When Selling Becomes Viral: Disruptions in Debt Markets in the COVID-19 Crisis and the Fed's Response

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Abstract

We document extreme disruption in debt markets during the COVID-19 crisis: a severe price crash accompanied by significant dislocations at the safer end of the credit spectrum. Investment-grade corporate bonds traded at a discount to credit default swaps; exchange-traded funds traded at a discount to net asset value, more so for safer bonds. The Federal Reserve's announcement of corporate bond purchases caused these dislocations to disappear and prices to recover. These facts inform potential theories of the disruption. The best explanation is an acute liquidity need for specific bond investors, such as mutual funds, leading them to liquidate large positions.

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Bond markets were distressed in March 2020 as the COVID-19 crisis affected financial markets. This paper quantifies and analyzes this distress and the effect of the subsequent interventions by the Federal Reserve. Both the empirical patterns of initial distress and the response to various Fed interventions allow us to speak to potential channels driving asset price movements in debt markets and significantly reduces the set of possible explanations for these movements. Doing so is important: the corporate bond market, one of the most important sources of funding for U.S. corporations, totals around $7 trillion, and the Fed went to great lengths to stabilize it.[1] Our empirical analysis suggests that the crisis triggered a large and persistent selling pressure from bond investors trying to obtain cash, and that dealers were not able to step in due to difficulties in taking on bonds on their balance sheet for an extended period.

As motivation, Figure 1 plots the evolution of the yield spread of a six-year bond issued by Google, one of the largest companies in the world, with a AA credit rating and nearly $120 billion in cash as of the end of 2019—exceeding total liabilities by around $45 billion. We also report the spread of a five-year credit default swap (CDS) for Google. Both the CDS spread and the bond spread are around 25 basis points (bps) through early February. Google's bond spread spikes dramatically in March, increasing to around 150 bps. Meanwhile, the CDS spread barely budges. This picture highlights that bond prices of even the safest firms in the economy plummeted substantially more than what one would reasonably attribute to default based either on their CDS spread or on their financial position.

The case of Google is not special. Rather, we document it illustrates a much broader pattern in financial markets in the first half of March 2020. During that period corporate bond prices crash: the cumulative return on investment-grade corporate debt is –20%,

[1] More generally, disruptions in debt markets and spikes in credit spreads are often associated with negative real effects. Gilchrist and Zakrajek (2012) show that, historically, elevated credit spreads are strongly associated with declines in future economic activity. See also López-Salido, Stein, and Zakrajšek (2017) and Krishnamurthy and Muir (2018).

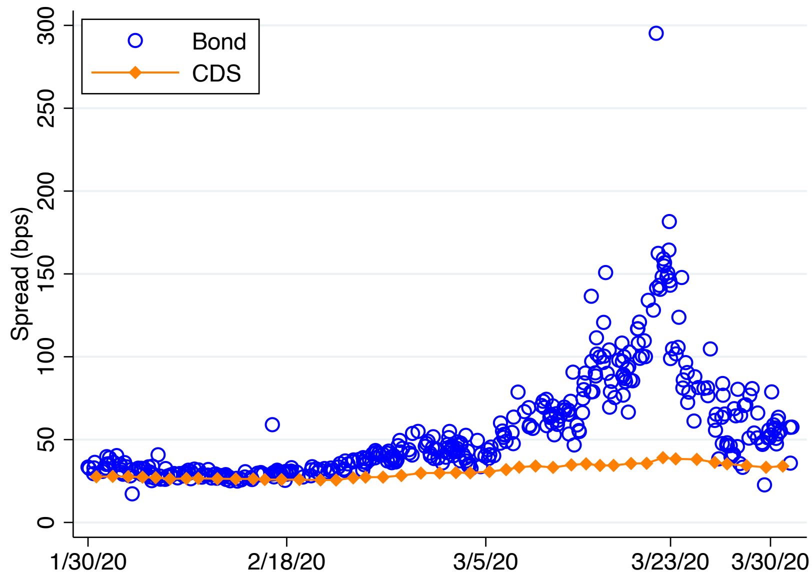


Figure 1
Google: Bond spread and CDS spread
The bond spread is in blue. Each dot is a transaction in the TRACE data. The CDS spread is in red. See Section 2.2 for data construction.

about as much as the stock market. Taken alone, such a large price movement is already unusual: debt, particularly investment-grade, typically has a beta far below one.[2] We go further and show that, in keeping with the case of Google, much of this fall coincides with price dislocations in debt markets. We match individual corporate bonds with their CDSs and show that a large basis opens up throughout the market. This disruption is most extreme in investment-grade bonds. There, bond spreads experience a large increase, while CDS spreads see little change. If investment-grade bond spreads had behaved like CDS spreads, the cumulative return on investment-grade bonds would have been only –6% instead of –20%. In contrast, while a basis also opens up in the high-yield market, CDS and bond spreads there increase much more in tandem. In addition to the time series,

[2]Haddad and Muir (forthcoming) present theory and evidence that this type of behavior is symptomatic of distress in the financial sector.

we show that a similar pattern holds for the cross-section. Across investment-grade firms, movements in bond spreads are poorly related to movements in CDS spreads, while they are much more aligned across high-yield firms.

The departure of bond spreads from CDS spreads is not the only dislocation in debt prices during this episode. Exchange-traded funds (ETFs) offer a way to trade bonds often viewed as a much more liquid alternative to direct trading.[3] During the crisis, however, investment-grade ETFs trade at a large discount to the value of their underlying bonds (net asset value, or NAV), by about 5%. Here again, the disruption concentrates on safer forms of debt. Other types of safe debt, municipal bonds and Treasury bonds, experience a similarly sized ETF-NAV basis. In contrast, high-yield ETFs, while they also experience a strong price decline, do not see such a dislocation. Importantly, we confirm that these patterns reflect actual differences in market prices. While investors generally cannot sell their ETF shares at the reported NAV, we show that some large ETFs have identical "twin" open-end funds. These funds hold the same portfolio and can actually be redeemed at the same NAV.

Overall, as prices in debt markets crashed, our results draw a picture of a pervasive pattern of dislocations of comparable size to the drop in price. The overall magnitude of these dislocations is reminiscent of the great financial crisis (GFC) of 2008. However, both the very fast speed at which they emerged and their location in the safest segments of the markets suggest different causes. Another aspect specific to this episode is the speed at which prices recovered, following a set of unprecedented interventions by the Federal Reserve in debt markets.

We conduct high-frequency event studies to assess the role of the Federal Reserve's interventions in the recovery. The Fed's interventions did have a large effect on debt prices, but more important is the where and how. We compare the response to various

[3]Bond ETFs have grown tremendously in importance over the past decade, with over $800 billion of assets managed by about 350 funds.

types of policies, and across various assets. The heterogenous response to these various treatments is informative of the ultimate channels at play during this episode. While standard liquidity policies did not move corporate bond prices much, we document a sharp recovery right after the announcement of large-scale corporate bond purchases. In particular, at the first announcement of these purchases on March 23 investment-grade bond prices recover by 7%, or a reduction in yields of about 75 bps. In contrast, the prices of other assets such as high-yield bonds, stocks, and Treasury bonds see virtually no movements. The recovery is stronger for bonds directly targeted by the program—below five years to maturity or belonging to ETFs—but also concentrated on the safer credit ratings within investment-grade bonds. Even more closely related to the crash, we find that bonds with a larger CDS-bond basis experience stronger recovery on announcement, while those with a higher CDS spread do not. When the Fed announces on April 9 an extension in the scale and scope of bond purchases—in particular to include "fallen angels" and high-yield ETFs—corporate bond markets see again a sharp increase. However, this time around the effect is much broader, felt in both investment-grade and high-yield bonds, reducing spreads of firms that had experienced large increases in CDS spreads, and also with a large response in other asset classes.

Taken together, this evidence—the structure of the crash and the effect of the Fed—speaks to the channels behind asset price movements in March 2020. First, standard theories of asset price movements rely on variation in cash flow or compensations for risk. The relative behavior of investment-grade and high-yield bonds and the behavior of bond spreads compared to CDS or ETFs compared to NAV speak against these as full explanations for the drop in investment-grade bonds. A default and risk premium channel should have equal effects on the CDS and the bond spread. Further, a risk premium channel would have a larger effect on high-yield compared to investment-grade bonds. This is because high-yield debt has a higher probability of default and so is more sensitive to an increase in the premium per unit of default risk.

Instead, the evidence suggests an explanation relying on frictions in financial markets. Specific investors tried to liquidate a large set of positions in bonds, pushing prices down, and the inability of arbitrageurs such as dealers to smooth across markets allowed dislocations to persist. Our results help delineate this mechanism more precisely.

First, what happened to dealers? We confirm dealers did not step in to buy corporate bonds as prices were dropping; actually, they initially reduced their exposure, if anything. There are many plausible reasons behind the limited reaction of dealers. After 2008, the introduction of new regulations such as the leverage ratio and liquidity coverage ratio, as well as an overall increase in the cost of balance sheet space (Berndt, Duffie, and Zhu 2019), has pushed dealers out of corporate bonds. Their typical holdings are about 0.1% of the market relative to 7% before the GFC. Naturally, all these intermediation costs only increase in periods of distress. In addition, corporate bond trades might have been crowded out by better opportunities in the also disrupted Treasury market (see Duffie 2020 and He, Nagel, and Song 2020). One manifestation of this lower willingness to intermediate is that the price that dealers charge for trading bonds rose during this period (Kargar et al. (2020)). However, our findings suggest these explanations are not enough and other forces pushed dealers away. First, most of the costs to intermediate are as large or larger for high-yield debt than investment-grade debt, going against the pattern of disruptions we document. Second, while immediate purchases by the Fed might solve short-term liquidity problems, the Fed had a large effect by only announcing these purchases. By early June, the Fed still had virtually not bought any corporate bonds. Third, other announcements directly targeting dealers' ability to intermediate trade had only a limited impact on bond prices.

A natural explanation for why these disruptions were so difficult to alleviate is that the selling pressure behind them is particularly large and persistent. Here again, our evidence sheds light on what triggered the selling pressure. The concentration of dislocations in cash instruments rather than synthetic exposures of the CDS suggests that some investors were trying to obtain cash quickly. Also consistent with the idea of a response to a liquidity shock is the relative depression for the price of the easy-to-trade ETFs relative to the less liquid bonds. One challenging observation for this view, though, is that selling the most liquid assets first is optimal only as long as these assets do not as a consequence become more illiquid than others. Still, the cross-section of bonds provides more evidence for a liquidity shock, and helps better delineate how it played out. First, more liquid bonds experienced larger spread increases during the crash. Second, bonds more exposed to liquidation by mutual funds also had bigger price drops, consistent with the view that this growing investment vehicle is a source of fragility.[4] Third, in line with an increased demand for funding in the corporate sector, bonds of firms with larger subsequent issuance also experience more depressed prices.

In summary, by examining nuances in the behavior of asset prices during the COVID-19 crisis, we are able to considerably reduce the set of possible explanations for the large price movements in debt markets. In particular, our results suggest natural next steps to sharpen the understanding of this episode as more data on quantities become available and uncertainty gets resolved. Data from the Flow of Funds offer an aggregate low-frequency glance suggesting multiple sources of large flows, but more disaggregated data will be necessary for reaching sharp conclusions.[5] In addition, the large responses to the new set of policies by the Fed suggest they might stay in its toolkit, but more work is needed to understand their functioning and optimality. The contrast we already observe between March 23 and April 9 offers a hint that their impact might flow through multiple mechanisms.

Several papers focus specifically on liquidity in bond markets in the COVID-19 crisis as well, including O'Hara and Zhou (2020), Kargar et al. (2020), Fleming and Ruela

[4]Falato, Goldstein, and Hortaçsu (2020) and Ma, Xiao, and Zeng (2020) dig deeper into the causes and implication of this fragility during the crisis.

[5]See Flow of Funds Table F.213. See also Vissing-Jorgensen (2020) for more discussion of quantities.

(2020), Schrimpf, Shin, and Sushko (2020), and Boyarchenko, Kovner, and Shachar (2020). Falato, Goldstein, and Hortaçsu (2020) and Ma, Xiao, and Zeng (2020) focus instead on the sources and implications of large redemption by bond mutual funds. Vissing-Jorgensen (2020) discusses the case for corporate bond purchases in the current crisis. This relates to a broader literature on asset pricing and intermediation in various asset classes (He and Krishnamurthy 2018; Haddad and Muir forthcoming; Haddad and Sraer 2020). Financial frictions appear to play a role in other markets as well during the crisis. Duffie (2020), Fleming and Ruela (2020), He, Nagel, and Song (2020), and Schrimpf, Shin, and Sushko (2020) highlight issues in the Treasury market. Bahaj and Reis (2020) show CIP deviations in the current crisis and point to strain in dollar funding markets. Finally, Gormsen and Koijen (2020) take a more fundamental approach to study the impact of COVID-19 on future growth expectations by studying dividend futures, while Augustin et al. (2020) focus on sovereign credit risk.

A broader literature studies how these disruptions arise more generally. First, there may be large changes in asset market liquidity. Investment-grade bonds may be liquid in normal times, but become far less liquid in periods of severe stress (Moreira and Savov 2017).[6] This fits more generally into a literature on safety demand (Longstaff 2004; Greenwood and Vissing-Jorgensen 2018; Krishnamurthy and Vissing-Jorgensen 2012; Greenwood and Vayanos 2014). Second, the ability to obtain funding can have a significant impact on bonds. That is, disruptions in repo markets, increases in haircuts, and so on can lead to difficulties in funding in debt markets that then feed back into prices (Brunnermeier and Pedersen 2009; Duffie 2010; Lewis, Longstaff, and Petrasek 2017). Bai and Collin-Dufresne (2019) and Fontana (2010) study the CDS bond basis with a focus on 2008, while Longstaff, Mithal, and Neis (2005) examine CDS and bond spreads over a longer sample. For overviews of disruptions in the 2008 crisis see also Duffie (2010) and Mitchell

[6] See also Longstaff (2009).

and Pulvino (2012).[7] Further, He and Milbradt (2014) show how bond liquidity can feed back into default. Third, investment vehicles such as mutual funds can increase the susceptibility of bond markets to fire sales, as studied in Chen, Goldstein, and Jiang (2010), Falato et al. (forthcoming), and Goldstein, Jiang, and Ng (2017).

Another focus in the literature is on the effects of bond purchases by the Federal Reserve on asset prices. The leading example is Krishnamurthy and Vissing Jorgensen (2011), who use an event study to assess the effects of quantitative easing in 2008–2009.[8] Greenwood, Hanson, and Liao (2018) discuss this event-study approach when asset markets are partially segmented.

1. Aggregate Changes in Debt Prices

We first document aggregate movements in debt prices during the COVID-19 crisis. We highlight the size of the crash and subsequent recovery, in absolute and relative to other assets, and the speed at which they occurred.

1.1 Price movements during the COVID-19 crisis

Figure 2 reports cumulative returns for a variety of debt markets between February 1 and April 23, 2020. As a benchmark, we compare to the cumulative returns on the S&P 500 index. Of the asset classes we report, stocks experience the largest decline: a cumulative return around –35% from peak to trough, with the minimum reached in the third week of March. Equities subsequently rebound, but the cumulative return is still as low as about –15% in late April.

Next in terms of poor performance is corporate debt. We report the returns on two

[7] See also Hu, Pan, and Wang (2013), Du, Tepper, and Verdelhan (2018), Siriwardane (2019), and Fleckenstein, Longstaff, and Lustig (2014) for specific examples.

[8] See also Hanson and Stein (2015) and Greenwood, Hanson, and Stein (2016).

large corporate bond ETFs of the iShares family, LQD and HYG. These funds aim to capture the universe of investment-grade and high-yield corporate bonds, respectively. We provide more details on the ETFs in Section 2.3. For now, we just take them as representative of returns in these asset classes. Both indices exhibit a pattern similar to stocks. While their decline starts almost two weeks after stocks, its magnitude is substantial: the two indices drop by about 20% from peak to trough. Notably, the drop for the three weeks from March 1 to March 20 is about the same for investment-grade bonds, high-yield bonds, and the overall stock market, with investment-grade bonds actually suffering slightly larger losses. After that, the two corporate bond indices recover. By the end of our sample, investment-grade bonds are virtually back to their early 2020 level and the loss in high-yield debt is –10%.

Similarly, we measure the returns of municipal bonds using MUB, which tracks Standard & Poor's National AMT-Free Municipal Bond Index. The performance of this fund has an extremely similar trajectory to investment-grade debt, albeit of somewhat smaller magnitude. For example, the dip in returns is only of about –12%. Finally, we use TLT to track long-term Treasury bonds. Consistent with an environment of decreasing interest rate, cumulative returns on Treasury bonds are positive. However, they also experience a large drop between March 9 and March 19, which reverts quickly after that.

The prompt recovery across markets at the end of March coincides with a host of announcements by the Federal Reserve—the dotted vertical lines in Figure 2. On March 15, the Fed drops interest rates to zero, and starts to unveil a series of interventions at a brisk pace. These interventions can be split into two broad categories. A first set is targeted at short-term funding markets in line with what was done in 2008, an example of which is the Primary Dealer Credit Facility. The second set intervenes directly in credit markets instead of focusing on intermediaries. On March 23, the Fed unveils new facilities that explicitly take on credit risk by directly buying investment-grade corporate debt, asset-backed securities, and short-term municipal securities. The Treasury provides an

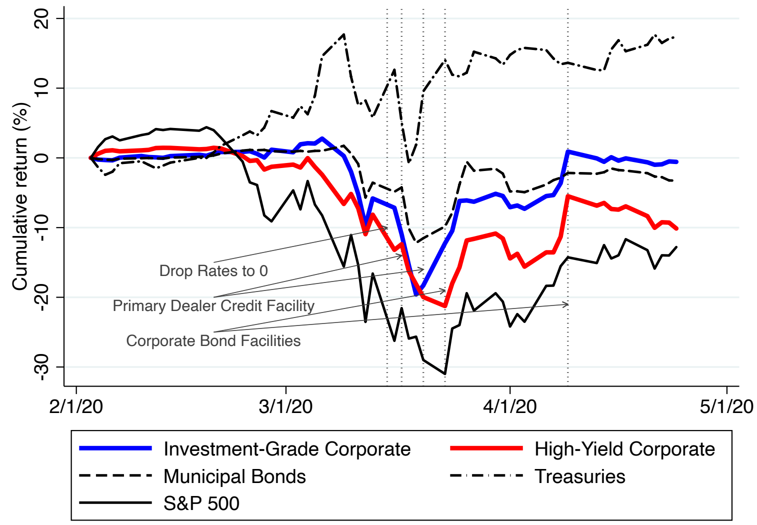


Figure 2
Returns during the COVID-19 crisis across asset classes
This figure reports the cumulative log returns for the stock market (S&P500), an investment-grade corporate bond ETF (LQD) , a high-yield corporate bond ETF (HYD), a long-term Treasury ETF (TLT), and a municipal bond ETF (MUB) through the COVID-19 crisis, from February to early April 2020.

equity backstop to these facilities. On April 9, the Fed further expands these programs, including in particular some high-yield debt. The timing of the recovery in prices broadly follows the Fed announcements. But, with the time-series evidence of Figure 2 alone, it is difficult to attribute an effect of the intervention on prices, in particular due to the highly volatile environment. In Section 3, we overcome this issue by measuring the response to the Fed announcements using a combination of high-frequency data and cross-sectional evidence within debt markets.

