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Over-the-Counter Market Liquidity and Securities Lending*

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Abstract

This paper studies how over-the-counter market liquidity is affected by securities lending. We combine micro-data on corporate bond market trades with securities lending transactions and individual corporate bond holdings by U.S. insurance companies. Applying a difference-in-differences empirical strategy, we show that the shutdown of AIG's securities lending program in 2008 caused a statistically and economically significant reduction in the market liquidity of corporate bonds predominantly held by AIG. We also show that an important mechanism behind the decrease in corporate bond liquidity was a shift towards relatively small trades among a greater number of dealers in the interdealer market.

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Introduction

The financial crisis of 2007-2009 kindled a wider interest in studies of liquidity in over-the-counter (OTC) markets, in which participants trade without centralized exchanges.[1] In the absence of such exchanges, buyers and sellers in OTC markets must devote time and resources to trade, which impedes market liquidity, the ability to transact efficiently (Duffie, Gârleanu & Pedersen 2005, Lagos, Rocheteau & Weill 2011). Intermediaries, such as broker-dealers, may emerge to match buyers and sellers and to maintain an inventory of securities (Hugonnier, Lester & Weill 2014, Chang & Zhang 2015, Neklyudov & Sambalaibat 2015, Wang 2016). Nevertheless, costs associated with dealing securities, such as inventory holding costs or time to search for and bargain with counterparties, mean that frictions remain an important feature of OTC markets.

Securities lending markets offer dealers a way to mitigate the consequences of frictions inherent to OTC markets. As illustrated in Figure 1, a dealer that receives a buy order from a client will try to find another client with a matching sell order. While searching, the dealer can fill the buy order using its own inventory, by locating the security in the interdealer market, or by borrowing the security from a securities lender. In exchange for paying a fee and posting collateral, dealers borrow securities from other financial institutions with large portfolios of securities, such as insurance companies. To be sure, the lending market itself may not be frictionless and impediments to the ability to borrow securities could impinge on market liquidity. Such frictions may arise from high lending fees for borrowing certain securities (Duffie 1996, Krishnamurthy 2002, D'Avolio 2002) or from search and bargaining in the securities lending market (Duffie, Gârleanu & Pedersen 2002, Vayanos & Weill 2008, Sambalaibat 2017). Nevertheless, when the costs of interdealer trading and inventory are relatively high, securities lending can improve market liquidity by reducing the costs of dealing securities.[2] However, identifying and quantifying the importance of securities lending to OTC market liquidity is far from trivial due to the many confounding determinants of market liquidity.[3]

[1] For an overview of OTC markets and some research and policy issues, see Duffie (2012).

[2] In addition to reducing the costs of dealing securities directly, the ability to lend securities can improve OTC market liquidity indirectly, for example by helping to avoid delivery fails and by facilitating other market participants' short positions and certain arbitrage strategies.

[3] A few papers seek to connect securities lending and market liquidity in non-OTC markets, including Saffi & Sigurdsson (2011), and Kolasinski, Reed & Ringgenberg (2013). Existing empirical studies of corporate bond securities lending describe market details, with a particular focus on borrowing costs, but do not connect bond securities lending transactions with corporate bond market liquidity (Nashikkar

In this paper, our objective is to better understand the causal effect of securities lending on OTC market liquidity. We exploit a shock to corporate bond securities lending during the 2007-2009 financial crisis to identify this causal effect. Figure 2 illustrates the size of the shock that occurred during the financial crisis. The figure shows that, in the period before the financial crisis, around \$100 billion of corporate bonds were lent against cash collateral on any given day. The corporate bond securities lending market collapsed by about half towards the end of 2008, largely due to insurance companies, which at that time accounted for more than three-quarters of all loans.[4] While AIG was not solely responsible for the market-wide collapse in late 2008, its narrative is the canonical example for the shock (Peirce (2014) and McDonald & Paulson (2015)). Amid concerns about the quality of cash collateral reinvestment that were unrelated to liquidity in the market for corporate bonds, securities borrowers demanded the return of their cash and precipitated the collapse in securities lending.

To analyze the interaction between corporate bond market liquidity and securities lending, we construct a new dataset by combining micro-level data on corporate bond transactions with individual corporate bond loans. We obtain a comprehensive overview by matching the Trade Reporting and Compliance Engine (TRACE) records of OTC corporate bond transactions with bond-level securities lending transactions from Markit Securities Finance, which provides the most extensive coverage of the securities lending market. Lastly, we add information on the bond-level holdings and securities lending activity of U.S. insurance companies from their annual statutory filings. Our basic empirical strategy is to study the impact of the effect of insurance companies lending programs on the dynamics of corporate bond market liquidity.

The main empirical challenge is to obtain a shock to the supply of corporate bonds in the securities lending market that is independent of the demand for corporate bond borrowing and liquidity in the spot market. Insurers, who make their bonds available

& Pedersen 2007, Asquith, Au, Covert & Pathak 2013).

[4] Insurance companies are the largest institutional investors in corporate bonds, accounting for 20 percent of all corporate bonds outstanding as of 2018Q2 (Table L.213 of the Financial Accounts of the United States available at `https://www.federalreserve.gov/apps/FOF/Guide/L213.pdf`). Insurance companies are natural corporate bond securities lenders as a consequence of their buy-and-hold investment strategy. The income earned from lending corporate bonds is one way for institutional investors such as insurance companies to enhance the return on their asset holdings (`http://www.naic.org/capital_markets_archive/140911.htm`). In addition, insurance companies can use securities lending transactions to manage the duration mismatch between assets and liabilities on their balance sheet (Foley-Fisher, Narajabad & Verani 2016).

to the securities lending market, naturally respond to both supply and demand factors. The availability of corporate bonds in the securities lending market reflects conditions in the spot market that simultaneously affect bond borrowing demand and bond lending supply. Thus, to measure the effect of securities lending on bond liquidity requires an identifying shock.

We exploit our institutional setting to address this identification challenge. In particular, we distinguish between AIG and other U.S. life insurers that had securities lending programs. AIG experienced a complete shutdown of the securities lending program operated by its life subsidiaries, falling from over $80 billion to almost nothing in less than one year.[5] By contrast, while other life insurers' securities lending programs shrank somewhat during the crisis, they continued to be active. For example, MetLife remained a significant corporate bond securities lender and has since become the largest lender of corporate bonds.

Figure 3 illustrates the size of the shock to AIG relative to other securities lenders. We divide our data into three mutually exclusive subsamples. The first subsample contains those corporate bonds that are held by insurance companies excluding AIG. The second subsample contains those corporate bonds that are held predominantly by AIG.[6] The third and final subsample contains those corporate bonds that are not held by any insurer. Figures 3a and 3b show coefficient plots from regressions of corporate bond availability for securities lending and actual lending, respectively, using quarterly dummies to reveal the time-series dynamics.[7] The evolution of the gap between the blue diamonds and green squares is the variation underpinning our empirical strategy. Figure 3a shows how the availability of those corporate bonds held predominantly by AIG fell relative to those bonds held by other insurers. To be sure, the availability of corporate bonds held by *all* insurance companies falls in the second half of 2008 as their securities lending programs shrink. However, as indicated by the gap between the blue diamonds and green squares,

[5] Existing studies of corporate bond securities lenders examine transaction level data for lending programs smaller than $15 billion (Nashikkar & Pedersen (2007) and Asquith et al. (2013)).

[6] In the figure, we used the threshold of 40 percent of total holdings by insurance companies with securities lending programs. This threshold is not crucial to the empirical results.

[7] For each subsample of bonds b in month t with variables $\text{Y}_{bt} \in \{\text{Availability}_{bt},\ \text{Lending}_{bt}\}$ we estimate $\text{Y}_{bt} = \alpha_b^1 + \alpha_t^2 + \sum_{q=2007Q3}^{2010Q4} \beta^q \text{Quarter}_t^q + \epsilon_{bt}$ where Quarter_t^q is a dummy variable that takes the value 1 in quarter q and 0 otherwise. Figures 3a and 3b plot three time-series of β^q coefficients, which measure the average deviation of $\text{Y}_{bt} \in \{\text{Availability}_{bt},\ \text{Lending}_{bt}\}$ from the mean of bond b in each quarter q and in each of the three subsamples. The point estimates from the regressions using the first, second, and third subsamples are denoted by blue diamonds, green squares, and red circles, respectively. The horizontal lines drawn through each symbol are the 95 percent confidence intervals.

the decrease in availability was especially pronounced for AIG. This gap opens slowly and becomes significant as early as 2008Q3 because AIG's securities lending program was shut down gradually. Figure 3b shows that the actual lending of corporate bonds also fell for AIG relative to other insurers. The gap between the blue diamonds and green squares opens sharply in 2008Q4 and widens only slightly in subsequent quarters, which could, of course, potentially reflect both supply and demand factors.[8]

Our empirical analysis exploits the shutdown of AIG's securities lending program to implement a difference-in-differences strategy. The dependent variable is an individual bond's market liquidity, measured as the bond's monthly average realized bid-ask spread.[9] The first difference in our strategy is between those bonds that AIG held a high fraction of industry holdings in 2006 and those bonds in which AIG held a low fraction. The second difference is between the period before and the period after the shutdown in AIG's lending programs at the end of 2008. These differences together identify the effect of an exogenous reduction in corporate bond securities lending on market liquidity.[10]

Our identification strategy relies on three key assumptions. First, we assume that AIG did not reinvest their cash collateral mostly in corporate bonds. Regulatory filings confirm that AIG indeed reinvested less than 20 percent of its cash collateral in corporate bonds. Second, we assume that the shutdown of AIG's securities lending program was not due to concerns about corporate bond market liquidity. We show that the shift in corporate bond market liquidity occurred *after* the shutdown of AIG's securities lending program. In addition, anecdotal evidence suggests that the run by securities borrowers was driven by losses on AIG's cash collateral reinvestment portfolio (Peirce 2014). Our third and final assumption is that those corporate bonds held and lent by AIG and those bonds held and lent by other insurance companies differ only along observable dimensions, for which we include all available control variables. We compare holdings and lending portfolios of AIG and other insurance companies with securities lending programs and find no evidence of differences, in particular with respect to the key outcome variable,

[8] It is tempting to analyze bond liquidity using the same methodology, but that would be a mistake because this simple analysis omits many first-order determinants of bond liquidity. We will rely on a more sophisticated estimation strategy that includes controls for other determinants.

[9] This well-established measure of market liquidity is the gap between the price that a client pays to a dealer to purchase a bond and the price a dealer pays to a client for buying a bond.

[10] Our identification strategy shares features with other studies that exploit differential effects of shocks originating in the crisis. Examples include the Lehman bankruptcy (Aragon & Strahan 2012, Kovner 2012, Chodorow-Reich 2014) and fiscal stimulus programs (Mian & Sufi 2012).

market liquidity.

Our results suggest that securities lending markets have a significant statistical and economic effect on corporate bond market liquidity. We find that the shutdown of AIG's securities lending program lowered the market liquidity of those bonds that were held by AIG. Specifically, a one standard deviation increase in the share of a bond that was held by AIG is associated with a reduction in that bond's liquidity of about 2 basis points in the period after AIG's securities lending program was shut down. This point estimate can be compared with typical corporate bond trading costs, which are in the order of 10 basis points for smaller traders, to gauge the economic importance of securities lending to OTC market liquidity (Schultz 2001, Hong & Warga 2000).

We further exploit our empirical setting and identification strategy to study how dealers responded to the shutdown of AIG's securities lending program. As suggested by Figure 1, in the absence of an available securities lender, dealers resort to other markets to meet their clients' orders. Applying our difference-in-differences identification strategy to analyze the dynamics of interdealer trading in those bonds predominantly held by AIG, we find that, after an adjustment period, the interdealer market partly compensated for disruption to the securities lending market. For a bond predominantly held by AIG, the ratio of interdealer trading volume to total trade volume increased by 1 percentage point.[11] As this ratio is on average 10 percent across all bonds, the increase in interdealer trading volume was about 10 percent. We also show that the increased cost of trade—measured using price dispersion—was eventually passed on by dealers to their clients.

Our paper contributes to several broad research topics in the literature. We provide the first evidence that OTC market liquidity is vulnerable to run risks arising in the securities lending market, particularly in corporate bond securities lending by non-bank financial institutions. The financial crisis of 2007-2009 initiated a surge of interest in the activity of so-called shadow banks and the risks those activities may pose to the broader financial system.[12] While many studies have sought to understand the determinants of market liquidity, few have explored the important contribution of the shadow banking system.[13] Our finding helps to understand the determinants of corporate bond market

[11] We calculate this effect using the difference between the 90^{th} percentile of the fraction held by AIG (30 percent) and the 10^{th} percentile held by AIG (0 percent).

[12] See Gorton & Metrick (2012) for a survey of the literature.

[13] The effects of corporate bond illiquidity on the level and volatility of investor returns have a wide range of potential real and financial consequences, including for corporate structure (Hoshi, Kashyap

liquidity and, especially, the connection between market liquidity and the shadow banking system.

Our paper also contributes empirical evidence to the literature studying OTC markets through the lens of search-based models (Duffie et al. 2005, Lagos & Rocheteau 2009). Although our empirical analysis is not a direct test of search-based models, it is closely related to the frontier of this literature that studies the liquidity feedback from the securities lending market to the corresponding spot market (Vayanos & Weill 2008, Sambalaibat 2017). We use a shock to the securities lending market to identify a causal link between bond availability in the securities lending market and liquidity in the spot market. We then use the same shock to estimate the dynamics of price dispersion and trading between dealers and between clients and dealers. Our findings offer new insight into the mechanics of the relationship between the two markets.

Lastly, our paper contributes to a growing literature on corporate bond market liquidity during and after the financial crisis. Dick-Nielsen, Feldhütter & Lando (2012) find evidence of short-run illiquidity, potentially as a consequence of (i) distress at lead underwriters e.g., Bear-Sterns and Lehman Brothers, (ii) investor flight towards more highly rated securities, and (iii) information asymmetry. Other studies examine long-term corporate bond market liquidity in the aftermath of the financial crisis. As surveyed by Adrian, Fleming, Shachar & Vogt (2017), the literature has found little to no evidence of a long-lasting decline in corporate bond market liquidity.[14] We offer a nuanced view that long-term corporate bond market liquidity did decline for those bonds that were both held in large amounts by insurance companies and were made available to market participants through securities lending programs that were shut down. In addition, we show that dealers eventually passed the trading cost increase on to their clients.

