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Dealers and the Dealer of Last Resort: Evidence from MBS Markets in the COVID-19 Crisis

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Abstract

We study price dislocations and liquidity provision by dealers and the Federal Reserve (Fed) as the “dealer of last resort” in agency MBS markets during the COVID-19 crisis. As customers sold MBS to “scramble for cash,” dealers provided liquidity by taking inventory in the cash market and hedging inventory risk in the forward market. The cash and forward prices diverged significantly beyond the difference in the quality of MBS traded on the two markets. The Fed first facilitated dealers’ inventory hedging and then took holdings off dealers’ inventory directly. The price dislocations began to revert only after the Fed’s latter action, when customer selling was still strong.

Key words: arbitrage, cash, dealer, liquidity, MBS, specified pool, TBA

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To view the authors’ disclosure statements, visit
https://www.newyorkfed.org/research/staff_reports/sr933.html.

1 Introduction

*“Asset purchases are a standard tool of monetary policy implementation. Traditionally, the Desk has used Treasury purchases to maintain the supply of reserves... Following the Global Financial Crisis, the FOMC used asset purchases primarily to exert downward pressure on longer-term interest rates, or in the case of MBS to ease mortgage rates ... The purchases during this most recent episode have been distinct in both their purpose, **to address disruptions in market functioning**, and their scale and speed, which have been unparalleled.”*

— Lorie Logan, Executive Vice President of the Federal Reserve Bank of New York, Remarks at SIFMA Webinar on July 15, 2020.

The COVID-19 pandemic caused substantial disruptions in market functioning of most U.S. fixed-income securities, including corporate bonds, municipal bonds, mortgage-backed securities (MBSs), and even Treasury bonds. Liquidity dried up abruptly in March 2020: yields soared, volatility skyrocketed, and prices of securities with similar fundamentals diverged. “To support the smooth functioning of markets”, the Federal Reserve (Fed) announced on March 15 that it would conduct outright purchases of Treasury securities and agency MBSs. Soon after, the Fed extended the purchases to cover agency commercial MBSs and corporate bonds.¹

Security broker-dealers, especially primary dealers recognized by the Fed, are key intermediaries in these over-the-counter markets. They possess great expertise and are natural liquidity providers. Confronting the large market disruptions, did dealers provide enough liquidity to help normalize market functioning, or only an insufficient amount of liquidity due to balance sheet constraints? Did liquidity provision by the Fed in its role as the “dealer of last resort” improve market conditions, and if so, through which channels? Answering these questions is important not only for understanding the market disruptions due to COVID-19 but also for the evaluation and optimal design of the Fed’s new policy — of using asset purchases to address

¹For an overview of the Fed’s various policies, see <https://libertystreeteconomics.newyorkfed.org/2020/04/the-covid-19-pandemic-and-the-feds-response.html>.

market functioning (as outlined in the quote above).

In this paper, we provide evidence on market disruptions during the COVID-19 crisis and liquidity provision by dealers and the Fed. We focus on the agency MBS market, which is one of the largest fixed-income markets in the U.S. and plays a critical role in facilitating mortgage borrowing by U.S. households.² We analyze both the cash and forward markets of agency MBSs. Including the forward market in our analysis is crucial because dealers take on inventory when providing liquidity and often hedge inventory risk by taking positions in derivatives, like forward contracts in the agency MBS market (Gao, Schultz, and Song (2017)), futures contracts in the Treasury market (Fleming and Rosenberg (2007)) and credit-default swap (CDS) contracts in the corporate bond market (Siriwardane (2019)). Examining both markets jointly leads to a natural focus on price dislocation or divergence between cash and forward prices, which endows our analysis with a limits-of-arbitrage perspective. Indeed, a large price divergence between securities of similar risk exposure like the cash and derivative contracts often points to constraints on “arbitraging” activities of institutional investors like dealers and hedge funds.³

Both market features and data availability make agency MBSs particularly suitable for studying cash and derivative markets jointly to understand dealers’ liquidity provision. Specifically, the cash and forward markets of agency MBSs — known as the specified pool (SP) and to-be-announced (TBA) markets, respectively — are both over-the-counter markets with broker-dealers as the main intermediaries (Gao, Schultz, and Song (2017)). And our access to the supervisory-level transactions data from the Trade Reporting and Compliance Engine (TRACE) allows us to track the changes in customers’ selling and dealers’ positions in both the cash and forward markets.⁴ Our analysis provides results that shed lights on dealers’ limited liquidity

²The outstanding amount of agency MBS is about \$8.8 trillion as of December 2019. See <https://www.sifma.org/resources/research/us-mbs-issuance-and-outstanding/> for details on the issuance and outstanding amounts of agency MBS, provided by the Securities Industry and Financial Markets Association (SIFMA).

³For limits of arbitrage studies of cash versus derivative markets, see Fleckenstein and Longstaff (2020) on cash-futures arbitrage in the Treasury market and Bai and Collin-Dufresne (2019) and Choi, Shachar, and Shin (2018) on bond-CDS arbitrage in the corporate bond market, among others. While the cash-forward arbitrage strategy of agency MBSs has been long employed in practice (Lai (1987)), our paper provides the first academic study of this strategy, to the best of our knowledge.

⁴In the Treasury market, instead, the cash trading occurs over-the-counter but the futures trading is on the Chicago Mercantile Exchange, with different main intermediaries, trading protocols, and arrangements of settle-

provision and the effects of the Fed's market-functioning interventions during the pandemic.

To set the stage and provide a benchmark for the COVID-19 crisis period results, we first study dealers' liquidity provision using the pre-crisis historical sample from May 2011 to December 2018. We find that dealers regularly take long inventory positions in the cash market and short positions in the forward market to hedge inventory risk. Quantitatively, for a one-dollar-increase in the long cash position, dealers take a \$0.47 short forward position. We further examine the cash-forward price difference that should reflect dealers' cost of liquidity provision or arbitrage between the two markets. In practice, this price difference, known as the payup, is often positive because high-value MBSs with superior prepayment characteristics are traded in the cash market while low-value "cheapest-to-deliver" MBSs are traded in the forward market (Hayre and Young (2004)). Indeed, we find that the average payup in the historical sample is about \$0.3 per \$100 par value. Importantly, the payup is substantially reduced and becomes statistically insignificant once we control for the quality differential using MBS characteristics, implying that dealers' cost of liquidity provisions is negligible in normal times.

Turning to the COVID-19 crisis, we show that, starting in early March, MBS prices plummeted and the cash-forward prices diverged greatly. In particular, during the period beginning on March 9 (when a market-wide circuit breaker was triggered in the stock market for the first time since 1997) and ending on March 13 (right before the Fed started the outright MBS purchases), which we define as the COVID shock period, the MBS yield spread (the option-adjusted spread in particular) increased significantly by about 38 basis points, relative to January 1 – March 6 that we define as the pre-COVID period. Further, the payup decreased significantly by \$0.5 per \$100 face value controlling for the quality differential, i.e., the cash price dropped significantly relative to the forward price with the same MBS risk exposure.