Table 1 explores the behavior of bond spreads in more detail. We use daily data from TRACE from January 2020 to June 2020 to study which bonds were most affected. Specifically, we construct daily log spread changes at the bond level based on an average of the last five trades in TRACE on a given day.[9] We include bond fixed effects in this regres-

[9]Bonds with zero trades in a day are assigned zero change for this day, but will be reflected the next

sion to soak up any potential composition effects. The crisis dummy is from February 28 to March 20 (the first three weeks of March), while the recovery period is March 23 to April 16 (the following three weeks). Bond spreads increase, on average, by 80% during the crisis. Including a dummy for investment-grade bonds shows an additional effect on investment grade of 12%. The third column shows that spreads rose the most for shorter maturity investment-grade bonds, where *short* is a dummy for maturity being less than five years. The fourth and fifth columns include interactions with a dummy for a bond's liquidity that is equal to one if the number of daily trades for the bond was above the 75th percentile in TRACE before the crisis (January and February 2020). More-liquid bonds saw a relatively larger increase in spreads, especially those that were investment-grade bonds with shorter maturity. This highlights the patterns in the aggregate data: safer, more liquid corporate bonds experienced larger spread increases during this period. Similarly, these same bonds experienced the largest recovery, which we will tie specifically to announcements by the Federal Reserve. In Internet Appendix Table IA.2 we show these results are robust to the inclusion of controls for a host of additional variables, including interactions for COVID-affected industries and firm leverage. We compute standard errors using the Driscoll-Kraay HAC estimator with a Newey-West kernel with a bandwidth of five days.

1.2 How abnormal are the price movements?

The price drops for corporate debt, while smaller in terms of absolute size, are of the same order of magnitude as the stock market. Such commensurate changes are atypical: debt prices tend to be much more stable than equity prices. This observation suggests a "larger" price change for debt; we quantify this idea. We place these asset price movements in context by scaling all returns to have a beta of one with the stock market in

time the bond trades. This is because our focus is on the broad behavior of spreads during this period and not individual daily movements.

Table 1
Crisis and recovery in bond spreads

	(1)	(2)	(3)	(4)	(5)
crisis	80.92***	71.19***	49.96***	61.21***	41.93***
	(4.07)	(3.67)	(3.70)	(4.00)	(4.14)
recovery	–20.41**	–17.44	–10.47	–4.69	1.15
	(–2.11)	(–1.59)	(–1.26)	(–0.56)	(0.17)
$IG \times crisis$		12.50**	5.32	11.84***	7.86**
		(2.21)	(1.02)	(2.74)	(2.21)
$IG \times recovery$		–3.81	–0.20	–3.09	–2.45
		(–0.86)	(–0.06)	(–1.01)	(–1.03)
$short \times crisis$			44.98***		43.71***
			(3.39)		(3.43)
$short \times recovery$			–14.94**		–13.34*
			(–2.04)		(–1.94)
$IG \times short \times crisis$			24.13***		20.72***
			(3.25)		(3.34)
$IG \times short \times recovery$			–10.98*		–4.50
			(–1.86)		(–1.00)
$liquidity \times crisis$				21.52*	18.65*
				(1.85)	(1.69)
$liquidity \times recovery$				–27.59***	–26.74***
				(–2.82)	(–2.83)
$IG \times liquidity \times crisis$				22.36***	12.13**
				(2.65)	(1.97)
$IG \times liquidity \times recovery$				–28.35**	–25.65**
				(–2.15)	(–2.07)
Observations	1,597,523	1,597,523	1,597,523	1,597,523	1,597,523
Bond FE	Y	Y	Y	Y	Y
R^2	0.01	0.01	0.01	0.01	0.01

This table regresses spread changes at the bond level ($\Delta ln(s_{i,t})$) from TRACE on dummies for crisis (first three weeks of March) and recovery (following three weeks), interacted with bond-level characteristics: investment-grade (IG), short (maturity under five years), and liquidity (pre-COVID daily trades in TRACE above 75th percentile). T-statistics using Driscoll-Kraay standard errors with five lags in parentheses.

Internet Appendix Figure IA.1. In particular, we use the last two years of daily data up to January 2020 to estimate the beta of each fund with respect to the stock market. We then use this estimate to leverage each fund to have a beta of one. This calculation provides a simple way to illustrate how unusual the price movements in investment-grade credit are during the recent period. By this beta-adjusted metric, cumulative log returns for investment-grade corporate bonds drop by more than 100%, versus only 30% for stocks and about 50% for high-yield bonds. An alternative way of seeing this fact is that the market beta of investment-grade credit would have predicted a 5% drop in bond prices, in line with the 5% drop predicted by movements in CDS spreads discussed in the introduction, but much smaller than the 20% drop we observe in bond prices.[10]

These observations suggest that the investment-grade market in particular, which is the core funding market for U.S. companies and totals over $7 trillion, was dysfunctional; we more sharply characterize this dysfunction in Section 2. Another possibility is that the beta of debt increases mechanically as firms become distressed. Such an increase is qualitatively plausible and would somewhat mitigate the abnormality of the price variations. However, the quantitative challenge remains: rarely does the beta of debt increase to values close to one in standard approaches to reconcile debt and equity prices such as the model of Merton (1974).

Another way to assess the specificities of price movements during the COVID-19 crisis is to compare them to what happened during one of the worst historical episodes, the great financial crisis of 2008–2009 (see Internet Appendix Figure IA.2). In terms of magnitude, the March 2020 decline in prices is comparable to the 2008 crisis for the stock market. However, the two episodes differ on a couple of important dimensions. In the 2008 episode, high-yield bonds closely track the stock market, falling around 40% from the spring 2008 until January 2009, while investment-grade bonds decline by about 15–20% over the same period. This stands in contrast to comparable decline in investment-grade and high-yield debt in March 2020. Again, this result suggests significant disruption in debt markets, in particular the safer end of the spectrum.

A salient aspect compared to 2008 is the extremely high speed at which asset price

[10] Internet Appendix Figure IA.5, repeats this with controls for the market, daily changes in the VIX, and long term Treasury returns and still finds a large cumulative abnormal return for investment-grade corporate bonds.

movements take place in the recent episode. While one can think of the start of the GFC going back to the summer of 2007 when it became clear that the subprime segment of the mortgage market had issues, it was not until October 2008 that the stock market had a decline as large as experienced in the first two weeks of March, and markets only bottomed by March 2009. The policy response was also slower, as can be gauged from the behavior of long-term Treasury bonds. During the recent period Treasury bonds rallied by 20% as the market went down, while they meaningfully climbed only much later during the GFC.[11]

2. Disruptions in the Pricing of Debt

We now document a pervasive pattern of price dislocations for debt securities during the COVID-19 crisis: breakdowns in how prices are connected across markets. These disruptions have the appearance of arbitrage opportunities. Their emergence is often seen as the sign of a limited ability of the financial sector to absorb differential shocks across markets. This can occur because intermediaries are distressed or the shocks are particulary large. For example, Duffie (2018), Mitchell and Pulvino (2012), and Krishnamurthy (2010) give an overview of such disruptions in previous episodes.[12] But, beyond their mere presence, the magnitude and structure of these dislocations shed light on the sources of price fluctuations during the recent episode. In March 2020, corporate bonds trade at a large discount relative to credit-default swaps, and ETFs trade at a discount to the underlying bond portfolio. Both divergences are particularly pronounced in investment-grade debt, where their magnitude represents a large share of the overall drop in price.

[11] Another distinctive aspect of the recent episode is that the long-term Treasury market seems to have malfunctioned in the second week of March, while in 2008 they only started rallying in mid-November (by 30%) and peaked in the end of the year.

[12] Bai and Collin-Dufresne (2019) and Fontana (2010) study the CDS bond basis in 2008; Fleckenstein, Longstaff, and Lustig (2014) and Hu, Pan, and Wang (2013) focus on disruptions in Treasury bonds; and Du, Tepper, and Verdelhan (2018) document violations of covered interest parity.

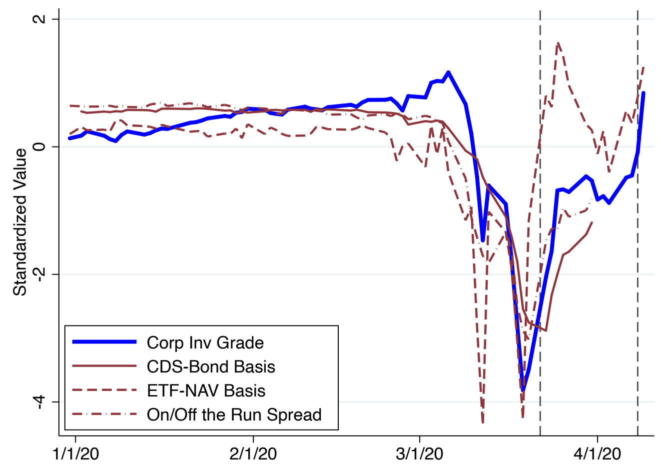


Figure 3
Debt price dislocations

We plot the CDS-bond basis for investment-grade bonds, the on-the-run/off-the-run spread for Treasuries, and the average NAV discount for investment-grade corporate bonds, municipal bonds, mortgage-backed securities, and long-term Treasury bonds. All series are standardized to have unit standard deviation.

2.1 Synchronization of dislocations

We first show that, as prices were deteriorating, a set of dislocations emerged, and subsequently disappeared during the recovery. Figure 3 plots price dislocations across different bond categories; each measure is normalized to have unit standard deviation so that they are at the same scale in the figure. We return to absolute magnitudes and the details of the construction of each series shortly. We plot the CDS-bond basis for investment-grade bonds—the difference between the yield spread of CDSs and bonds—along with the on-the-run/off-the-run spread, which compares yields for a newly issued 30-year Treasury bond and an "old" 30-year Treasury bond with remaining maturity 29.5 years. We also add the average deviation between bond ETF net asset values (NAV) and their ETF price averaged across corporate bonds, municipal bonds, mortgage-backed securities (MBSs), and long-term Treasury bonds. A negative value indicates the ETF price is below the NAV. Again, we discuss this construction in more detail shortly.

The most salient feature of Figure 3 is that these disruptions are fairly synchronized despite being across different asset categories in the fixed income space, and all occur in line with the height of the crash in investment-grade debt in March. This observation points to widespread issues in liquidity, funding, or arbitrage capital across many assets. To better understand the source of these deviations, we zoom in on individual disruptions. We focus mostly on spreads related to corporate bonds, in search of an explanation of what seem to be the largest abnormal price movements, in the pricing of investment-grade debt. Duffie (2020), Fleming and Ruela (2020), He, Nagel, and Song (2020), and Schrimpf, Shin, and Sushko (2020) offer thorough studies of the Treasury bond market.

2.2 CDS-bond basis

We compare the prices of corporate bonds with CDS contracts written on them. Because CDS contracts insure against the default of a bond issuer, their spread should equal the spread on corresponding bonds in a frictionless setting. Departure of the spreads from each other is therefore indicative of a combination of two elements: a relative selling pressure in bonds relative to CDS contracts—for example, due to a preference for cash over synthetic instruments—and a limited ability of arbitrageurs to equalize the prices—for example, due to distress in dealers, like in 2008. In Section 4, we discuss in more detail the interpretation of the basis for this specific episode.

The TRACE database allows us to observe all bond trades up to June 2020. We complement these data with daily CDS data from ICE through Capital IQ. To make sure that these CDS prices are representative of market conditions, we focus only on names that both belong to the on-the-run CDX indices and are part of the most liquid bond ETFs. That is, we first restrict our attention to components of CDX IG for investment-grade bonds and CDX HY for high-yield bonds; these tend to be the most liquid names in the CDS market. We use the index for a maturity of five years, the most liquid point of the credit curve. Then, we use the bonds held by the iShares LQD ETF (as of March 2, 2020) for investment-grade bonds and the iShares HYD ETF for high-yield bonds. We only use bonds with durations ranging from three to seven years. We match bonds from the ETF portfolios with trades on TRACE and CDS prices for each name. We duration-match each bond with a corresponding Treasury bond to compute the bond spread and compute the CDS-bond basis by subtracting the bond spread from the CDS spread. Therefore, a negative basis indicates that the bond is cheap relative to a portfolio that approximately replicates the bond's cash flow by combining the corresponding CDS contract with Treasury bonds. While this implementation is not an exact arbitrage trade, the magnitude of the basis we document appears difficult to reconcile with frictionless pricing.

2.2.1 Time series of the basis. Figure 4 reports the median bond spread, CDS spread, and basis for investment-grade bonds (panel A) and high-yield bonds (panel B). Bond spreads increase sharply starting on the week of March 2 for both investment-grade and high-yield bonds. But, strikingly, the CDS spread for investment-grade bonds barely moves. At the peak on March 20, three-fourths of the bond spread is due to the basis, which reaches 280 bps. In the high-yield market we see instead a large increase in CDS spreads along with bond spreads: these firms are mostly getting more risky.[13] While the basis also increases, it does so proportionally much less. This observation contrasts sharply with the 2008 crisis. Then, riskier bonds experienced a much larger basis than safer bonds. Mitchell and Pulvino (2012) show a peak basis of about 700 bps for high-yield and 250 bps for investment-grade bonds. Some safe bonds like the ones issued by Berkshire Hathaway even famously experienced a positive basis back then.

To put the size of the basis in perspective, we show what these numbers imply in terms of bond returns. The bond (log) return is $\Delta ln(p) \approx -d \times \Delta y$, where p represents

[13] In addition, for more risky firms, one could expect the disruption to feed back into default risk as suggested by He and Xiong (2012) and He and Milbradt (2014).

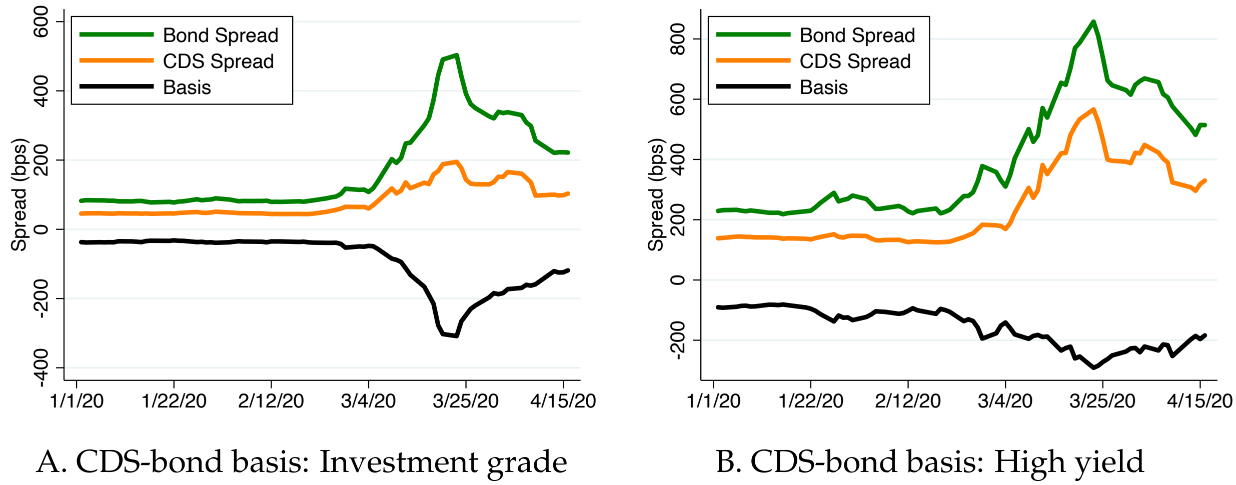


Figure 4
CDS-bond basis
The figure plots the median CDS-bond basis (green line) for investment-grade bonds in the LQD portfolio that have CDS contracts present in the CDX IG basket (panel A) and high-yield bonds in the HYG portfolio with CDS contracts present in the CDX HY basket (panel B). The green line is the bond spread, the orange line is the CDS spread, and the black line is the basis. See text for data construction.

the bond price, d represents duration, and y represents yield. We can decompose it as: $d \times \Delta y = d \times \Delta\left(s + r_f\right) = d \times \Delta\left(-basis + CDS + r_f\right)$, where r_f represents the yield on a duration-matched Treasury bond, s represents the bond spread, and $basis$ is the CDS bond basis $(CDS - s)$. For investment-grade debt, the overall change in spread at the peak reaches about 400 bps. Given that we target a duration of five years, this suggests a price decline of about 20%. Such a large decline is in line with the observations of Section 1. At the same time, the basis widens by about 280 bps. This corresponds to a drop in prices of about 14%. In other words, roughly 75% of the price decline in investment-grade bonds comes from the disruption.

Our conclusions hold if, instead of matching bonds to single-name CDSs we look at broad indices. Internet Appendix Figure IA.3 plots the spreads for CDX investment-grade and high-yield indices along with the investment-grade and high-yield spreads from LQD and HYG and shows the same pattern. This alleviates possible concerns about

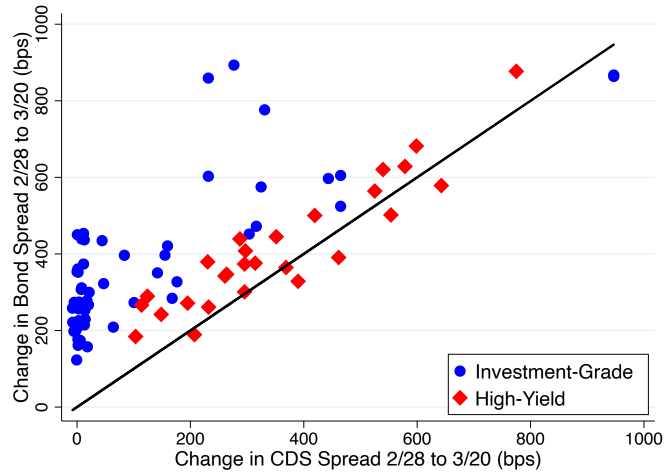


Figure 5
CDS-bond basis at the firm level
The figure plots firm-level changes in CDS spread against changes in bond spread from the start of the COVID-19 crisis at the end of February 2020 to March 20, one day before the first Fed announcement on corporate bonds purchases. It uses firms with bonds that have a duration between three and seven years and the five-year CDS spread. The back line denotes the 45-degree line.

liquidity of single-name CDSs as the CDX index is highly liquid.

2.2.2 Cross-section of the basis. The pattern of larger dislocations for safer bonds also holds within the investment-grade segment. Figure 5 illustrates the cross-section of the basis. The figure shows in the x-axis the CDS spread change from February 28—roughly the start of events in financial markets—to March 20—one business day before the first Federal Reserve announcement directly targeting the corporate bond market. On the y-axis, we have the bond spread change during the same period. Each dot is a firm, so the bond spreads and the basis are averaged within firms.