The remainder of the paper proceeds as follows. In Section 1 we provide an overview of the market for corporate bond securities lending and the experience of insurance companies during the financial crisis. Section 2 describes our data and summary statistics. Sections 3 and 4 present our empirical strategy and main results. Section 5 investigates one mechanism behind our results. We conclude in Section 6.

& Scharfstein 1991), for portfolio management (Amihud & Mendelson 1988, 2006), and for financial stability (Adrian & Shin 2010).

[14] Exceptions include Bao, O'Hara & Zhou (2018) and Choi & Huh (2017), who find some evidence that regulations, in particular the Volcker Rule, may have reduced market liquidity for some corporate bonds.

1 Institutional background

In this section, we first outline the role of securities lending in OTC corporate bond markets. Then we describe a typical corporate bond securities lending transaction, including the specific role played by insurance companies. Furthermore, we provide an overview of the experience of AIG, which in the pre-crisis period operated the largest corporate bond securities lending program ever maintained by an insurance company.

1.1 OTC corporate bond markets and securities lending

The OTC corporate bond market is huge. In 2015, U.S. corporations issued almost \$1,500 billion of debt, compared with only \$256 billion in equity.[15] After their initial offering in the primary market, most of this debt is tradable in an OTC spot market. In 2015, over 25,000 unique corporate bonds were publicly traded, with most of the trading taking place in investment grade bonds (61 percent). Between 2006 and 2016, there were 44,082 daily transactions on average that amounted to almost \$30 billion in daily volume traded. About two-thirds of these transactions were between a client and a dealer, and the other third of these transactions were between dealers.[16]

To buy and sell corporate bonds, participants in this OTC market search for counterparties (Duffie et al. 2005). The associated costs of search can be reduced by some participants acting as intermediaries—such as broker-dealers—that match buyers with sellers.[17] Dealers typically facilitate efficient market functioning either by swiftly finding a matching counterparty for a client in the market, or by trading itself with the client and maintaining its own inventory of securities. Although dealers can help to reduce search costs, they cannot fully eliminate such costs because their inventories are naturally limited by the supply of individual bonds and the associated inventory maintenance costs.

The limitations on dealers' ability to make markets create an opportunity for institutional investors, as natural large repositories of securities, to smooth the matching process by lending their securities. Among institutional investors in corporate bonds, insurance companies have the largest holdings, giving them a dominant position as

[15] `www.sifma.org`. The value of new corporate debt excludes the issuance of convertible debt, asset-backed securities, and non-agency mortgage-backed securities.

[16] `www.finra.org`. All these statistics exclude convertible debt transactions.

[17] A recent literature has studied the reasons for certain institutions to act as dealers (Hugonnier et al. 2014, Chang & Zhang 2015, Neklyudov & Sambalaibat 2015) and the equilibrium number of broker-dealers as an outcome of the cost of inventory and the liquidity of the market (Wang 2016)

potential bond lenders.[18] When a client wants to buy a bond that a dealer does not hold in its inventory, the dealer may borrow the bond elsewhere and deliver it to the buyer. The dealer can then wait until it can find another client willing to sell the same bond, which the dealer can return to the lender.

In addition to aiding dealers in their inventory management, corporate bond securities lending can improve OTC market liquidity by facilitating short positions and certain arbitrage strategies and by avoiding delivery fails.[19] For example, in a capital structure arbitrage trade, a firm's bond is shorted to hedge a long position in the firm equity. Another example is a convertible bond arbitrage trade, in which firm's equity is sold short to hedge a long position in a bond issued by that firm. In this second example, the dealer might also borrow the convertible bond.

1.2 Corporate bond securities lending transactions

In a prototypical corporate bond loan, as depicted in Figure 6, full legal and economic ownership of the bond is transferred from the lender (e.g. insurance company) to the borrower. The ownership is essential for borrowers (e.g. dealers) to be able to deliver the bond to other counterparties (clients). To allow the borrower flexibility in the time needed to find another seller of the same bond, the term of the loan is usually open-ended, but either party is able to terminate the deal at any time by returning the security/collateral.[20]

In exchange, the bond borrower gives the bond lender collateral in the form of cash, which the lender may reinvest according to its own strategy and regulatory limitations.[21] Typically, the loan is marked to market daily and is "*overcollateralized*," with borrowers providing, for example, \$102 in cash for every \$100 in notional value of a security. The percentage of overcollateralization is called the "*margin*," which serves to insure the securities lender against the cost of replacing the lent security if the borrower defaults.

[18] Insurance companies account for 20 percent of all corporate bonds outstanding as of 2018Q2 (Table L.213 of the Financial Accounts of the United States available at `https://www.federalreserve.gov/apps/FOF/Guide/L213.pdf`).

[19] For more details, see Duffie (1996), Faulkner (2006), Nashikkar & Pedersen (2007), Faulkner (2008), Musto, Nini & Schwarz (2011), Keane (2013) and Asquith et al. (2013).

[20] Even in the unusual cases of term lending, parties often have the ability to break the contract early by paying a nominal penalty. More than 90 percent of the corporate bond loans in our data sample are open-ended.

[21] In principle, the contract may allow a borrower to post non-cash collateral against the bond, but this is uncommon in the U.S. In our data on corporate bond loans, more than 90 percent of transactions are against cash collateral.

Lastly, the bond lender pays a percentage of the reinvestment income to the bond borrower, called the "*rebate rate*." This equilibrium price is negotiated at the outset of the deal and reflects the scarcity of the bond on loan: A hard-to-find "*special*" bond may command a low or negative rebate rate.

In addition to the ultimate owner and the borrower, a corporate bond securities lending transaction may involve one or two other parties. First, owners of large portfolios like AIG and MetLife often conduct their own lending programs with an affiliated agent lender, while smaller owners typically execute their programs through third-party agent lenders, such as custodian banks or asset managers, that act as large warehouses for securities made available for lending.[22] Second, the end users of the borrowed securities, such as hedge funds, may be small and weakly regulated. In such cases, they will often borrow through dealers who help to assuage lenders' concerns about counterparty risk. Since these smaller end-users interact repeatedly with the same dealers, corporate bond securities lending may sometimes involve more than one dealer intermediating between the bond lender and the bond borrower.

As discussed in Foley-Fisher, Narajabad & Verani (2016), some insurers aim to supply their securities so as to create and maintain a pool of cash collateral that they use to finance a portfolio of longer-duration, higher-yielding assets. The greater return associated with reinvesting the cash collateral in less liquid and/or longer-term assets is not without cost. In particular, insurers that pursue this strategy create and bear run risk associated with liquidity and maturity transformation. The reinvestment of cash collateral in U.S. mortgage-related securities was one of the root causes for the collapse of AIG in 2008.

1.3 AIG's securities lending program during the 2007-2009 financial crisis

Although it has been told in greater detail elsewhere, an overview of AIG during the crisis is helpful to understand the shock to corporate bond securities lending that we will exploit in our empirical exercise.[23] Beginning in the 1980s and through the run-up to the 2007-2009 financial crisis, AIG increased profits by diversifying its operations into

[22] Agent lenders that warehouse bonds from many ultimate owners typically use an algorithm to determine which owner will be matched with borrowing requests.

[23] For more details about AIG, see Peirce (2014) and McDonald & Paulson (2015).

non-traditional insurance activities that, for the most part, occurred beyond regulatory oversight. Many of these activities created direct and indirect exposures to the U.S. housing market. In addition to exposure through its credit default swap (CDS) portfolio and mortgage insurance business, AIG lent vast quantities of bonds from the general accounts of its life insurance subsidiaries in exchange for cash collateral. At the end of the third quarter of 2007, AIG's consolidated securities lending business amounted to $88.4 billion.[24] The insurer reinvested less than 20 percent of its cash collateral in corporate bonds and instead reinvested mostly in non-agency residential mortgage-backed securities (RMBS) and other illiquid medium-term securities.[25] When the U.S. housing market collapsed, AIG's massive exposures to the housing-related securities and credit derivatives caused a severe liquidity crisis.

From early 2008, AIG's mortgage insurance business began to experience losses due to poorly performing loans. At about the same time, concerns about the credit quality of securities referenced by CDS sold by AIG led to a combination of losses and collateral calls that began to drain the company's cash and cash-like assets. As AIG's financial condition deteriorated, securities borrowers reduced the amount of cash collateral they were willing to provide to roll over the securities AIG had lent. Throughout the summer of 2008, many securities borrowers returned the securities and demanded their cash collateral. AIG's securities lending program shrank from $88.4 billion in September 2007 to $69 billion at the end of August 2008.[26] The Wall Street Journal later reported that AIG had instructed its portfolio managers to shrink the program in response to investors' concerns about the firm's exposure to the subprime mortgage market.[27] By September 2008, AIG had exhausted all of the cash and cash-like assets in its securities lending pool and began to make calls on their life insurance companies to avoid selling their reinvestment holdings of RMBS at fire sale prices.[28] After several attempts to structure a private-sector rescue for AIG failed, the Federal Reserve Board of Governors, the Federal Reserve Bank of

[24] See pg. 108 of AIG's Form 10-Q for September 30, 2007 available here: `https://www.sec.gov/Archives/edgar/data/5272/000095012307015058/y38903e10vq.htm`

[25] See pg. 87 of AIG's Form 10-K for 31 December 2007 available here: `https://www.sec.gov/Archives/edgar/data/5272/000095012308002280/y44393e10vk.htm`

[26] See pg. 40 of AIG's Form 10-K for 2008 available here: `https://www.aig.com/content/dam/aig/america-canada/us/documents/investor-relations/2008-10k-report.pdf`

[27] `https://www.wsj.com/articles/SB123380106666350625`

[28] The combination of actual losses and lack of cash-like assets undermined the market's confidence in AIG and led to rating downgrades, which prevented the parent company from rolling over the repurchase agreements and commercial paper that many AIG subsidiaries relied on for funding.

New York, and the U.S. Treasury conducted a number of interventions beginning in September 2008, which ultimately stabilized AIG (GAO 2011). At the same time that AIG released its third-quarter financial report in 2008, the firm publicly announced that it would terminate its securities lending program.[29] The accelerated contraction shrank the securities lending program to only $3 billion in December 2008.[30]

2 Data

We use several data sources to construct the dataset we use in our analysis. This section lays out how we combine data on corporate bond liquidity, securities lending, insurers' holdings of corporate bonds, and their bond lending activity.

We follow the established literature in calculating corporate bond liquidity using data on spot market OTC trading of corporate bonds from TRACE, created by the Financial Regulatory Authority (FINRA). Under regulations introduced in 2002 by FINRA, dealers are required to file detailed reports of their transactions, including trade time, quantity, price, and counterparty.[31] We follow standard procedures for cleaning these data, including deleting all small noise-generating trades below $10,000 and removing duplicate transactions.[32] For our measure of liquidity, we first calculate for each bond on each day the volume-weighted average buy and sell prices across client-dealer trades. We then compute bond market liquidity as the *average realized spread*, which is the difference between the average daily price at which a dealer sells a bond to a client and the average daily price at which a dealer buys the same bond from a client. We take the negative of the spread to make the interpretation of the sign of the coefficients easier: The transformed variable is increasing in liquidity. With our daily measure of bond liquidity, we compute the average (mean) over days to obtain a monthly unbalanced panel of bond-specific liquidity.

For our analysis of interdealer trading, all data are aggregated from transaction-level

[29] See page 45 of AIG's Form 10-Q for 2008Q3 available here: https://www.aig.com/content/dam/aig/america-canada/us/documents/investor-relations/q308-10-report.pdf

[30] See Page 6 of the financial supplement to AIG's Form 10-K available here: https://www.aig.com/content/dam/aig/america-canada/us/documents/investor-relations/fin-supp-report.pdf

[31] Our sample, by necessity, begins in 2005 because, although FINRA began collecting data in 2002, the coverage was limited until 2005.

[32] See, for example, Dick-Nielsen (2009) and Bao et al. (2018). We use confidential regulatory data with dealer identifiers, which allows us to match trades by buyer, seller, amount, and trade time when removing duplicates.

data to monthly data. The regulatory version of TRACE allows us to identify dealers and observe the trading behavior of a single dealer in a single bond during a given month. We calculate the total trading volume of a given dealer in a given bond as well as the number of trades between dealers in a given bond.

We merge the TRACE data with Mergent's Fixed Income Securities Database (FISD) by CUSIP identifier to obtain bond characteristics, including offering amount, offering yield, amount outstanding, credit rating, and a range of indicators on the type of each bond. We exclude from our sample all bonds that are convertible, putable, privately placed, asset-backed, or sold as part of a unit deal. We account for reissuance and early retirement when computing the amount outstanding over time and we define rating changes using the date of the first action by a rating agency (Ellul, Jotikasthira & Lundblad 2011). Our final dataset consists of 279,404 bond-month observations covering 17,994 unique bonds between 2006 and 2010. The median initial maturity of the corporate bonds in our sample is 9 years, with a median residual maturity across the entire sample of 5 years.

The major data contribution of our study is to combine the information on corporate bond liquidity with data on corporate bond lending. We match the corporate bond liquidity data from TRACE with loan-level transactions recorded in the Markit Securities Finance (MSF) dataset by CUSIP identifier. These data include both equity and fixed income loans and cover about 85 percent of the global market and more than 90 percent of the U.S. securities lending market. Securities lenders report information about each loan they have outstanding on a given day, including the identifier of the security on loan, the value of the loan, duration, lending fee, rebate rate, and the type of collateral posted. In addition, securities lenders report on each day the total value of every security that they have available to lend. We first aggregate these transaction-level data to a daily frequency by calculating the daily total value on loan, as well as the median value, fee, and rebate rate. Then, using these daily measures across the stock of loans outstanding, we compute monthly median values for each security. After merging the two datasets, we find that MSF reports data on the availability of a corporate bond for a securities lending transaction for more than 90 percent of all bond-month observations in TRACE. Information on actual loan transactions are available for almost 80 percent of all bond-month observations. We assume that the available and loan amounts are zero for the minority of TRACE bond-month observations that do not match to MSF.

