						
- non-financial reference entities	21,338	44.57 %				
- financial reference entities	14,078	29.40 %				
- sovereign reference entities	12,462	26.03 %				

This table reports summary statistics for the main variables employed in the analysis over the pre-period, that is, from January to September 2014.

[12] The dynamic analysis with time trends relies on longer panels and spans from January 2012 to June 2015.

3.2 Bond Market Data and Investor Portfolios

For the analysis of the bond market, we first collect data on bond yields. We employ individual bond data extracted from the comprehensive Centralized Securities Database (CSDB). The CSDB is a security-by-security database containing monthly data on instruments, issuers and prices for debt securities, equity instruments and investment fund shares issued worldwide. For example, more than 10 million securities were covered in June 2018 alone. The objective of the CSDB is to cover all securities relevant to the analyses carried out by the European System of Central Banks (ESCB). For each live bond, we have an entry per month, with the time-variant information referring to the last day of the month. Relying on a variety of private and public sources, the database includes various time-varying characteristics of the securities, including volumes issued and outstanding, original and residual maturities, yields to maturity, coupon characteristics, as well as information on the country and industry of the issuer. From this database, we extract information on the bonds issued by corporations in the top 1,000 reference entities with traded CDS. We then add ratings information as well as our treatment variable at issuer level.

In the second step, we study investor bond holdings. For this, we investigate how German banks active in both CDS and bond markets rebalance their portfolios across the two assets after the CDS liquidity shock. We exploit the Security Holdings Statistics Database (SHS-Base Plus), also collected by the Deutsche Bundesbank.[13] Financial institutions domiciled in Germany report securities that they hold for domestic or foreign customers. In addition, domestic banks also provide information about their own holdings, irrespective of where the securities are held. The data are collected by means of a full census. The reports include information on debt securities, shares, and investment fund shares or units. The identifier is the International Securities Identification Number (ISIN). A basic set of information is required to be reported on a security-by-security basis. This includes the nominal amount and the market value of the securities, as well as the sectoral classification and residency of the holder. Since January 2013, the reports are collected monthly, and, since January 2014, the holdings are further disaggregated into securities in the trading portfolio, securities held to maturity, and securities lent or borrowed.

From this dataset, we extract the holdings of the 43 banks in our sample. These are the banks actively trading both bonds and CDSs. Then, for each live security held, we extract additional characteristics at ISIN level from the CSDB, as described in the previous paragraph. We extract instrument attributes (CFI codes, amount issued, amount outstanding, issue date, original maturity, residual maturity), issuer attributes (identifier, domicile, sector, NACE code), price data (monthly average price, volume traded), as well as coupon and redemption attributes.

Regarding the selection of the sample, we focus on bond holdings, as they are

[13]The dataset is also used in Fecht, Hackethal, and Karabulut (2018) and Abbassi, Iyer, Peydró, and Tous (2016).

the closest instruments to CDSs when trading credit risk. For this, we select all securities with a CFI code starting with "D", and we drop warrants ("DW") and miscellaneous ("DM"). We also drop bonds with missing information on amounts issued, issue date, and maturity, as well as bonds with residual maturities shorter than 90 days. The bond analysis follows the same period as the CDS analysis: 1 January 2014 to 30 June 2015, with three quarters as a pre-treatment period and three quarters as a post-treatment period. We collapse the data at bank-bond level and we construct balanced panels over the pre-period and post-period.

Our final dataset of bank bond holdings comprises 37,327 bonds issued by 4,544 firms. Table 2 shows descriptive statistics on the bond portfolios of the 43 German banks. 35% of the bonds held in the portfolios are issued by 387 firms with traded CDSs. Among these, 17% (6.3% of the total) of the holdings are hedged with CDS contracts, while 24% (9.4% of the total) of the holdings are doubled up with sold CDS protection.

Table 2. Summary Statistics: Bond Analysis

	N **(1)**	Mean **(2)**	SD **(3)**	P10 **(4)**	P50 **(5)**	P90 **(6)**
Bond yield analysis						
Bond yields (%)	13,627	2.76	2.08	0.62	2.18	5.75
Bank bond holdings						
CDS buyer (%)	52,338	6.27	24.24	0	0	100
CDS seller (%)	52,338	9.39	29.17	0	0	100
CDS traded (%)	52,338	35.11	47.73	0	0	100
Nominal value (EUR mn)	52,338	6.97	46.21	0	0.13	11.11
Nominal value (EUR mn)	52,338	7.15	46.69	0	0.14	11.57
Outstanding (EUR mn)	52,338	386.57	744.47	0.17	100	1,000
Amount issued (EUR mn)	52,338	1,524.87	72,028.73	0.57	300	1,500
Original maturity (years)	52,338	7.90	8.66	2	6	12
Residual maturity (years)	52,338	1.66	5.01	0	0.11	3.55
Rating score	52,338	11.82	9.07	1	9	23

This table reports summary statistics for the main variables employed in the bond and investor-level analysis over the pre-period, i.e. from January 2014 to September 2014.