This figure shows a striking pattern. The high-yield bonds are all close to the 45-degree line. This implies that within high-yield firms, changes in CDS, and bond spread changes are consistent with one another. In investment-grade firms, on the other hand, we have a cloud of firms with very small changes in CDS spreads and huge increases in bond spreads. In addition, every single investment-grade firm is above the 45-degree line; that is, for all these firms the basis went up and for some almost the entire spread change is due to the basis. We highlight a few examples of such specific firms shortly.

A natural interpretation of these findings is that for these very safe firms bond prices got disconnected from fundamentals and were instead shaped exclusively by some investors needing to sell these bonds quickly. Furthermore, arbitrage activity did not occur strongly enough to counteract the disruptions. The intensity of disruptions, in particular relative to frictionless variation, appears less sharp in other markets. We come back to this interpretation at length in Section 4.

2.2.3 Do transactions occur at these discounted prices? A potential threat to this interpretation of the basis is that the low bond prices are not reflective of any trading activity. For example, if a trading freeze is occurring, the prices we observe might not be what anybody actually transacted at. We find this is not the case. Substantial discounts occur in liquid bonds that trade frequently, even during this period. More concretely, we use TRACE data to assess weekly trading volume for investment-grade and high-yield corporate bonds. Weekly trading volume for investment grade was around $140 billion for the last week of February, and increased slightly to around $150 billion in the last week of March.[14] Volume in investment-grade bonds did not decline substantially, and if anything appears to fall more for high-yield bonds toward the end of March. These observations alleviate measurement concerns one might have about the basis. However, they do not imply an absence of trading frictions—for example, Kargar et al. (2020) document increases in trading costs—or that these frictions are not important to understand overall price movements. Our observation that volume does not dry up also follows from our initial example of Google in Figure 1. In Internet Appendix Figure IA.8, we show several

[14]For more details, see Internet Appendix Figure IA.7, which plots trading volume by week from February to April.

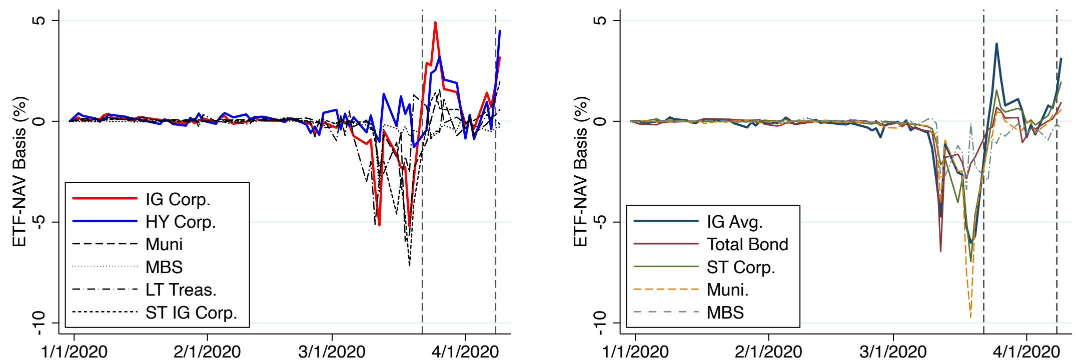
additional examples including AT&T, Amazon, and Goodyear that illustrate this point in more detail.

2.3 ETF-NAV basis

We turn to another prominent way to gain exposure to corporate debt: exchange-traded funds (ETFs). Fixed-income ETFs have grown substantially over the past decade, passing $1 trillion in assets as of June 2019.[15] ETFs are investment vehicles that invest in a portfolio of assets and are often seen as a substitute for mutual funds. In contrast to open-end mutual funds, shares of ETFs cannot be redeemed by most participants, but rather have to be traded on the secondary market. Still, their price should closely relate to the underlying assets. We compute deviations of ETF prices from net asset value (NAV) for several categories of funds. We refer the reader to Pan and Zeng (2019) for more details on ETFs and a longer history of ETF-NAV deviations.

First, we plot the ETF-NAV discounts for the iShares ETFs of Section 1. We also choose these particular funds because they are some of the largest and most liquid ETFs available. Panel A of Figure 6 reports the results. The investment-grade corporate fund LQD (the solid red line) trades at a discount to its NAV during the month of March until the Fed announcement of corporate bond purchases. The usually more liquid ETF becomes cheaper than its more illiquid counterpart, the bond portfolio. The distance between the two is large, with the ETF trading at 5% lower than the reported value of the underlying bond portfolio. This deviation represents about a quarter of the overall price drop for the ETF during this period and is large by historical standards: Pan and Zeng (2019) only report two days between 2004 and 2016 with a discount over 4%. In contrast, the high-yield fund HYD (the solid blue line) does not experience such a large discount, oscillating around zero. This pattern echoes again our previous findings of deeper distortions in safe

[15] Asjylyn Loder, "Bond Exchange-Traded Funds Pass $1 Trillion in Assets," *Wall Street Journal*, July 1, 2019, https://www.wsj.com/articles/bond-exchange-traded-funds-pass-1-trillion-in-assets-11561986396.



A. iShares ETFs B. Vanguard ETFs

Figure 6
ETF-NAV discounts

Panel A plots the discount of ETF price relative to NAV for iShares ETFs: an investment-grade corporate bond ETF (LQD), a high-yield corporate bond ETF (HYG), a Treasury ETF (TLT), a municipal bond ETF (MUB), an MBS ETF (MBB), and two ETFs that track separately short- and long-term investment-grade corporate bonds (IGSB and IGLB). Panel B plots discounts between matched Vanguard ETF and mutual fund shares trading the same portfolio for corporate bonds, municipal bonds, mortgage-backed securities, and a total bond index (70% Treasury bonds, 30% investment-grade bonds). Discounts are given in percent, with negative value indicating that an ETF price is lower than its NAV.

debt. The deep discounts are not unique to corporate debt. During the same period, other forms of safe debt see a large ETF-NAV discount: short-term corporate, municipal bonds, or long-term Treasury bonds.

One potential limitation of this analysis is that the NAV for an ETF is not a price investors are entitled to trade at, unlike for open-end mutual funds. We overcome this issue by repeating the analysis for Vanguard ETFs in panel B of Figure 6, another set of large and liquid funds. Each of these ETFs corresponds to a Vanguard mutual fund with the exact same portfolio. We find that, not surprisingly, the NAV reported for the ETF coincides perfectly with the NAV for the matched fund. The advantage of this setting is that now the NAV is the actual price of a trade one can do. During March, a mutual fund investor could have redeemed her mutual fund shares, purchased the ETF, and captured this difference in prices while having the exact same portfolio of underlying assets. Just like for iShares, the discounts are very large—up to 10%, with an average peak of around

5%. Another way to materialize the size of the discounts is to compare them to typical returns of the funds. The average annual return across the four fixed income funds we report—municipal, corporate, Treasury, and MBS—is around 4%, around the same size as the average peak discount.

Of course, to understand the source of these disruptions, it is important to look beyond the case of twin funds. If an investor does not already own the mutual fund, how does she capture the basis when the ETF trades at a discount to the NAV? The arbitrage can be done only by authorized participants (APs) who are allowed to redeem or create shares. For bond ETFs, APs consist mainly of primary dealers (Pan and Zeng 2019).[16] The AP would buy the ETF, redeem the shares, and receive the underlying basket of securities, which they would then sell. Internet Appendix Figure IA.4 shows that APs did in fact redeem shares in large amounts ($30 billion) exactly when the disruptions arose, suggesting they view them as a mispricing. However, this activity was not large enough to close the price difference.

What does the price difference between the price of ETFs and the price at which the underlying bonds trade reveal? This disruption could be the result of a combination of large selling pressure by investors of safe debt ETFs, and limitations to the ability of dealers to engage in the arbitrage. For the latter, APs might have been reluctant to take on those trades due to the balance sheet space they take on, or the adverse selection and volatility risk going associated with them. Drechsler, Moreira, and Savov (2018) and Pan and Zeng (2019) highlight the importance of these latter costs outside of this crisis. But, and maybe more importantly, the price disruption also helps narrow down where the selling pressure happened. ETFs are often viewed as much more liquid than the underlying

[16]BlackRock lists among the most common APs: Bank of America Merrill Lynch, Citigroup, Credit Suisse, Deutsche Bank, Goldman Sachs, JP Morgan, Morgan Stanley, UBS Securities, and Jefferies. BlackRock, "A primer on ETF primary trading and the role of authorized participants," https://www.blackrock.com/corporate/literature/whitepaper/viewpoint-etf-primary-trading-role-of-authorized-participants-march-2017.pdf.

bonds, with higher trading volume and lower trading costs. So, among cash instruments, it appears that the desire to liquidate positions was even stronger for more liquid instruments. In addition this pattern was more pronounced for the safer investment-grade ETFs than high-yield ETFs, a pattern that echoes what we saw for the CDS-bond basis. In Section 4, we discuss in more detail which mechanisms can and cannot reconcile these facts.

2.3.1 Are NAVs simply stale? Comparing the various ETFs allows us to rule out more mechanical interpretations of the basis. One such interpretation is that prices used to compute the NAV are somewhat stale. For example, one could argue that the NAV in the mid-March period reflected prices that lagged the large drop actually reflected in the ETF prices. However, the lack of a large basis for the high-yield ETF on panel A of Figure 6 goes against such an explanation. The high-yield ETF experienced larger price movements than investment-grade bonds during that period. If anything, high-yield bonds tend to be less liquid and likely more prone to price staleness than investment-grade debt, municipal bonds, MBSs, and so on.

We can further rule out a mechanical link between large price variations and the basis by observing the joint evolution of the ETF price and its NAV across various funds. We find no divergence between the ETF price and NAV for stocks—despite stocks being more volatile. For Treasury ETFs, the NAV experienced larger movements than the ETF price. This suggests again that the gap that opened up between ETF prices and bond prices in their basket was not about slow updating of the NAV, but rather about the more liquid asset, the ETF in this case, trading at lower prices than the less liquid asset, the basket of individual bonds. Finally, we report in the Internet Appendix several of these individual NAV departures in more detail, plotting the evolution of ETF prices along with the implied discounts. Internet Appendix Figure IA.9 shows the evolution of the NAV and ETF prices across broad asset categories; Internet Appendix Figure IA.10 focuses in on corporate bonds and MBS; Internet Appendix Figure IA.11 shows a total bond index and municipal bond index. Again, these results reinforce the interpretation that the disruptions were more salient in safer parts of the investment universe.

3. The Effect of the Fed's Interventions

As we have seen, both aggregate prices and the disruptions broadly recovered following a series of announcements by the Fed. To get at a causal interpretation of these responses, we now conduct event studies around the Fed's revelation of large interventions in the corporate bond market.[17] We find that the first announcement on March 23 yielded a sharp recovery for prices and disruptions in the safest segments of the bond market. In contrast, the announcement of wider interventions on April 9 leads to a broader recovery in prices. The pattern of these responses is informative not only about the effectiveness of the various policies, but also because it sheds light on the mechanisms behind the price drop preceding them.

3.1 The Federal Reserve's interventions in debt markets

Starting on March 15 the Fed unveils a series of interventions at a brisk pace; we briefly review them. Table 2 summarizes announcement dates and the respective policy interventions. Most of the early announcements target short-term funding markets in line with what was done in 2008: swap lines with core central banks (March 15), commercial paper lending and Primary Dealer lending facilities (March 17), money market lending facilities (March 18 and March 20), swap lines with periphery central banks (March 20), certification of large foreign institutions to use Treasury securities in repo transactions with the

[17] See also O'Hara and Zhou (2020), Boyarchenko, Kovner, and Shachar (2020), Kargar et al. (2020), Gilchrist et al. (2020), and D'Amico, Kurakula, and Lee (2020), who study the effect of Fed interventions during this period on market liquidity and prices along various dimensions.

FED (March 31), and exclusion of Treasury securities and deposits from the leverage calculation for holding companies (April 1). These interventions target what are broadly described as money markets and to a large extent are classic liquidity operations. But, on March 23, the Fed goes beyond the playbook used in 2008 by unveiling new facilities. These facilities explicitly take on credit risk with an equity backstop provided by the Treasury. They ought to buy investment-grade corporate debt, asset-backed securities, and short-term municipal securities. On April 9, the Fed further expands the scale and scope of these programs. In particular, it expands the size of the corporate credit facilities from less than $300 billion to $850 billion, includes "fallen angels" (high-yield bonds that were previously investment-grade) and high-yield bond ETFs, and even engages in a Main Street lending facility. Importantly for the interpretation of the response to these announcements, all these facilities take a long time to set up. No purchases were made for months, and by June the Fed had still not purchased a meaningful amount of corporate bonds.

3.2 Event study around policy announcements

3.2.1 Debt prices. To identify the effect of the announcements on prices, we implement a high-frequency event study around a few of the interventions from Table 2. ETFs are particularly suitable for this purpose. They allow us to get high-frequency intraday observations of prices to see the immediate impact of the announcements. In contrast, individual corporate bonds tend to be less liquid and trade less frequently. Frequent observations allow us to isolate the effect of the Fed intervention from other news, something particularly important in this period that sees a lot of intraday price movement. Of course, this approach limits our ability to exploit the entire cross-section of bonds, something we do in daily data in Section 3.3.[18]

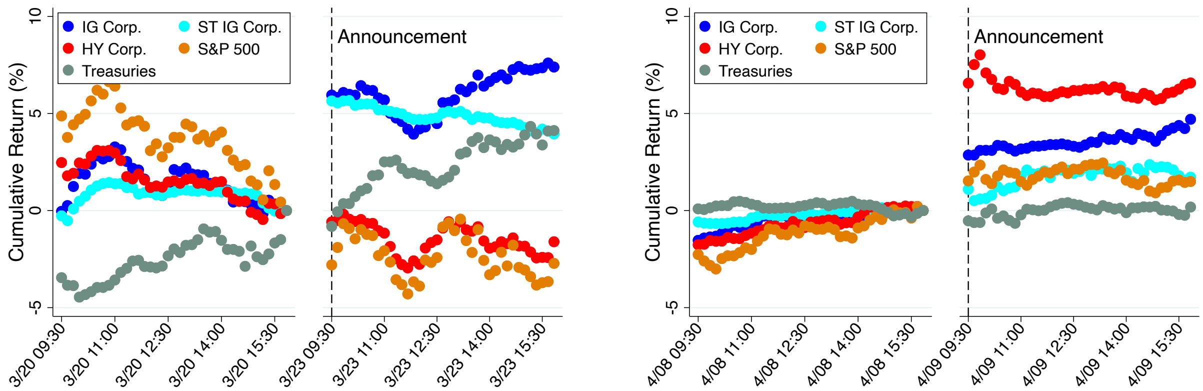
[18] D'Amico, Kurakula, and Lee (2020) conduct an event study of the policy announcements using a cross-section of ETFs.

Table 2
Interventions announced by the Federal Reserve during Spring 2020

Date	Time	Description
March 15	5:00 p.m.	Lower policy rate to zero
		Swap lines with core central banks
		Purchase $500 billion of Treasury bonds and $200 billion of agency mortgage backed securities (MBSs)
March 17	10:45 a.m.	Commercial paper funding facility (CPFF)
		Purchase high-quality commercial paper with a $10 billion equity tranche from the Treasury
		First time 13(3) is invoked
March 17	6:00 p.m.	Primary dealer credit facility (PDCF)
		Allow primary dealers to pledge a wide range of assets as collateral
March 18	11:30 p.m.	Money market funding facility (MMFF)
		Provide funding for primary dealers to purchase money market funds assets
March 19	9:00 a.m.	Swap lines with periphery central banks
March 20	11:00 a.m.	Extend MMFF to municipal assets; PDCF goes online
March 23	**8:00 a.m.**	Primary and secondary market corporate credit facilities (PMCCF and SMCCF): purchase of investment-grade bonds on primary and secondary markets
		Term asset-backed securities (ABS) loan facility: provide loan against high-quality ABS
		Extend range of municipal securities that qualify for MMFF and CPFF
		$300 billion total capacity across the facilities
		Agency commercial MBSs can be purchased with the $200 billion allotment from March 15
March 31	8:30 a.m.	Allow certain foreign counterparties to directly repo Treasurys with the FED
April 1	4:45 p.m.	Exclude Treasury securities and deposits of leverage calculations for bank holding companies
April 9	**8:30 a.m.**	Establish $500 billion Municipal lending facility (primary market) for maturities of up to 24 months
		Extend PMCCF and SMCCF to $850 billion (from less than $300 billion)
		Extend SMCCF to purchase high-yield bonds if they were investment-grade as of March 22
		$600 billion Main Street lending facility to lend to medium-sized companies through banks
May 11	6:00 p.m.	FRBNY: SMCCF to begin purchases of exchange-traded funds on May 12
June 15	6:00 p.m.	FRBNY: SMCCF to begin buying corporate bonds on June 16

We focus on the two announcements affecting the corporate bond market the most directly: the announcement of the new corporate credit facilities on March 23 and their extension on April 9.[19] Figure 7 reports the evolution of the ETFs of Section 1 around these two dates. Each point represents an observation of the price at 10-minute intervals. We take the log of all series and normalize them to zero just before the event; hence, the y-axis denotes the return relative to the value immediately before the event. For example, for investment-grade corporate bonds on March 23, we see a 6% return at the announcement.

[19]These announcements coincide with other policies, that appear to be less relevant for bond prices. The extension of the range of municipal securities that qualify for MMF and CPPF was also announced on March 23. But the initial announcement of the MMF on March 18 did not affect the corporate bond market, and this extension on March 23 did not have a large effect on municipal bonds. The term ABS loan facility was announced on March 23, but there was no update on April 9 despite a strong corporate bond response on April 9.



A. March 23 B. April 9

Figure 7
Event study around Fed announcements of bond purchases
The figure shows traded prices on selected ETFs around the Fed announcements of March 23 and April 9 at 10-minute intervals. We compute returns relative to last observation before the announcement to aid visualization. The timing of the Fed announcements is denoted by the dashed vertical line.

Because the two announcements occur outside of regular trading hours—at 8:00 and 8:30 a.m.—identification of the effect of the Fed's policies relies on comparing the closing price of the previous trading day with the opening price after the announcement. This feature reduces the sharpness of our empirical strategy. Still, the strong movements at the open support our approach. In addition, we provide evidence later in this section that the announcements indeed triggered a jump in asset prices.