We then delve into changes in customers' selling amounts and dealers' cash and forward positions. Specifically, investors' desire for cash is often cited as the motivation for asset sales

ment and clearing. Moreover, the TRACE data of Treasury transactions were collected starting from July 2017 and have not been made available to the public. Although the corporate bond and CDS markets are both over-the-counter with dealers as main intermediaries, trading in single-name CDS has been sparse after the 2008 crisis. In contrast, the forward market of agency MBSs remains extremely active (Vickery and Wright (2013)).

that occurred during this period. Consistent with this conjecture, customers' daily gross selling amount in the cash market increased by about \$0.65 billions (bns) when the cash price dropped substantially. Furthermore, both the dealers' daily long cash positions and short forward positions increased, relative to the pre-COVID average. Quantitatively, for a one-dollar-increase in their daily cash position, dealers increase their daily short forward positions by about \$0.57 bns, larger than that in the historical sample (about \$0.47 bns). Complementing these flow measures, the net MBS inventory reported by primary dealers increased from \$30 to \$70 bns in the COVID shock period, suggesting that dealers only hedged part of the acquired cash inventory.

These results so far imply that amid large selling by customers to scramble-for-cash in the COVID-19 shock period, dealers provide significantly more liquidity than their historical average. Yet, dealers bear significant costs that prevent them from providing a sufficient amount of liquidity to fully and immediately arbitrage away the cash-forward price divergence. Drawing from the theoretical literature on market liquidity and limits-of-arbitrage, we conjecture three potential (non-mutually exclusive) economic forces driving up dealers' costs of liquidity provision. First, dealers may face high funding costs for their market-making portfolios (Brunermeier and Pedersen (2009)). Second, dealers may not be able to find enough counterparties to accept their short forward positions and hedge inventory risk sufficiently. The remaining inventory risk that dealers cannot hedge away would severely limit their liquidity provision, given their own risk limits and the skyrocketing price volatility (Gromb and Vayanos (2010)). Third, regulations that have been implemented since the 2008 crisis, such as the supplementary leverage ratio (SLR), may have constrained dealers' balance sheet capacity regardless of the level of risk (Duffie (2018)).

Intriguingly, the Fed's interventions in the agency MBS market involved actions related to all three economic forces and were implemented in roughly successive stages. First, from March 9 to 13 (i.e. the COVID shock period), the Fed offered huge amounts of funding to primary dealers, which can reduce their funding costs. Second, from March 16 to 18, the Fed announced the agency MBS purchases and implemented them through standard TBA contracts that settle

on a monthly cycle.⁵ Although the Fed takes deliveries ultimately, such TBA purchases serve to facilitate dealers' inventory risk hedging in the very short horizon (up to three weeks) of the COVID-19 crisis. Third, from March 19 to 27, the Fed conducted unconventional TBA purchases that settled within three days, resulting in transactions that were very similar to cash transactions. Such t+3 TBA purchases would immediately reduce the amount of MBSs dealers need to keep on their balance sheet, and thus can not only decrease dealers' funding and hedging needs but also cut their balance sheet costs. After March 30, and until April 27 when our sample ends, the Fed reverted to using standard TBA contracts. We denote the three periods after the COVID shock period as FED1, FED2, and FED3, respectively.⁶

We track the changes in both dealers' positions and MBS prices across these periods to understand how dealers' funding, inventory risk, and balance sheet constraints affect their liquidity provision and are then mitigated by the Fed's actions. In particular, we are able to look into daily changes, taking advantage of the available transaction-level data. This approach of examining high-frequency changes can help reduce the effects of confounding factors, which is also used in studies of quantitative easing in the 2008-2009 crisis like [Gagnon, Raskin, Remache, and Sack \(2011\)](#) and [Krishnamurthy and Vissing-Jorgensen \(2011\)](#) and other studies of the COVID-19 crisis like [O'Hara and Zhou \(2020\)](#) and [Vissing-Jorgensen \(2020\)](#).

First, the Fed's actions in providing funding liquidity, including the \$1.5 trillion of repo funding on March 12-13 and the announcement of the Primary Dealer Credit Facility (PDCF) on March 17, had little effect in easing market disruptions. In fact, primary dealers' take-up of the repo funding offered by the Fed did not increase relative to the pre-COVID-19 period and, if anything, even decreased. Therefore, funding constraints were unlikely to have been binding during the pandemic.

⁵Since any eligible MBS can be used to settle the TBA contract, the Fed's actions were not limited to newly issued MBS.

⁶The specific time ranges defined in this paper and the key policy actions we attribute to these time ranges take a stance that an action should have larger effects, all else equal, the earlier it is taken during the crisis period when liquidity conditions were more adverse. Hence, we treat similar actions in the later period, e.g., the escalation of agency MBS purchases on March 23, as less consequential relative to the first round of agency MBS purchases announced on March 15. See Section 2.3 for detailed discussions.

Second, during the FED1 period, the Fed (and not dealers) increased the amount of net TBA purchases in aggregate since the COVID shock, and thereby facilitated the hedging of dealers' inventory risk with conventional TBA purchases. However, during this period, market disruptions continued to worsen as the MBS yield spread increased and the cash-forward price difference diverged even more.

Third, after the Fed started t+3 TBA purchases, dealers not only fully offloaded the inventories newly acquired from customers' selling but also some of their previously accumulated inventories to the Fed. Meanwhile, the downward spiral of MBS prices stopped and the cash-forward price divergence began to revert. Further, we find that the MBS yield spread (mainly associated with inventory risk premium) began to decline once the t+3 TBA purchases started, while the cash-forward price divergence (mainly associated with balance sheet costs) began to revert several days later.

In sum, we find that the Fed's provision of funding liquidity through repo operations and facilitation of inventory risk hedging through conventional TBA purchases had insignificant effects on market disruptions. In contrast, the Fed's actions in directly taking inventory off dealers' balance sheet had large mitigating effects. Hence, balance sheet constraints like SLR are particularly severe in constraining dealers' liquidity provisions.⁷

One may wonder whether the Fed's purchases slowed customers' selling by anchoring price expectations and reducing the endogenous price volatility (Allen, Morris, and Shin (2006)). We find that customers' gross selling amounts in the cash market increased the most when the Fed's t+3 TBA purchases reverted the MBS yield spread increase at the beginning of the FED2 period.⁸

⁷It is worth noting that the importance of dealers' constraints relative to other economic forces and even the relative importance of the different types of dealer constraints can differ across markets. For example, in the corporate bond market, trading costs fell immediately after the announcement of the PDCF on March 17, while the CDS-bond basis reverted greatly following the announcement of corporate bond purchases on March 23 (O'Hara and Zhou (2020); Haddad, Moreira, and Muir (2020)). However, as we show, the MBS yield spread kept increasing following the PDCF announcement on March 17 and the announcement of agency MBS purchases on March 15, but began to revert when the Fed started the t+3 TBA purchases before March 23. Another related issue is that there can be "spill-over" effects across markets in the liquidity provision of dealers and the Fed. Reconciling cross-market-differences in liquidity disruptions and responses to the Fed's interventions is a challenging but important topic for future research.

⁸Note that non-dealer investors who can potentially take the sold MBSs and provide liquidity are included as customers in the TRACE data. So even if some of these investors increased their purchases, the amount is low and

By contrast, customers' selling and cash-forward price divergence began to revert at the same time — in the middle of the FED2 period. These results suggest that the Fed's purchases significantly reduced customers' selling only towards the end of COVID-19 market disruptions. In this vein, [Ma, Xiao, and Zeng \(2020\)](#) and [Falato, Goldstein, and Hortacsu \(2020\)](#) analyze bond mutual funds that were among the main asset sellers in the COVID-19 crisis, while [Li, Li, Macchiavelli, and Zhou \(2020\)](#) study outflows of money market funds.