Lastly, we combine our TRACE-MSF merged data with specific information about insurance company security holdings and lending activity from the NAIC Annual Statutory Filings.[33] Within these filings, Schedule D reports all insurers' individual fixed income holdings at year end, together with cross-sectional information about each security, including the CUSIP identifier, first date of purchase, and whether the bond was on loan as part of the insurer's securities lending program.[34] We calculate aggregate holdings by all life, property and casualty, and health insurers including bonds that are held in their separate accounts, as well as aggregate holdings by all insurance companies that have active corporate bond lending programs. We identify securities lenders as those insurance companies that have at least one bond on loan at year-end during the sample period. Unsurprisingly, as insurance companies are one of the largest institutional holders of corporate bonds, we find that about 88 percent of our dataset of bond-month observations have non-zero holdings by insurance companies, and about 86 percent have non-zero holdings by insurance companies that have active securities lending programs.

We present summary statistics for our final dataset in Table 1. Our main dependent variable on corporate bond market liquidity exhibits substantial variation, both between corporate bonds and within each corporate bond over time (this variation is not shown in the table). The variables derived from MSF indicate that, on average across the corporate bonds in our sample, securities lenders make roughly one quarter of the amount outstanding available to lend. Nevertheless, only about two percent of the amount outstanding is actually on loan at any given time. The median rebate rate is about 1 percent, while the median lending fee is about 0.1 percent. Finally, data on insurance company holdings at year end reveal that they hold, on average, about 16 percent of the amount outstanding with a distribution that is positively skewed. Insurance companies with active bond lending programs account for the lion's share of the holdings, which is simply a reflection of the tendency of larger insurance companies to lend their bond holdings.

[33] Historical NAIC Annual Statutory Filings are contained in the NAIC Financial Data Repository, a centralized warehouse of financial data used primarily by state and federal regulators.

[34] Unfortunately, we do not observe more detailed information on the insurers' securities lending programs at this time. Beginning in 2011, after state regulators adopted regulatory guidelines established by the NAIC, insurance companies started to report information about their securities lending programs (Foley-Fisher, Narajabad & Verani 2016).

3 Identification

Insurance companies are the largest institutional investors in corporate bonds as part of their asset-liability management, and thus naturally occupy a dominant position as large corporate bond lenders. Moreover, insurers select bonds with certain maturities, ratings, and issuers according to their asset-liability management strategy, creating heterogeneity across their bond portfolios. This heterogeneity has implications for the securities lending market and is the variation that we will exploit in our empirical strategy. Our basic empirical strategy is to study the impact of the effect of insurance companies' securities lending programs on the dynamics of corporate bond market liquidity.

Because insurers make their corporate bonds available for securities lending transactions in response to both supply and demand factors, estimating the effect of securities lending on bond liquidity requires a shock to bond lending supply that is orthogonal to conditions in the spot market. The main threats to identification are potentially unobserved bond demand factors that are correlated with the amount of a particular bond held by insurers and made available to the securities lending market.

One such potentially confounding factor is suggested by Brunnermeier & Pedersen (2009), who describe the relationship between funding liquidity and market liquidity. This relationship might mean that the effect of shocks to funding liquidity on market liquidity may be correlated with insurers' bond holdings. For example, a negative shock to funding liquidity will make it more difficult for broker-dealers to borrow any bond. But the harder it is for a broker-dealer to match buyers and sellers of a particular bond, the stronger will be the effect of the greater difficulty to borrow that bond on its market liquidity. By holding and not trading a bond, an insurer reduces the ability of broker-dealers to match buyers and sellers of that bond. Thus, the relationship between insurance companies' bond holdings and market liquidity may be confounded by the relationship between funding liquidity and market liquidity.

Ideally, we would address this identification challenge by comparing the market liquidity of two identical bonds that are held and lent by different insurance companies in the aftermath of an exogenous closure of one insurer's lending program. In what follows, we explain how we can approximate this ideal test by contrasting the experience of corporate bonds predominantly held by AIG with observationally-identical bonds predominantly held by other insurers.

As discussed in Section 1.3, AIG was the largest lender of corporate bonds prior to the crisis. In 2008, securities borrowers developed concerns about the liquidity of cash collateral reinvestment portfolios of AIG, which contained a large fraction of higher yielding securities related to the U.S. housing market. Following a run by securities borrowers and the massive intervention by the federal government, AIG was forced to shut down its securities lending program by the end of 2008. We tease out the effect of corporate bond lending on corporate bond market liquidity by exploiting the collapse of AIG as the source of exogenous reduction in insurers' bond lending around 2008. What is crucial to our identification is that although AIG was forced to shut down its securities lending program, other insurers holding observationally-identical bonds continued to lend them to dealers. Figures 4 and 5 confirm that across broad categories including rating classifications, residual maturity buckets, and most importantly liquidity, AIG's bond holdings and bonds on loan do not appear different from other U.S. life insurance companies with securities lending programs at the end of 2006. That said, our detailed data let us implement tests that fully control for unobservable heterogeneity with bond and time fixed effects and time-varying bond characteristics with bond-specific control variables interacted with time fixed effects.

3.1 Graphical illustration

We can graphically illustrate our identification strategy with an example. MetLife, the second largest insurance company lending corporate bonds in the pre-crisis period, remained a relatively active bond lender after the collapse of AIG. MetLife had a securities lending program of around $45 billion at its peak in 2007, and, like AIG, MetLife experienced enormous unrealized losses on its asset portfolio in 2008.[35] As the crisis unfolded, MetLife experienced large withdrawals by investors—including by securities borrowers requesting the return of their cash collateral. MetLife was creative in finding sources of cash and cash-like assets that enabled these withdrawals to be

[35] See GAO report 13-583, "Impacts of and Regulatory Response to the 2007-2009 Financial Crisis." MetLife's losses were second only to those of AIG. The unrealized losses stemmed in part from significant exposures to the U.S. housing market. Both insurance companies funded a material fraction of their assets using short-term non-traditional non-insurance liabilities. This included securities lending cash collateral and other debt-like instruments such as Funding Agreement-Backed Securities with embedded put options (Foley-Fisher, Meisenzahl, Narajabad, Perozek & Verani 2016).

met.[36] Specifically with regards to its securities lending program, MetLife swapped illiquid securities in its securities lending cash reinvestment portfolio for cash and short-term investments in other investment portfolios to avoid selling the illiquid securities in the reinvestment portfolio at fire sale prices.[37] By the beginning of 2009, not only was MetLife's asset portfolio still available to securities borrowers with about $25 billion on loan, but the company had replaced AIG as the largest lender of corporate bonds in the insurance industry.

The contrast between the experience of AIG and that of other insurers, such as MetLife, is the basis for our identification strategy. We exploit cross-sectional differences in the corporate bonds held and lent by AIG and other insurance companies. Holding fixed the total amount of each bond held by all insurance companies, we compare the liquidity of those bonds held in large amounts by AIG with observationally-identical bonds held by other insurers that were not forced to close their bond lending programs. Intuitively, the disproportionate shock to AIG's lending program in 2008 will asymmetrically affect the market liquidity of the bonds held by all insurers.

Figure 7 illustrates our identification strategy by focusing on the differences in lending behavior between MetLife and AIG. We calculate and fix the fraction of bonds held by AIG and MetLife at the end of 2006, and we scatter-plot the bonds that they exclusively lent through the crisis, as a function of their holdings.[38] In this example, our difference-in-differences strategy combines the difference between the bonds held by AIG and those

[36]At the time, MetLife was a Bank Holding Company, which allowed it to borrow from the Federal Reserve Bank of New York Discount Window and from the Federal Reserve Term Auction Facility (See Bloomberg, "The Fed's Secret Liquidity Lifelines," available at `http://www.bloomberg.com/data-visualization/federal-reserve-emergency-lending/#/MetLife_Inc` and Board of Governors, Term Auction Facility, available at `http://www.federalreserve.gov/newsevents/reform_taf.htm`). In addition, MetLife's life insurance subsidiaries ramped up borrowing from the federal government by issuing funding agreement backed commercial paper to the Federal Reserve's Commercial Paper Funding Facility and by increasing funding agreement backed borrowing from the Federal Home Loan Banks (See Board of Governors, Commercial Paper Funding Facility, available at `http://www.federalreserve.gov/newsevents/reform_cpff.htm` and MetLife's Form 10-K for 2007 and 2008.).

[37]From MetLife's 2009Q2 Form 10-Q: "During the three months ended March 31, 2009, a period of market disruption, internal asset transfers were utilized extensively to preserve economic value for MetLife by transferring assets across business segments instead of selling them to external parties at depressed market prices. Securities with an estimated fair value of $3.7 billion were transferred across business segments in the three months ended March 31, 2009 generating $509 million in net investment losses, principally within Individual and Institutional, with the offset in Corporate & Other's net investment gains (losses). Transfers of securities out of the securities lending portfolio to other investment portfolios in exchange for cash and short-term investments represented the majority of the internal asset transfers during this period."

[38] For graphical clarity, we restrict our sample to only those bonds in which the combined end-2006 holdings of MetLife and AIG are in the upper quartile of that distribution.

held by MetLife, and exploits AIG's exit from securities lending in 2008.[39] We adapt this approach using the fraction of a bond held and lent by AIG while controlling for the fraction of the bond's total amount held by the insurance industry.

3.2 Implementation of the difference-in-differences

Adopting a difference-in-differences approach, we test the hypothesis that corporate bonds held by insurers that were held in larger fraction by AIG became more illiquid after AIG's securities lending program shut-down as these corporate bonds became relatively less available to securities borrowers. Our dependent variables are bond-month measures of liquidity, availability, lending, rebate, and volume. We measure liquidity as the negative of the average realized spread between the price paid by a dealer to a client for purchasing a bond b in month t and the price at which the dealer sells the same bond to a client. We take the negative of the spread to make the interpretation of the sign of the coefficients easier: The transformed variable is increasing in liquidity.

The first difference in our difference-in-differences strategy is between bonds that AIG held a large fraction relative to industry holdings and bonds that AIG held a small fraction. The second difference is between the period before the shutdown in AIG's lending program and the period after the shutdown, measured using a set of dummy variables (Year_t^y) for each year y. We interact these year dummy variables with the fraction of each bond b in our sample held by AIG relative to the total amount held by all insurance companies with bond lending programs at the end of 2006 (AIGFrac2006_b).[40]

We implement our difference-in-differences strategy using the following specification:

$$\begin{aligned}\text{Liquidity}_{bt} =& \alpha_b^1 + \alpha_t^2 + \sum_{y=2008}^{2010} \beta^y \text{AIGFrac2006}_b \times \text{Year}_t^y \\ &+ \zeta \text{InsFrac2006}_b \times \text{Month}_t + \tilde{\mathbf{X}}_{bt}\tilde{\boldsymbol{\gamma}} + \epsilon_{bt}. \end{aligned} \tag{1}$$

where the coefficients β^y on the interaction terms allow us to trace the difference-in-differences effect of the reduction in the lending supply of corporate bonds that were mostly held by AIG that occurred during the financial crisis. We include both bond fixed

[39] Bond characteristics interacted with time-specific fixed effects absorb the variation in liquidity associated with bond heterogeneity (Friewald, Jankowitsch & Subrahmanyam 2012).

[40] The variable AIGFrac2006_b does not appear by itself in any specification because it is time-invariant and we include bond fixed effects in every specification.

effects (α_b^1) to control for time-invariant heterogeneity across bonds, and we also include month fixed effects (α_t^2) to control for time-varying common shocks to bond market liquidity, including shocks to investors' or dealers' bond demands.

We include the fraction of all insurers' holdings of the amount outstanding in 2006 (InsFrac2006_b) interacted with time as a control variable because insurers were potentially different from other securities lenders, such as mutual funds and sovereign wealth funds.[41] Figures 2 and 3a suggest that this might have been the case. We need to include this control to ensure we are comparing otherwise-identical corporate bonds across insurance companies. In the absence of this control, we would be comparing corporate bonds held by AIG with those corporate bonds held (disproportionately) by other types of securities lenders. That is a potentially inappropriate control group because the corporate bond lending strategy of other securities lenders is different from that of insurance companies. Including the interaction of time with the variable InsFrac2006_b as a control variable ensures that we are comparing the effect of the shutdown of AIG's securities lending program within those corporate bonds held by insurance companies.

Lastly, we include a vector ($\tilde{\mathbf{X}}_{bt}$) of 32 corporate bond-specific control variables interacted with time fixed effects. The interaction between bond characteristics and time is essential to control for, as an example, potential changes in bond demand that occurred during the crisis period (e.g. flight to quality) and the development of the low interest rate environment (e.g. reach for yield). In addition to controlling for unobservable heterogeneity with fixed effects and time-varying bond characteristics, we cluster our standard errors by both month and bond to alleviate concerns that shocks may be correlated within months or across bonds.[42]

[41] The timing of the calculation is not important because insurers' holdings vary more across bonds than across years. Results using a time-varying measure of insurers' holdings (InsFrac_{bt}^y) are included in Online Appendix A. The between-variation in InsFrac_{bt}^y measured by the standard deviation across our sample of 18,000 corporate bonds is 0.25. By contrast, the within-variation of the same sample is only 0.07.

[42] Across specifications, our standard errors have roughly 55 month clusters and more than 3,000 bond clusters. The findings reported are not dependent on the clustering choice. We obtain statistically significant results if we one-way cluster our standard errors by month or bond and if we replace the clustered standard errors with Eicker-White heteroscedasticity robust standard errors. These results are available from the authors on request.

4 The effect of the collapse of AIG's securities lending program on corporate bond liquidity

Table 2 presents the results from estimating equation 1. The dependent variable in columns 1 and 2 is the liquidity of bond b in month t measured using the negative average realized spread. Column 1 excludes the interaction between the fraction of insurers' holdings of the amount outstanding in 2006 and time fixed effects. Column 2 includes that interaction term. The point estimates of the coefficients on the key explanatory variables are slightly smaller, especially the interaction with 2008, indicating that confounding effects may indeed be present. The point estimates for the effect of the shutdown are smaller in 2008 than in 2009 or 2010. This result is unsurprising because the measured effect in 2008 is a yearly average. Our earlier discussion of the gradual shut down of AIG's securities lending program suggests that the effect would be strongest only towards the end of 2008. The results indicate that a one standard deviation increase in the ratio of AIG holdings of a bond to the total amount of the bond held by insurers with bond lending programs (15 percentage points) lowers the liquidity of that bond by about 2 basis points in 2009. Because trading costs are in the order of 10 basis points for smaller traders, this estimate suggests that the collapse of AIG caused the costs of trading bond predominantly held by AIG to increase by at least 20 percent.[43]

The remaining columns of Table 2 show results from replacing bond liquidity as the dependent variable in equation 1 with a set of variables related to bond lending and spot market trading. The coefficients on the interaction terms suggest that, after AIG's securities lending program collapsed, the availability of bonds predominantly held by AIG fell (column 3) and lending fell (column 4), even as those bonds became more special (column 5). Finally, column 6 reveals that the volume of spot market trading was lower in the bonds predominantly held by AIG after the collapse of their securities lending program.