The announcement of purchases of investment-grade bonds on March 23 increases the price of the investment-grade ETF by 6%. This discrete shift upward stands in contrast to stocks or high-yield bonds, which do not see any movement. The statistical and economic significance of the changes following these announcements is obvious to the naked eye. In Table 3, we confirm this impression, showing strong statistical significance of the response. In addition, a return of this magnitude is exceptionally large, even for this time period. It represents a recovery of more than a quarter of the drop of the previous month. While the figure reports returns, it is useful to consider the implied effect on yields for investment-grade corporate bonds. The average duration in the LQD ETF is around 9.5 years; hence the corresponding decrease in yield is around 70 bps. Notably, the price of the short-term corporate bond ETF—which focuses on maturities below five years—also increases by about the same amount, around 6%. While this amount represents the same change in terms of price, it implies a much larger change in yields because of the shorter duration. The short-term corporate bond ETF has a duration of about 2.65 years; hence the implied drop in yield is over 200 bps. This larger effect is consistent with the program's targeting of investment-grade corporate bonds with a maturity below five years.

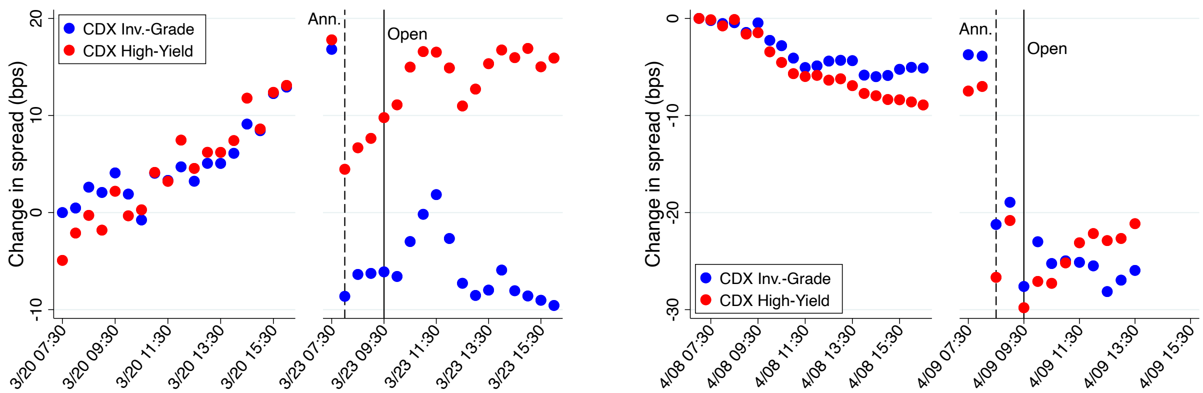
The dramatic expansion of the bond purchase programs on April 9 also has a large impact on prices, but with a very different empirical signature. We observe a strong recovery across markets, with a response more in line with riskiness. The investment-grade ETF experiences an increase of about 3% using the immediate reaction and about 4.7% using the change through the end of the day. This translates roughly to a decline in yields of about 30–50 bps. High-yield debt recovers even more, by about 6%. Because the effective duration of bonds in this ETF is shorter, at about four years, this price increase translates roughly to a decline in yields around 150 bps. Short-term corporate bonds and the stock market experience mild increases of about 1%, while Treasury bonds see virtually no change. This broad pattern is not necessarily inconsistent with the segmented response of March 23. While markets might still be segmented, the intervention is not: in this second announcement, the Fed is casting a much wider net with its intervention. We come back to potential interpretation of the different responses to the two announcements in Section 4.3.

What about the many other policy announcements in that period? While these other policies do not intervene directly in the corporate bond market, one might think that their impact on dealers would translate to a price recovery. We repeat the exercise for these events in Internet Appendix Figure IA.13, but find no sharp discontinuity in prices for these other releases. Particularly informative is the lack of response to the Primary Dealer Credit Facility on March 17 and the exemption of Treasury securities for leverage constraints calculations on April 1. This lack of response is information in itself about the mechanism behind the movements in debt prices during the crisis.

3.2.2 Credit default swaps. We complement this analysis by looking at the response of CDS spreads, using high-frequency variation in the investment-grade and high-yield CDX baskets. We plot these spreads in Figure 8. A first reason to study the CDX baskets is that they are actually traded during the two announcements, so we do not have to rely on close-to-open reactions. For both dates, we see that CDS spreads stay in line with the level of the previous trading day in the early hours of the morning. They then jump down right after the announcements, in line with our hypothesis that the Fed releases are what triggered the sharp price movements.

A second advantage of considering these data is that it helps separate whether the recovery after the announcement occurs throughout credit instruments, or reflects a closure of disruptions, here the CDS-bond basis. On March 23, the investment-grade spread decreases by a little over 20 bps, while high-yield recovers by 10 bps. Both of these amounts are much smaller than the reaction of bond yields, suggesting that most of the response on that date comes from bond spreads converging back toward CDS spreads. On April 9, the picture is more ambiguous, with a recovery of about 25 bps for both investment-grade and high-yield debt. This is again in line with the pattern of a broad recovery in response to this second set of interventions.[20]

[20]In Internet Appendix Figure IA.12 we also look at high-frequency data on S&P 500 futures and show a response consistent with the close-to-open evidence for the announcements on March 23 and April 9.



A. March 23 B. April 9

Figure 8

Event study around Fed announcements of bond purchases: CDS spreads

The figure reports the value the spread of the CDX IG and CDX HY every 30 minutes using transaction data. We report the implied increases in CDS spreads from the market opening one day before the announcement. The dashed lines are the policy announcements, while the solid lines are the openings of the stock market.

3.2.3 Broader event study. Table 3 conducts a broader event study by regressing daily returns on the investment-grade and high-yield ETFs. We include dummies for March 23 and April 9 but also expand to several other Fed actions, in particular the Primary Dealer Credit Facility (announced after market hours on March 17 and hence dated as March 18 for returns) and the relaxation of the leverage ratio for dealers (April 2). The fact that there is no effect on these days shows that policies aimed at relaxing dealer constraints had little effect on corporate bond prices. We also see that our conclusions for March 23 and April 9 hold when controlling for the stock market or Treasury market responses, suggesting these announcements primarily affected corporate bonds. Importantly, these few events are also responsible for a huge fraction of the variation in corporate bond returns over this period. For example, the event dummies alone have an R^2 of 28% even though they make up only six of the 244 days in our sample. Finally, we also look at the actual bond purchases. On May 12, the Fed announced it would begin its purchases of

ETFs and we see a modest increase in returns. On June 16, the Fed announced it would begin its purchases of corporate bonds, though we see little effect on prices. However, we also compute actual purchases of corporate bond ETFs by the Fed for each day in our sample (labeled "ETF Buys") and find no significant result from actually buying. Thus, our main takeaway is that announcements of the Fed to step into corporate bond markets and purchase securities had large effects, while actual purchases and policies aimed at relaxing dealer constraints had no effect. These facts are critical for understanding the behavior of the corporate bond market and what forces were responsible for the large crash in March.

3.3 Which bonds responded to the Fed interventions?

The March 23 announcement targeted investment-grade companies in particular, and we see that bonds of high-yield firms do not respond. We dig deeper into this heterogenous response and ask where exactly the effects of the Fed intervention were felt more strongly. To get at this question, we use bond-level data from TRACE. Because individual bonds trade less frequently and with larger transaction costs, we consider data at the daily frequency. For each day and bond, we compute the end-of-day spread as the average spread over the last five trades of the day. Then, we compare the spread on the trading day of the announcement to the spread on the trading day before the announcement.

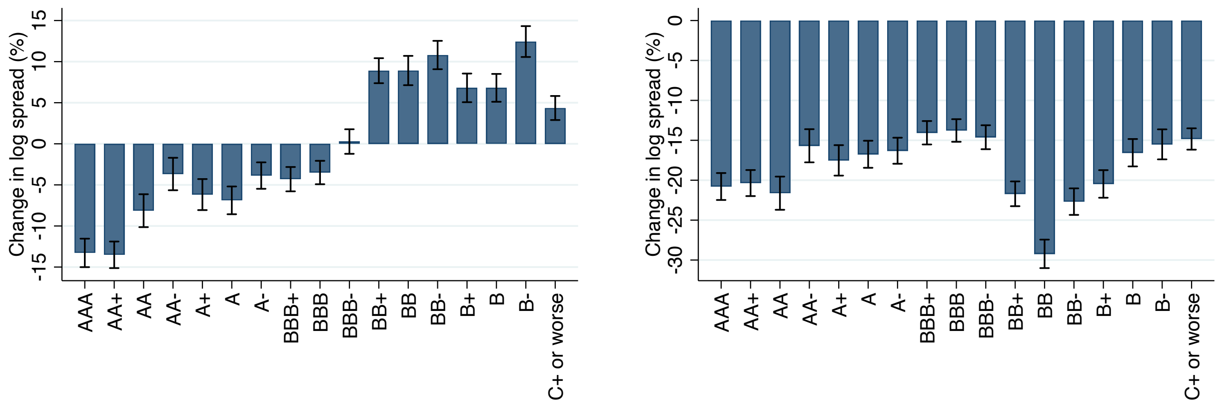
3.3.1 Ratings. A first step is to separate ratings more finely than between investment-grade and high-yield. We zoom in on the bonds owned by the two ETFs LQD and HYD. In Figure 9, we report the response of spreads to the announcements and confidence intervals across ratings; Internet Appendix Table IA.4 has the numerical values. We report the change in log spread—that is, the proportional change in spread—for both March 23 and April 9. Why log spreads? A simple benchmark is to view bond spreads as broadly

Table 3
Effect of Federal Reserve Announcements

	Investment-grade				High-yield			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
March 18 (PDCF)	–3.13***	–0.17	–0.16	–0.04	–3.24***	–0.05	–0.05	–0.08
	(–5.31)	(–0.39)	(–0.37)	(–0.09)	(–3.75)	(–0.15)	(–0.14)	(–0.23)
March 23 (P/SMCCF)	4.03***	4.63***	4.63***	5.00***	0.48	0.48	0.49	0.69**
	(6.83)	(11.45)	(11.48)	(13.01)	(0.55)	(1.54)	(1.58)	(2.24)
April 2 (LCR)	0.18	0.04	0.05	–0.24	–0.23	0.08	0.09	–0.12
	(0.30)	(0.10)	(0.12)	(–0.63)	(–0.27)	(0.24)	(0.28)	(–0.40)
April 9 (P/SMCCF)	2.75***	2.42***	2.42***	2.59***	6.09***	5.41***	5.42***	5.57***
	(4.67)	(6.04)	(6.06)	(6.88)	(7.06)	(17.37)	(17.55)	(18.34)
May 12 (Buy)	1.26**	1.03**	0.97**	0.98**	0.70	0.52*	0.29	0.34
	(2.14)	(2.59)	(2.38)	(2.58)	(0.82)	(1.68)	(0.88)	(1.03)
June 16 (Buy)	0.47	–0.03	–0.02	0.25	1.26	–0.27	–0.26	–0.12
	(0.80)	(–0.07)	(–0.06)	(0.66)	(1.46)	(–0.85)	(–0.83)	(–0.38)
Mkt		0.44***	0.44***	0.33***		0.49***	0.49***	0.41***
		(15.98)	(16.01)	(10.13)		(22.90)	(23.04)	(14.11)
Treas		0.35***	0.35***	0.37***		–0.11***	–0.11***	–0.10***
		(8.95)	(8.96)	(10.12)		(–3.53)	(–3.62)	(–3.49)
CDX				–5.89***				–0.78***
				(–5.82)				(–3.71)
ETF Buys			0.44	0.42			2.10*	1.95*
			(0.85)	(0.87)			(1.86)	(1.77)
const	0.03	–0.03	–0.04	–0.04	–0.05	–0.05**	–0.06***	–0.07***
	(0.71)	(–1.32)	(–1.45)	(–1.49)	(–0.87)	(–2.59)	(–2.92)	(–3.14)
N	244	244	243	240	244	244	243	240
Adj. R^2	0.283	0.671	0.672	0.714	0.201	0.896	0.898	0.905

This table shows the effect of announcement days on investment-grade and high-yield firms and complements our event study plots. We regress daily returns on LQD (investment-grade ETF) and HYG (high-yield ETF) on announcement day dummies. The remaining columns add additional controls, including the stock market, long-term Treasury bonds, the corresponding investment-grade and high-yield CDX indices, and a variable capturing total Fed purchases of investment-grade and high-yield ETFs on each day. Events are dated based on their effect on opening prices (for example, an announcement occurring after market hours is dated to affect prices at the next open). All announcements are in nontrading hours, and we compute close-to-open returns to capture the announcement effects. t-statistics are given in parentheses.

driven by a loading on credit risk multiplied by a credit risk premium. A change in the credit risk premium has an equal effect in percentage terms across all bonds, so it would lead to the same log change in spreads across the board. This is what we see for April 9, with spreads roughly falling by the same percentage amount across the ratings categories.



A. March 23 B. April 9

Figure 9
Response to the Fed announcements of bond purchases across ratings

This figure shows the regression coefficients and standard errors from a panel regression of daily bond spread changes on ratings interacted with the two announcement dummies. The regression includes bond fixed effects. Standard errors are computed using the Driscoll-Kraay HAC estimator with a Newey-West kernel with a bandwidth of five days. See Internet Appendix Table IA.4 for numerical values. The sample runs from January 1, 2020 to May 20, 2020. Daily spread changes are constructed using the average traded price of the last five transactions on each trading day.

The response to the April 9 announcement looks like a broad decrease in default risk or a decrease in the credit risk premium. The one exception to this pattern are the bonds rated just below the investment-grade threshold, which include the so-called “fallen angels” directly targeted by the policy, which experience a stronger response. March 23 is quite different. First, there is a clear break going from the investment-grade to the high-yield rating category, consistent with the target of the purchases. High-yield bonds, across the credit spectrum, see increases in spreads of the same percentage amount. We note this increase for high-yield bonds is likely about other news coming out on March 23 throughout the day; remember that our high-frequency approach does not suggest a large change in HYD on announcement but rather later in the day. Investment-grade spreads decrease the most for the safest end of the credit spectrum—that is, as one gets closer to AAA—-consistent with this being where the largest disruptions were.

3.3.2 Maturity and ETF inclusion. To better understand the effects of the interventions, we expand our sample to bonds not included in the ETFs. We drop bonds with a median of fewer than five trades per day in our sample to eliminate illiquid bonds and stale price effects. Table 4 runs a panel regression of log spread changes at the bond level from January through May of 2020. We include bond fixed effects in all regressions and report standard errors in parentheses. Column (1) includes announcement dummies for March 23 and April 9 along with interactions of the announcement dummy with an investment-grade dummy (IG). The results are consistent with Figure 9. The March 23 dummy is 7%, consistent with an increase in high-yield bond spreads, and the March 23 dummy interacted with IG has a coefficient of –13%. This implies an effect on investment-grade bonds of about –6%. April 9 shows economically fairly similar magnitudes for high-yield and investment-grade bonds with spreads declining by 15–20% across the board.

Columns (2)–(4) consider various sources of heterogeneity across bonds. In its initial announcement, the Fed describes a focus on bonds under five years in maturity and we see a significant additional decline in spreads for shorter maturity bonds, but only those that are investment grade and hence qualify for purchases. Internet Appendix Figure IA.6 explores this maturity effect with more granularity. In column (2), we include the dummy $short$ for such bonds, interacted with the announcement dates. In column (3), we include the dummy ETF for bonds that belong to either the LQD or HYG ETFs. This restriction is interesting because the Fed also announced it would purchase ETFs directly. Ownership by these two large and prominent funds likely proxies for the holdings of other ETFs that the Fed might trade.[21] These interactions help us assess how broad or narrow the effects of announced bond purchases are. The interactions of IG and shorter maturity bonds or bonds in the IG ETF on March 23 are significantly negative, meaning the bonds that are more directly targeted benefit substantially more. The same is true for high-yield bonds on April 9, where bonds included in the high-yield ETF experience a 10% larger drop in

[21] Internet Appendix Table IA.3 reports data on who owns ETFs.

spreads, while those in the investment-grade ETF show no change relative to the rest of the investment-grade bonds. Further, for April 9, the announcement dummy itself is still large and negative, suggesting all bonds benefit from the announcement.

These results are very much in line with our conclusions from the aggregate data. Segmented effects are more pronounced on March 23, while April 9 appears broader in its scope.

3.3.3 Disruptions. The announcements of large Fed interventions in the corporate bond market were likely, at least in part, motivated by the unusual price movements in bond markets.[22] In this sense, if they are a "treatment" for these disruptions, the response should be stronger for more afflicted firms, that is, those with a larger CDS-bond basis. We investigate this behavior in Table 5.

Columns (1)–(3) correspond to March 23. In column (1), we regress in the cross-section of bonds the one-day change in bond spread on the increase in basis between February 28 and March 20. We define the basis as the difference between the bond spread and the CDS spread, so that larger values correspond to bonds experiencing more disruption before the announcement. We find a strongly significant negative effect: bonds with larger basis recover more strongly following the announcement. The decrease in bond spread is about 14% of the basis increase over the course of the previous weeks. In column (2), we separate investment-grade and high-yield bonds. We find that the closure of the dislocation is concentrated on investment-grade bonds with a significantly negative coefficient of –0.15. Since the median CDS-bond basis increased by about 300 bps for investment grade, this implies a decline in spreads on announcement of about 45 bps. This decline is a bit larger than the 30-basis-point change of investment-grade bonds overall. In contrast,

[22] A discussion of this motivation is, for example, N. Boyarchenko, R. Crump, A. Kovner, O. Shachar, and P. Van Tassel, "The primary and secondary market corporate credit facilities," Liberty Street Economics, available at https://libertystreeteconomics.newyorkfed.org/2020/05/the-primary-and-secondary-market-corporate-credit-facilities.html.

Table 4
Cross-sectional response to the Fed announcements of bond purchases

	$\Delta ln(s_{i,t})$			
	(1)	(2)	(3)	(4)
March 23	7.03***	5.70***	7.39***	5.96***
	(9.67)	(10.29)	(10.62)	(11.92)
April 9	–14.21***	–11.57***	–8.96***	–5.54***
	(–19.84)	(–20.96)	(–13.22)	(–11.28)
IG × March 23	–11.69***	–8.28***	–10.12***	–2.13***
	(–26.47)	(–31.26)	(–13.69)	(–3.42)
IG × April 9	–3.21***	–2.26***	–7.97***	–2.83***
	(–8.22)	(–10.93)	(–12.16)	(–12.92)
short × March 23		2.66***		2.62***
		(7.05)		(6.82)
short × April 9		–5.32***		–6.28***
		(–14.81)		(–17.08)
IG × short × March 23		–6.33***		–10.65***
		(–14.42)		(–16.29)
IG × short × April 9		–1.01**		–4.05***
		(–2.30)		(–6.55)
ETF × March 23			–0.68***	–0.45**
			(–3.42)	(–2.16)
ETF × April 9			–10.07***	–10.64***
			(–46.51)	(–46.52)
ETF × IG × March 23			–3.25***	–7.71***
			(–4.75)	(–12.97)
ETF × IG × April 9			9.09***	3.83***
			(14.56)	(12.64)
IG × short × ETF × March 23				0.32
				(0.55)
IG × short × ETF × April 9				1.29***
				(2.60)
Observations	313,809	313,809	313,809	313,809
R^2	0.002	0.002	0.002	0.003

This table shows the results of a panel regression of daily changes in log spreads on the two announcement dummies and interactions with dummies capturing different bond characteristics. IG equals 1 for a bond that is investment-grade as of March 20, 2020. Short equals 1 for bonds with maturity shorter than five years on March 20, 2020. ETF equals 1 is the bond belongs to the baskets of either the LQD ETF or the HYG ETF. The regression includes bond fixed effects. t-statistics are computed using the Driscoll-Kraay HAC estimator with a Newey-West kernel with a bandwidth of five days. The sample runs from January 1, 2020 to May 20, 2020. Daily spread changes are constructed using the average traded price of the last five transactions of the day. Bonds must have a median of at least five daily transactions to be included.