Finally, we examine the difference in primary dealers' selling prices to the Fed between t+3 trades and conventional TBA trades. This difference is equivalent to the cash-forward price difference because the t+3 TBA purchases are essentially cash trades. Hence, it captures the balance sheet cost just like the payup but with the Fed as the sole counterparty, which is a unique setting not present in the Fed's interventions in other markets. We find that in the first half of the FED2 period, primary dealers are willing to accept a discount ranging from \$0.6 to \$1.2 per \$100 face value to sell MBS via t+3 versus conventional TBA trades. In the latter half, this discount shrank to less than \$0.4 and becomes statistically insignificant. Thus, the amount dealers were willing to pay to ease balance sheet constraints decreased as the Fed mitigated these constraints.

Other works that study liquidity stress in fixed-income markets during the COVID-19 crisis include, among others, [Duffie \(2020\)](#), [He, Nagel, and Song \(2021\)](#), [Schrimpf, Shin, and Sushko \(2020\)](#), [Kruttili, Monin, Petrasek, and Watugala \(2021\)](#), and [Vissing-Jorgensen \(2020\)](#) on Treasury securities, [Aramonte and Avalos \(2020\)](#), [D'Amico, Kurakula, and Lee \(2020\)](#), [Boyarchenko, Kovner, and Shachar \(2020\)](#), [Haddad, Moreira, and Muir \(2020\)](#), [Kargar, Lester, Lindsay, Liu, Weill, and Zuniga \(2020\)](#) and [O'Hara and Zhou \(2020\)](#) on corporate bonds, and [Li, O'Hara, and Zhou \(2021\)](#) on municipal bonds. Sharing our perspective on the constraints of financial intermediaries broadly or dealers specifically, [Duffie \(2020\)](#), [Kargar, Lester, Lindsay, Liu, Weill, and Zuniga \(2020\)](#) and [O'Hara and Zhou \(2020\)](#) focus on the micro-structure of trading and [He, Nagel, and Song \(2021\)](#) and [Haddad, Moreira, and Muir \(2020\)](#) focus on price divergence dominated by the increase in selling by other customers.

and limits-of-arbitrage. Our paper complements these works but conducts distinctive analyses, benefiting from the institutional feature and data availability in the agency MBS market. In particular, we study the cash and derivative markets jointly, and for both markets, we study changes in prices and positions together. Our results demonstrate not only dealers' inventory taking but also inventory hedging as important components of their liquidity provision. The successive nature of the Fed's interventions through these two inventory channels allows us to document the associated effects separately, which are directly relevant for the design of the Fed's policy tools going forward.

To the best of our knowledge, we provide the first academic analysis of cash-forward arbitrage in the agency MBS markets, contributing to the literature on fixed-income arbitrage strategies (such as Duarte, Longstaff, and Yu. (2007), Fleckenstein, Longstaff, and Lustig (2014), Klingler and Sundaresan (2019), Jermann (2019), Du, Tepper, and Verdelhan (2018), and Boyarchenko, Eisenbach, Gupta, Shachar, and Tassel (2018)). This focus also relates our study to the literature on limits of arbitrage and intermediary-based asset pricing (see Gromb and Vayanos (2010) and He and Krishnamurthy (2018) for surveys).⁹

2 Institutional Background, Economic Framework, and Data

In this section, we provide a brief background on the agency MBS market, present a simple economic framework, introduce the design for our empirical analysis, and discuss the data used.

2.1 Cash and Forward Trading of Agency MBSs

We first discuss the agency MBS market briefly, focusing on the cash and forward trading related to dealers' inventory taking and hedging. To start, most agency MBSs are issued as pass-through

⁹Our paper also contributes to the literature on MBS pricing (Gabaix, Krishnamurthy, and Vigneron (2007), Chernov, Dunn, and Longstaff (2017), Boyarchenko, Fuster, and Lucca (2019), Diep, Eisfeldt, and Richardson (2017), Carlin, Longstaff, and Matoba (2014), Krishnamurthy and Vissing-Jorgensen (2011), Song and Zhu (2019), and He and Song (2020)), as well as MBS market liquidity (Bessembinder, Maxwell, and Venkataraman (2013), Gao, Schultz, and Song (2018), Schultz and Song (2019), Li and Song (2020), and Kim and Huh (2019)).

securities in which interest (subtracting the credit guarantee and mortgage service fees) and principal payments on the underlying mortgages are passed through pro rata to MBS investors. All agency MBS are effectively default-free with credit guarantees provided by Fannie Mae, Freddie Mac, or Ginnie Mae. They are, however, subject to uncertainty on the timing of cash flows, known as prepayment risk (Gabaix, Krishnamurthy, and Vigneron (2007)).

The cash market of agency MBSs is known as the specified pool (SP) market in which standard trading of individual MBSs occurs, while the forward market is known as the to-be-announced (TBA) market in which a forward contract is traded and takes any eligible MBS in a cohort. For example, a TBA forward contract might specify the delivered MBSs to be guaranteed by Fannie Mae, contain 30-year fixed-rate mortgage loans, and pay a coupon of 4%. Different MBSs delivered into the same TBA contract will receive the same price. Thus, the cash/forward trading of agency MBSs is analogous to the cash/futures trading of Treasury securities and cash/CDS trading of corporate bonds. In fact, the TBA forward contract settles once a month and is priced on a “cheapest-to-deliver” basis because of the cohort feature, just like Treasury futures (Labuszewski and Sturm (2011); Fusari, Li, Liu, and Song (2019)).¹⁰ On any trading day, TBA contracts with settlement days up to three months in the future are available, but those with the next immediate settlement day are the most actively traded and usually known as front-month contracts.

The cash and forward markets of agency MBSs are both over-the-counter, with the same group of broker-dealers as key intermediaries.¹¹ This feature makes the agency MBS market particularly appealing for studying dealers’ liquidity provision because they usually take inventory in the cash market and hedge inventory risk with derivatives positions. Indeed, as shown in Gao, Schultz, and Song (2017), broker-dealers hedge their cash inventory mainly using forward contracts. In contrast, the cash trading of Treasury securities occurs over-the-counter while the

¹⁰Details of the TBA settlement schedule are available at <https://www.sifma.org/resources/general/mbs-notification-and-settlement-dates/>.

¹¹Almost all major institutional investors have significant holdings of agency MBS. For example, in Q1 2019, MBS holdings were about \$2.29 trillion, \$0.58 trillion, \$0.38 trillion, \$0.31 trillion, \$0.26 trillion, and \$0.21 trillion for U.S.-chartered depository institutions, mutual funds, life insurance companies, mortgage REITs, and private pension funds, respectively (according to the Financial Accounts Z.1 of the Federal Reserve).

futures trading is on the Chicago Mercantile Exchange, so the trading protocols, settlement and clearing arrangements and, importantly, the set of intermediaries can be quite different.