4 CDS Market Response to the Supply Shock

In this section, we study how the CDS market reacts to a plausibly exogenous reduction in the number of dealers that provide liquidity. We do so by analysing the effects of the shock in the cross-section of CDS-traded reference entities. Under the null hypothesis of a perfectly competitive market and free flowing capital, there should be no effect on the quantities and prices at which CDSs are traded in equilibrium. In this case, profitable trade opportunities would be met with liquidity supply from the remaining dealers or from new market entrants. Alternatively, the reduction in the number of dealers could lead to a decrease in liquidity with lower traded volumes and higher prices. This can occur due to barriers to capital flows, barriers to market entry, or to limited risk taking by the remaining dealers.

We begin below by discussing possible identification concerns as well as the steps we take to mitigate them. The effect on the CDS market is then explored with an analysis of how traded quantities and prices react to the change in CDS market liquidity. A few considerations on the robustness of the results follows.

4.1 Identification Challenges

There are two important identification challenges that affect the analysis of the CDS market. The first challenge is to disentangle the supply of CDS liquidity – shocked by the reduction in the number of dealers – from confounding trends at the level of investor demand. The second challenge is to account for any possible correlation between the market share of the exiting dealer and the characteristics (and, in particular, the risk profiles) of traded reference entities. We explain below how we tackle these two challenges.

We start by studying the composition of new CDS trades during the period from January 2014 to July 2015 in Figure 1. In particular, we track the share of new trades that are conducted on reference entities that are highly treated, as a percentage of the total. We consider highly treated reference entities to be those with exposures to the treatment above the median. While roughly 50% of the trades were conducted on highly treated reference entities prior to October 2014, their share in total new trades falls to around 30% over the six months following the exit. This forensic analysis is consistent with a shock to the supply of CDS liquidity that affects reference entities proportionally to their ex ante exposures to the dealer.

Figure A1 in the appendix plots the aggregated monthly volume of new CDS trading by German buyside investors from July 2013 to June 2015.

Another important tool that allows us to separate the estimation of supply and demand effects is the inclusion of a set of fixed effects at investor level. While the evidence presented above suggests that there is a decrease in CDS trading that coincides with the supply shock, it could still be possible that German investors reduce their demand faster for the reference entities treated with higher intensity. Investor fixed effects help us alleviate this problem. In particular, by including investor fixed effects in our estimations, we effectively estimate the effect of the supply shock for highly treated reference entities versus lowly treated ones for the same investor and at the same time.

Finally, we can confirm the supply shock because we observe full market outcomes: volumes and prices. If demand frictions prevail, we should observe the CDS market converging to an equilibrium with lower traded volumes and prices. If, however, supply frictions drive equilibrium outcomes, then there would be lower traded volumes but higher prices at the new equilibrium. In addition, because we can use the heterogeneous worldwide market shares of the exiting dealer, we can

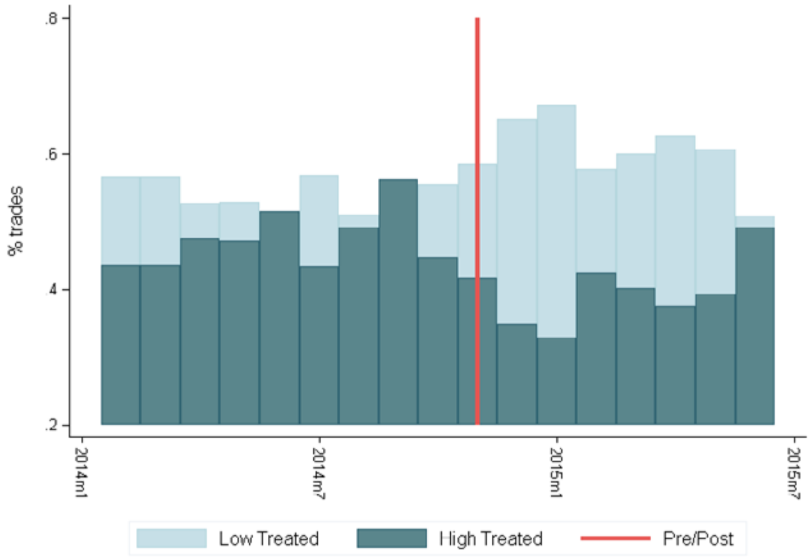

Figure 1. High-Treated and Low-Treated Contracts in Total

Figure 1 shows the evolution of the share of high-treated CDS contracts versus low-treated contracts in the total new CDS trades done by German buyside investors. The underlying data are sourced from the DTCC.

test whether any changes in volume and prices are directly proportional to these market shares.

What still remains is the possibility that German investors start reducing their demand for certain segments of the CDS market (for instance, the riskiest or the safest reference entities or exposures to certain industries or geographical areas) and that this occurs concurrently with the exit of the dealer. To mitigate these concerns, our specifications include investor × country, investor × industry, and investor × rating score fixed effects. Simply plotting the inventories of the top three dealers against the remaining dealers in the CDS market shows that concerns regarding concentrations in particular risk buckets at the top three German dealers are unfounded. They hold inventories that are similarly distributed in terms of risk as the overall CDS market. Figure A2 in the appendix shows these results.

Below, we describe the different steps of the empirical analysis of CDS volumes and prices.

4.2 Quantity Response: CDS Volumes

To quantify the volume effects, we employ a standard pre-post difference-in-differences specification with heterogeneous treatment, as described in Section 3.2. Our horizon of analysis spans from January 2014 to June 2015.[14] For this, we first collapse our initial dataset of 47,923 transactions at investor × reference level, and we construct a balanced panel. Each observation then captures the total notional in new trades that an investor contracted on a certain reference entity in the pre-treatment and post-treatment periods. We then calculate how the rate of growth of CDS notional, at the investor and reference levels, varies with the treatment intensity variable. This model is equivalent to including investor × reference entity fixed effects, and it is robust to serial correlation.