Table 5
Response to the Fed announcements of bond purchases: reversal in spreads

	Δspread on March 23			Δspread on April 9		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	49.51***			–64.81***		
	(5.41)			(–10.28)		
$\Delta \text{basis}_{2/28 \to \text{day before ann.}}$	–0.14***			0.13***		
	(–3.74)			(2.94)		
IG		31.33**	13.75		–60.93***	–16.81*
		(2.49)	(0.95)		(–8.55)	(–1.74)
$\text{IG} \times \Delta \text{basis}_{2/28 \to \text{day before ann.}}$		–0.15***	–0.11**		0.23***	–0.07
		(–3.15)	(–2.23)		(4.94)	(–1.06)
$\text{IG} \times \Delta \text{cds}_{2/28 \to \text{day before ann.}}$			0.07**			–0.26***
			(2.37)			(–6.24)
HY		68.75***	49.08***		–68.71***	–33.51**
		(6.06)	(2.62)		(–6.33)	(–2.54)
$\text{HY} \times \Delta \text{basis}_{2/28 \to \text{day before ann.}}$		0.11*	0.09		–0.33***	–0.26***
		(1.88)	(1.50)		(–3.52)	(–2.99)
$\text{HY} \times \Delta \text{cds}_{2/28 \to \text{day before ann.}}$			0.06			–0.19***
			(1.31)			(–4.08)
Observations	310	310	310	308	308	308
R^2	0.04	0.20	0.21	0.03	0.14	0.27

This table shows results of two cross-sectional regressions of spread changes on the announcement dates on bond characteristics. $\Delta basis_{2/28 \to ann.}$ is the increase in the bond-CDS basis from February 28 to the day before each of the Fed announcements. The bond-CDS basis is defined as the difference between the bond spread and the CDS spread. $\Delta cds_{2/28 \to ann.}$ is the change in CDS spread over the same period. IG and HY are dummies indicating whether the bond has an investment-grade or high-yield rating. Only bonds that belong either to the investment-grade or high-yield iShares ETFs and have a duration between three and seven years are included in the regression.

there is no such effect for high-yield bonds, with a mildly significant positive estimate. In column (3), we control in addition for the change in CDS spread during this period. This addition does not suppress the effect of the basis in the investment-grade segment. Actually, the positive coefficient on the CDS spread suggests that during this time the fundamental riskiness of bonds was increasing, more so for more risky bonds. This multivariate evidence similarly reflects the broad increase in risk for high-yield bonds, with both coefficients being positive and insignificant. Columns (4)–(6) repeat the analysis for April 9. In line with our previous observations, that date sees a much more spread-out effect, reflecting a recovery of both the basis and fundamentals. For example, in column (6) all coefficients are negative, with larger and more significant responses to the CDS spread and in high-yield bonds.

Overall, these results establish a connection between the structure of the response to the announcement of the Fed's corporate bond facilities and the intensity of disruptions before these announcements. In particular, the March 23 intervention reduces spreads of bonds experiencing a high amount of disruption. However, they also highlight that, as the scope and size of the interventions increased, their effects went beyond closing the disruptions. For example, the April 9 announcement also reduces the spread of bonds that experienced deterioration in fundamentals as measured by their CDS spread.

We now piece together all this evidence to draw inference about the mechanisms behind the price movements during the COVID-19 crisis.

4. What Explains the Price Movements in Debt Markets?

When taken together, these results inform our understanding of why bond markets suffered so much during March 2020. We review several potential explanations for this phenomenon in light of this evidence. Frictionless views of asset markets focusing on cash-flow and economy-wide risk premium effects cannot easily explain the disruptions in debt markets we have documented. Theories of financial frictions and limits to arbitrage show more promise, but here as well our evidence helps differentiate various mechanisms. Importantly, we focus mainly on bond markets; we do not claim, for example, that some of these mechanisms do not play any role in other asset classes such as the stock market over the same period.

4.1 Frictionless explanations

4.1.1 Fundamental distress. A first explanation for the drop in price experienced across markets is that expected payoffs of the assets have dramatically decreased. After all, the COVID-19 crisis and the policy response to it have led the way to a sharp drop in GDP, unemployment has hit extreme heights, and many firms are on the brink of bankruptcy. This uncontroversial negative effect on the economy suggests poor performance of firms' stocks and bonds ahead. However, several of our findings challenge this view.

First, safe debt and high-yield debt experienced comparable losses. Both declined less than the stock market, but overall losses were of a similar order of magnitude. As we have already pointed out, it is difficult to explain these relative magnitudes in standard models. When economic conditions deteriorate, equity holders lose first, and it is likely that the most fragile high-yield firms default before investment-grade firms. This simple mechanism suggests a clear ranking of losses that does not show up in the data. Said otherwise, if we are in a state of the world where Google and Amazon are likely to fail, all other firms would be in dramatic trouble. One potential resolution of this tension would be to rely on expectations of a total economic collapse, where all firms default simultaneously. Only a high probability of such an event—and no possibility of a milder intermediate recession—would affect all debt contracts and stocks similarly. Such a view does not appear very plausible because of the high probability this event would need to have: over 10% over the next five years to explain the price of safe bonds.

Second, the large disruptions we document are directly at odds with such an explanation. Unlike bond spreads, CDS spreads of safe firms, which insure against their default, experience very little movement in this episode. Similarly, the observation that ETFs trade at large discounts relative to the bonds also points to frictions in financial markets. More than the presence of these distortions, their magnitude suggests that they are behind most of the price movement: the CDS-bond basis amounts to about three-quarters of the price drop in investment-grade bonds, and the ETF-NAV basis about one-quarter. Thus, while fundamental distress is a plausible explanation for the behavior of riskier bonds, it cannot account for the behavior of the safer part of the corporate bond market.

4.1.2 Risk compensations. If bond prices did not drop due to a fall in cash-flow expectations, it has to be that bonds had high expected returns looking forward. A prominent set of theories of expected returns is based on the idea that they constitute compensation for aggregate risks affecting everybody in the economy.[23] These theories face similar challenges to explanations based on cash flow. Increases in economic risk naturally have a larger impact on more risky firms. And, a lower willingness to bear risk should move more the price of more risky assets. Here again, the concentration of large price drops, as well as pricing disruptions, in the safer firms runs sharply against the grain of these models. This observation contrasts with previous episodes where the risk explanation and explanations based on financial frictions line up more closely. For example, during the financial crisis of 2008, nonagency mortgage-backed securities suffered large losses, and it is difficult to assess the relative role of unusual default prospects and financial distress among investors.

4.2 Financial frictions

We next turn to theories of financial frictions and limits to arbitrage. These theories are promising because they entertain deviations from the law of one price and can generate amplification effects that lead prices in some markets to depart from fundamentals.[24] Under this approach, the emergence of price dislocations indicates the confluence of two forces: some participants in these markets are unwilling to buy some assets relative to

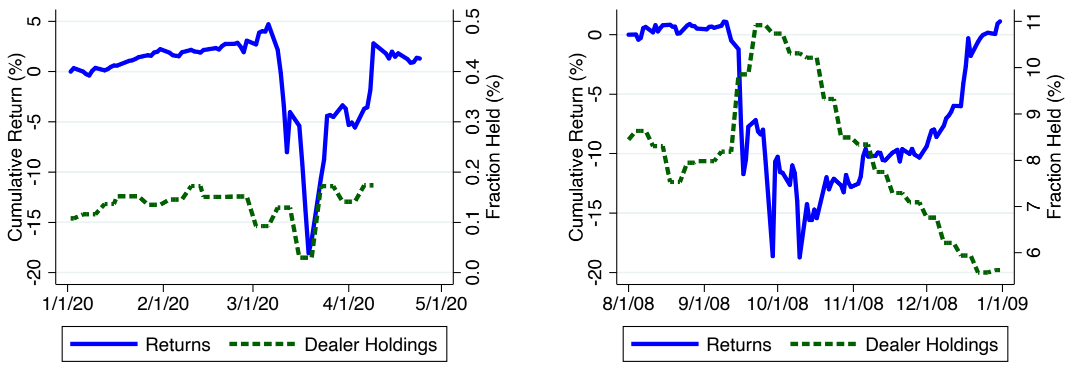
[23]Risk premia could vary due to changes in the risk of the economy (as in Bansal and Yaron 2004) or variations in willingness to bear risk (as in Campbell and Cochrane 1999).

[24]Here we broadly define fundamentals to include macroeconomic-driven variation in risk premia.

others, and typical arbitrageurs such as dealers do not step in enough to equate prices. Casually stated, such a narrative is natural in the context of the COVID-19 crisis. To obtain liquidity to face financial difficulties or outflows, many institutions investing in corporate bonds try to sell off their most liquid positions. ETFs are the most effective way to do so, followed by the safer bonds. In contrast, CDS contracts do not free up liquid resources. Dealers, facing their own constraints, are unable to absorb this selling pressure until they can find investors willing to buy the assets at a reasonable valuation.

The nuances of our findings on the behavior of asset prices, combined with information on trading by various institutions, help delineate more precisely these mechanisms. We discuss first the nature of what prevented dealers from stepping in, then the origins of the selling pressure.

4.2.1 Dealers. Primary dealers are actively involved in bond markets and play an important role of intermediating trades, so understanding their behavior can shed important light on this episode. They are a natural starting place as well because weak dealer balance sheets in 2008 were important to understand asset prices and the severity of the crisis. However, one must likely look for another mechanism: in contrast with the GFC, where the weak balance sheets of banks were front and center to understand the severity of the crisis, banks appear much better capitalized in 2020. In 2007 U.S. banks had 6% of their assets in tier 1 capital, while at the end of 2019 they had 15%. Asset prices suggest that dealers did not step in to close the dislocations; quantities give a similar message. Figure 10 plots primary dealers' positions in corporate bonds along with the cumulative returns on investment-grade corporate bonds in 2020 and 2008. First, notice that, even before the crash, dealer positions in 2020 are a small fraction of their 2008 level, making up just 0.1% of the total investment-grade market capitalization, compared to about 10% in 2008. While one could interpret this low exposure as having a lot of dry powder, if anything, dealer positions actually shrink through the first half of March, suggesting they



A. 2020 B. 2008

Figure 10
Primary dealer positions in the COVID-19 crisis and the great financial crisis

This figure shows cumulative returns of an investment-grade corporate bond ETF—solid blue line—through the acute phase of the 2008 crisis and the COVID-19 crisis. The dashed green line reports the net position of primary dealers in corporate bonds (from the Federal Reserve Bank of New York) normalized by the size of the investment-grade corporate bond market.

viewed activity in this market as less appealing despite the potential gains from the disruptions. Here again, this pattern contrasts with 2008; then, they increased their holdings from 7% of the investment-grade market to about 11%.

There is no scarcity of plausible explanations for this lack of intermediation services provided by dealers. The shrinkage of their holdings has been attributed, for example, to post-GFC regulation, such as the introduction of the leverage ratio or liquidity regulations. In addition, Duffie (2017) discusses increases in the cost of balance sheet space.[25] Furthermore, it is likely that intermediation opportunities in other disrupted markets were more profitable at that point. In particular, Duffie (2020), He, Nagel, and Song (2020), and Schrimpf, Shin, and Sushko (2020) discuss disruption in Treasury markets during the same period.

However, three features of the data challenge the view that these constraints on deal-

[25] Andersen, Duffie, and Song (2019) develop a framework for calculating these costs; Fleckenstein and Longstaff (2020) provide empirical evidence for the pricing of derivatives.

ers are enough to explain the presence of disruptions. Rather, they suggest that specific aspects of the disruptions in debt markets made dealers particularly unwilling to step in.

First, both dislocations we documented, the CDS-bond basis and the ETF-NAV basis, were more pronounced for safer debt, in particular for investment-grade relative to high-yield bonds. Most of the costs related to intermediation activity are instead larger for more risky and less liquid bonds. There are some notable exceptions to this: the leverage ratio, for example, does not distinguish between positions based on risk. Still, what one needs is for the total cost of intermediation to increase more sharply for investment-grade relative to high-yield debt.

Second, interventions that actually relaxed dealer constraints had virtually no effect on corporate bond prices. For example, on March 17 the Fed announced the Primary Dealer Credit Facility that allows dealers to post a broad array of securities as collateral with the central bank, including corporate bonds. If short-term balance-sheet constraints were the problem, one would expect powerful effects on prices of such a lender-of-last-resort-type policy. Or, on April 1, the Fed directly relaxes balance-sheet constraints on very safe assets by excluding Treasury and deposits from leverage calculations. This change helps dealers confront the distortions in the Treasury market and might have enabled them to intermediate corporate bond trades. However, bond prices did not experience a meaningful recovery at either of these announcements—and neither did dealers' net holdings of corporate bonds increase.

Third, dislocations strongly closed in response to the announcement of corporate bond buying facilities, as opposed to their implementation. If the issue leading to the disruptions was a temporary lack of capacity to intermediate short-term trades, merely announcing bond purchases would not solve the issue. Importantly, by June 15 the Fed still had not bought any corporate bonds. This is the flip side of our previous point: the large price response despite a wide gap between announcement and implementation suggests that immediate balance-sheet constraints are not the only issue. Further consistent with the idea that dislocations did not close because of improved short-term liquidity, Kargar et al. (2020) find little immediate impact of the announcements on trading costs overall and no differential effects for high-yield relative to investment-grade bonds.

While these three facts we document push against an explanation of the disruptions centered entirely on dealer frictions, they do not imply that there were no dealer frictions at all. Rather, they suggest that the nature of the selling pressure behind the emergence of the disruptions made it especially costly for dealers to step in. Potential sources of this extra cost are the size and duration of the selling pressure. For example, in the face of a very widespread and persistent desire to sell by investors, dealers can only mitigate the disruptions by engaging in asset warehousing—holding assets for long periods of time—and hope to weather the storm. The costs to dealers of participating in such strategies are much larger than for their more traditional short-term intermediation activities.[26]

4.2.2 Selling pressure. As previously discussed, the low price of cash instruments—bonds—relative to synthetic instruments—CDSs—indicates a strong demand for cash by investors. This implies that the driver of the sell-off was likely a liquidity shock for specific institutions or investors.

The pattern of which cash instruments experienced larger price depression further supports this hypothesis. In response to a liquidity shock, it is often optimal to first sell the most liquid assets in a portfolio. Theory and evidence for this type of response abound in the literature—Moreira and Savov (2017) for shadow banks, or Chernenko and Sunderam (2016) and Ma, Xiao, and Zeng (2020) for mutual funds, are recent examples—and this idea structures liquidity regulation in practice. Our evidence is very much in line with this view: the assets typically viewed as more safe and liquid experienced the largest price dislocations. That is, investment-grade bonds are more liquid than high-yield bonds, and

[26]Weill (2007) shows theoretically how, in presence of persistent demand shocks, market-makers do not immediately provide liquidity.

Table 6
Selling pressure: Evidence from mutual fund sales and debt issuance

	$\Delta ln(s_{i,t})$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$ln(MFsales)$			12.95***		12.61***	14.72***	12.78***	13.12***
			(6.30)		(6.21)	(3.56)	(3.29)	(2.87)
$ln(issuance)$				11.01**	9.08**	13.64**	13.94***	12.55*
				(2.44)	(2.04)	(2.42)	(2.63)	(1.95)
liquidity		8.63***			7.87***	11.41***	11.87***	13.82***
		(4.95)			(4.76)	(4.55)	(4.91)	(4.76)
leverage						–1.53	–3.22	
						(–0.20)	(–0.40)	
cash						–0.76	–0.35	
						(–0.41)	(–0.19)	
debt structure						0.17	–29.48*	
						(0.01)	(–1.76)	
$\Delta ln(cds_{i,t})$								0.08*
								(1.73)
IG	23.55***	25.28***	29.21***	23.58***	30.66***	37.76***	42.89***	32.55***
	(10.58)	(11.08)	(12.19)	(10.58)	(12.40)	(7.63)	(8.17)	(6.51)
short	72.00***	71.05***	70.96***	71.98***	70.10***	66.10***	65.65***	73.03***
	(49.57)	(48.46)	(50.21)	(49.44)	(48.77)	(29.25)	(28.77)	(25.68)
constant	72.16***	67.25***	55.55***	70.84***	50.42***	40.11***	42.29***	35.27***
	(37.17)	(30.18)	(16.62)	(35.12)	(14.22)	(5.29)	(5.45)	(3.67)
Industry FE	N	N	N	N	N	N	Y	Y
Observations	5,320	5,320	5,320	5,320	5,320	2,355	2,341	1,761
R^2	0.39	0.40	0.41	0.40	0.41	0.39	0.45	0.50

This table regresses spread changes at the bond level ($\Delta ln(s_{i,t})$) on bond level liquidity, mutual fund selling pressure, and firm level debt issuance with controls for rating (IG) and maturity (*short*). t-statistics using clustered standard errors in parentheses. See text for details.

ETFs are more liquid than the underlying bonds.

Table 6 shows a similar relation among bonds and provides a further window into the liquidation story. In column (2), we regress the cross-sectional change in log bond spreads during the distress period (March 1 through March 20) on dummies for investment grade, short maturity (less than five years), and liquidity of the bond (equal to one if the median daily number of trades for the bond were above the 75th percentile in January 2020, before the pandemic began). All three of these dummies contribute a significant amount to spread changes, notably with the more liquid bonds experiencing an 8.6% larger increase in spreads. Further, it is worth noting these three variables capture 40% of the cross-sectional variation in spread changes during the height of the crisis in March.

One caveat to this simple view of the response to liquidity needs relates to dynamic concerns: if a liquidity shock today goes along with an increased likelihood of deeper future liquidity shocks, it can become optimal to hoard liquid assets to weather an even worse crisis—Morris, Shim, and Shin (2017) and Jiang, Li, and Wang (2017) discuss this phenomenon in asset management. The rather sudden and acute nature of the COVID-19 crisis, and initial perceptions that it would be short-lived—as illustrated by discussions of only short-term lockdown policies at that time—could explain why these dynamic aspects were less relevant than in previous episodes.