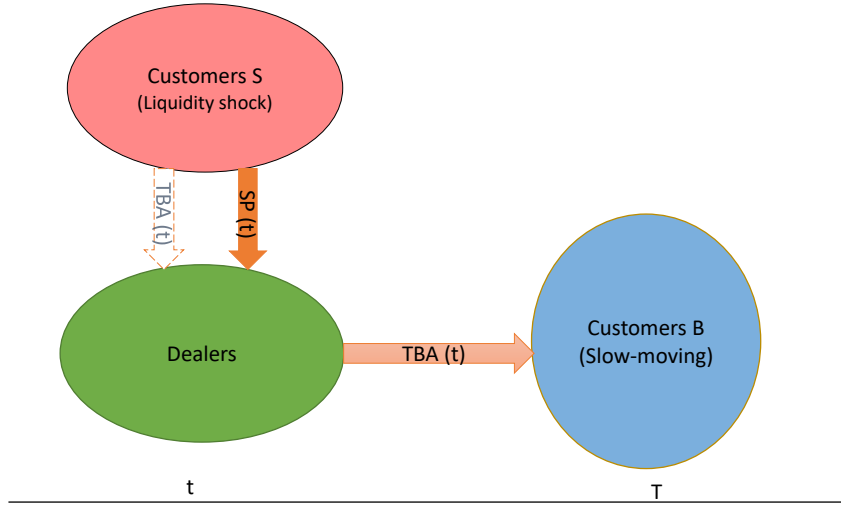
2.2 Economic Framework

To guide our empirical investigation, we postulate a simple economic framework by adapting the [Grossman and Miller \(1988\)](#) model to the agency MBS market with both cash and forward trading. [Figure 1](#) presents a diagram that illustrates the framework, without delving into details. There are three groups of traders, MBS sellers (customers S), dealers, and MBS buyers (customers B), and two periods t and T . Without loss of generality, we assume there is one MBS in the market. Two types of trades are available at time t : an SP trade in the cash market and a TBA trade in the forward market. The former settles immediately with cash changing hands at time t , while the latter will only be settled at time T .¹² Trades can only occur between dealers and customers. The time discount is assumed to be zero.

At time t , customers S are hit by a liquidity shock and need to sell q units of MBSs to raise cash immediately, so they strictly prefer selling in the SP market. Customers B deploy capital slowly to the market: they can only take MBS holdings at time T , after $\tau = T - t$ units of time, so they can either buy in the SP market at time T or buy in the TBA market at time t . Dealers can take the MBSs sold in the SP market into inventory at time t (at price $SP(t)$) to provide liquidity. In doing so, they need to hold the MBSs from time t until T and then sell them to customers B (at price $SP(T)$). Risk-averse dealers hedge the inventory risk by taking a short TBA position at time t . Note that dealers can also offer to purchase MBSs through TBA contracts at time t that would not take up their balance sheet space over $[t, T]$, but customers S prefer selling in the SP

¹²All the key implications hold in a more general setup with heterogeneous MBSs being available, like that in [Fusari, Li, Liu, and Song \(2019\)](#). Some additional implications regarding the quality differences of MBSs traded in TBA vs SP markets may be derived from such a more general setup. For example, liquidity-shock customers would move low-quality MBSs that were sold in the TBA market into the SP market because of the need to acquire cash immediately (opposite to the standard case in which a deterioration in SP liquidity would make investors re-allocate high-quality MBSs that were sold in the SP market into the TBA market). This would lead to a decrease in the average quality of the MBSs sold into the SP market. Such implications are, however, less essential for our focus on dealers' cost of liquidity provision so we leave them for future investigation.

Figure 1. Diagram of the Economic Framework



Summary: Dealers hold SP from t to T , and short TBA to be settled on T

Notes: This figure presents a diagram of the economic framework.

market.

To examine the cash and forward prices, first consider the scenario that dealers simply hold the MBS inventory from t to T . The difference between the cash price and expected value (EV) of the MBS equals

$$SP(t) - EV = -\gamma(q, \tau) - f(q, \tau) - RP(q, \tau), \quad (1)$$

where $\gamma(q, \tau)$ is the balance sheet cost, $f(q, \tau)$ is the funding cost, and $RP(q, \tau)$ is the risk premium. The balance sheet cost can arise from post-crisis regulations like the supplementary leverage ratio (SLR) that constrains dealer's balance sheet capacity regardless of risk profiles (Duffie (2018)). The funding cost captures dealers' cost in raising capital to purchase the MBS inventory (Brunnermeier and Pedersen (2009)). The risk premium is the compensation for the inventory risk dealers bear as in the classical models of market-making (Ho and Stoll (1981)). All these costs can increase with the holding amount q and the expected holding time τ (Tuckman and Vila (1992)).

Now, consider the scenario that dealers fully hedge the inventory risk using the TBA con-

tracts. Entering the TBA contract does not involve either funding costs or balance sheet costs but incurs risk exposure, so that the TBA price equals the expected value minus the risk premium:

$$TBA(t) - EV = -RP(q, \tau). \quad (2)$$

In consequence, the cash-forward price difference equals

$$SP(t) - TBA(t) = -\gamma(q, \tau) - f(q, \tau). \quad (3)$$

That is, dealers should be able to close the cash-forward price gap totally unless they bear funding costs or balance sheet costs.

Though very stylized, the economic framework delivers testable implications regarding both prices and quantities related to customers' liquidity shock and dealers' liquidity provision. In terms of prices, when there is a liquidity shock to customers S, the cash-forward price difference becomes negative as long as the funding and balance sheet costs are positive (based on equation (3)), while the difference between the cash price and the expected value becomes even more negative due to the additional component of inventory risk premium. In terms of quantities, customers S sell MBS holdings because they experience liquidity shocks and cannot wait until T to acquire cash, so they prefer selling in the SP market in spite of a negative cash-forward price difference. As dealers provide more liquidity, their long cash positions and short forward positions both increase.

The framework also demonstrates how the Fed can improve market conditions as the "dealer of last resort". First, the Fed can provide low-cost funding to dealers, e.g., in the repo market, to reduce $f(q, \tau)$. Second, the Fed can facilitate dealers' inventory risk hedging in the forward market to reduce $RP(q, \tau)$. Third, the Fed can grant an exemption from regulations like the SLR to reduce dealers' balance sheet costs $\gamma(q, \tau)$ in times of market distress. In practice, although some of the Fed's operations can address different types of inventory costs separately, others

may mitigate multiple frictions jointly. For example, if the Fed's purchases take customers' selling away from the market immediately, the quantify q dealers need to take into inventory will be lower and all three components of inventory costs in (1) will be reduced.

This simple framework also illustrates that the Fed's interventions may reduce the market disruptions by affecting customers. For example, some customers may be selling due to expectations of future price drops, while other customers with capital are unwilling to step in and purchase also due to such expectations (Allen, Morris, and Shin (2006)). The Fed's interventions can reduce selling and encourage buying by providing an anchor for price expectations. Accordingly, we shall study customers' selling and buying amounts to examine these customer-centric channels.

2.3 COVID-19 Market Disruptions and Empirical Design

We now discuss the timeline of COVID-19 market disruptions and the Fed's interventions, which we use to set up the design of the empirical analysis. Table 1 provides a list of major events and policy actions during the COVID-19 period that we focus on — from January to April of 2020. The financial markets did not show much stress before March 9 when a market-wide circuit breaker was tripped in the stock market for the first time since 1997. Immediately after March 9, yields soared and volatility skyrocketed in most U.S. fixed-income securities markets such as the corporate bond, municipal bond, and even Treasury markets (Duffie, 2020; Haddad, Moreira, and Muir, 2020; O'Hara and Zhou, 2020).

In response to the severe market disruptions, the Fed implemented a number of policy actions to provide credit and liquidity to the market. Intriguingly, the interventions in the agency MBS market are implemented in roughly successive stages and involve actions related to all three types of inventory costs listed in (1). Accordingly, we set up the design of our empirical analysis to map the Fed's specific actions to each type of inventory costs. In particular, we break up the sample period into four sub-periods (beginning on March 9) and track changes in both prices and quantities across the sub-periods.