[43] Our estimate of trading costs is based on data reported by Hong & Warga (2000) and Schultz (2001). Our estimate may be on the high side given the downward trend in trading costs since the early 2000s (Mizrach 2015). As an alternative benchmark, the first line of Table 1 shows that the median average realized spread in our sample is 26 basis points.

4.1 Testing for parallel trends

Checking for parallel trends in the period before the shock to AIG's lending program is an important test for the validity of our difference-in-differences approach to identify the effect of the shutdown of AIG's securities lending program on corporate bond market liquidity. We need to show that the corporate bonds in the treatment and control groups during the pre-shock period are not statistically different in terms of the outcome variables (liquidity, availability, lending, rebate and volume). Figure 3 already offers some reassurance. In this section, we go further and include bond-level controls to compare the pre-shock trends of otherwise-identical corporate bonds held by insurance companies.

To test for parallel trends, we repeat our baseline specifications replacing the annual dummy variables with quarterly dummy variables. For example, when the dependent variable is the liquidity of bond b in month t, our specification is

$$\begin{aligned}\text{Liquidity}_{bt} =& \alpha_b^1 + \alpha_t^2 + \sum_{q=2008Q1}^{2009Q1} \beta^q \text{AIGFrac2006}_b \times \text{Quarter}_t^q \\ &+ \eta \text{AIGFrac2006}_b \times \text{Post2009Q1}_t \\ &+ \zeta \text{InsFrac2006}_b \times \text{Month}_t + \tilde{\mathbf{X}}_{bt}\tilde{\boldsymbol{\gamma}} + \epsilon_{bt} \qquad (2)\end{aligned}$$

where Quarter_t^q is a dummy variable that takes the value 1 in quarter q and 0 otherwise. Similarly, Post2009Q1_t is a dummy variable that takes the value 1 in the months after 2009Q1 and 0 otherwise. The coefficient estimate of η measures the long-term change in liquidity of those bonds that were predominantly held by AIG. All other variables are defined as before. These specifications include the full set of control variables that are essential for us to compare otherwise-identical corporate bonds across insurance companies.

As a visualization of our results, Figure 8 shows plots of the coefficients $\{\beta^q,\ \eta\}$ for each of our five dependent variables in separate panels. The blue diamonds indicate the point estimates of the coefficients and the blue lines are the 95 percent confidence intervals. Figure 8a shows there is no difference between the liquidity of those corporate bonds predominantly held by AIG and the liquidity of those corporate bonds held by other insurers before 2008Q4. This finding confirms the key parallel trends in the period before the shock to AIG's securities lending program. The decline in liquidity occurs only after 2008Q3 and after AIG begins to shut down its securities lending program. Figure 8b corroborates the results in Figure 3a that AIG scaled back its lending program before the decline in liquidity. Figures 8c and 8d show that the quantity of actual lending and the rebate both fell, consistent with a shock to the *supply* of AIG's corporate bonds in the securities lending market. Figure 8e shows there was a decline in the volume of those bonds in the spot market, but this generally occurred later and the results are not as statistically strong. All of these results with quarterly dummy variables are similar to the results we obtain with annual dummy variables.

4.2 Robustness

In this section, we test the robustness of our findings to alternative measures of the AIG's corporate bond holdings. We also report results from testing whether AIG disproportionately sold its corporate bonds following the shutdown of its securities lending program.

We implemented two robustness tests for the timing of when we calculate our key control variable. As noted in the previous section, we calculated the fraction of corporate bonds held by AIG as of 2006 because it was the earliest year available in our data sample. As a first alternative control variable, we calculate the fraction as of 2007 and report the results in Table 5. As a second alternative, we calculate the fraction as of the end of each year and report the results in Table 6. We find a very similar pattern of results to our baseline variable using either alternative.[44] The liquidity of bonds held by AIG began to decline in the aftermath of the shock to AIG's securities lending program. At the same time, those bonds became less available for borrowing. The quantity of lending and the rebate both declined at the same time, consistent with an adverse shock to the supply of AIG's bonds in the securities lending market.

To test whether corporate bond trading by *all* insurers might be affecting the estimates, we restrict our sample only to those bonds that insurers continued to hold at the end of 2010. We repeated the baseline specifications on this restricted sample. Table 3 presents the results. Broadly speaking, they are the same as Table 2. We implemented all our other robustness tests using both the original sample and the restricted sample,

[44] In the latter case, we must include the fraction of AIG's bond holdings at the end of each year (AIGFrac_{bt}^{y}) as a separate time-varying control variable in addition to interacting the variable with time. As a consequence, the interpretation of the coefficients is slightly different.

reporting the latter in Online Appendix A.

A reasonable concern is that the observed effect on liquidity may derive from AIG disproportionately selling its corporate bonds. Although insurance companies' asset management strategy is generally to buy and hold bonds, AIG may have sold some bonds as part of its overall response to the financial crisis. As we discussed in Section 1, investors withdrawal from AIG forced the insurer to find sources of cash and cash-like assets. In principle, AIG might have sold bonds to raise cash, and this may have had a direct effect on the market liquidity of these bonds, unrelated to the termination of AIG's bond lending program.

We investigate this concern by constructing monthly sales by volume for the largest 60 life insurance groups. Using transaction-level data from life insurance companies' statutory filings (NAIC Schedule D Parts 4 and 5) we sum the individual daily corporate bond sales within a month for each insurance group identified by the NAIC. The variable S_{it} is the par value of total corporate bond sales by insurance group i in month t. We then estimate a fully saturated model

$$S_{it} = \alpha_i + \gamma_t + \beta \text{AIG}_i \times \text{PostAug2008}_t + \epsilon_{it} \tag{3}$$

where AIG_i is a dummy variable that equals 1 for sales by AIG and PostAug2008_t is a dummy variable that equals 1 for sales after August 2008.[45] The coefficient estimate of β measures the differential effect of AIG's sales in the period after August 2008.[46]

The results from estimating equation 3, shown in Panel A of Table 4, indicate that AIG's life insurance subsidiaries did not liquidate their corporate bond portfolio. Using a two-year window around August 2008, the results reported in columns 1 and 2 indicate that there was no statistically significant change in the volume of AIG's corporate bond sales relative to other life insurers. Column 1 shows the results for all corporate bond sales identified in the statutory filings. Column 2 shows the results based on a subset of sales obtained by merging the individual corporate bond transactions from the statutory

[45] We chose August as the breakpoint because AIG reported that its securities lending program came under strong pressure in September 2008. See page 40 of AIG's Form 10-K regulatory filing available here: `https://www.aig.com/content/dam/aig/america-canada/us/documents/investor-relations/2008-annual-report.pdf`

[46] In equation 3, we did not take logs because the sales of an insurance group can be zero. We also ran a specification taking logs and omitting the months when sales were zero. The data compression increases the statistical significance of the results slightly, which indicates that, if anything, some extreme data points were working against us.

filings with our TRACE-MSF-Mergent database to identify only the sales of corporate bonds that are included in our data. The coefficient estimate on the interaction term is zero in both cases. Extending the window around August 2008 to four years, the results reported in columns 3 and 4 suggest that, if anything, AIG might have *reduced* the volume of its corporate bond sales relative to other insurers over this longer time period.

We repeated our analysis using life insurers' corporate bond purchases and we report the results in Panel B of Table 4. As we did for sales, we sum the individual daily corporate bond purchases within a month for each life insurance group identified by the NAIC. Using a two-year window around August 2008, reported in columns 1 and 2, there was no change in the volume of AIG's corporate bond purchases relative to other insurers. The difference between the data samples in the two columns is the same as in Panel A. Using an extended window of four years around August 2008, reported in columns 3 and 4, we find weak evidence that AIG decreased its purchases of corporate bonds relative to other insurers. Taken together, these findings for corporate bond sales and purchases are consistent with the narrative that AIG was carefully managing its insurance business under close regulatory scrutiny in the post-crisis period.

As a further check that disproportionate corporate bond trading by AIG is not confounding our findings, we implemented two robustness tests using AIG's corporate bond holdings at the end of each year. First, we continue to interact dummy variables for each year with the fraction measured at the end of 2006—as in the main analysis of the paper—and we add the fraction held by AIG at the end of each year y (AIGFrac_{bt}^{y}) as a control variable. The results are reported in Table 7. Second, we replaced the fraction measured at the end of 2006 with the fraction at the end of each year. The results are reported in Table 6. The results presented in these tables add weight to our main finding that the liquidity of AIG's bonds declined following the shutdown of AIG's securities lending program.

5 The dynamics of corporate bond liquidity and interdealer trading

In this section, we investigate whether the interdealer market was affected by the collapse of AIG's securities lending program. Although search and bargaining frictions are likely to affect both the securities lending market and the spot market, as we explained in Section 1, dealers are willing to borrow corporate bonds from institutional investors, such as insurance companies, suggesting that the severity of frictions in the securities lending market is lower than that of the spot market. Consequently, a decrease in the availability of bonds for securities lending transactions may force dealers to fulfill client orders by searching for those bonds in the interdealer market. The shift by dealers to the interdealer market may increase the severity of search and bargaining frictions and the cost of intermediation, which reduces bond liquidity. Naturally, in times when the interdealer market is likely to have more frictions—such as during the financial crisis—the effect of disruption in the securities lending market will be amplified. Nevertheless, we find that liquidity was significantly lower several years after AIG's securities lending program shut down and after the crisis had been declared over. This finding suggests that the interdealer market could not fully compensate for the shock to the securities lending market even in "normal" times.

We confirm the economic relevance of this particular channel by studying the dynamics of trading between dealers and between clients and dealers. Unlike the results in Section 4, the results in this section are only suggestive of the *causality* for this particular channel. That said, we show that, at the very least, there was a significant change in the pattern of interdealer trading *following* the shutdown of AIG's securities lending program. In particular, for the bonds that were predominantly held by AIG, we show that dealers traded smaller amounts of those bonds more frequently. Price dispersion on those bonds initially rose for all trades, but remained significant only for dealer-client trades. Our findings are thus consistent with the interdealer market partly compensating for disruption to the securities lending market with the associated increase in trading costs eventually borne only by clients.

5.1 Interdealer trading dynamics

We use the difference-in-differences framework discussed in Section 3.2 to investigate how interdealer trading changed for the corporate bonds that were the most affected by the collapse in AIG's securities lending program. We estimate the equation

$$\begin{aligned}\text{IntDealerTrade}_{bt} =& \alpha_b^1 + \alpha_t^2 + \sum_{y=2008}^{2010} \beta^y \text{AIGFrac2006}_b \times \text{Year}_t^y \\ &+ \zeta \text{InsFrac2006}_b \times \text{Month}_t + \tilde{\mathbf{X}}_{bt}\tilde{\boldsymbol{\gamma}} + \epsilon_{bt} \ , \end{aligned} \tag{4}$$

using the same explanatory and control variables and two-way clustered standard errors by bond and month throughout.

Columns 1 and 2 in Table 9 show that there was a higher volume of interdealer trades among a greater number of dealers in the aftermath of the collapse of AIG's securities lending program. The coefficient estimates suggest that when AIG held 50 percent of the industry's holding, the volume of interdealer trade and the number of dealers increased by 5 and 4 percent, respectively.[47] For a bond predominantly held by AIG, the ratio of interdealer trading volume to total trade volume increased by 1 percentage point.[48] Since this ratio is on average 10 percent across all bonds, the increase in interdealer trading volume was about 10 percent.

Next, we analyze dealer-level trades in those bonds predominately held by AIG. The confidential version of TRACE provides information about the identity of dealers for each bond trade. We use this information to estimate the effect of the collapse of AIG on dealer-level bond trades with the following equation:

$$\begin{aligned}\text{IntDealerTrade}_{bdt} =& \alpha_b^1 + \alpha_d^2 + \alpha_t^3 + \sum_{y=2008}^{2010} \beta^y \text{AIGFrac2006}_b \times \text{Year}_t^y \\ &+ \zeta \text{InsFrac2006}_b \times \text{Month}_t + \ \mathbf{X}_{bdt}\boldsymbol{\gamma} + \epsilon_{bdt} \ . \end{aligned} \tag{5}$$

Note that equation 5 implements the same difference-in-differences strategy as before, using bond-dealer-month observations rather than bond-month observations, where the index d indicates *dealer*. This specification includes dealer fixed effects α_d^2 to control for fixed heterogeneity across dealers.

Columns 3 and 4 in Table 9 summarize the results. In column 3, the dependent

[47] Although AIG holds 7 percent, on average, of the industry's holdings, this fraction is significantly higher if we exclude the corporate bonds in our sample not held by AIG. Conditional on holding a bond in 2006, AIG held one-fifth on average. For about 10 percent of its bond holdings, AIG held more than 50 percent of the industry holdings.

[48] We calculate this effect using the difference between the 90^{th} percentile of the fraction held by AIG (30 percent) and the 10^{th} percentile held by AIG (0 percent).

variable is the volume of dealer d trades in bond b in month t expressed as a fraction of total volume of trade in bond b in month t. In column 4, the dependent variable is the volume of interdealer trade in bond b by dealer d in month t expressed as a fraction of the volume of dealer d trades in bond b in month t. Taken together, these coefficient estimates suggest that dealers more frequently trade smaller volumes of bonds with others dealers. If AIG held half of the industry's holdings of a particular bond, then on average a dealer's trading in that bond as a fraction of total trading in the same bond decreased between 4 and 8 percent.