How did the pandemic give rise to such an increased demand for immediate liquidity? One view is that the negative economic shock was amplified by specific structures in the financial sector, such as bond mutual funds. For these, the illiquidity of corporate bonds creates negative spillovers from liquidating investors to those staying inside the fund, or even to the value of other funds. In turn, these complementarities can lead to amplification of the initial shock, providing a rationale for extreme liquidations. Chen, Goldstein, and Jiang (2010), Falato et al. (forthcoming), and Goldstein, Jiang, and Ng (2017) provide theory and evidence of these forces before the recent episode. Consistent with this view, Falato, Goldstein, and Hortaçsu (2020) and Ma, Xiao, and Zeng (2020) document large redemptions from bond mutual funds during the COVID-19 crisis. Falato, Goldstein, and Hortaçsu (2020) show that both the illiquidity of fund assets and the vulnerability to fire sales were important factors in explaining outflows. And, particularly in line with our evidence, Ma, Xiao, and Zeng (2020) document that in response to these redemptions, funds sold their most liquid securities first.

We confirm the relevance of mutual funds: bonds held by funds with more redemptions experience larger spread increases. In column (3) of Table 6 we include a proxy for mutual fund sales at the issuer level. Our measure of mutual fund selling pressure follows Coval and Stafford (2007). Specifically, we take the sum of mutual fund positions in a given issuer (normalized by the funds' total assets under management, or AUM) as of their last reporting date before March 1, 2020. We then multiply by mutual fund gross outflows for the month of March. We normalize this issuer level variable by total debt outstanding at the issuer level. This calculation gives us how much mutual fund outflows would have contributed to sales if the fund sold proportionally. The estimated coefficient on this variable is significant and has value around 12, which implies a 12% elasticity of spread changes to mutual fund sales. This result directly supports the idea that liquidations from mutual funds facing redemption are associated with more severe price declines.

Naturally, the evidence from mutual funds does not imply that they were the only institutions suffering liquidity shocks. For example, life insurance companies are another prominent investor in corporate bonds, and, while they are usually a source of stability in bond markets, Chodorow-Reich, Ghent, and Haddad (forthcoming) and Ellul et al. (2018) discuss how they can amplify distress when sufficiently affected. In particular, Koijen and Yogo (2020) show how losses due to variable annuities contribute to this distress in the crisis. The depression of ETF prices also suggests a broader source of liquidity demand. In Internet Appendix Table IA.3, we document ownership of some of the largest investment-grade and high-yield ETFs using 13F filings. Interestingly, some mutual funds are present among the largest investors, suggesting they might use ETFs as a tool for liquidity management. But, most of the ownership resides in other types of financial institutions such as investment banks and asset managers, and of course retail investors also participate in a share of this market.

The demand for liquidity also comes from corporations. Faced with a transitory negative income shock, it is natural to use financial markets to stay in operation. While this demand for debt might not be realized immediately, the expectation of future issuance can depress prices immediately—in the same way that the expectation of future purchases by the Fed can increase prices immediately. Chodorow-Reich et al. (2020), Fahlenbrach, Rageth, and Stulz (2020), and Greenwald, Krainer, and Paul (2020) analyze the expansion of corporate borrowing because of firms' demand for liquidity during the COVID-19 crisis. Consistent with the role of corporate demand, we show that the firms that subsequently issued more debt experienced the larger increase in bond spreads in March. We compute future debt issuance as the log of total firm-level bond issuance from March 23 through August divided by the total amount outstanding before the crisis.[27] In column (4) of Table 6, we find a positive coefficient of 11, so that a doubling of the total amount of debt outstanding for a firm in terms of future issuance is associated with an increase of 11% in spreads during March. Further, including this variable has little effect on the mutual fund sales coefficient.

Both the mutual fund sales and future debt issuance results are robust to a variety of controls for firm fundamentals. In column (6), we include issuer-level data from Compustat as of Q4 2019 on leverage (net debt divided by total debt plus market capitalization), cash (cash equivalents divided by market cap), and debt structure (short-term debt divided by total liabilities). Column (7) includes industry fixed effects to absorb direct exposure to the consequences of the disease, following Fahlenbrach, Rageth, and Stulz (2020). Column (8) adds the change in the issuer's log CDS spread. Overall, our conclusions for the main variables capturing the liquidation pressure are not meaningfully altered.

These two broad explanations for the selling pressure go along with two reasons why this crisis is different from the 2008 financial crisis. First, this episode appears mostly related to a sudden demand for liquidity. While liquidity concerns certainly played an important role in 2008, their source appeared most related to shocks to the supply of liquidity—for example, the ability of dealers to intermediate. Second, the organization of financial markets, and bond markets in particular, is much different than in 2008. Mutual

[27]This variable introduces a source of look-ahead bias in the regression. However, the effect we find goes in the opposite direction from the effect that high spreads should lower the incentives of firms to subsequently raise capital.

funds have grown sharply in importance in terms of bond investing, and it appears the instability they create played an important role in amplifying the liquidity shock.

Finally, it is worth noticing a potential challenge for this explanation. Some of our results are suggestive of a form of "liquidity inversion": some of the usually more liquid assets experience price discounts beyond those of their more illiquid counterparts. For example, investment-grade bonds, or at least their basis to CDS, drop below high-yield bonds. Even more sharply, the price of ETFs drops below the price of underlying bonds. One explanation for this relation is that, given the speed at which the prices occur, investors stuck to their usual pecking order for liquidating assets, not accounting for the price distortions occurring in real time. This interpretation is consistent with the lack of distortion in high-yield ETFs, with these usually more risky assets not seen as part of the liquidity management toolkit, just like stocks, for example. Another explanation for these differences is that some aspects of liquidity beyond price and transaction costs became particularly relevant. For example, trading bonds instead of ETFs can prevent obtaining immediate execution, or can even come with a probability of no execution at all.[28]

4.3 Why should the Fed intervene in the corporate bond market?

Beyond uncovering the sources of the crisis, another important question is whether the policy response was appropriate. Answering this question is relevant beyond this specific episode: many of the policy actions during this period were unprecedented and not part of the standard central bank toolkit. In particular, we saw that the announcements of large-scale bond purchases in March and April had powerful effects on corporate bond markets. We briefly discuss a few potential rationales for such an intervention and some of the negative side effects that this policy can have.

A first rationale for corporate bond purchases is as a form of supplement for deal-

[28] Hendershott et al. (2020) study these dimensions in the context of CLO contracts.

ers' risk-bearing capacity through a peak of trading activity, with a goal of supporting well-functioning markets. For instance, Duffie (2020) argues that this is essentially what the Fed did in Treasury markets in March 2020 when it bought large quantities of Treasury bonds extremely quickly. As we have already discussed, because corporate bond purchases were not immediate, this simple interpretation is not enough to understand the effect of the announcements. One can take a broader view and argue that the Fed is trying to go against a more long-lasting imbalance causing disruptions in markets. This view is consistent in particular with response to the March 23 announcement, where the main effect is a closure of disruptions.

Alternatively, one can think of these policies as an overall price support for the provision of credit. Under this view, the Fed is using a portfolio rebalancing channel to push prices up. Then, the presence of price dislocations or disruptions in the functioning of financial markets is irrelevant. The response to the April 9 announcement shows signs of such a mechanism. Such a credit subsidy can make sense in a world where the social costs of bankruptcies are substantially larger than the private costs.[29] However, implementing this persistent subsidy to credit can also come at the cost of creating a large cohort of zombie firms and result in real investment distortions; see Brunnermeier and Krishnamurthy (2020) for a discussion.

Naturally, an important question is what created such distinct market responses between March 23 and April 9. One view is that there is a threshold in terms of quantity of intervention necessary to put a stop to the large selling pressure. Such a view could be particularly relevant if a large share of the liquidation is the results of amplification due to liquidity complementarities, such as those we discussed in the previous section for mutual funds. Another view, put forward by Ma, Xiao, and Zeng (2020) is that, by targeting high-yield bonds on April 9, the Fed went directly at the assets that had fun-

[29] Examples of externalities include the crowding of bankruptcy courts (Iverson 2018) or limited debt-in-possession financing.

damental trouble and that then triggered liquidation. Consistent with this view, they document strong inflows in illiquid funds following this intervention. However, it is not straightforward to square this observation with the large absolute outflows (that is, in dollars) that occurred in investment-grade funds. Finally, it could just be that various announcements conveyed different signals to market participants in terms of future policy decisions. Along this line, many commenters in real time likened the April 9 announcement to a commitment to continue expanding interventions until markets recovered.

Also, as we move through these motivations, the long-term financial risks for the Fed also increase. While supporting instantaneous market-making requires taking positions only for a short amount of time, waiting for selling pressure to cool down might take a few months, and obtaining long-term price effects might put corporate bonds on the Fed's balance sheet for the long run. What if the COVID-19 pandemic lasts for two years? Stein, Hanson, and Zwick (2020) propose alternative interventions that could potentially reduce the fiscal cost of such a policy. However, longer horizons can also be a source of flexibility. Announcements allow to make commitments to buy bonds only if prices get low enough. Interpreted through this lens they provide a clear credit backstop and can be effective in eliminating bad equilibria. This logic is often evoked to rationalize the successful "whatever it takes" approach Mario Draghi took toward the end of the 2008–2012 crisis.

5. Conclusion

Debt markets, especially for investment-grade bonds, have experienced significant disruption during the COVID-19 crisis. Not only did prices crash during the first three weeks of March 2020, but several large dislocations appeared. Corporate bonds traded at a large discount to their corresponding CDSs, and this basis widened most for safer bonds. Liquid bond ETFs traded at a large discount to their NAV, more so for investment-grade corporate, Treasury, and municipal bonds than high-yield corporate bonds. We attribute a large share of the recovery from this disruption to the unprecedented actions the Fed took to purchase corporate debt. The March 23 announcement to buy investment-grade debt increased prices and lowered bond spreads—particularly at shorter maturities and the safer end of the investment-grade segment—while having virtually no effect on high-yield debt. The expansion of debt purchases in size and scope on April 9 also had a large effect, but with a different pattern. Following this announcement, prices recover for investment-grade and high-yield bonds, even at the riskier end of the high-yield segment, which would only indirectly benefit from the policy. In contrast, more standard policy announcements by the Fed did not have a pronounced impact on bond prices.

These facts help explain the drivers of the extreme price movements during the start of the COVID-19 crisis in March 2020. It appears difficult to rationalize this episode without a prominent role for financial frictions. The data are most consistent with a large and persistent selling pressure from bond investors trying to obtain cash by selling their safer and more liquid securities, in part at the time of the crash but also in expectation over the next few weeks or months. We provide evidence of a specific role of bond mutual funds in the sell-off, but cannot rule out that other actors also participated in the wave of liquidations. Arbitrageurs such as dealers were not able to close price dislocations and smooth out this selling pressure because of its size and persistence, above and beyond issues associated with their usual balance sheet constraints.

Of course many questions remain, both on the specific identity of who drove the selling pressure and on the institutional structure leading to this selling pressure. We expect the availability of more data on positions, as well as a sharper understanding of the incentives of investors our evidence points to, to drive more progress on these questions. Another important avenue for future research is understanding the new policies of the Fed and their optimality. While the announcement bond purchases appeared to successfully push prices up, it remains to be seen if they have done so too much.

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Internet Appendix

A. Data Description

We discuss the data sources for the paper.

ETF prices and NAV are are from Bloomberg. CDS data are from ICE obtained through CapitalIQ. The price data for the CDX indices are from Bloomberg. Mutual fund holdings data are from the NPORT-P filings to the SEC. We obtain them through web scraping of EDGAR. Ownership of ETFs are from the 13-F filings obtained from Bloomberg. Issuer characteristics such as leverage, cash on hand, and debt maturity structure are from COMPUSTAT. Bond characteristics are from Mergent.

Bond price data are from Trace. We exclude foreign currency bonds, Canadian bonds, yankee bonds, and convertible bonds. To compute bond spreads we duration match the bond with the US treasury yield curve from Gürkaynak, Sack, and Wright (2007). The associated bond spread is the difference between the bond yield and the interest rate of the relevant duration-matched rate. In tables and figures that compute the CDS-bond basis (the difference between the CDS spread and the bond spread), we require firms to belong to either to the CDX-IG or CDX-HY indices and the bonds to be held by the largest investment-grade ETF (LQD) or the largest high-yield ETF (HYG). Both filters work as proxies for the liquidity of the CDS contracts and the bonds. We also restrict the sample to bonds with duration close to five years (more than three years and less than seven years) since we choose to only use CDS prices for the five-year tenor which is typically the most liquid.

B. Appendix Tables and Figures

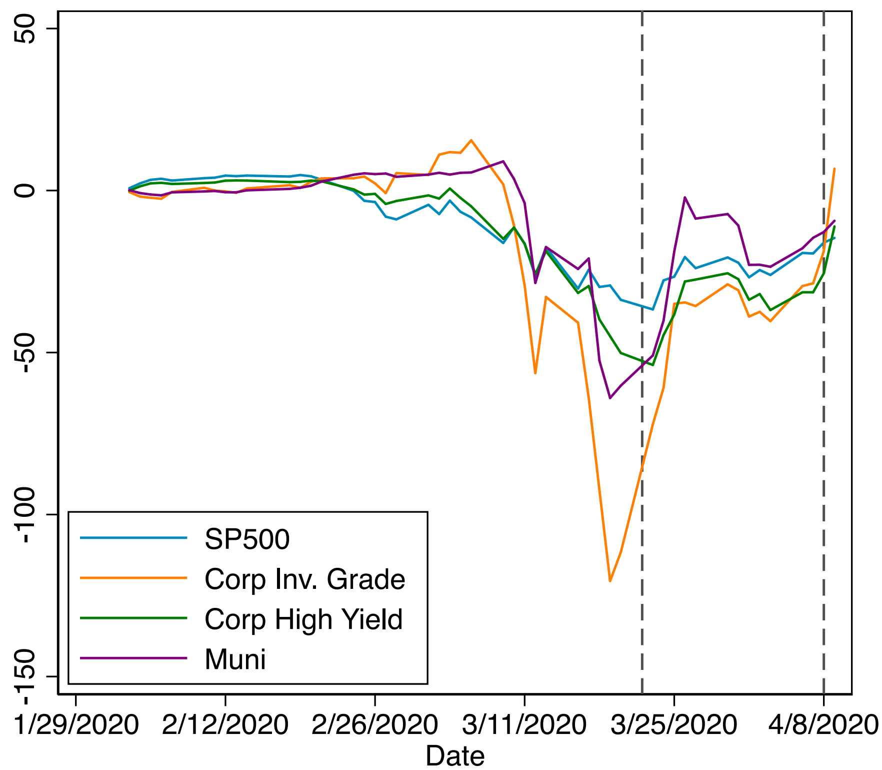


Figure IA.1
Returns during the COVID-19 crisis across asset classes, normalized by beta
This figure reports the cumulative log returns for the stock market (S&P500), an investment-grade corporate bond ETF (LQD) and a high-yield corporate bond ETF (HYD) through the COVID-19 crisis, from February to early April 2020. Returns are scaled to all have a market beta of 1 based on the previous two years of data.

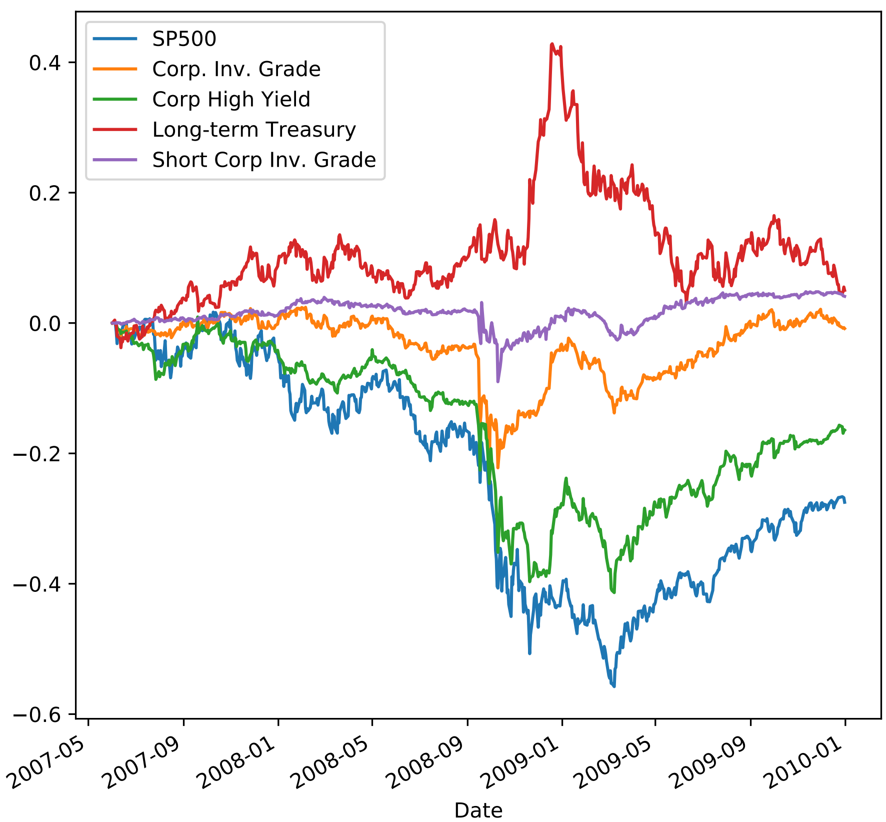


Figure IA.2
Returns during the 2008-2009 crisis across asset classes

This figure reports the cumulative log returns for the stock market (S&P500), an Investment-Grade corporate bond ETF (LQD) , a High-Yield corporate bond ETF (HYD), a long-term Treasury ETF, and a Municipal Bond ETF through the 2008 financial crisis, from late 2007 to late 2009.

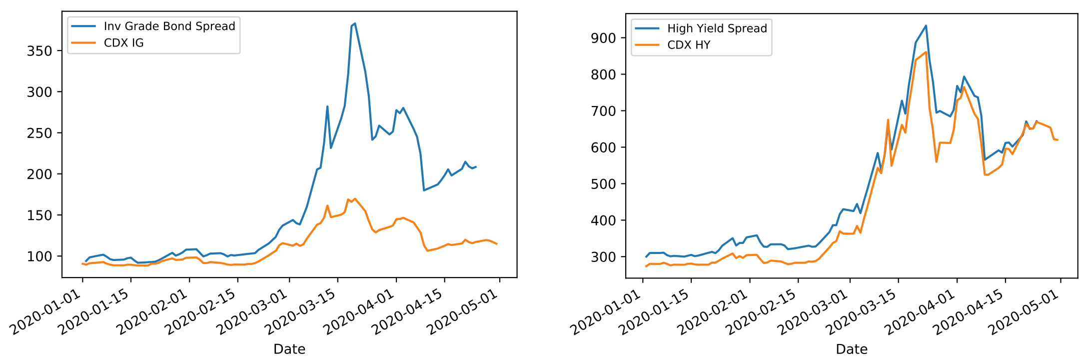


Figure IA.3
Bond and CDS spreads of investment-grade and high-yield bond portfolios
The figure shows the implied average bond spreads of Investment-Grade (LQD, left panel) and a High-Yield (HYG, right axis) ETFs and the traded spreads on CDX contracts that track baskets of Investment-Grade (left) and High-Yield (right) firms. The implied ETF spread is obtained from the price by using the average duration of bonds in the portfolio and subtracting the yield of a matched treasury. The ETF and CDX baskets have different bonds; Appendix Table IA.5 shows that the CDX skews riskier in terms of ratings. The CDX basket tells the same story as matched single name CDS and bond pairs but avoids concerns that single name CDS are less liquid.