Table 1. Major Events in the COVID-19 Pandemic and Empirical Design

Date	Events	Stage
1/21	First U.S. case of COVID-19 announced.	Pre-COVID
1/30	The WHO declares a “public health emergency of international concern.”	
2/29	First confirmed U.S. death from COVID-19.	
3/3	Federal funds rate target range lowered by 50 bps in an unscheduled FOMC meeting.	
3/9	The first market-wide circuit breaker triggered in equity markets since 1997.	COVID
3/12	The second market-wide circuit breaker triggered in equity markets; NY Fed announces an additional \$1.5 trillion of term repo operations.	
3/16	The third market-wide circuit breaker triggered in equity markets, and the Fed started the outright purchases of Treasury securities and agency MBSs following the announcement on Sunday, March 15.	FED1
3/17	Fed establishes the Primary Dealer Credit Facility (PDCF) and Commercial Paper Funding Facility (CPFF).	
3/18	The fourth market-wide circuit breaker triggered in equity markets; the Fed establishes the Money Market Liquidity Facility (MMLF).	
3/19	The Fed begins to purchase agency MBSs through unconventional (t+3) TBA trades that take deliveries quickly like SP trades.	
3/23	The Fed announces Treasury and agency MBS purchases “in the amounts needed”, the purchases of agency commercial mortgage-backed securities (CMBSs), and the establishment of the Primary Market Corporate Credit Facility (PMCCF), the Secondary Market Corporate Credit Facility (SMCCF), and the Term Asset-Backed Securities Loan Facility (TALF).	FED2
3/27	The Corona-virus Aid, Relief, and Economic Security (CARES) Act is signed into law.	
3/30	The Fed stopped purchasing t+3 TBA contracts.	
3/31	The Fed announces the establishment of a temporary repurchase agreement facility for foreign and international monetary authorities.	FED3
4/1	The Fed announced temporary exemption of Treasury securities and reserve bank deposits from the SLR calculation.	
4/6	Fed announces the Paycheck Protection Program Lending Facility (PPPLF).	
4/24	The Paycheck Protection Program and the Health Care Enhancement Act are signed into law.	

Notes: The first two columns provide a list of major events and dates related to the COVID-19 crisis, the agency MBS market, and the Fed’s policy actions, from January to April 2020. The last column shows the sub-periods we define.

First, from March 9 to 13, the Fed offered a substantial amount of repo funding to primary dealers, which can potentially reduce their funding costs. Second, from March 16 to 18, the Fed announced its agency MBS purchases and implemented them through standard TBA contracts that settle on a monthly cycle, as discussed in Section 2.1.¹³ We treat such TBA purchases as serving to facilitate dealers' inventory risk hedging in the forward market, over a short horizon before they take MBSs out of the market at settlement. Third, from March 19 to 27, the Fed conducted unconventional TBA purchases by settling in three days as in the SP market. Such t+3 TBA purchases immediately reduce the amount of MBSs that dealers need to take or allow dealers to offload their previously accumulated inventories. Fourth, starting from March 30, the Fed terminated the t+3 TBA purchases and only used standard TBA contracts. We denote the four sub-periods as COVID, FED1, FED2, and FED3, respectively.¹⁴

We caution that there may be some ambiguity on exactly how the sub-periods should be specified and what are the main policy actions in a sub-period. For example, on March 17 in the FED1 period, the Fed announced the PDCF that provides short-term funding to primary dealers. On March 23 in the FED2 period, the Fed announced an expansion of agency MBS purchases. Our empirical design takes a view that one type of action should have a larger effect earlier in the crisis period when liquidity conditions were more adverse. Hence, we treat similar actions taken in a later period as less consequential than in the first instance – e.g., the PDCF on March 17 relative to the series of repo funding provided in the COVID period and the expansion of agency MBS purchases on March 23 relative to the first announcement of agency MBS purchases on March 15. That being said, we do not rule out the possibility that a type of action can exert observable effects only after a series of operations.

¹³The Fed implements these purchases with primary dealers as exclusive direct trading counterparties. See [Bonaldi, Hortacsu, and Song \(2015\)](#), [Song and Zhu \(2018\)](#), and [An and Song \(2020\)](#) for studies on the mechanisms and outcomes of the trades between the Fed and primary dealers.

¹⁴Note that we use weekdays to define sample periods so there are some gaps between the end of one subperiod and the start of the next sub-period due to weekends.

2.4 Data and Measurement

In this section, we introduce the data and our empirical measures.

We use the supervisory TRACE dataset of agency MBS transactions that the Financial Industry Regulatory Authority (FINRA) started to collect from May 2011. Each trade record contains the trade type (TBA or SP), CUSIP, trade date, settlement date, price, and par value, among others. Both inter-dealer trades and trades between dealers and customers are included. Importantly, dealer identifiers are included for each trade, which allows us to separate out dealers' trades with the Fed from those with non-Fed customers (as further explained below). We apply a number of standard algorithms for data cleaning,¹⁵ and keep trades for generic pass-through MBSs with coupon rates in increments of 50 bps. To ensure that we use actively traded MBSs, we restrict the sample to those with moneyness (defined as the difference between the generic pass-through rate and the current-coupon rate for a synthetic par TBA contract that is obtained by interpolation of TBA prices trading near par) in the range of $[-1\%, 4\%]$. For TBA trades, we restrict the sample to the liquid front-month contracts (results remain robust when including back-month contracts). We also drop transactions with very low prices (less than 80 cents per dollar face value) or those of very small sizes (less than \$1,000 face value) to avoid outliers.

We obtain the records of the Fed's agency MBS purchases from the Federal Reserve Bank of New York. As the Fed's purchases are executed through TBA contracts, each trading record includes the TBA CUSIP, trading date, settlement date, price, and face value.¹⁶ These trades are reported by dealers as customer-dealer trades in TRACE with customers remaining anonymous. We match the Fed's trades with TRACE data based on TBA contract specification, trade date, trading quantity, price, and direction, and then separate the Fed's trades from those of non-Fed

¹⁵In particular, we correct trade revisions, cancels, reversals, and duplicated reports. We assign a trade to the dealer who executed this trade rather than the reporting dealer for give-up trades and locked-in trades. We also merge different reporting identities to the same underlying dealer who has multiple reporting identities in TRACE for historical reasons. We keep regular TBA trades and standard TBA-eligible SP trades of 30-year MBSs issued by Fannie Mae, Freddie Mac, and Ginnie Mae. Hence, the trades of stipulated TBA contracts and dollar rolls, as well as those not qualified for TBA delivery and with non-standard coupon rates, are excluded. The SP trades of Mega securities, stripped MBS, and collateralized mortgage obligations are also excluded.

¹⁶These data are available at <https://www.newyorkfed.org/markets/ombs/operations/search>.

customers.