Lastly, Figure 9 plots the dynamics of corporate bond trading by dealers over the period when AIG's securities lending program was progressively shut down. We repeated the specifications of equation 2 using quarterly dummy variables interacted with the fraction of each corporate bond held by AIG to trace out the dynamics.[49] Figures 9a to 9c plot the key coefficient estimates we obtain from running these regressions. Figure 9a shows that the share of interdealer trading in bonds predominantly held by AIG increases after the shutdown and remains elevated. Figure 9b shows that the increase in interdealer trading involved a greater number of participating dealers. Focusing the analysis on dealer-bond level observations, Figure 9c shows that a dealer is more likely to trade a bond predominantly held by AIG after its securities lending progam was shut down. Taken together, the results in Figure 9 suggest that, although the shut down of AIG's securities lending program produced a hump-shaped response in price dispersion, the increase in interdealer trading that can be attributed to the shock remained elevated after the shock.

5.2 Price dispersion dynamics

We can further test whether securities lending helps to assuage search costs for dealers by analyzing the dynamics of price dispersion separately for dealer-dealer and dealer-client trades. We measure price dispersion as the monthly average of the daily differences between an individual corporate bond's highest and lowest prices.[50] For each measure of

[49] We obtain the same results using annual dummy variables.

[50] To be clear, the benchmark measure of liquidity used in the literature and in our paper is the average realized spread that captures some price dispersion in dealer-client trades. We use the daily high and low prices to obtain a more direct measure of price dispersion. We calculated this measure separately for all trades, for dealer-dealer trades, and for dealer-client trades.

price dispersion, PD_{bt}, we estimated the equation

$$\begin{aligned}\text{PD}_{bt} =& \alpha_b^1 + \alpha_t^2 + \sum_{q=2008Q1}^{2009Q1} \beta^q \text{AIGFrac2006}_b \times \text{Quarter}_t^q \\ &+ \eta \text{AIGFrac2006}_b \times \text{Post2009Q1}_t \\ &+ \zeta \text{InsFrac2006}_b \times \text{Month}_t + \tilde{\mathbf{X}}_{bt}\tilde{\boldsymbol{\gamma}} + \epsilon_{bt} \ , \end{aligned} \tag{6}$$

which is the same as equation 2 using price dispersion as the dependent variable. The interaction between AIGFrac2006_b and the quarterly dummy variables traces out the dynamics.[51] Figure 10 plots the key coefficient estimates we obtain from running these regressions. The results show that dealer-client trades exhibit the strongest effect on price dispersion for corporate bonds predominantly held by AIG. Price dispersion for those bonds in trades between dealers increases only after AIG's securities lending program is shutdown (Figure 10b). Thereafter, the effect diminishes and becomes insignificant in the long run. Meanwhile, the price dispersion in dealer-client trades remains significantly higher (Figure 10c).

5.3 Correlation between interdealer trading and liquidity and price dispersion

Lastly, to confirm the association between our interdealer trading variables and our measures of corporate bond liquidity and price dispersion, we estimate

$$\text{Y}_{bt} = \beta \text{Trading}_{bt} + \alpha_b^1 + \alpha_t^2 + \tilde{\mathbf{X}}_{bt}\tilde{\boldsymbol{\gamma}} + \epsilon_{bt} \tag{7}$$

where $Y_{bt} \in \{\text{Liquidity}_{bt},\ \text{PD}_{bt}\}$ represents our measures of corporate bond liquidity and price dispersion. The control variables $\tilde{\mathbf{X}}_{bt}$ are the same as in our baseline specifications. We continue to cluster the standard errors by bond and month. The coefficient β is the conditional correlation between our interdealer trading variables and our measures of liquidity and price dispersion. We also estimated similar specifications measuring price dispersion calculated for bond b in month t *for each dealer* d.

The results are reported in Table 8, where Panel A shows the results from the bond-

[51] We obtain the same results using annual dummy variables. Online Appendix A reports the results from estimating the equations without the 32 control variables interacted with time.

time specifications and Panel B shows the results from the bond-dealer-time specifications. Columns 1 and 5 report the results using our measure of liquidity as the dependent variable. In Panel A, Column 2 shows that the relative importance of interdealer trading, which is measured by the ratio of dollar trading volume in a bond between dealers over total monthly trading volume for that bond, is positively correlated with price dispersion. However, columns 3 and 4 show that this relationship is only significant in dealer-client trades. In the same Panel, columns 6 to 8 show that the (log) number of dealers, which can be interpreted as a proxy for the length of the intermediation chain, is positively correlated with price dispersion. In Panel B, Columns 6 to 8 show that the price dispersion of a bond is positively correlated with how frequently a dealer trades that bond with other dealers.

6 Conclusion

The theoretical literature on over-the-counter markets suggests that natural frictions in those markets prevent fully efficient trading. In this paper, we show that securities lending markets can help dealers to mitigate those frictions. We empirically identify and measure the effects of a shock to a securities lending market on market liquidity. During the financial crisis of 2007-2009, AIG's securities lending program was shut down, for reasons unrelated to the demand for corporate bond borrowing or to corporate bond market liquidity, while other insurance companies' securities lending programs remained active. Differences in these insurers' corporate bond holdings allows us to tease out the causal effect of corporate bond securities lending on corporate bond market liquidity. We find a statistically and economically significant decrease in the market liquidity of those corporate bonds predominantly held by AIG.

Our estimate of the effect of securities lending on corporate bond market liquidity includes the general equilibrium effects of substitution by dealers towards interdealer markets or inventory. We show how the pattern of interdealer trading changed and client-dealer trading costs increased following the shutdown of AIG's securities lending program. In times when the interdealer market is likely to have more frictions—such as during the financial crisis—the effect of disruption in the securities lending market will be amplified. That said, it is worth recalling that the usefulness of the securities lending market depends on the severity of frictions in the interdealer market relative to the securities lending market. As dealers use the securities lending market in "normal" times, we would therefore expect disruption in the securities lending market to have an effect on liquidity even then. Indeed, we identify a significant decline in liquidity several years after AIG's securities lending program had shut down suggesting that the interdealer market could not fully compensate for the shock to the securities lending market. More generally, our findings highlight the importance of the shadow banking system as a potentially fragile determinant of market efficiency.

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7 Figures

Figure 1: Corporate bond trading in over-the-counter markets In this illustration, broker-dealer 1 receives a *buy* order from client 2. The dealer will try to find a matching *sell* order (client 1). While searching, the dealer can fill the client buy order either by using its inventory, by locating the securities in the interdealer market (broker-dealer 2), or by borrowing the securities from a securities lender. Thus, the ability to borrow securities (as well as the costs associated with inventory holding, interdealer trading, and finding the matching client order) have a bearing on overall market liquidity.

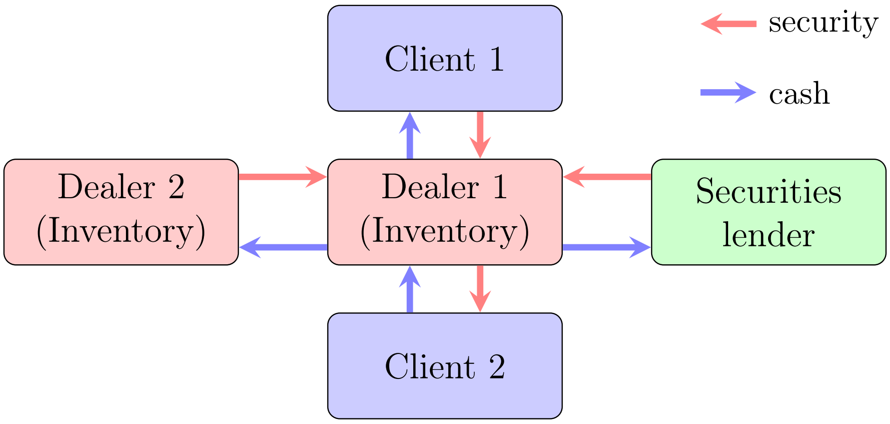


Figure 2: Corporate bond securities lending against cash collateral in the United States. These daily data aggregate the fair value of all corporate bonds lent against cash collateral in the United States. The category of other securities lenders includes corporations, endowments, foundations, and government bodies. Source: Markit Securities Finance.

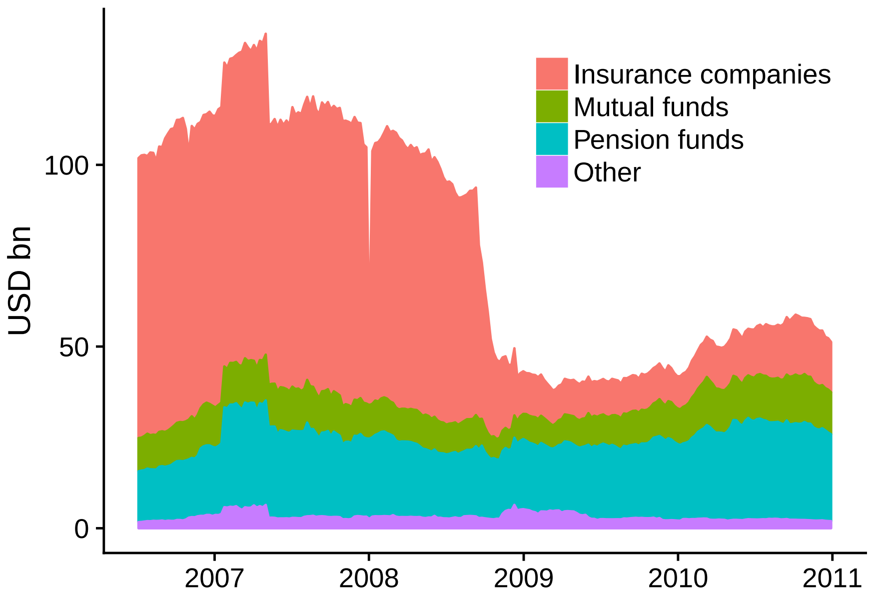
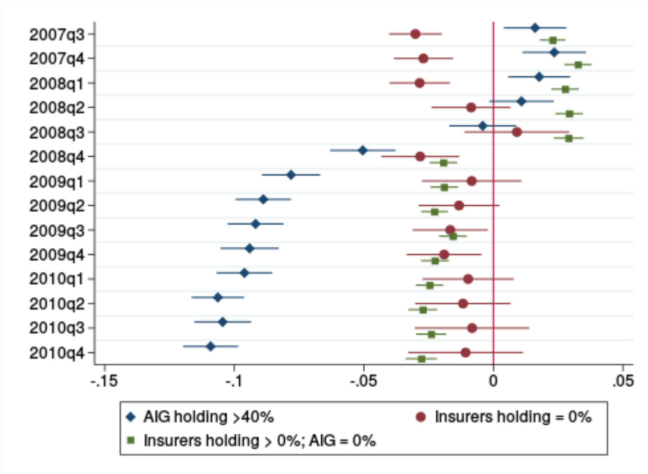


Figure 3: Dynamics of corporate bond securities lending. The two panels of this figure show coefficient plots from regressions of the fraction of the amount of each corporate bond that is available for securities lending and the fraction that is actually on loan, respectively, using quarterly dummies to reveal the dynamics. The data are divided into three mutually exclusive subsamples. The first subsample contains those corporate bonds that are held by insurance companies excluding AIG. The second subsample contains those corporate bonds that are held predominantly by AIG (using a 40 percent threshold). The third subsample contains those corporate bonds that are not held by any insurance company. The point estimates from the regressions using the first, second, and third subsamples are denoted by blue diamonds, green squares, and red circles, respectively. The horizontal lines drawn through each symbol are the 95 percent confidence intervals. These panels show the *unconditional* change in corporate bond securities lending because these specifications contain only the quarterly dummy variables. Source: NAIC Statutory Filings and Markit Securities Finance.

(a) Availability



(b) Lending

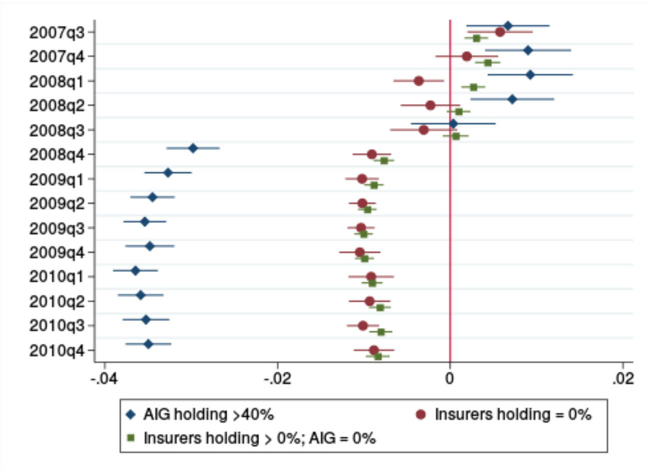


Figure 4: Comparing total bond holdings AIG and other life insurance companies with securities lending programs The charts in the left column show the fraction of total bond portfolio par value held at the end of 2006 across (i) broad categories; (ii) NAIC rating classifications; and (iii) residual maturity buckets. The charts in the right column show the same breakdown restricted to the set of bonds that are flagged as being on loan at the end of 2006. Source: Statutory Filings.