The resulting panel includes the rates of growth of CDS exposures for 4,944 investor × reference entity pairs. This implies that, on average, a German bank has new CDS exposures to 116 reference entities. The baseline model is as follows:

$$DeltaVolume_{i,f,pre-post} = TreatmentIntensity_{f,pre} + \epsilon_{i,f,pre-post} \tag{1}$$

We measure changes in the volume of CDSs traded by an investor on a given reference entity, between the pre and post periods, as follows:

$$DeltaVolume_{f,i,pre-post} = \frac{(CDSNotional_{f,i,post} - CDSNotional_{f,i,pre})}{0.5(CDSNotional_{f,i,post} + CDSNotional_{f,i,pre})}$$

where f is the reference firm and i is the investor.

The average of $DeltaVolume_{f,i,pre-post}$ is -0.96, consistent with a decline observed in CDS traded volumes over the period, while its standard deviation is 1.42. The measure is bounded between [-2,2]. In order to ensure that our results are not driven by unobservable trends, the regression includes controls for the reference entity (industry, country and rating buckets) as well as, progressively, fixed effects for investor, investor × industry, investor × country, and investor × rating bucket. We cluster standard errors at reference entity level – the level at which treatment is applied.

We also estimate models with time trends at several levels: investor, investor × sector, investor × country, and investor × rating bucket. This is to ensure that any volume effects observed are unrelated to pre-existing investor-level trading strategies aimed at cutting exposures to specific industries, countries or risk levels. Finally, we separate the sample into trades where investors are buying protection and trades where they are selling protection. Finally, we look at the effects by type of reference entity: corporate non-financial, corporate financial, and sovereign.

Table 3 presents the results of the volume estimations on the CDS market,

[14] The results are robust to different time frames. One example is shown in the appendix for a horizon spanning from January 2012 to June 2015.

following Equation 1. We find that German investors decrease their holdings of CDSs and that this decrease is proportional to the treatment intensity – the exposure to the withdrawing dealer. Due to confidentiality restrictions, we do not evaluate the results using the actual market shares, but employ a 10 pp change in the intensity of treatment. Moreover, to facilitate interpretation, we evaluate the coefficients in the regression tables directly at 10 pp.

Therefore, a 10 pp increase in the treatment intensity leads to a rate of growth that is lower by 13 pp in CDS notional at the level of investor × reference entity. The coefficient is relatively stable when we include the various fixed effects. Moreover, the effects are strongest for corporate reference entities – both financial and non-financial – but also present for sovereigns.

Figure A3 in the appendix looks at the effects of the treatment on the probability of trading CDS contracts over the longer-term horizon from January 2012 to June 2015. These results confirm that the effect mostly kicks in from autumn 2014 and that it is not driven by pre-existing investor trends at the country, industry or rating-bucket levels. The slight anticipation effect may be related to the fact that we are looking at the probability of trading. Trades with smaller investors might have been slowly phased out before the public announcement, without a visible effect on volumes, as is apparent from Figure 1.

4.3 Price Response: CDS Upfront Fees

This section provides an empirical study of CDS prices surrounding the withdrawal of the dealer. In particular, we analyse how changes in the transaction costs incurred on every CDS trade vary with the measure of treatment intensity. Most CDS contracts trade with standardized notionals, maturities, and fixed coupons.[15] The buyer and the dealer exchange upfront payments at the start of the contract in order to compensate for the discrepancy between the fixed coupon, which reflects the regular protection payment, and the actual price of protection agreed upon at the time of entering the contract. Our data include both the actual traded upfront payments and the corresponding upfront fees from Markit quoted by the dealers on the different types of standardized contracts. By taking the difference between the actual upfront fees and the quoted ones, we arrive at an estimate of the bid-ask spread, or the transaction cost.

While any declines in CDS traded volumes could be consistent with both decreases in the supply of CDS liquidity and with declines in investor demand, an analysis of prices sheds light on which of the two explanations prevails. To analyse the effect on the realized CDS spreads, we start with our initial dataset of transac-

[15]Since the implementation of the Big Bang and the Small Bang protocols in 2010, the contracts have been trading on standardized terms. The notional amount is typically US$5 million, there are four maturity dates in a year, known as the IMM dates – on 20 March, 20 June, 20 September and 20 December, respectively – and typically one of two coupons: 100 bps or 500 bps, depending on the risk of the underlying entity.