For front-month TBA contract i on day t , we compute the transaction-volume-weighted average price, denoted as $P_{i,t}^{TBA}$. We then compute the transaction-volume-weighted average price of all SP transactions that fall under the TBA cohort i also on day t , denoted as $P_{i,t}^{SP}$. We use the price difference between cash (SP) and forward (TBA) trades, known as payup in practice (Hayre and Young, 2004), to measure the price dislocation, i.e., $Payup_{i,t} \equiv P_{i,t}^{SP} - P_{i,t}^{TBA}$. Accordingly, for date t and cohort i , we only keep the observations when neither prices have a missing value. In general, the payup is positive because high-value MBSs with superior prepayment characteristics are traded in the SP market, while low-value “cheapest-to-deliver” MBSs are traded in the forward market (as discussed in Section 2.1). Controlling for potential differences in the quality of MBSs traded on the two markets, the payup measure captures the cash-forward price difference that reflects the funding and balance sheet costs, as defined in (3). Further, we obtain from J.P. Morgan the daily series of option-adjusted spread (OAS) relative to swap rates for front-month TBA contracts (based on MBS prices and swap curves on the same day). As also used in Gabaix, Krishnamurthy, and Vigneron (2007), Boyarchenko, Fuster, and Lucca (2019), and Song and Zhu (2019), the OAS mainly captures the difference between the TBA price and expected value, as defined in (2).¹⁷

To measure how much liquidity dealers provide, for the front-month contract of TBA cohort i on day t , we compute their daily inventory change, in par value, as the difference between their total purchase and total selling amounts with non-Fed customers, aggregated across all dealers, and denoted as $V_{i,t}^{TBA}$. We then compute a similar daily SP inventory change $V_{i,t}^{SP}$ using dealers’ SP trades (all of which are with non-Fed customers) that fall under the TBA cohort i . We also compute customers’ gross selling amount to dealers $Q_{i,t}$ of all SP trades that fall under the TBA cohort i on day t . Finally, we separate the Fed’s trades into two categories, those with standard settlement dates and those with unconventional arrangements to settle in up to 3

¹⁷We have repeated the analysis using the series of OAS relative to the Treasury curve, and find that our main results remain robust. Hence, the variations in OAS of agency MBS are in addition to those in the Treasury market, which also experienced dislocations in the COVID-19 crisis (Duffie (2020); He, Nagel, and Song (2021)).

days ($t+3$). We then compute the Fed's total purchase amounts $F_{i,t}^{TBA}$ and $F_{i,t}^{t+3}$ for the trades with standard and ($t+3$) settlements, respectively, for TBA cohort i on day t .

To control for the quality differential between the cash and forward markets, we use two important characteristics — the weighted average original credit score (WAOCS) and the weighted average original loan size (WAOSIZE) — for each TBA-eligible MBS in each month from eMBS (see [Fusari, Li, Liu, and Song \(2019\)](#) for detailed discussions of these characteristics).¹⁸ To measure the prepayment characteristics of the MBSs traded in the TBA market (with the associated price $P_{i,t}^{TBA}$), we use the 80th percentile of WAOCS and WAOSIZE within a cohort i for each month. To measure the prepayment characteristics of the MBSs traded in the SP market (with the associated price $P_{i,t}^{SP}$), we use the transaction-volume-weighted average of the three characteristics, respectively, for all SP trades that fall under cohort i for each day t . We then take the differences, e.g., between the average WAOCS of SP MBSs and that of TBA MBSs, as control variables for quality differential. Note that the MBS characteristics are available at the monthly frequency, so the average characteristics for the TBA of a coupon cohort only vary at the monthly level. However, because potentially different specific MBSs are traded on different days, the average characteristics of the SPs in a coupon cohort can vary at the daily level.

There was a reform of the agency MBS market in June 2019 ([Goodman and Parrott \(2018\)](#)), when the Fannie Mae and Freddie Mac MBSs began to be issued using a standardized and uniform design (UMBS). Since then, only UMBS TBA contracts are traded, and these positions can be closed with the delivery of either Fannie Mae or Freddie Mac MBS. However, the SP MBSs of Fannie Mae and Freddie Mac continue to trade separately. Our main focus is on the COVID-19 period, from January to April of 2020, during which $P_{i,t}^{TBA}$ is the price of a UMBS TBA and $P_{i,t}^{SP}$

¹⁸There are other MBS characteristics that can also be used to measure the quality differential. The main reason for our choice of WAOCS and WAOSIZE is simplicity. Another reason is that while credit score and loan size have a mostly monotonic effect on prepayment rates and hence MBS values, other characteristics have non-monotonic effects. For example, the loan-to-value ratio usually affects prepayment rates negatively in normal times when default is not a major concern. However, in stressful times with impending defaults, the loan-to-value ratio positively affects the default likelihood and so positively affects prepayment rates because with agency guarantee, default results in full prepayment. In fact, in the previous version of the paper, we found that controlling for quality differentials based on the loan-to-value ratio increased the pre-COVID average payup precisely because its effect on prepayment rates was the opposite during the COVID-19 period as compared to normal times.

is calculated using SP trades of both Fannie Mae and Freddie Mac MBSs. We also consider a pre-crisis historical sample from May 2011 to December 2018 to study dealers' liquidity provision in normal times. During this period, both $P_{i,t}^{TBA}$ and $P_{i,t}^{SP}$ are calculated using the MBSs of individual agencies. The sample from 2019 is omitted to avoid potential measurement issues in the transition period. We now turn to the analysis using the historical sample.

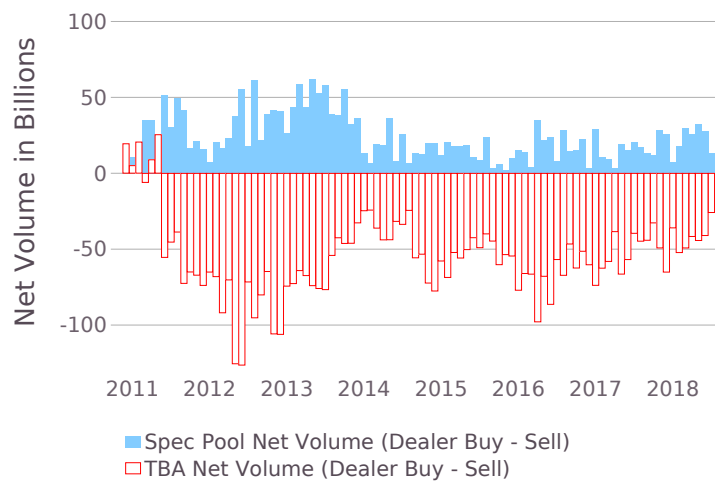
3 Dealers' Liquidity Provision Before the COVID-19 Crisis

Analyzing dealers' liquidity provision and the cash-forward price difference in this historical sample period serves several purposes. First, this analysis demonstrates dealers' basic strategy of liquidity provision – taking long positions in the cash market and hedging inventory risks by shorting in the forward market. Second, the extent of liquidity provision in this long historical period can be used as a benchmark for evaluating dealers' performance in meeting the substantial liquidity demand during the pandemic. Third, the analysis illustrates how well the quality differential component in the payup measure can be controlled for using MBS characteristics.

Figure 2 plots the monthly series of dealers' net SP and TBA positions (in \$bns) aggregated across coupon cohorts from May 2011 through December 2018, computed by taking the respective sums of $V_{i,t}^{TBA}$ and $V_{i,t}^{SP}$ across all days t within a month and all i . This sample contains agency MBS purchases by the Fed associated with its quantitative easing programs that were initiated in 2008. However, as revealed in the quote from Lorie Logan, the intent of such purchases was to exert downward pressure on longer-term interest rates and mortgage rates, different from the recent purchases that address market functioning issues and involve unprecedented purchase amounts and speed of execution. Therefore, we treat the Fed's purchases similarly to those coming from regular customers for this historical sample. In particular, we compute the $V_{i,t}^{TBA}$ measure using dealers' trades with both Fed and non-Fed customers.