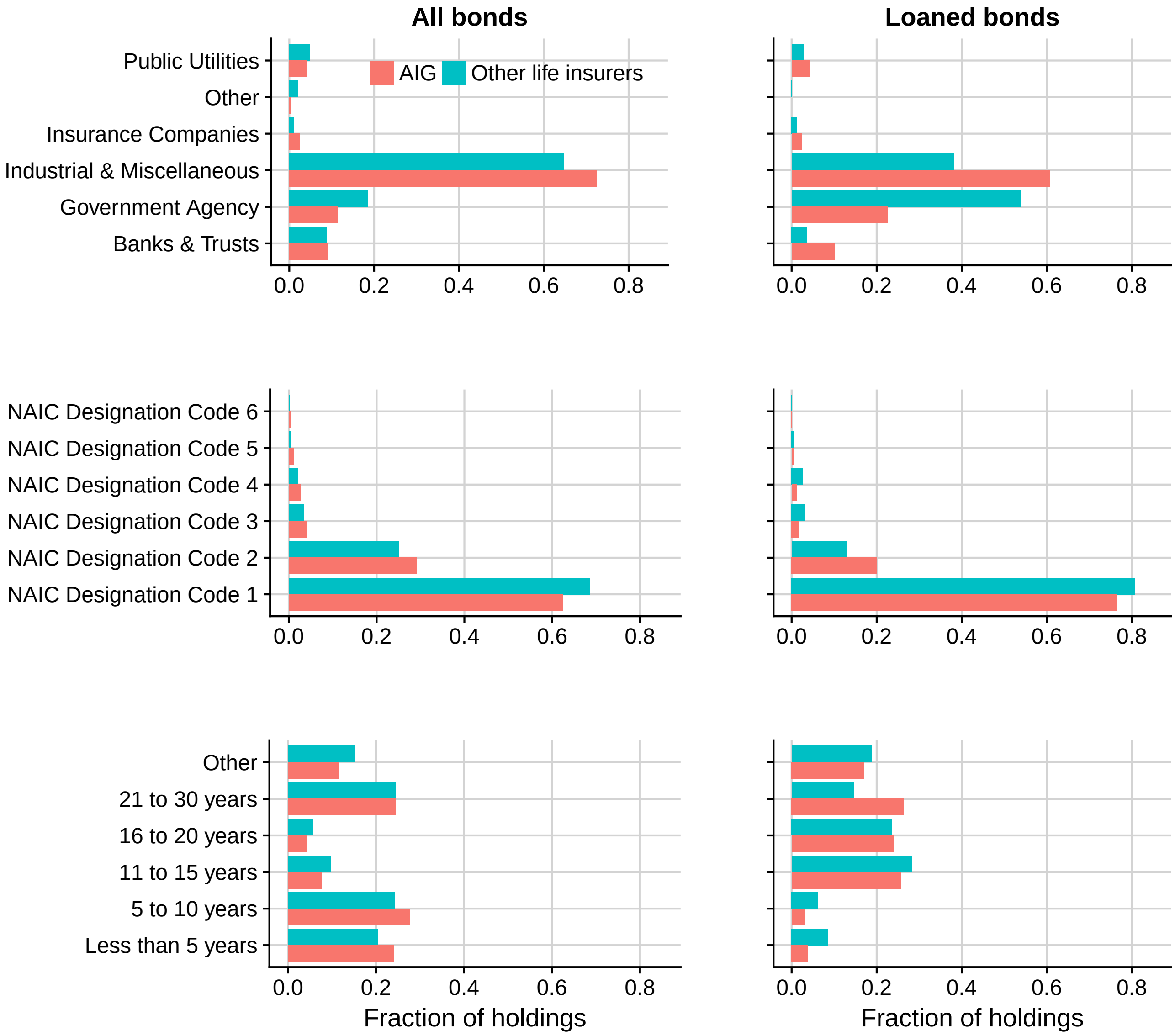


Figure 5: Comparing corporate bond holdings of AIG and other life insurance companies with securities lending programs The chart on the left shows the fraction of total bond portfolio par value held at the end of 2006 that was in the first quartile, interquartile, and fourth quartile of the distribution of corporate bond market liquidity. Market liquidity is measured as the realized bid-ask spread on transactions between dealers and clients. The chart on the right shows the same breakdown restricted to the set of bonds that are flagged as being on loan at the end of 2006. Source: TRACE and Statutory Filings.

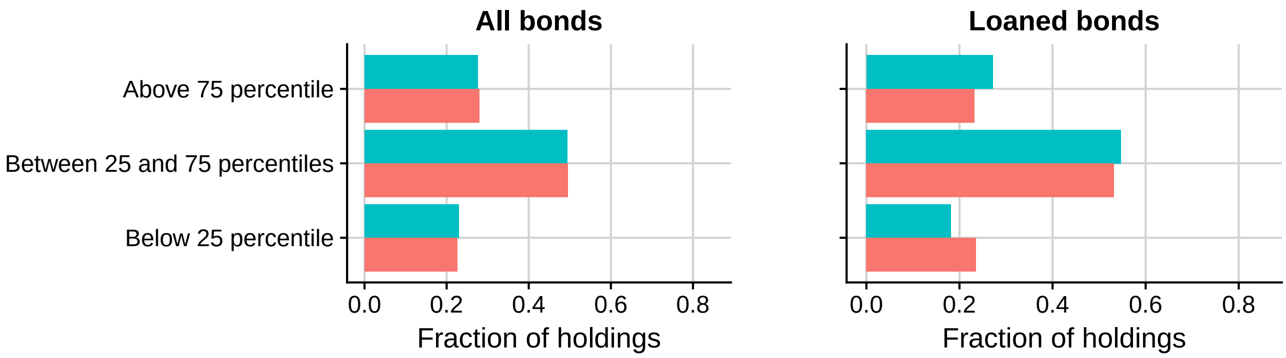


Figure 6: A simplified securities lending transaction Securities lenders exchange assets from their portfolios for collateral in the form of either cash or in other securities, from broker-dealers. A portion of the cash reinvestment return is rebated back to the securities borrower.

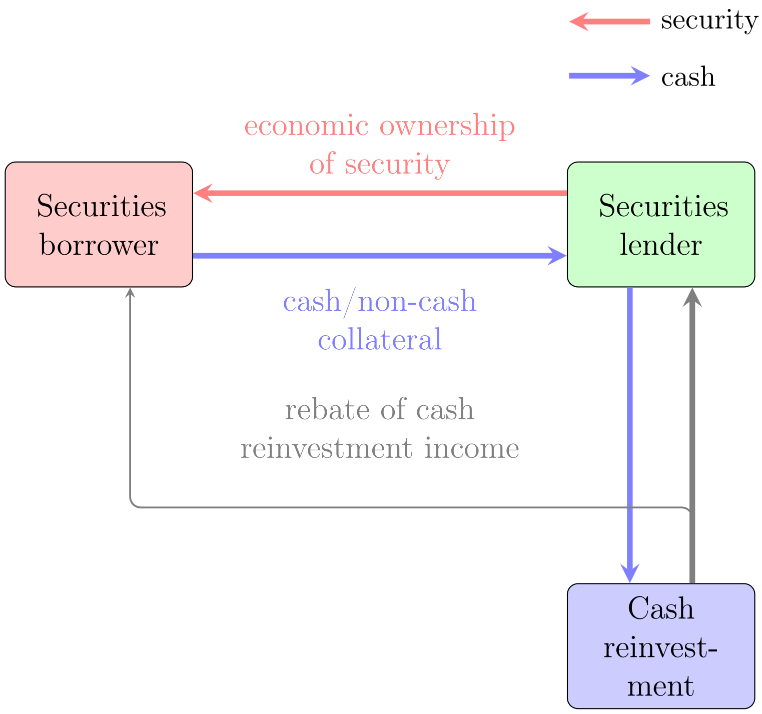


Figure 7: Corporate bond holdings and lending by MetLife and AIG. These data provide a graphical representation of our identification strategy. Each dot represents a single bond in the last month of the year. We first calculate, at the end of 2006, the fraction of MetLife and AIG's corporate bond holdings as a share of all holdings by insurance companies with securities lending programs. For graphical clarity, we restrict our sample to only those bonds in which the combined end-2006 holdings of MetLife and AIG are in the upper quartile of that distribution. Keeping the fraction of holdings fixed at their end-2006 values, we plot for each year from 2007 to 2009, the securities that MetLife is lending and AIG is not lending (blue crosses) and the securities that MetLife is not lending and AIG is lending (red diamonds). The time-series indicates the source of our difference-in-differences empirical strategy. The first difference is that both MetLife and AIG tend to lend bonds in which they individually hold a relatively larger fraction. The second difference is that AIG exits the lending market in 2008, while MetLife remains active. Source: NAIC Statutory Filings and Markit Securities Finance.

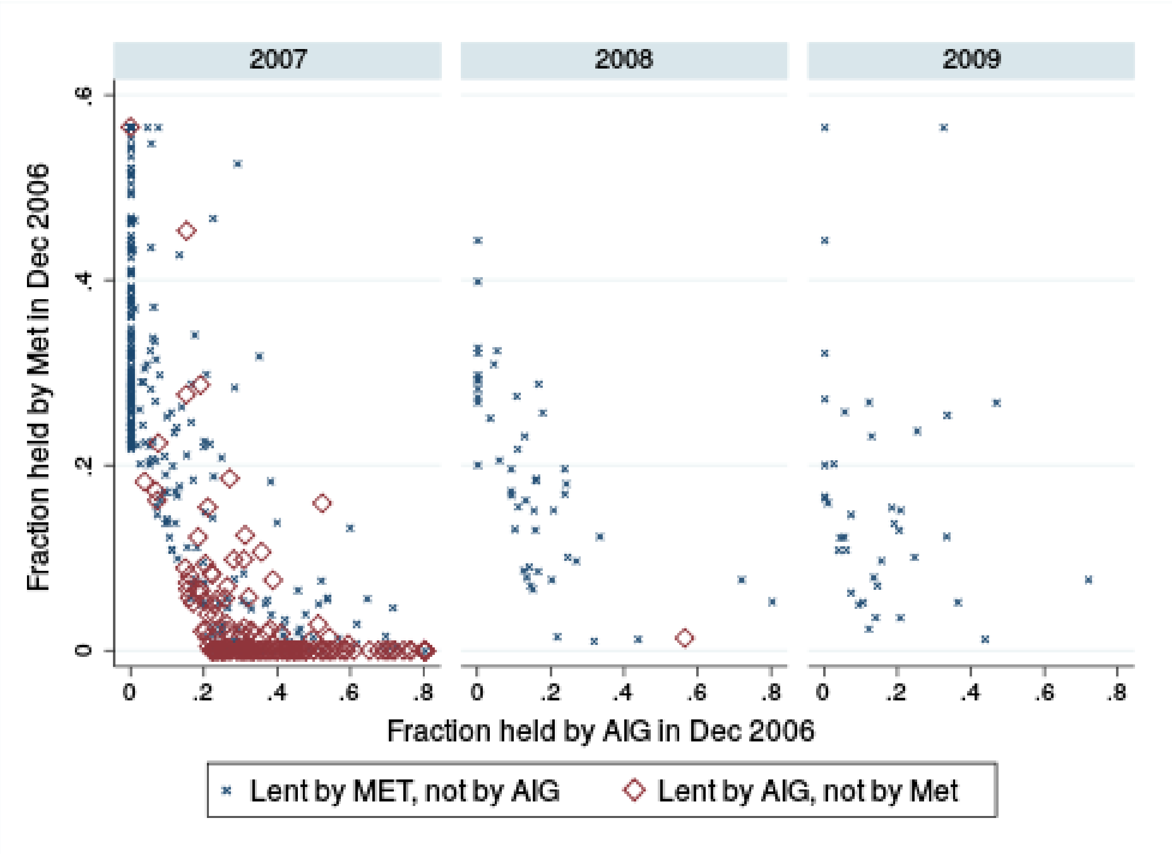
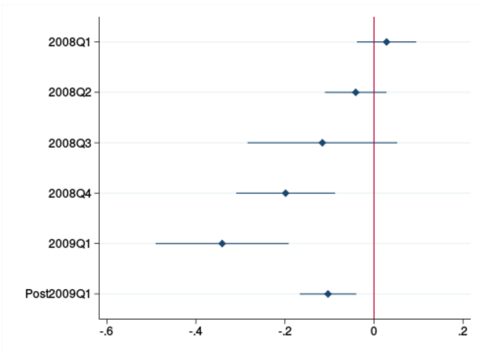
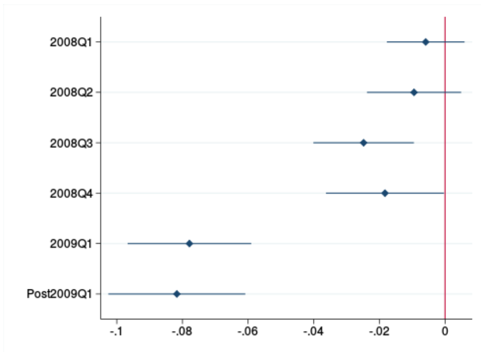


Figure 8: Testing for parallel trends. The five panels of this figure show plots of the coefficient estimates for each of our dependent variables: liquidity, availability, lending, rebate, and volume. The specifications are the same as those used in Table 2 replacing the annual dummy variables in our main specifications with quarterly dummy variables. The unit of observation is a bond b in month t. The blue diamonds are the point estimates of the coefficients on the interaction terms between the fraction of bond b held in 2006 by AIG (AIGFrac2006_b) and quarter fixed effects. The blue lines are the 95 percent confidence intervals. All specifications include month and bond fixed effects, the fraction of bond b held in 2006 by insurers with bond lending programs (InsFrac2006_b) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. Standard errors are two-way clustered by bond and month. Source: Authors' calculations based on data from TRACE, Markit Securities Finance, NAIC Statutory Filings, and Mergent FISD.