Table 3. Effect on CDS Traded Volumes

	Delta total CDS notional at investor X reference entity, pre/post							
	Delta notional					Non-financial	Financial	Sovereign
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TreatmentIntensity	-0.134**	-0.124**	-0.156***	-0.159***	-0.135***	-0.169***	-0.209**	-0.365
	(0.055)	(0.053)	(0.055)	(0.052)	(0.051)	(0.058)	(0.104)	(0.817)
Reference controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Investor FE	No	Yes	No	No	No	Yes	Yes	Yes
Investor×industry FE	No	No	Yes	No	No	No	No	No
Investor×country FE	No	No	No	Yes	No	No	No	No
Investor×rating FE	No	No	No	Yes	No	No	No	No
Observations	4,944	4,944	4,944	4,944	4,944	2,783	1,631	526
R^2	0.137	0.216	0.308	0.274	0.280	0.240	0.179	0.401

This table reports the coefficients of OLS regressions where the dependent variable is the growth of CDS exposure between the pre-treatment period, January to September 2014, and the post-treatment period, October 2014 to June 2015. The independent variable, *TreatmentIntensity* is our measure of treatment heterogeneity and is given by the market share of the dealer calculated for each of the top 1,000 CDS reference entities. The coefficients on the treatment intensity are directly evaluated at a 10 pp standard deviation. We start with a simple difference-in-difference estimation in Model (1) and we add investor fixed effects in Model (2). In Models (3) and (4), we explore the effects on the extensive margin, while in Models (5) and (6), we separate the contracts into buy and sell. Standard errors are clustered at reference entity level and reported in brackets, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

tions entered into by the remaining German banks. For each trade, we have the upfront payment, which captures all of the variation in the price of the contract. In this part of the analysis, we will focus on the realized spreads, defined as the difference between the bid or ask upfront prices and a benchmark mid upfront price. Because the (German) CDS market is not sufficiently liquid, we use daily quoted mid upfronts sourced from Markit in order to allow us to estimate mid prices directly from daily prices.

We therefore define the absolute half spread on a CDS contract traded on reference entity f entered at time t as follows:

$$\begin{aligned} |HalfSpread_{ft,s}| = & (UpfrontAsk_{ft} - UpfrontMid_{ft}) * \mathbf{1}[s \in selltrade] \\ & - (UpfrontBid_{ft} - UpfrontMid_{ft}) * \mathbf{1}[s \in buytrade] \end{aligned}$$

The $UpfrontAsk_{it}$ and the $UpfrontBid_{it}$ are the realised transaction prices. The $UpfrontMid_{it}$ is the daily Markit indicative dealer mid quote, and s is the direction of the trade.

Next, we study the effects of the liquidity shock on this half spread. For this, we run difference-in-differences specifications on the panel of transactions at contract level:

$$\begin{aligned} |HalfSpread_{cit}| = & TreatmentIntensity_f * Post_t + Firm_f + Month_t \\ & + \sum_k \gamma_k * \mathbf{1}[currency_j \in k] + \sum_l \gamma_l * \mathbf{1}[maturity_j \in l] \\ & + \sum_p \gamma_p * \mathbf{1}[rate_j \in p] + \epsilon_{cit} \end{aligned} \quad (2)$$

In this model, the dependent variable, $|HalfSpread_{idft}|$, captures the absolute value of the realized half spread on contract c, sold by dealer d on reference entity f at time t. The specification controls non-parametrically for contract characteristics in order to take into account changes in the composition of the trades. α_f are reference entity fixed effects. Since CDS contracts mostly trade with standardized maturities and fixed rates, the term $\sum_k \gamma_k * \mathbf{1}[maturity_i \in k]$ includes a full set of dummies for standardized CDS maturities, while the term $\sum_p \gamma p * \mathbf{1}[rate_i \in p]$ includes dummies for standardized fixed rates. $\sum_k \gamma k * \mathbf{1}[rate_i \in k]$ includes dummies for standardized currencies.

Crucially, because we work with deviations from the upfront fees quoted by Markit dealers for the same contract on the same day, our measure of price impact is robust with respect to daily changes in the characteristics and risk profiles of the underlying entities. Moreover, in some specifications, we control for market volatility, CDS trading activity and risk-free rates by including the VIX, the CDX and CDX high-yield indices, as well as the USD and EUR swap rates with maturities of one, five and ten years. We add reference entity, investor, and month fixed effects, as well as contract characteristics. In the most restrictive specification, we add investor × month fixed effects to account for time-variant, investor-specific pricing biases. Finally, we separate the analysis into buy and sell trades.

The price analysis further confirms the reduction in the supply of CDS liquidity. In the panel specifications presented in Table 4, we find that the bid-ask spreads on the upfront CDS payments increase, signalling an increase in transaction costs consistent with supply frictions. In particular, transaction costs on a round-trip CDS contract increase by 0.10 pp (0.056 pp for the buyside and 0.047 pp for the sell side), which is equivalent to 7.4% of the average upfront fee. This means that, in order to purchase standard CDS contracts of €5 million notional with a five year maturities, buyside investors have to pay an upfront that is, on average, €5,000 higher than prior to the dealer exit.

Finally, Figure 2 showing the dynamic effect confirms that this increase starts in October 2014 - coinciding with the event - and that it persists for at least four months.