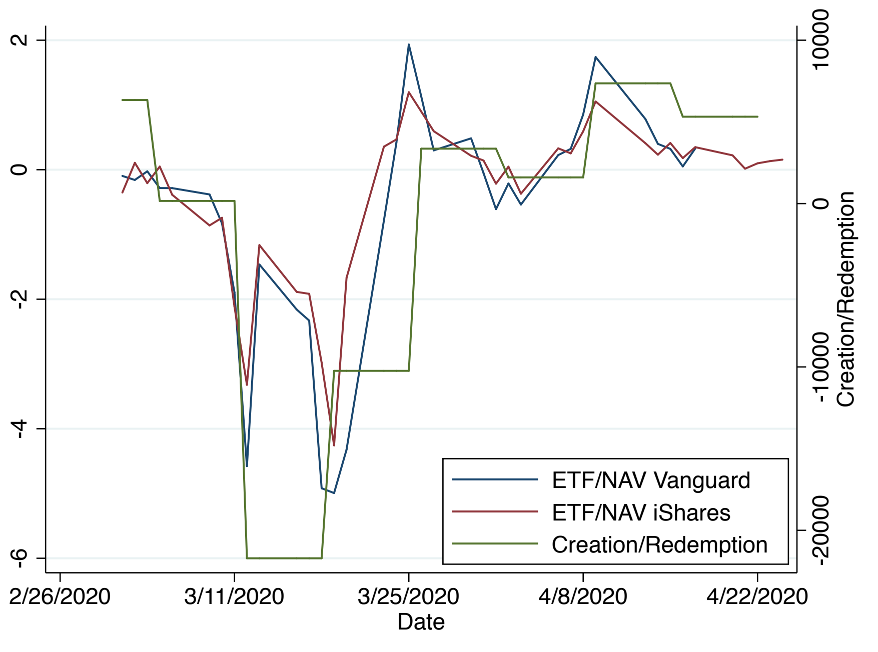


Figure IA.4
ETF-NAV discounts and redemption/creation of ETF shares

This figure plots average NAV discounts for Vanguard and iShares against net creation or redemption of ETF shares (plotted on the right scaled in millions of dollars, with negative numbers indicating net redemptions). When the ETF trades below NAV, authorized participants (typically primary dealers) can redeem ETF shares and sell the bonds to capture the spread. ETF NAV discounts are computed as the average discount across investment grade corporate, municipal, Treasuries, and MBS. ETF data are from the Investment Company Institute (ICI) and represent net issuance (gross issuance less gross redemptions).

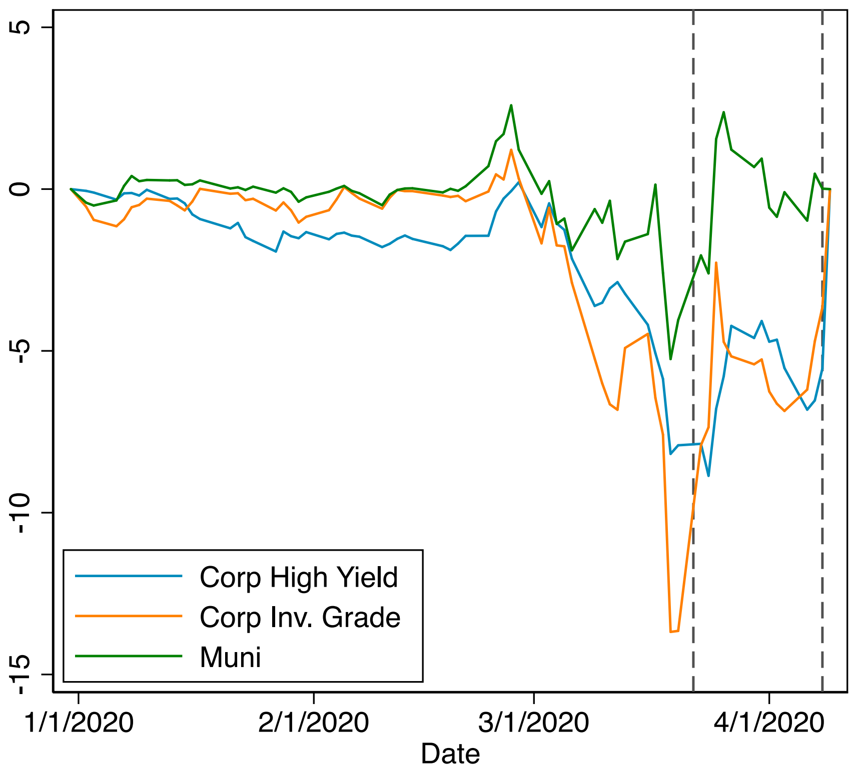


Figure IA.5
Cumulative abnormal returns during the Covid Crisis

This figure reports the cumulative abnormal log returns for an investment-grade corporate bond ETF (LQD), a high-yield corporate bond ETF (HYD), and a municipal bond ETF (MUB) through the COVID-19 crisis (January 2020 through early April). To compute abnormal returns, daily returns are regressed on the stock market returns, changes in the VIX, and changes in 10 year Treasury yields and we plot the cumulative sum of residuals. This highlights whether the movements in each series are well explained by changes in the market, volatility, or long term rates.

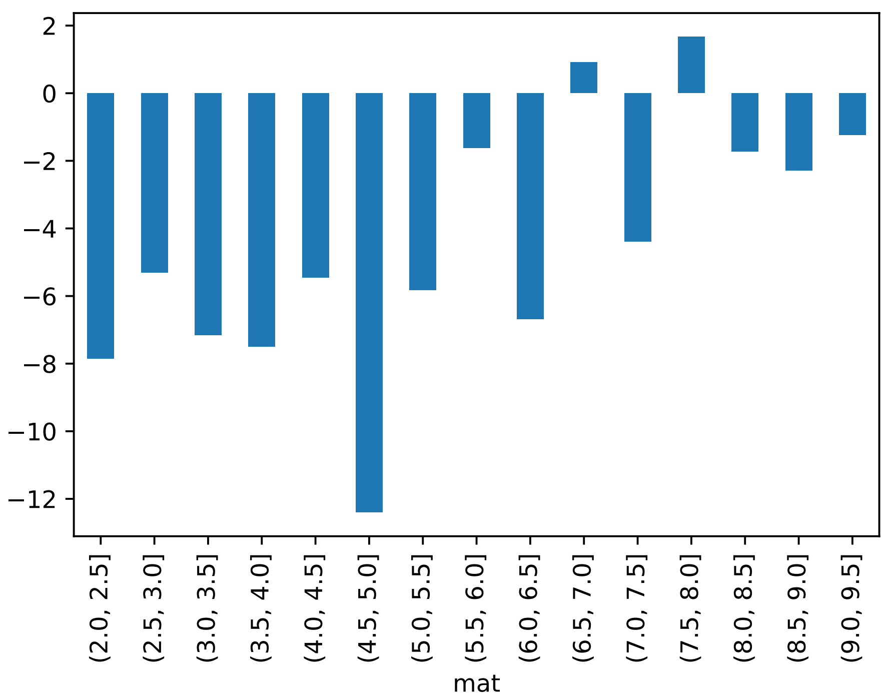


Figure IA.6
Maturity effect of the March 23 Fed announcement

This figure reports the response of investment-grade bonds on March 23 by 6 month maturity buckets (given in years on the x-axis). The y-axis is the log change in spreads on the announcement. The announcement targeted bonds below 5.5 years to maturity (specifically, bonds maturing before September 2025, hence 5.5 years to maturity as of the announcement date of March 23rd, 2020). See the main text for data construction.

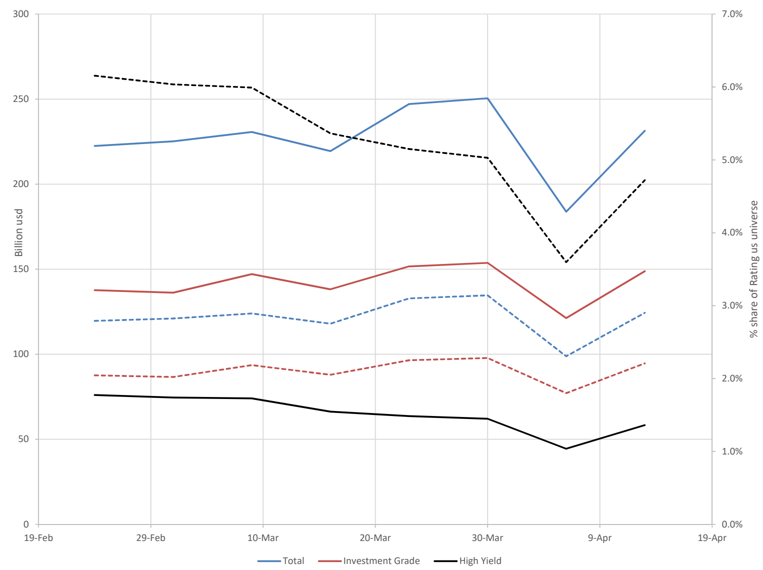
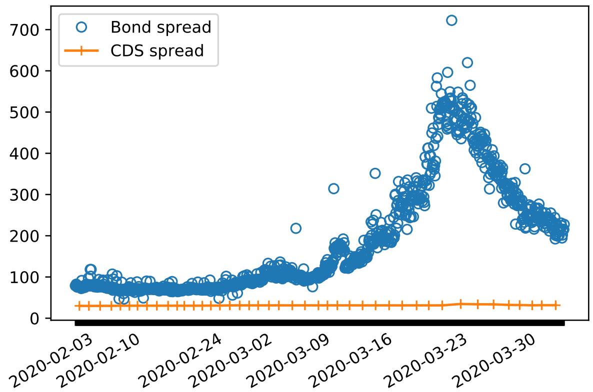
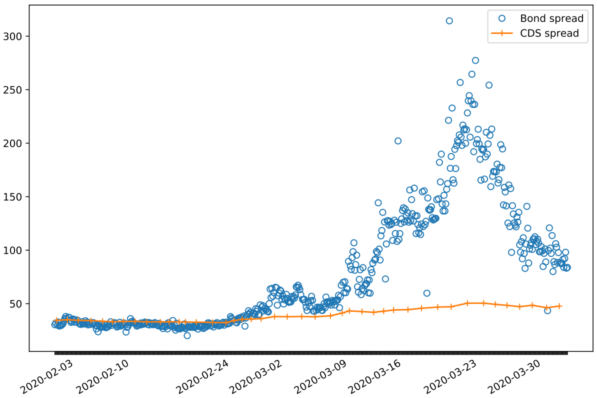


Figure IA.7
Weekly trading volume for corporate bonds

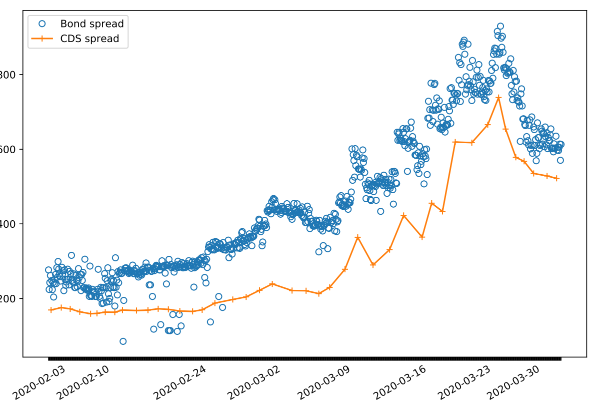
The solid lines depict weekly trading volume in each rating universe in billions of US, computed from TRACE (left axis). The dashed lines report trading volume divided by the total market cap of each bond universe (right axis).



A. AT&T.



B. Amazon.



C. Goodyear.

Figure IA.8
Examples of bond spreads and CDS spreads

The figure plots the bond spread — blue dots — and CDS spread —red line — for three bonds: AT&T (panel A), Amazon (panel B) and Goodyear (panel C). Each blue dot is a bond transaction in the TRACE database. The duration of these bonds is approximately 5 years, at 4.37, 5.25, and 5, respectively. AT&T and Amazon are investment-grade with strong credit ratings and balance sheets, and each has a bond spread and respective CDS around 30 bps in January. The dots in the graph highlight intraday movements in yield; each one represents a transaction in the TRACE database. As spreads widen going into March, prices also become more volatile with large intraday movements. One can also see that these bonds trade frequently throughout this period. Yet, the high-frequency price volatility is dwarfed by both the overall price movement and the difference with CDS spreads for these companies. For these firms, CDS spreads do not reflect substantially more risk and hardly move. The third panel plots Goodyear, which is in the high-yield index. Notably, spreads start out much higher, reflecting the lower credit rating, but also the CDS tracks spreads fairly closely as the crisis unfolds with both rising to nearly 700 bps. These examples are consistent with the earlier results of this section and representative of what happens broadly in bond markets.

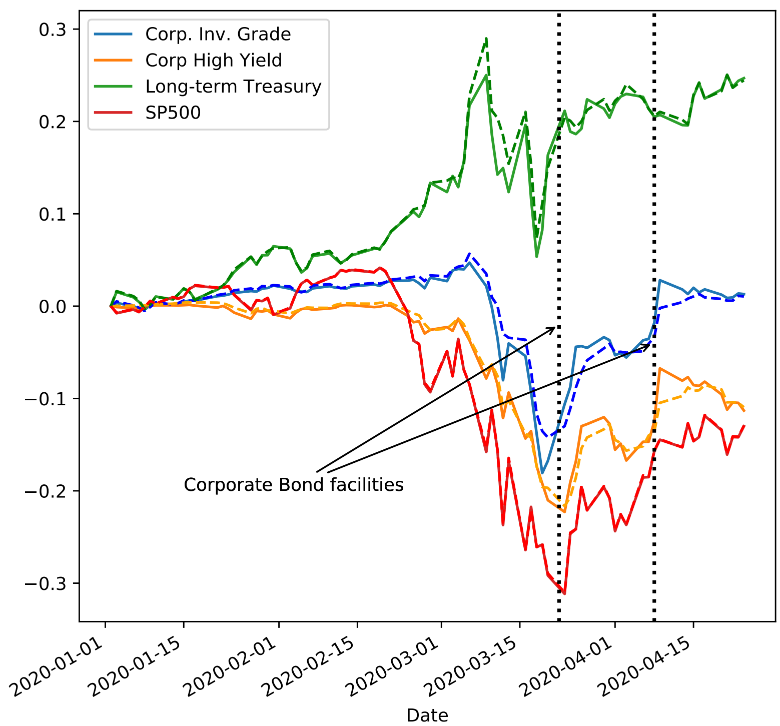
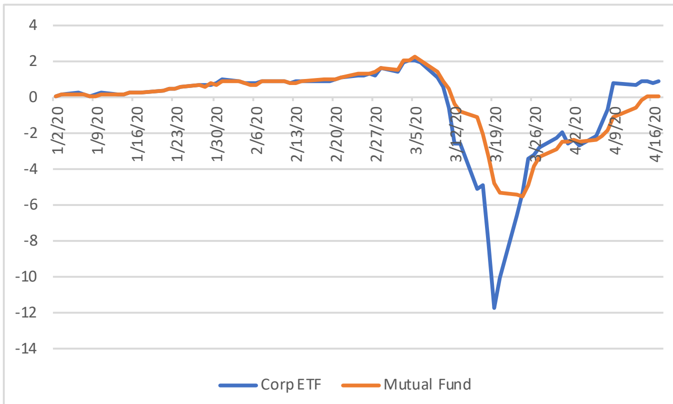
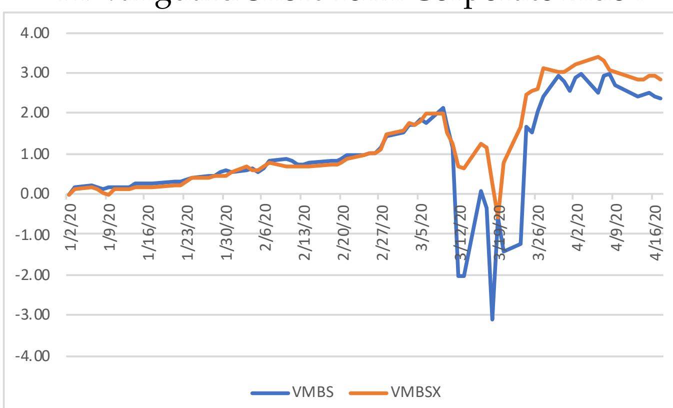


Figure IA.9
ETF prices and NAV

The figure shows the cumulative log returns for various ETFs along with their contemporaneous NAV-implied cumulative log return for an investment-grade corporate bond ETF (LQD), a high-yield corporate bond ETF (HYG), a Treasury ETF (TLT), and an S&P 500 ETF (IVV).



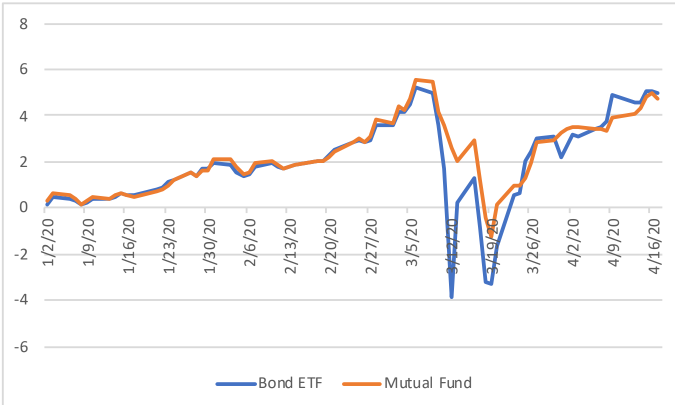
A. Vanguard Short Term Corporate Index



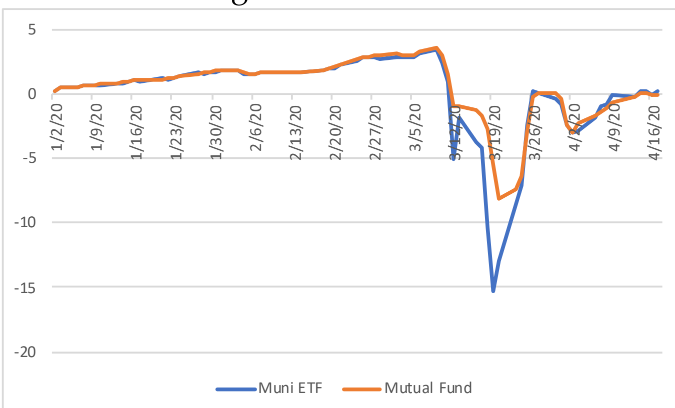
B. Vanguard MBS Index

Figure IA.10
Corporate bond and MBS ETF vs. mutual fund prices

This figure plots cumulative log returns based on Vanguard ETFs vs Mutual Funds. Panel A looks at corporate bonds where both the fund and ETF track the Bloomberg Barclays U.S 1-5 Year Corporate Bond Index (tickers are VCSH and VSCSX). Panel B looks at Mortgage-Backed Securities meant to track the Bloomberg Barclays U.S. MBS Float Adjusted Index (tickers are VMBS and VMBSX).