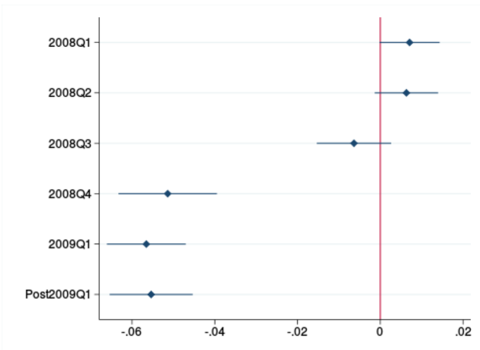
(a) Liquidity



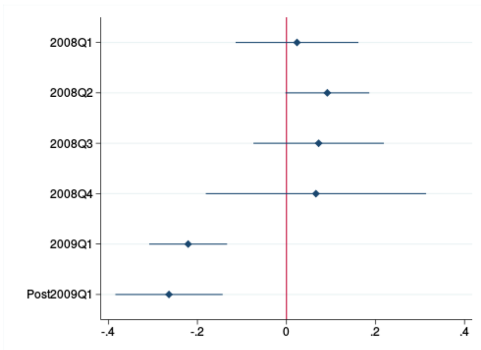
(b) Availability



(c) Lending



(d) Rebate



(e) Volume

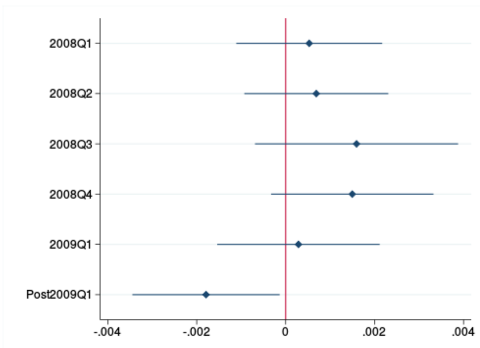
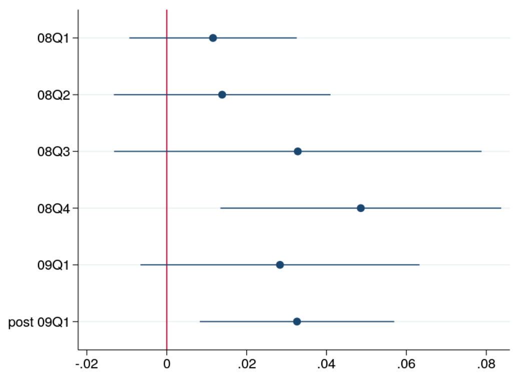
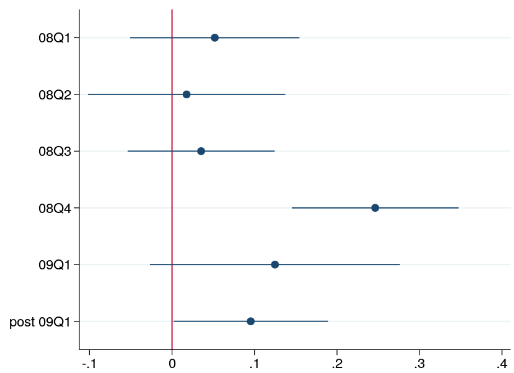


Figure 9: The difference-in-differences effect on corporate bond trading when AIG's securities lending program shut down. The three panels of this figure show coefficient plots for regressions using as dependent variables three different measures of corporate bond trading. Interdealer volume is the ratio of dollar volume traded by dealers of a given bond during one month over a bond's total dollar volume. Number of trades is the log number of trades of a bond during a month. Dealer-bond specific interdealer volume is the ratio of dealer's dollar volume traded with other dealers in a given bond over this dealer's total trading in this bond. The specifications are the same as those used in Table 2 replacing the annual dummy variables in our main specifications with quarterly dummy variables. Each panel plots the point estimates of the coefficients on the interaction terms between the fraction of bond b held in 2006 by AIG (AIGFrac2006_b) and quarter fixed effects. The blue lines are the 95 percent confidence intervals. All specifications include month and bond fixed effects, the fraction of bond b held in 2006 by insurers with bond lending programs (InsFrac2006_b) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. The specification in Panel (c) also includes dealer-bond and dealer-quarter fixed effects. Standard errors are two-way clustered by bond and month. Source: Authors' calculations based on data from TRACE, Markit Securities Finance, NAIC Statutory Filings, and Mergent FISD.

(a) Interdealer volume



(b) Number of trades



(c) Dealer-bond specific interdealer volume

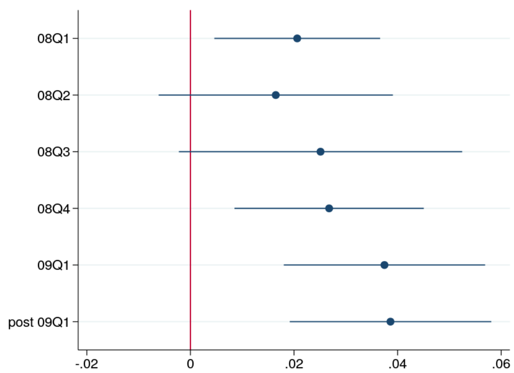
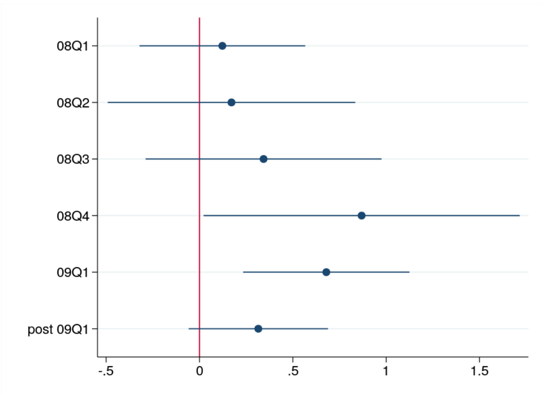
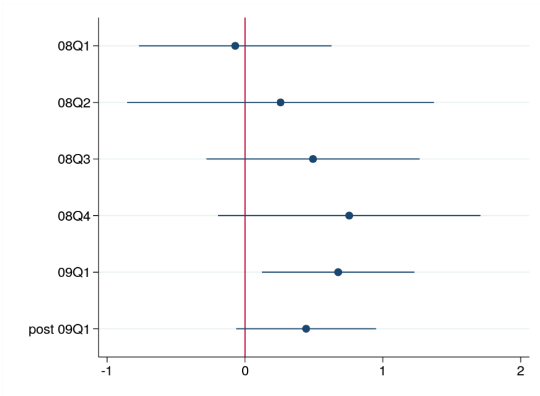


Figure 10: The difference-in-differences effect on corporate bond price dispersion when AIG's securities lending program shut down. The three panels of this figure show coefficient plots for regressions using as dependent variables the price dispersion among all trades, interdealer trades, and dealer-client trades, respectively. The specifications are the same as those used in Table 2 replacing the annual dummy variables in our main specifications with quarterly dummy variables. Each panel plots the point estimates of the coefficients on the interaction terms between the fraction of bond b held in 2006 by AIG (AIGFrac2006$_b$) and quarter fixed effects. The blue lines are the 95 percent confidence intervals. All specifications include month and bond fixed effects, the fraction of bond b held in 2006 by insurers with bond lending programs (InsFrac2006$_b$) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. Standard errors are two-way clustered by bond and month. Source: Authors' calculations based on data from TRACE, Markit Securities Finance, NAIC Statutory Filings, and Mergent FISD.

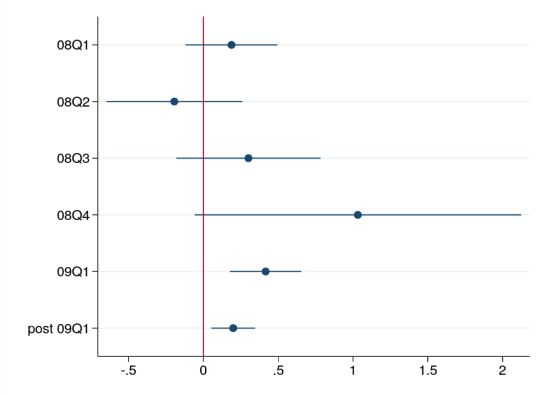
(a) Overall



(b) Interdealer



(c) Dealer-Client



8 Tables

Table 1: Summary statistics. Columns 1 through 8 report the number of observations, mean, standard deviation, minimum, maximum, and quartiles of the main variables we calculated from combining corporate bond spot market transactions reported in TRACE with corporate bond securities lending activity recorded in MSF. Bond market liquidity is the negative of the spread between the average price paid by clients to buy a bond from a dealer and the average price paid by dealers to buy the same bond from clients. We take the negative of the spread to make the interpretation of the sign of the coefficients easier: The transformed variable is increasing in liquidity. All variables are winsorized at the 1 percent level to remove outliers. Additional details on the construction of these variables is available in Section 2.

Variable	Obs	Mean	Std. Dev.	Min	Max	P25	P50	P75
Liquidity (negative average realized spread in percentage points)	279,404	-0.41	0.61	0.9	-2.89	-0.08	-0.26	-0.56
Fraction of bond amount outst. held by insurers in 2006	279,404	0.2	0.24	0	0.89	0	0.09	0.35
Fraction of bond amount outst. held by lending insurers in 2006	279,404	0.14	0.18	0	0.73	0	0.06	0.24
Fraction of bond held by lending insurers held by AIG in 2006	279,404	0.07	0.15	0	0.8	0	0	0.08
Fraction of bond that is available to lend	279,404	0.24	0.16	0	0.7	0.11	0.23	0.35
Fraction of bond that is on loan	279,404	0.02	0.04	0	0.21	0	0.01	0.03
Median rebate rate (percentage points)	223,331	2.12	2.24	-15.5	18	0.12	0.95	4.9
Ratio of volume traded to total amount outstanding	279,393	0.01	0.02	0	0.11	0	0.01	0.01
Amount issued (USD bn)	279,404	0.65	0.61	0	8	0.28	0.5	0.75
Initial maturity (years)	278,510	7.64	8.69	-7.67	99.92	2.67	5.17	8.5
Residual maturity (years)	278,510	7.48	7.69	.08	39.58	2.67	5.17	8.5
Number of dealers per bond	101,382	12.11	7.39	1	81	7	10	15
Interdealer volume in bond over total volume in bond	101,382	0.27	0.18	0	1	0.13	0.25	0.39
Volume by dealer in bond over total volume in bond	1,507,220	0.14	0.20	0	1	0.01	0.05	0.17
Ratio of interdealer trading to total trading in bond by dealer	1,507,220	0.484	0.397	0	1	0	0.5	1
Trades in bond by dealer	1,507,220	3.837	6.52	1	5,140	2	2	4
Trades in bond by dealer over total trades in bond	1,507,220	0.12	0.14	0	1	0.03	0.07	0.14

Table 2: Effect of AIG's collapse on corporate bond market liquidity. This table reports tests of the difference-in-differences strategy described in Sections 3 and 4 of the main text. In columns 1 and 2, the dependent variable is the liquidity of bond b in month t, measured using the negative average realized spread. In columns 3 and 4, the dependent variables are the fraction of the amount outstanding that is available to lend and the fraction that is actually lent, respectively. The dependent variable in column 5 is the rebate rate on the cash collateral reinvestment income. And the dependent variable in column 6 is the ratio of the volume traded to the amount outstanding. The main explanatory variables are the fraction of bond b held in 2006 by AIG ($AIGFrac2006_b$) interacted with year fixed effects. All tests include month and bond fixed effects, the fraction of bond b held in 2006 by insurers with bond lending programs ($InsFrac2006_b$) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. The bond characteristics are credit rating, amount outstanding, issue amount, bond type, residual maturity, time since issuance, and a dummy variable for whether the bond is held by any insurer. Standard errors two-way clustered by bond and month are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable	(1) Liquidity	(2) Liquidity	(3) Availability	(4) Lending	(5) Rebate rate	(6) Volume
$AIGFrac2006_b \times 2008$	-0.0711**	-0.0557*	-0.0113*	-0.00834	0.0437	0.000709
	(0.0319)	(0.0320)	(0.00653)	(0.00670)	(0.0495)	(0.000717)
$AIGFrac2006_b \times 2009$	-0.159***	-0.150***	-0.0766***	-0.0521***	-0.259***	-0.00202**
	(0.0378)	(0.0383)	(0.00927)	(0.00464)	(0.0682)	(0.000809)
$AIGFrac2006_b \times 2010$	-0.104***	-0.0988***	-0.0615***	-0.0531***	-0.231***	-0.00158*
	(0.0347)	(0.0347)	(0.0111)	(0.00523)	(0.0509)	(0.000934)
Bond and Month FE	Y	Y	Y	Y	Y	Y
Bond characteristics × time FE	Y	Y	Y	Y	Y	Y
$InsFrac2006_b$ × Month FE	N	Y	Y	Y	Y	Y
Observations	150,451	150,451	150,451	150,451	127,356	150,449
R^2	0.283	0.510	0.963	0.707	0.987	0.604

Source: Authors' calculations based on data from TRACE, Markit Securities Finance, NAIC statutory filings, and Mergent FISD.

Table 3: Effect of AIG's collapse on corporate bond market liquidity—robustness tests. This table reports tests of the difference-in-differences strategy described in Sections 3 and 4 of the main text. The tests are the same as those reported in Table 2 restricting the sample to those bonds that remained in the portfolio of securities lenders at the end of 2010. In column 1, the dependent variable is the liquidity of bond b in month t, measured using the negative average realized spread. In columns 3 and 4, the dependent variables are the fraction of the amount outstanding that is available to lend and the fraction that is actually lent, respectively. The dependent variable in column 5 is the rebate rate on the cash collateral reinvestment income. And the dependent variable in column 6 is the ratio of the volume traded to the amount outstanding. The main explanatory variables are the fraction of bond b held in 2006 by AIG (AIGFrac2006_b) interacted with year fixed effects. All tests include month and bond fixed effects, the fraction of bond b held in 2006 by insurers with bond lending programs (InsFrac2006_b) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. The bond characteristics are credit rating, amount outstanding, issue amount, bond type, residual maturity, time since issuance, and a dummy variable for whether the bond is held by any insurer. Standard errors two-way clustered by bond and month are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable	(1) Liquidity	(2) Availability	(3) Lending	(4) Rebate rate	(5) Volume
$\text{AIGFrac2006}_b \times 2008$	-0.0354	-0.0136	-0.0147*	0.0916*	-0.000711
	(0.0465)	(0.00883)	(0.00780)	(0.0465)	(0.000866)
$\text{AIGFrac2006}_b \times 2009$	-0.128**	-0.0801***	-0.0576***	-0.229***	-0.00214**
	(0.0481)	(0.0124)	(0.00592)	(0.0807)	(0.000931)
$\text{AIGFrac2006}_b \times 2010$	-0.0784*	-0.0657***	-0.0599***	-0.179***	-0.00195*
	(0.0423)	(0.0145)	(0.00648)	(0.0442)	(0.00103)
Bond and Month FE	Y	Y	Y	Y	Y
Bond characteristics $\times$ time FE	Y	Y	Y	Y	Y
$\text{InsFrac2006}_b \times$ Month FE	Y	Y	Y	Y	Y
Observations	83,928	83,928	83,928	75,659	83,928
R^2	0.518	0.967	0.694	0.990	0.577

Source: Authors' calculations based on data from TRACE, Markit Securities Finance, NAIC statutory filings, and Mergent FISD.