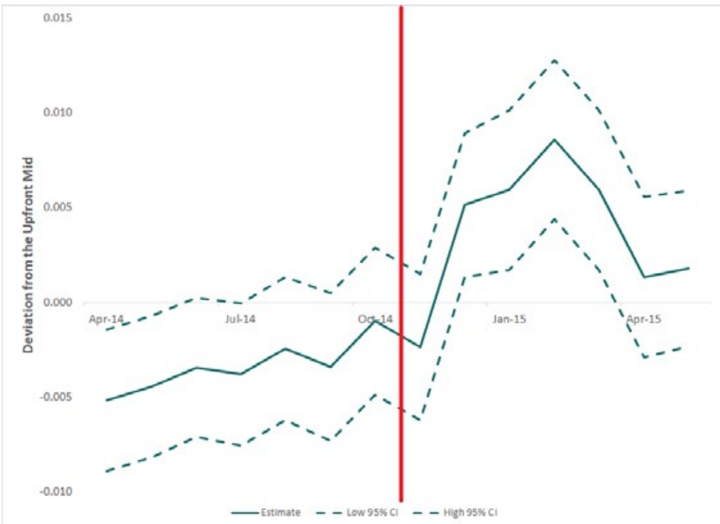

Figure 2. The Dynamic Estimate of the Treatment on the Bid-Ask Spread

This figure shows the dynamic difference-in-differences estimate of the effect of the treatment intensity on the half bid-ask spreads at CDS transaction level when treatment intensity increases by 1 pp. It is a panel version of Model (2) in Table 4.

Table 4. Effect on Traded Bid-Ask Spreads

	Panel regression on CDS transactions						
	Half BA spreads - Absolute deviations of traded upfronts from quoted mids						
Sample	All					Buy trades	Sell trades
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$TreatmentIntensity \times Post$	0.043**	0.044**	0.052***	0.050***	0.048***	0.056***	0.047***
	(0.020)	(0.020)	(0.018)	(0.018)	(0.018)	(0.009)	(0.008)
$Post$	0.284						
	(0.396)						
Macro controls	Yes	No	No	No	No	No	No
Contract characteristics	No	No	Yes	Yes	Yes	Yes	Yes
Reference firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Investor FE	No	No	No	No	Yes	No	No
Month FE	No	Yes	Yes	Yes	No	Yes	Yes
Investor × month FE	No	No	No	No	Yes	No	No
Observations	17,574	17,544	17,542	17,542	17,502	9,078	8,421
R^2	0.313	0.390	0.397	0.421	0.462	0.419	0.431

This table reports the coefficients of panel OLS regressions explaining the traded prices (upfronts) of CDS contracts. The dependent variable measures the half spread, which we calculate as the difference between the traded upfront price and the Markit mid quote for the same day. The unit of observation is a CDS contract. The analysis runs from January 2014 to June 2015. We estimate difference-in-differences specifications where the pre-period is January to September 2014 and the post-period is October 2014 to June 2015. $TreatmentIntensity$ is the measure of treatment intensity, calculated as the market share of the dealer for each of the 1,000 top CDS reference entities. The coefficients on the treatment intensity are directly evaluated at a 10 pp standard deviation. Standard errors are clustered at the reference entity and month levels, and are reported in brackets, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

5 Bond Market Response to the CDS Supply Shock

This section sets out our analysis of the spillover effects of the shock to CDS market liquidity on the corporate bond market. We start with an analysis of bond yields, and then we study whether investors engage in rebalancing of their bond portfolios in response to the CDS supply shock. The behaviour of investors will help us understand the channels through which there can be an effect on bond yields.

5.1 Analysis of Bond Spreads

We start the bond-level analysis by investigating the effects of the CDS shock on corporate bond spreads. CDS markets are linked to bonds markets in that they provide a means of insuring exposures against default (hedging), as CDSs are alternative assets for trading credit risk (speculation or investing), or simply through the market pricing of credit risk as reflected in the CDS-bond basis (arbitrage). In order to understand how strong these links are, we first study whether the negative CDS supply shock we explore has any impact on bond spreads. A negative impact is consistent with a strong hedging channel (as frictions affect hedge trading, investors offload the underlying bonds, which lowers prices and increases yields). A positive impact on bond spreads would be consistent with the speculation channel as investors look for substitute trading positions in the bond market. Finally, an increase in the CDS spreads that is matched by higher bond spreads is also consistent with no arbitrage conditions. We investigate these mechanisms by first studying the effects on bond yields, which we then follow up with an analysis of investor holdings.

For this, we extract all bonds issued by corporations with traded CDSs from the CSDB. We then estimate how bond yields vary with treatment intensity according to the following specification:

$$Log(yield_{bt}) = \beta TreatmentIntensity_b * Post_t + \alpha_t + \gamma_b + \mu_{bt} + \epsilon_{bt} \qquad (3)$$

The dependent variable $Log(yield_{bt})$ measures the logarithm of the yield to maturity on bond b in month t. α_t and γ_s are month and bond fixed effects respectively. μ_{bt} are time varying bond characteristics and they include the amount outstanding and the residual maturity of the bond. In some specifications, we drop the month fixed effects and add macroeconomic controls, which are measured on the same day as the bond yields. In this way, we control for market volatility, CDS trading activity and risk-free rates by including the VIX, CDX and CDX high-yield indices, as well as the USD and EUR swap rates with maturities of one, five and ten years. The specification is therefore in the spirit of a difference-in-differences analysis with heterogeneous treatment intensity. Effectively, the coefficient β measures the effect of the treatment intensity within the group of bonds with traded CDSs in the post-period.

Finally, in order to investigate how the effects vary with the underlying credit risk, we also interact the treatment variable in Equation (4) with the linear function of the rating score that we employed in the analysis of the CDS market.