We observe that dealers regularly hold net long cash positions and net short forward positions, consistent with dealers' taking inventory in the cash market and hedging inventory risk

Figure 2. Dealers' Aggregate Cash and Forward Positions Before the COVID-19 Crisis



Notes: This figure plots the monthly series of dealers' aggregate MBS cash (SP) and forward (TBA) positions in \$ bns. The sample includes Fannie Mae and Freddie Mac MBSs with moneyness in the range of $[-1\%, 4\%]$ from May 2011 to December 2018. For the TBA forward positions, only front-month contracts are included.

in the forward market to provide liquidity. The magnitude of aggregate forward positions is greater than that of aggregate cash positions. This is because MBS issuers heavily use TBA contracts to sell their newly-issued securities through TBA contracts (Vickery and Wright (2013); Gao, Schultz, and Song (2017)). For example, one of the largest MBS issuers Wells Fargo are a registered broker-dealer, so the sales of their newly-issued MBSs to investors would be recorded as the dealer's TBA sales to customers (without a record of the dealer's SP purchase from customers).

Both the net forward and cash positions vary over time, but their association seems to be strong. We run a panel regression of dealers' daily net forward positions on net cash positions to quantify the association between the two:

$$V_{i,t}^{TBA} = \beta_0 + \beta_1 \times V_{i,t}^{SP} + FE_{Coupon \times Agency} + \epsilon_{i,t},$$

where $FE_{Coupon \times Agency}$ is the fixed effect for coupon cohort and agency (Fannie Mae and Fred-

Table 2. Regressions of Dealers' Positions and Payup Before the COVID-19 Crisis

Dependent Variable:	Dealers' Forward Position		Payup	
	(1)	(2)	(3)	
Dealers' Cash Position	-0.474*** (0.119)			
Intercept	-0.167*** (0.011)	0.304*** (0.068)	0.054 (0.074)	
Moneyiness × Agency FE	Yes	No	No	
Quality Differential × Moneyiness FE	No	No	Yes	
Obs.	23,913	25,003	24,901	
Adj. R^2	0.206	-0.000	0.217	

Notes: Column (1) reports results from estimating the panel regression of dealers' daily net forward positions $V_{i,t}^{TBA}$ on daily net cash positions $V_{i,t}^{SP}$. Columns (2) - (3) report regressions of $Payup_{i,t}$ on a constant, with quality differential controls only included in the latter column. In the payup regressions, the observations are weighted by the log of total (i.e. TBA and SP combined) gross trading volume for the coupon cohort i on day t . The sample includes Fannie Mae and Freddie Mac MBSs with moneyiness in the range of $[-1\%, 4\%]$ over May 2011 – December 2018. Standard errors are clustered at the coupon cohort level and are reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

die Mac). We compute standard errors clustered at the coupon level (this will be used in all regressions unless noted otherwise).¹⁹ From column (1) of Table 2, we observe that β_1 is negative and significant, confirming that dealers hedge in the forward market the risk of inventory accumulated in the cash market. For an average coupon cohort on an average day, dealers increase their short forward position by about \$0.47 for a one-dollar-increase in their long cash position.

Column (2) of Table 2 reports a panel regression of $Payup_{i,t}$ on a constant. We weigh the observations using the log of total (i.e. TBA and SP combined) gross trading volume for the coupon cohort i on day t (such weights will be used for all regressions of MBS prices and yields unless noted otherwise). We observe that the average daily payup is significantly positive, about \$0.3 per \$100 par value. This is expected to reflect the quality differential between the MBS pools trading in the cash and forward markets. Indeed, after including the quality differential

¹⁹Our results remain robust to using standard errors clustered in the time dimension. To address concerns with stationarity, we conduct unit root tests and reject the null hypothesis that our main variables of interest (payup, OAS, and net positions) have a unit root.

controls (as discussed in Section 2.4), the results reported in column (3) show that the payup is substantially reduced to only 5 cents per \$100 par value, and becomes statistically insignificant. Hence, dealers' cost of liquidity provisions or arbitrage between the cash and forward markets is negligible in normal times.

4 COVID-19 Market Disruptions

In this section, we study the liquidity provision of dealers and the Fed's actions in its role as the dealer of last resort during the COVID-19 crisis.

4.1 Before the Fed's Market-Functioning Purchases

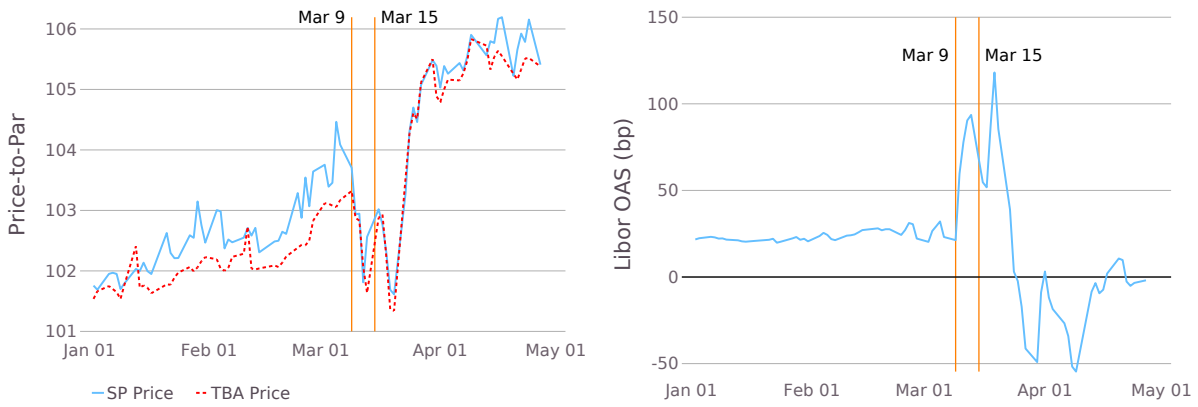
We first study dealers' liquidity provision and MBS prices before the Fed stepped in with direct MBS purchases. In particular, we focus on the sample period of January 1 – March 13, 2020 that consists of both the pre-COVID and COVID shock periods that are defined based on the empirical design discussed in Section 2.3.

4.1.1 MBS Prices in the COVID-19 Shock Period

Figure 3 plots the daily series of the prices $P_{i,t}^{SP}$ and $P_{i,t}^{TBA}$ (left panel), as well as the OAS (right panel), for 30-year UMBS with 3% coupon rate that is among the most-actively-issued cohorts. We make three observations. First, both SP and TBA prices dropped substantially since March 9. Second, before March 9, the SP prices are higher than TBA prices on average, implying a positive payup, but afterwards the payup dropped substantially and even disappeared for a while. Third, the OAS measure spiked up around the same time.

Although the price drops can be driven by worsening MBS fundamentals like prepayment risk and expected mortgage defaults (the expected value EV in equation (1)), the declining payup and increasing OAS point to price dislocations and limited arbitrage associated with dealers' inventory costs. To quantify the price changes, column (1) of Table 3 reports results

Figure 3. MBS Prices and Yields in the COVID-19 Crisis



Notes: The left panel plots the daily series of SP and TBA prices of the 30-year UMBS with 3% coupon rate, calculated using the TRACE transaction data. The right panel plots the daily OAS series of the 30-year UMBS TBA with 3% coupon rate, provided by JP Morgan. The sample period is from January 1 through April 27, 2020,

from estimating the regression of OAS on the dummy variable D_{COVID} :

$$OAS_{i,t} = \beta_1 \times D_{COVID} + FE_{Coupon} + \epsilon_{i,t} \quad (4)$$

The coefficient on D_{COVID} captures the change in the OAS, for an average coupon cohort, in the COVID period relative to the pre-COVID period. Because the intercept in a panel regression with coupon fixed effect captures the average OAS of one coupon cohort, suppressing it will not affect the coefficient on D_{COVID} . But to facilitate comparison with the pre-COVID period, we run another regression of OAS with intercept but without the coupon fixed effect, and report the estimated intercept that equals the pre-COVID average. We observe that the OAS increased significantly by about 38 basis points from the pre-COVID mean of about 45 bps.