Table 4: AIG's sales and purchases of corporate bonds after August 2008. This table reports tests for changes in the sales or purchases of corporate bonds by AIG relative to other insurers. In Panel A, the dependent variable is the total volume of individual corporate bond sales by insurance group i in month t. In Panel B, the dependent variable is the total volume of individual corporate bond purchases by insurance group i in month t. We include a full set of insurance group and month dummy variables. The key explanatory variable in both Panels is the interaction between a dummy variable for AIG's purchases and a dummy variable for purchases after August 2008. Columns 1 and 2 use a two-year window around August 2008. Columns 3 and 4 use a four-year window. Columns 1 and 3 are based on all corporate bond sales/purchases in statutory filings. Columns 2 and 4 are based only on sales/purchases of corporate bonds that are in our TRACE-MSF-Mergent database. Robust standard errors are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A - Corporate bond sales

	2007-2009		2006-2010	
	Full sample	Merged sample	Full sample	Merged sample
$AIG_i \times PostAug2008_t$	0.084	-0.096	-0.451*	-0.488***
	(0.331)	(0.236)	(0.232)	(0.168)
Insurer FE	Y	Y	Y	Y
Month FE	Y	Y	Y	Y
Observations	2,195	2,057	4,200	4,200
R^2	0.638	0.664	0.603	0.652

Panel B - Corporate bond purchases

	2007-2009		2006-2010	
	Full sample	Merged sample	Full sample	Merged sample
$AIG_i \times PostAug2008_t$	-0.326	-0.306	-0.427	-0.298*
	(0.341)	(0.218)	(0.262)	(0.162)
Insurer FE	Y	Y	Y	Y
Month FE	Y	Y	Y	Y
Observations	2,249	2,174	4,260	4,260
R^2	0.652	0.615	0.650	0.593

Source: Authors' calculations based on data from NAIC statutory filings.

Table 5: Effect of AIG's collapse on corporate bond market liquidity—robustness tests. This table reports tests of the difference-in-differences strategy described in Sections 3 and 4 of the main text. The tests are the same as those reported in Table 2 switching the control variable calculation from 2006 to 2007. In columns 1 and 2, the dependent variable is the liquidity of bond b in month t, measured using the negative average realized spread. In columns 3 and 4, the dependent variables are the fraction of the amount outstanding that is available to lend and the fraction that is actually lent, respectively. The dependent variable in column 5 is the rebate rate on the cash collateral reinvestment income. And the dependent variable in column 6 is the ratio of the volume traded to the amount outstanding. The main explanatory variables are the fraction of bond b held in 2007 by AIG (AIGFrac2007_b) interacted with year fixed effects. All tests include month and bond fixed effects, the fraction of bond b held in 2007 by insurers with bond lending programs (InsFrac2007_b) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. The bond characteristics are credit rating, amount outstanding, issue amount, bond type, residual maturity, time since issuance, and a dummy variable for whether the bond is held by any insurer. Standard errors two-way clustered by bond and month are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable	(1) Liquidity	(2) Liquidity	(3) Availability	(4) Lending	(5) Rebate rate	(6) Volume
$\text{AIGFrac2007}_b \times 2008$	-0.0917***	-0.0810***	-0.0131**	-0.00507	0.0735	-0.000137
	(0.0293)	(0.0295)	(0.00555)	(0.00609)	(0.0489)	(0.000772)
$\text{AIGFrac2007}_b \times 2009$	-0.147***	-0.136***	-0.0776***	-0.0457***	-0.185***	-0.00113
	(0.0305)	(0.0308)	(0.00807)	(0.00415)	(0.0534)	(0.000811)
$\text{AIGFrac2007}_b \times 2010$	-0.112***	-0.105***	-0.0622***	-0.0443***	-0.169***	-0.00139
	(0.0331)	(0.0330)	(0.00981)	(0.00449)	(0.0462)	(0.000870)
Bond and Month FE	Y	Y	Y	Y	Y	Y
Bond characteristics × time FE	Y	Y	Y	Y	Y	Y
InsFrac2007_b × Month FE	Y	Y	Y	Y	Y	Y
Observations	177,778	177,778	177,778	177,778	150,777	177,776
R^2	0.280	0.514	0.961	0.699	0.986	0.601

Source: Authors' calculations based on data from TRACE, Markit Securities Finance, NAIC statutory filings, and Mergent FISD.

Table 6: Effect of AIG's collapse on corporate bond market liquidity—robustness tests. This table reports tests of the difference-in-differences strategy described in Sections 3 and 4 of the main text. The tests are the same as those reported in Table 2 switching the control variable calculation from 2006 to the end of each year. In columns 1 and 2, the dependent variable is the liquidity of bond b in month t, measured using the negative average realized spread. In columns 3 and 4, the dependent variables are the fraction of the amount outstanding that is available to lend and the fraction that is actually lent, respectively. The dependent variable in column 5 is the rebate rate on the cash collateral reinvestment income. And the dependent variable in column 6 is the ratio of the volume traded to the amount outstanding. The main explanatory variables are the fraction of bond b held at the end of year y by AIG (AIGFrac_{by}) interacted with year fixed effects. All tests include month and bond fixed effects, the fraction of bond b held at the end of year y by insurers with bond lending programs (InsFrac_{by}) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. The bond characteristics are credit rating, amount outstanding, issue amount, bond type, residual maturity, time since issuance, and a dummy variable for whether the bond is held by any insurer. Standard errors two-way clustered by bond and month are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable	(1) Liquidity	(2) Liquidity	(3) Availability	(4) Lending	(5) Rebate rate	(6) Volume
AIGFrac_{by}	0.0288	0.0242	0.0290***	0.0290***	0.0680	-0.000132
	(0.0268)	(0.0265)	(0.00696)	(0.00423)	(0.0449)	(0.000745)
$\text{AIGFrac}_{by} \times 2008$	-0.0959***	-0.0886**	0.000527	-0.00584	0.109**	0.000282
	(0.0355)	(0.0356)	(0.00547)	(0.00582)	(0.0520)	(0.000748)
$\text{AIGFrac}_{by} \times 2009$	-0.202***	-0.195***	-0.0740***	-0.0409***	-0.131***	-7.34e-05
	(0.0355)	(0.0357)	(0.00824)	(0.00426)	(0.0391)	(0.000684)
$\text{AIGFrac}_{by} \times 2010$	-0.145**	-0.142**	-0.0704***	-0.0587***	-0.314***	0.000217
	(0.0567)	(0.0568)	(0.0131)	(0.00593)	(0.0588)	(0.000907)
Bond and Month FE	Y	Y	Y	Y	Y	Y
Bond characteristics × time FE	Y	Y	Y	Y	Y	Y
InsFrac_{by} × Month FE	N	Y	Y	Y	Y	Y
Observations	155,146	155,146	155,146	155,146	136,058	155,146
R^2	0.273	0.519	0.966	0.712	0.990	0.593

Source: Authors' calculations based on data from TRACE, Markit Securities Finance, NAIC statutory filings, and Mergent FISD.

Table 7: Effect of AIG's collapse on corporate bond market liquidity—robustness tests. This table reports tests of the difference-in-differences strategy described in Sections 3 and 4 of the main text. The tests are the same as those reported in Table 2 including as a control variable the fraction of each bond b held by AIG at the end of each year y (AIGFrac_{by}). In columns 1 and 2, the dependent variable is the liquidity of bond b in month t, measured using the negative average realized spread. In columns 3 and 4, the dependent variables are the fraction of the amount outstanding that is available to lend and the fraction that is actually lent, respectively. The dependent variable in column 5 is the rebate rate on the cash collateral reinvestment income. And the dependent variable in column 6 is the ratio of the volume traded to the amount outstanding. The main explanatory variables are the fraction of bond b held at the end of 2006 by AIG (AIGFrac2006_b) interacted with year fixed effects. All tests include month and bond fixed effects, the fraction of bond b held at the end of 2006 by insurers with bond lending programs (InsFrac2006_b) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. The bond characteristics are credit rating, amount outstanding, issue amount, bond type, residual maturity, time since issuance, and a dummy variable for whether the bond is held by any insurer. Standard errors two-way clustered by bond and month are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable	(1) Liquidity	(2) Liquidity	(3) Available	(4) Lending	(5) Rebate rate	(6) Volume
AIGFrac_{by}	-0.106***	-0.109***	-0.000868	0.000833	0.00650	-0.000555
	(0.0291)	(0.0293)	(0.00731)	(0.00361)	(0.0404)	(0.000693)
$\text{AIGFrac2006}_b \times 2008$	-0.0900**	-0.0782**	-0.0120	-0.0119*	0.0690	0.000144
	(0.0380)	(0.0383)	(0.00722)	(0.00688)	(0.0516)	(0.000722)
$\text{AIGFrac2006}_b \times 2009$	-0.182***	-0.177***	-0.0742***	-0.0533***	-0.223***	-0.00228***
	(0.0411)	(0.0416)	(0.0105)	(0.00513)	(0.0666)	(0.000784)
$\text{AIGFrac2006}_b \times 2010$	-0.152***	-0.150***	-0.0643***	-0.0576***	-0.184***	-0.00210**
	(0.0457)	(0.0458)	(0.0142)	(0.00618)	(0.0480)	(0.00101)
Bond and Month FE	Y	Y	Y	Y	Y	Y
Bond characteristics × time FE	Y	Y	Y	Y	Y	Y
InsFrac2006_b × Month FE	N	Y	Y	Y	Y	Y
Observations	130,955	130,955	130,955	130,955	114,644	130,955
R^2	0.276	0.515	0.967	0.720	0.990	0.595

Source: Authors' calculations based on data from TRACE, Markit Securities Finance, NAIC statutory filings, and Mergent FISD.

Table 8: Correlation between interdealer trading and liquidity and price dispersion. Panels A and B report analyses of data at the bond and dealer-bond levels, respectively. The dependent variable in columns 1 and 5 is liquidity measured using the negative average realized spread. The dependent variable in all other columns is price dispersion measured as the monthly average of the daily differences between the highest and lowest trade prices. Columns 2 and 6 consider all trades, columns 3 and 7 only consider dealer-dealer trades, and columns 4 and 8 consider client-dealer trades. All tests include month and bond fixed effects, and bond characteristics interacted with time fixed effects. The bond characteristics are credit rating, amount outstanding, issue amount, bond type, residual maturity, time since issuance, and a dummy variable for whether the bond is held by any insurer. Standard errors two-way clustered by bond and month are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	Liquidity	Price dispersion			Liquidity	Price dispersion		
Trade sample:		All	Dealer-Dealer	Client-Dealer		All	Dealer-Dealer	Client-Dealer
$\text{vol}_b^{DD}/\text{vol}_b$	-0.243***	0.954*	0.826	0.404***				
	(0.019)	(0.480)	(0.568)	(0.109)				
log(dealers)					-0.19***	0.471***	0.360**	0.353***
					(0.004)	(0.073)	(0.145)	(0.028)
Bond and Month FE	Y	Y	Y	Y	Y	Y	Y	Y
Bond chars. × time FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	148,672	109,138	83,608	90,576	148,680	109,143	83,613	90,578
R^2	0.744	0.156	0.161	0.050	0.661	0.156	0.161	0.051

Panel B								
Dependent variable:	Liquidity	Price dispersion			Liquidity	Price dispersion		
Trade sample:		All	Dealer-Dealer	Client-Dealer		All	Dealer-Dealer	Client-Dealer
$\text{vol}_{bd}^{DD}/\text{vol}_{bd}$	-0.049***	0.115**	0.109**	0.012				
	(0.005)	(0.055)	(0.052)	(0.023)				
$\log\left(\text{trades}_d^{DD}\right)$					-0.0007	0.236***	0.145***	0.154***
					(0.001)	(0.026)	(0.025)	(0.016)
Bond and Month FE	Y	Y	Y	Y	Y	Y	Y	Y
Bond chars. × time FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	2,267,237	2,124,137	1,992,359	1,948,349	2,267,247	2,124,137	1,992,359	1,948,349
R^2	0.662	0.224	0.214	0.118	0.662	0.224	0.214	0.118

Source: Author's calculations based on data from TRACE, Markit, Securities Finance, NAIC Statutory Filings, and Mergent FISD

Table 9: The effect of AIG's collapse on interdealer trading. This table reports the results from applying the difference-in-differences empirical strategy described in Section 3.2 to interdealer trading. Columns 1 and 2 are at the bond level, columns 3 and 4 are at the dealer-bond level. In column 1, the dependent variable is the ratio of the volume of interdealer trade to the total volume of trade in bond b in month t. In column 2, the dependent variable is the log of the number of dealers trading b in month t. In column 3, the dependent variable is the ratio of the volume of trading by dealer d in bond b in month t to the total volume of trade in bond b in month t. In column 4, the dependent variable is the ratio of the volume of interdealer trading by dealer d in bond b in month t to the total volume of trading by dealer d in bond b in month t. The main explanatory variables are the fraction of bond b held in 2006 by AIG (AIGFrac2006_b) interacted with year fixed effects. All tests include month and bond fixed effects, the fraction of bond b held in 2006 by insurers with bond lending programs (InsFrac2006_b) interacted with month fixed effects, and bond characteristics interacted with time fixed effects. The bond characteristics are credit rating, amount outstanding, issue amount, bond type, residual maturity, time since issuance, and a dummy variable for whether the bond is held by any insurer. Standard errors two-way clustered by bond and month are reported in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable	(1) $\text{vol}_b^{DD}/\text{vol}_b$	(2) log(dealers)	(3) $\text{vol}_{bd}/\text{vol}_b$	(4) $\text{vol}_{bd}^{DD}/\text{vol}_{bd}$
$\text{AIGFrac2006}_b \times 2008$	0.038**	0.070	-0.010*	0.013
	(0.017)	(0.044)	(0.005)	(0.009)
$\text{AIGFrac2006}_b \times 2009$	0.052***	0.077	-0.010*	0.026**
	(0.017)	(0.047)	(0.005)	(0.011)
$\text{AIGFrac2006}_b \times 2010$	0.039**	0.111**	-0.015**	0.031***
	(0.017)	(0.050)	(0.006)	(0.011)
Bond & Month FE	Y	Y	Y	Y
Bond characteristics × Month	Y	Y	Y	Y
InsFrac2006_b × Month	Y	Y	Y	Y
Dealer × Bond			Y	Y
Dealer × Month			Y	Y
Observations	64,857	115,892	974,321	974,324
R^2	0.631	0.943	0.625	0.807

Source: Author's calculations based on data from TRACE, Markit Securities Finance, NAIC Statutory Filings, and Mergent FISD

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