5.2 Analysis of Investor Bond Holdings

In the last part of the analysis, we study whether investors adjust their bond portfolios in response to the shock in the CDS market. This unique perspective will allow us to draw conclusions regarding the mechanisms that could be driving any changes in bond spreads. For this, we augment the analysis with one crucial dataset – detailed bank bond holdings. By combining the bond holdings with the CDS position data, we can identify when investors hedge and double up their bond exposures by using CDSs. Subsequently, we study the elasticity of these bond holdings to the CDS market shock.

Using these investor-level bond portfolios, we estimate models explaining the rate of growth of holdings at investor × bond level. We treat the bonds on which the investor was long or short CDS protection, in the pre-period. To make sure that our results are not driven by selection on unobservables across issuers with traded CDSs versus issuers without traded CDSs, we first restrict the sample to the bond holdings corresponding only to issuers with traded CDSs. In the appendix, however, we estimate the same specification on the full sample of holdings, and we include an additional indicator for all those bonds issued by firms with CDSs traded globally. We estimate the following specifications:

$$\Delta Holdings_{ib,pre-post} = \alpha CDSBuyer_{ib} + \beta CDSSeller_{ib} + \gamma_i + \epsilon_{ib} \quad (4)$$

where $\Delta Holdings_{ib,pre-post}$ measures the change in bond holdings from the pre-period to the post-period, for investor i and bond b. We calculate this rate of growth as follows:

$$\Delta Holdings_{ib,pre-post} = \frac{Holdings_{ib,post} - Holdings_{ib,pre}}{0.5 * (Holdings_{ib,post} + Holdings_{ib,pre})}$$

$CDSBuyer_{ib}$ is a dummy variable that equals 1 if the investor had CDS protection on bond i in the pre-period, and zero otherwise. $CDSSeller_{ib}$ is a dummy variable that equals 1 if the investor had doubled up on their bond holdings i by selling CDS protection in the pre-period, and zero otherwise. γ_i are investor fixed effects. We therefore investigate different trends in portfolio rebalancing, depending on whether the banks were active buying or selling CDS investors on the same bonds they held. By means of this specification, we simultaneously compare how a single bank adjusts its portfolio of a hedged bond position versus a non-hedged bond position (within investor), and how a bank with a hedged bond position rebalances its holdings with respect to a different bank holding the same bond, but not the CDS (across investors).

While the base specification is equivalent to including bond fixed effects, we saturate the model further with investor, investor × industry, investor × country, and investor × rating score. We cluster standard errors at issuer level. Finally, we explore how the effects vary with the riskiness of the underlying by separating the analysis into rating buckets as well as by interacting the dummy variables $CDSBuyer_{ib}$ and $CDSSeller_{ib}$ with the linear function of the rating score.

5.3 Results

The estimates in Table 5 reveal that the supply shock in the CDS market raises bond yields. On average over the sample, a 10 pp increase in treatment intensity leads to a 2% increase in the average yield, or the equivalent of 6 bps. Interacting the treatment intensity measure with the rating score shows that the effect increases with the riskiness of the bond: the link to the derivative market is strongest for the riskiest bonds.

The results thus suggest that changes in the liquidity of CDS markets affect the secondary bond markets. Moreover, the two assets appear to be complementary. The increase in the cost of the hedge is followed by an increase in the cost of the underlying. Finally, the effects could also transmit to the primary markets: In fact, both the price as well as the ease of selling a bond in the secondary market are likely to be very important determinants of primary market yields.

Table 5. Effect on the Yields of CDS Traded Bonds

	Log(Bond yield)			
	All			Sensitivity to rating
	(1)	(2)	(3)	(4)
$TreatmentIntensity \times Post$	0.021***	0.021***	0.022***	0.001
	(0.005)	(0.005)	(0.005)	(0.009)
$Post$	-0.002	-0.001		
	(0.036)	(0.036)		
$TreatmentIntensity \times Post \times RatingScore$				0.004***
				(0.000)
$RatingScore \times Post$				0.010***
				(0.002)
Macro controls	Yes	No	No	No
Bond controls	Yes	Yes	Yes	Yes
Bond fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	No	Yes	Yes	Yes
Observations	25,160	25,160	25,160	25,160
R^2	0.933	0.943	0.927	0.905

This table estimates the effects of the CDS dealer exit on the yields of bonds issued by the top 1,000 CDS-traded reference entities. The unit of observation is bond × month. The yield of the bond is collected at month end. $TreatmentIntensity$ is the CDS market share of the dealer for each of the 1,000 top CDS reference entities. $Post$ takes a value of zero between January and September 2014 and a value of one between October 2014 and June 2015. $RatingScore$ is a linear function of the rating of the bond. Macro controls include the VIX, CDX and CDX HY CDS trading indices, as well as US dollar and the euro swap rates for one-year, five-year and ten-year maturities. Time varying bond controls include the logarithms of the outstanding amount and the residual maturity. The coefficients on the treatment intensity are directly evaluated at a 10 pp standard deviation. Standard errors are clustered at the industry and month levels and are reported in brackets, $^{\star}p < 0.10$, $^{\star\star}p < 0.05$, $^{\star\star\star}p < 0.01$.

Afterwards, we study bank bond portfolios in order to understand the drivers behind the increase in bond yields. In particular, while Siriwardane (2019) presents evidence supporting the no arbitrage channel, we find that the hedging channel is also a driver of bond spreads. Table 6 shows that the investors using the CDSs as a hedging device for their existing bond exposures reduce their affected bond holdings after the shock. The results hold and are relatively stable as we saturate the models with investor and industry, country or rating fixed effects.