A. Vanguard Total Bond Index

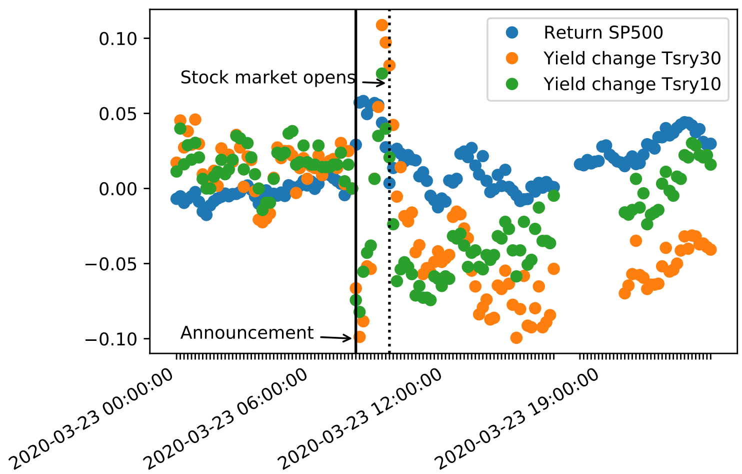


B. Vanguard Municipal Bond Index

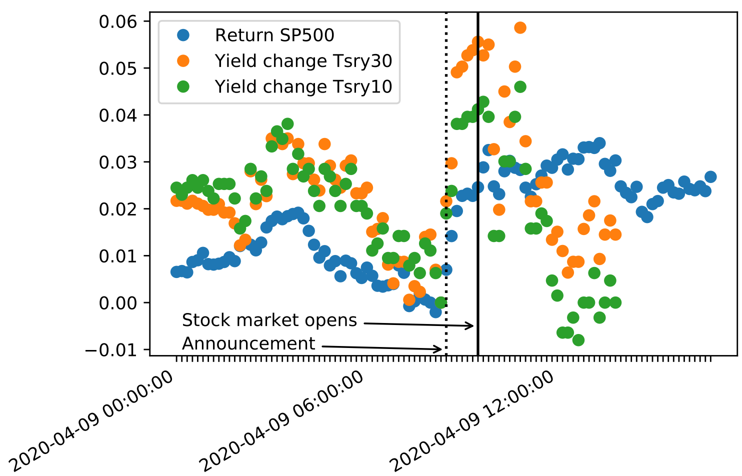
Figure IA.11

Total bond index and municipal bond ETF vs. mutual fund prices

Panel A plots cumulative log returns based on Vanguard ETF vs Mutual Fund. Vanguard Total Bond Market Index Fund ETF Shares (BND) and Vanguard Total Bond Market Index Fund Admiral Shares (VBTLX). Both are meant to track the Bloomberg Barclays U.S. Aggregate Float Adjusted Index. Panel B plots cumulative log index based on Vanguard Tax-Exempt Bond Index Fund ETF Shares (VTEB) and Vanguard Tax-Exempt Bond Fund Admiral Shares (VTEAX). Both track the Standard & Poor's National AMT-Free Municipal Bond Index.

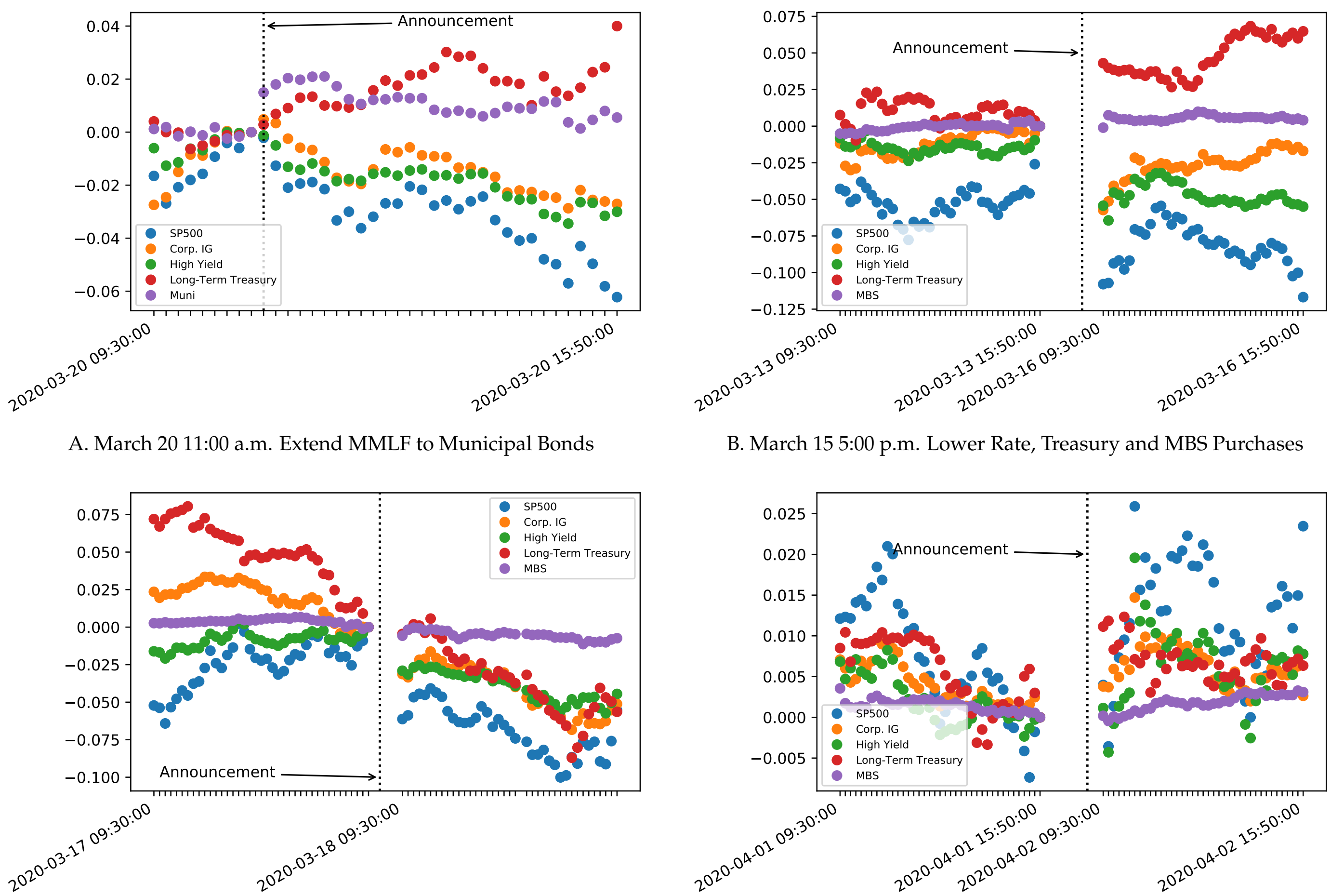


A. March 23



B. April 9

Figure IA.12
Event study of Fed announcements of corporate bond purchases: stocks and Treasury bonds
We look at indirect effects of the policy intervention. The figure reports returns for S&P500 futures and the yields of 10- and 30-year treasury bonds. Yield changes are computed from 15 minutes before the announcement. Returns are computed from 15 minutes before the announcement.



A. March 20 11:00 a.m. Extend MMLF to Municipal Bonds

B. March 15 5:00 p.m. Lower Rate, Treasury and MBS Purchases

C. March 17 6:00 p.m. Primary Dealer Credit Facility Announced

D. April 1 4:45 p.m. Exclude Treasuries and Deposits from Leverage Ratio

Figure IA.13
Event study around other Fed announcements

This figure shows traded prices every 10 minutes for selected ETFs around four Fed announcements. See Table 2 for a more detailed description of each announcement.

Table IA.1
Summary statistics

	N	Mean	Std Dev	5%	50%	95%
$\Delta basis$	315	198.602900	149.134378	-36.681595	201.828762	428.482091
Δcds	318	209.006594	249.560191	-0.633315	113.860200	774.845000
$\Delta spread_{March23}$	318	20.191756	97.541878	-108.752993	4.869682	164.197354
$\Delta spread_{April9}$	316	-56.127772	98.588118	-218.672944	-35.754955	4.825899
IG	339	0.696165	0.460592	0.000000	1.000000	1.000000
$duration$	333	4.852394	1.103223	3.231430	4.753412	6.631952

	N	Mean	Std Dev	5%	50%	95%
$spread_{Feb28}$	5320	256.424317	1093.711365	52.258726	141.538629	559.031899
$\Delta ln(spread_{crisis})$	5320	123.999934	59.315580	48.538870	118.330366	219.088404
IG	5320	0.725940	0.446081	0.000000	1.000000	1.000000
$short$	5320	0.482519	0.499741	0.000000	0.000000	1.000000
$liquidity$	5320	0.477256	0.499529	0.000000	0.000000	1.000000
$maturity$	5319	8.857270	9.333685	0.613291	5.199285	27.617268
$leverage$	2355	0.214768	0.239612	-0.042658	0.171296	0.632698
$debtstructure$	2355	0.131158	0.136191	0.002097	0.090591	0.426503
$cash$	2355	0.243872	0.623016	0.003719	0.057684	1.172821
$ln(MFsales)$	5320	1.004118	0.596893	0.051348	0.892631	2.102582
$ln(issuance)$	5320	0.119098	0.214819	0.000000	0.000000	0.474012
$\Delta ln(cds)$	1781	113.671488	62.665509	25.695826	114.125182	204.215462
$covidsectors$	5320	0.207519	0.405568	0.000000	0.000000	1.000000
oil	5320	0.080451	0.272016	0.000000	0.000000	1.000000
$banks$	5320	0.169925	0.375602	0.000000	0.000000	1.000000
$financials$	5320	0.303008	0.459602	0.000000	0.000000	1.000000

This table shows summary statistics for the bonds in our sample.

Table IA.2
Crisis and recovery in bond spreads: expanded set of controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
crisis	80.67***						
	(4.03)						
recovery	-23.26*						
	(-1.65)						
IG × *crisis*		11.51**	15.36***	21.27***	27.87***	29.39***	32.47***
		(2.01)	(2.63)	(3.39)	(2.72)	(3.21)	(2.63)
IG × *recovery*		-11.33**	-13.18**	-22.79***	-22.55*	-33.03***	-24.91**
		(-2.02)	(-2.31)	(-2.71)	(-1.82)	(-3.04)	(-1.97)
short × *crisis*			63.24***	59.52***	67.44***	57.54***	66.88***
			(3.55)	(3.66)	(3.27)	(3.72)	(3.27)
short × *recovery*			-30.69**	-24.64**	-40.26***	-22.22**	-39.96***
			(-2.34)	(-2.37)	(-2.69)	(-2.28)	(-2.69)
liquidity × *crisis*				27.77**	15.50	20.70*	15.18
				(2.00)	(1.39)	(1.76)	(1.37)
liquidity × *recovery*				-44.78*	-28.60	-36.10*	-28.45
				(-1.90)	(-1.44)	(-1.73)	(-1.43)
ln(*MFsales*) × *crisis*						22.78**	12.96*
						(2.30)	(1.84)
ln(*MFsales*) × *recovery*						-28.45***	-6.84
						(-3.26)	(-1.48)
ln(*issuance*) × *crisis*						12.94	12.89*
						(1.64)	(1.94)
ln(*issuance*) × *recovery*						-14.74	-6.13
						(-1.39)	(-0.73)
covidsectors × *crisis*					5.41**		5.65**
					(2.06)		(2.13)
covidsectors × *recovery*					7.08**		6.93**
					(2.35)		(2.19)
banks × *crisis*					14.95**		14.97**
					(2.55)		(2.52)
banks × *recovery*					4.99		5.04
					(0.53)		(0.51)
debtstructure × *crisis*					-0.77		-4.43
					(-0.06)		(-0.36)
debtstructure × *recovery*					-32.73*		-31.13*
					(-1.89)		(-1.86)
financials × *crisis*					3.42		-0.69
					(0.68)		(-0.17)
financials × *recovery*					2.76		4.90
					(0.50)		(0.85)
leverage × *crisis*					-15.47		-22.23*
					(-1.40)		(-1.82)
leverage × *recovery*					37.16**		40.89**
					(2.31)		(2.42)
cash × *crisis*					-2.08		-0.39
					(-0.62)		(-0.12)
cash × *recovery*					12.12***		11.37***
					(3.71)		(3.62)
oil × *crisis*					26.24		27.32
					(0.91)		(0.94)
oil × *recovery*					9.11		8.66
					(0.70)		(0.67)
Observations	1,597,523	1,597,523	1,597,523	1,597,523	521,926	1,597,417	521,926
Bond FE	Y	Y	Y	Y	Y	Y	Y
Time FE	N	Y	Y	Y	Y	Y	Y
R-squared	0.0101734	0.0276046	0.0288076	0.0291978	0.043332	0.0296156	0.04338

This table regresses spread changes at the bond level ($\Delta ln(s_{i,t})$) on dummies for crisis and recovery. T-statistics using clustered standard errors in parenthesis. COVID-exposed sectors are from Fahlenbrach, Rageth, and Stulz (2020).

Table IA.3
ETF Holders

Investor category ETF tickers	LQD	IGIB	IGSB	VCIT	VCSH	HYG	JNK
Bank	9.65	6.47	4.92	14.38	10.9	7.84	4.43
Brokerage	3.4	0.97	1.58	0.67	1.48	2.16	1.35
Hedge Fund Manager	2.01	0.48	1.3	0.21	0.48	2.25	0.7
Insurance Company	3.69	3.47	1.13	5.16	1.45	3.87	3.63
Investment Advisor	53.88	57.54	51.97	45.81	30.92	66.52	54.45
Pension Fund	4.53	0	0.01	0	0.04	3.94	0.4
Sovereign Wealth Fund	0.08				0.06	1.68	
Grand Total	77.36	69.06	60.98	66.64	45.38	88.93	65.13

Holder	LQD US EQUITY	VCIT US EQUITY
Bank of America Corp	6.98	13.16
Fisher Asset Management LLC	3.51	7.65
Charles Schwab Investment Advisory		6.77
Creative Planning LLC	0.02	5.97
Columbia Management Investment Adv	2.67	2.08
Envestnet Asset Management Inc	3.37	0.68
Eastspring Investments Singapore L	3.98	0
LPL Financial LLC	0.8	2.88
Meiji Yasuda Life Insurance Co	0.5	2.81
Teachers Advisors LLC	2.86	
Wells Fargo Clearing Services LLC	0.68	2.14
Citigroup Inc	2.71	0.01
Dai-ichi Life Insurance Co Ltd/The	0.64	1.91
UBS Group AG	1.9	0.5
Morgan Stanley Smith Barney LLC	1.31	0.84
Allianz Investment Management LLC	2.07	
Manulife Investment Management US		1.99
Guggenheim Partners Investment Man	1.61	
Financial Engines Advisors LLC	1.55	
RBC Capital Markets LLC	0.21	1.19
Goldman Sachs Group Inc/The	1.16	0.1
Barclays PLC	1.2	0
JPMorgan Chase & Co	1	0.07
Ameriprise Financial Services Inc	0.58	0.49
BlackRock Advisors LLC	1.03	

Holder	HYG US EQUITY	JNK US EQUITY
Goldman Sachs Group Inc/The	7.24	3.85
Bank of America Corp	5.23	3.75
Wells Fargo Clearing Services LLC	2.69	4.84
State Street Corp		7.24
Barclays PLC	5.92	
BlackRock Advisors LLC	5.41	0.41
TD Asset Management Inc	5.72	
Prudential Financial Inc	2.86	2.64
Morgan Stanley Smith Barney LLC	4.4	0.77
JPMorgan Chase & Co	3.47	1.21
RBC Global Asset Management Inc	1.17	2.76
Allstate Corp/The	1.43	1.5
Citigroup Inc	1.42	1
SEI Investments Management Corp	0	2.17
State of Wisconsin Investment Boar	1.98	0
Envestnet Asset Management Inc	1.26	0.68
Nan Shan Life Insurance Co Ltd	0.8	1.02
Eaton Vance Management	0.01	1.77
Bnp Paribas Arbitrage Sa	1.04	0.72
Northwestern Mutual Life Insurance	0.67	0.88
Guggenheim Partners Investment Man	1.5	
TD Ameritrade Investment Managemen	0.19	1.2
Northern Trust Corp	1.39	
AMP Capital Investors Ltd	0.06	1.32
K2/D&S Management Co LLC		1.32

This table provides information on the holders of the largest eight corporate bond ETFs by assets. The columns denote ETF tickers. Panel A gives broad ownership categories. We report only categories that hold more than 1% of one the ETFs. Panels B and C look at specific institutions for two of the largest investment grade ETFs and high yield ETFs (HYG and JNK), respectively, and reports the top 25 investors. All numbers given in percent.

Table IA.4
Response to the Fed announcements of bond purchases across ratings

	3/23		4/9	
AAA	-13.10	(1.16)	-21.33	(1.12)
AA+	-13.33	(1.11)	-21.15	(1.11)
AA	-9.03	(1.35)	-22.55	(1.40)
AA-	-4.75	(1.30)	-16.86	(1.38)
A+	-7.06	(1.30)	-18.43	(1.31)
A	-7.57	(1.17)	-17.69	(1.17)
A-	-4.65	(1.11)	-17.13	(1.13)
BBB+	-5.02	(1.03)	-14.82	(1.02)
BBB	-4.24	(0.98)	-14.57	(0.97)
BBB-	-0.61	(1.03)	-15.54	(1.03)
BB+	8.12	(1.05)	-22.56	(1.08)
BB	8.14	(1.25)	-30.10	(1.25)
BB-	9.82	(1.21)	-23.61	(1.16)
B+	5.61	(1.21)	-21.48	(1.19)
B	5.57	(1.17)	-17.72	(1.19)
B-	11.38	(1.34)	-16.55	(1.34)
C+ or worse	3.73	(0.94)	-15.46	(0.88)
R-squared	1.67			
n	145997			

This table shows the regression coefficients and standard errors of a panel regression of daily bond spread changes on ratings interacted with the two announcement dummies. See Figure 9 for more details. The regression features bond fixed effects. Standard errors are computed using the Driscoll-Kraay HAC estimator withe a Newey-West kernel with a bandwidth of five days.

Table IA.5
Rating composition of ETF and CDX baskets

	CDX	LQD
BB	5.66%	0.06%
BBB	69.81%	46.75%
A	20.75%	41.93%
AA	2.83%	8.29%
AAA	0.94%	2.32%

This table gives the credit rating composition for the LQD ETF and the CDX IG. LQD invests in investment grade-bonds, and this gives the percent of market value in the ETF in each rating category as of May 2020. CDX IG gives the rating of the basket of companies in the investment-grade CDX index.