Table 6. Bond Divestments - Hedging Portfolios vs. Investment Portfolios

	Pre/post change in bond holdings at investor × bond level				
	Delta holdings				
	(1)	(2)	(3)	(4)	(5)
CDS Buyer	-0.188***	-0.199***	-0.157***	-0.132**	-0.115**
	(0.053)	(0.052)	(0.055)	(0.055)	(0.051)
CDS Seller	-0.046	-0.085*	-0.087	-0.096*	-0.027
	(0.057)	(0.049)	(0.058)	(0.055)	(0.047)
Bond FE	Yes	Yes	Yes	Yes	Yes
Investor FE	No	Yes	No	No	No
Investor × industry FE	No	No	Yes	No	No
Investor × country FE	No	No	No	Yes	No
Investor × rating FE	No	No	No	No	Yes
Observations	21,310	21,310	21,310	21,310	21,310
R^2	0.006	0.018	0.035	0.060	0.049

This table reports the coefficients of linear regressions where the dependent variable is the change in bank bond holdings between the pre-period and post-period. The independent variable *CDS Buyer* is an indicator variable that takes a value of one if the investor hedged the position in the pre-period (i.e. if the investor purchased both the bond and CDS protection on the issuer). *CDS Seller* takes a value of one if the investor used the CDS market to double up on credit risk exposure (i.e. if the investor purchased the bond and sold CDS protection on its issuer). In this table the sample of bonds includes only bonds issued by corporations with traded CDSs. The unit of observation is bank × bond, and the specifications include, in turn, investor fixed effects, investor × industry fixed effects, investor × issuer country, and investor × rating bucket fixed effects. Standard errors are clustered at issuer-firm level and reported in brackets, $^{\star}p < 0.10$, $^{\star\star}p < 0.05$, $^{\star\star\star}p < 0.01$.

Finally, we study how the effects vary with the risk of the underlying issuer. In Table 7, we study how the estimates vary with the rating class. The effects are more pronounced for relatively riskier bonds: Lower-investment grade, speculative and below-speculative bond holdings are the most responsive. These results hold in the full sample.

Table 7. Overall Effects on Bond Exposures by Rating Class

	Pre/post change in bond holdings at investor × bond level					
	All	Prime & high	Upper medium	Lower medium	Speculative & below	Interaction w. score
	(1)	(2)	(3)	(4)	(5)	(6)
CDS Buyer	-0.188***	0.004	-0.126	-0.138**	-0.332***	0.077
	(0.053)	(0.088)	(0.094)	(0.066)	(0.115)	(0.078)
CDS Seller	-0.046	-0.020	-0.018	0.119**	-0.184	0.099
	(0.057)	(0.072)	(0.090)	(0.054)	(0.128)	(0.073)
Rating Score						0.013***
						(0.006)
CDS Buyer × *Rating Score*						-0.023***
						(0.008)
CDS Seller × *Rating Score*						-0.013
						(0.008)
Bond fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,310	2,975	4,076	3,364	10,895	21,310
R^2	0.006	0.000	0.001	0.004	0.005	0.008

This table reports the coefficients of linear regressions where the dependent variable is the change in bank bond holdings between the pre-period and post-period. The independent variable *CDS Buyer* is an indicator variable that takes a value of one if the bank purchased both the bond and CDS protection on it. *CDS Seller* takes a value of one if the bank purchased the bond and sold CDS protection on it. The unit of observation is bank × bond, and since we model rates of growth, the models are equivalent to including bond fixed effects. *RatingScore* is a linear function of the long-term rating assigned by one of the three main rating agencies. The score ranges from one, in the case of a triple AAA or prime bond, to 23 for non-rated bonds. In this table, the sample of bonds includes only bonds issued by corporations with traded CDSs. We estimate the models in turn for different rating buckets and by interacting the investor dummies with the score measure. Standard errors are clustered at issuer-firm level and reported in brackets, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

6 Conclusion

We study the direct and spillover effects on CDS and bond markets of an event that negatively affects CDS market liquidity. We document causal evidence that CDS traded volumes decrease and bid-ask spreads increase for affected reference firms. This negative shock to the liquidity of the CDS market affects the secondary market for bonds, most likely through the hedging channel. We find that bond yields of CDS-traded firms increase proportionally to the ex ante market share of the exiting dealer. Moreover, investors engage in portfolio rebalancing and sell the bonds on which they had previously purchased credit protection. The effects are concentrated in the lower rating buckets.

There are important takeaways for market regulators from our analysis. Possible ways of correcting the negative externalities that we discover might require intervention to increase the competitiveness of and ease of entry into OTC markets. Our findings also highlight that the regulators should be alert during times of market stress so as to enable direct provision of liquidity if necessary.

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Appendix

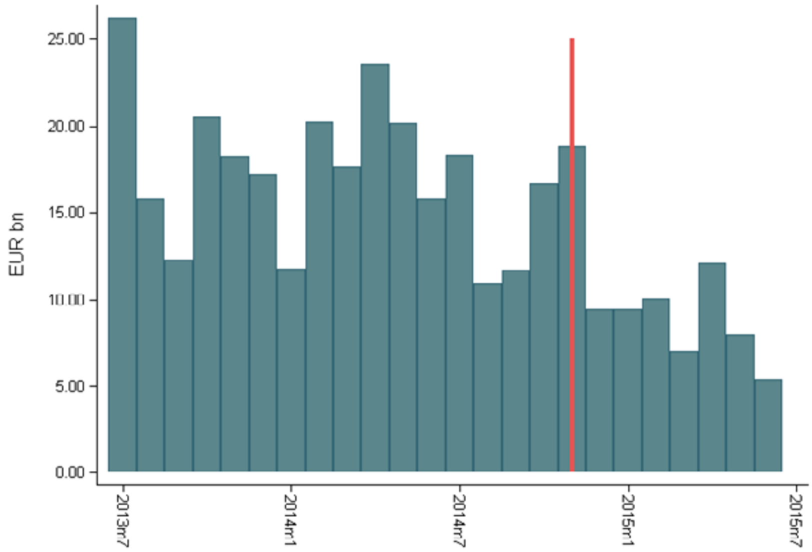

Figure A1. Total Trading in Single-Name CDS Contracts by the German Buyside

Figure A1 shows the aggregated new trades purchased by the 43 German buyside banks. The underlying data is sourced from DTCC.

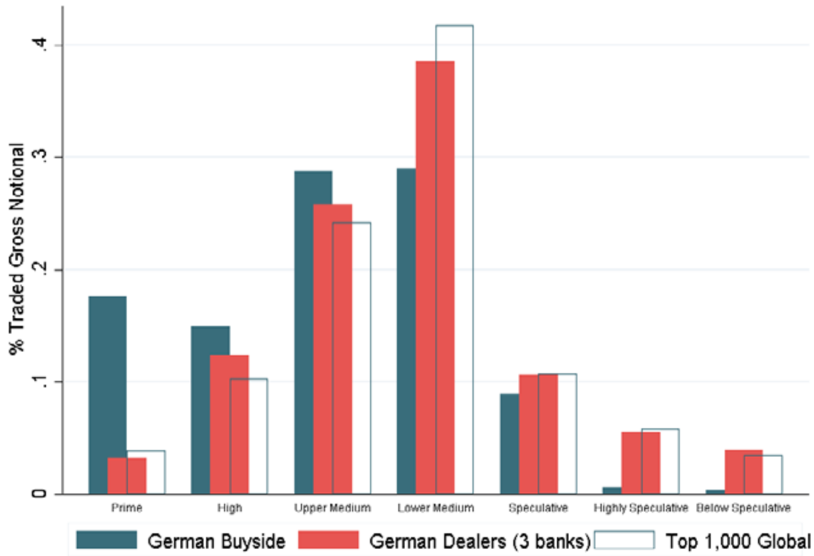

Figure A2. Risk Distribution of CDS Traded Volumes

This figure shows the distribution of gross notional on the top 1,000 CDS reference entities across rating buckets for three groups: total world notional, total gross notional of the top three German dealers, and total notional of the German buyside. The data underlying the figure comes from DTCC and Bloomberg.

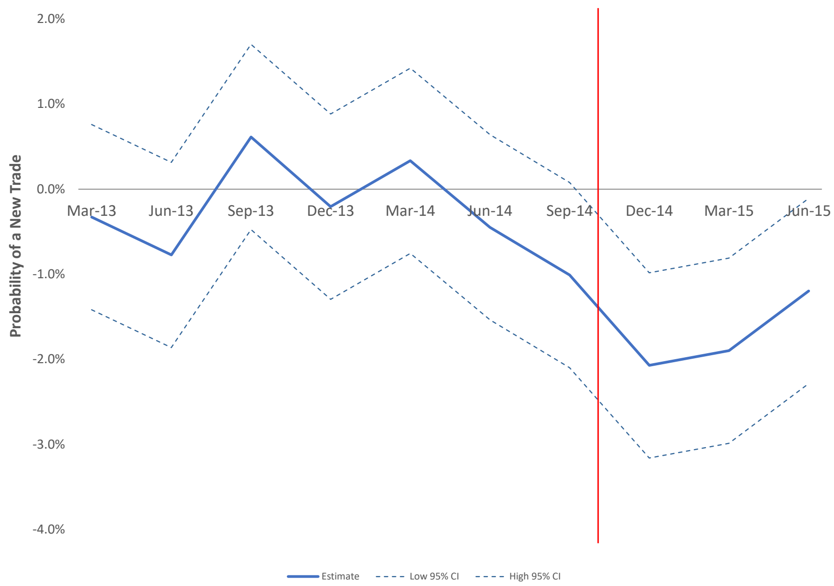

Figure A3. Dynamic Estimate of the Treatment on the Probability to Trade

This figure shows the dynamic difference-in-differences estimate of effect of the treatment intensity on the probability that an investor enters a new contract on a given reference entity. For this, we build a quarterly balanced panel at investor $\times$ reference entity $\times$ quarter. We then estimate a linear probability model as: $ProbaNewTrade_{ift} = TreatmentIntensity_f * Post_t + TreatmentIntensity_f + Post_t + \epsilon_{ift}$, where f stands for the reference firm, i stands for the investor and t stands for quarter. $ProbaNewTrade_{bft}$ takes value 1 in quarters when there is at least one new trade of a buyside investor on a reference entity, and it takes value 0 in quarters without any trades. $Post_t$ takes value 1 from the forth quarter of 2014 onwards.

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