Column (2) reports results from estimating the regression of $Payup_{i,t}$ on the dummy D_{COVID} , also with the pre-COVID average payup reported in the first row. The average payup decreased significantly by \$0.883 in the COVID shock period, more than 50% below the pre-COVID average of \$1.365. Column (3) adds quality differential controls interacted with the coupon fixed

Table 3. Regressions of MBS Prices in the COVID-19 Crisis

	OAS	Payup	
	(1)	(2)	(3)
Pre-COVID Average	45.098*** (11.248)	1.365*** (0.366)	0.825*** (0.282)
D_{COVID}	37.963*** (2.425)	-0.883** (0.298)	-0.535** (0.167)
Coupon FE	Yes	Yes	Yes
Coupon FE×Quality Differential	No	No	Yes
Obs.	328	328	328
Adj. R^2	0.923	0.519	0.830

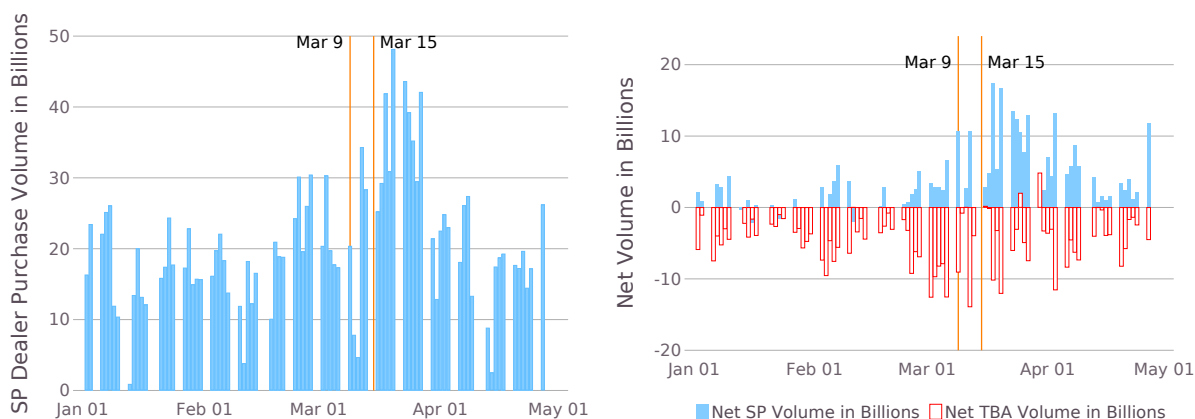
Notes: The “Pre-COVID Average” row reports the estimated pre-COVID average of the OAS in column (1) and of the payup in columns (2) - (3), using regressions on D_{COVID} with an intercept but without the coupon fixed effect. The remaining rows report estimates from regressions on D_{COVID} . Specifically, column (1) reports the regression of OAS on D_{COVID} including the coupon fixed effect and without an intercept. Columns (2) - (3) report estimates from similar regressions of payup, without and with quality differential controls, respectively. The sample consists of 30-year UMBS with moneyness in the range of $[-1\%, 4\%]$ over the sample period of January 1 – March 13, 2020, which covers both the pre-COVID and the COVID shock periods. Observations are weighted by the logarithm of the gross TBA and SP volume. Standard errors are clustered at the coupon level and are reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

effect to the regression, with the pre-COVID average also estimated including quality differential controls.²⁰ We observe that the coefficient D_{COVID} is still significantly negative, confirming that the substantial decrease in payup during the COVID shock period is not due to potential changes in the quality of MBSs sold in the cash relative to the forward markets.²¹

²⁰Note that these quality differential controls are not needed for the OAS measure, which captures the relative pricing of MBSs to swaps rather than that of SP to TBA markets. The “quality difference” of MBSs relative to swaps, which is about the prepayment option, has been controlled for in the calculation of OAS (Gabaix, Krishnamurthy, and Vigneron (2007); Boyarchenko, Fuster, and Lucca (2019)).

²¹We also observe that the pre-COVID average payup is reduced significantly from \$1.365 to \$0.825, but still positive, after controlling for quality differentials. One possible reason is that the flight-to-safety from January to early March prompts investors to purchase MBSs in the cash market (He, Nagel, and Song (2021)). In fact, as shown by Roberts, Sarkar, and Shachar (2018), He and Song (2020) and Gete and Reher (2020), the demand for holding agency MBSs has been rising since the 2008 crisis, especially after the liquidity coverage ratio was introduced.

Figure 4. Customers' Selling Amounts and Dealers' Positions in the COVID-19 Crisis



Notes: This figure plots the customers' daily gross SP selling amount (top panel) and dealers' aggregate daily changes in net cash and forward positions (bottom panel).

4.1.2 Customers' Selling and Dealers' Liquidity Provision

We now complement the above evidence on price dislocations with evidence on changes in customers' and dealers' positions. The top panel of Figure 4 plots the daily series of customers' gross selling amount (sum of $Q_{i,t}$ across i) in the cash market. We observe a notable increase entering the COVID shock period since March 9. That is, when the MBS price in the cash market dropped substantially, investors increased their selling amounts significantly. This points to customers' scrambling-for-cash in response to a liquidity shock, which is corroborated by anecdotal reports.²²

The middle panel plots the daily series of dealers' net purchases in the cash market (sum of $V_{i,t}^{SP}$ across i) and net purchases in the forward market (sum of $V_{i,t}^{TBA}$ across i). We observe that dealers accommodated customers' liquidity needs by taking long cash positions and short forward positions, as in the historical sample (see Section 3). Importantly, the magnitudes of both the cash and forward positions increased greatly in the COVID shock period, as compared to the historical sample.²³

²²See <https://www.wsj.com/articles/coronavirus-puts-a-premium-on-cash-even-for-biggest-u-s-companies-11585153040> for related media reports. The COVID-19 pandemic sparked a scramble-for-cash not just among small investors and households, but also the largest U.S. companies (Kashyap (2020)).

²³Certain non-dealer investors like hedge funds, mutual funds, and banks can potentially take the MBSs sold in

We quantify these changes in regressions. Column (1) of Table 4 reports results from a regression of customers' gross selling amount $Q_{i,t}$ on the COVID dummy, similar to regression (4). We find that customers' daily gross selling amount of an average coupon cohort increased by about \$0.654 bns from the pre-COVID average of about \$0.823 bns. Columns (2) and (3) report estimates from similar regressions of $V_{i,t}^{SP}$ and $V_{i,t}^{TBA}$, respectively. Dealers' daily cash positions increased by \$0.607 bns, while their daily short forward positions increased by \$0.145 bns in the COVID shock period. The statistical significance is weak, though, likely because the COVID shock period of March 9–13 is very short.²⁴ Importantly, as shown in column (4), for a one-dollar-increase in the cash position, dealers increase their short forward positions by \$0.574, larger than the magnitude in the historical sample (\$0.474 as reported in column (1) of Table 2). That is, dealers hedged more in the COVID-19 market turmoil than the historical average.

What type of customers were selling MBS during the pandemic? Do dealers hedge inventory risk completely or maintain some risk exposure? The TRACE data is limited to understand these issues: (1) it does not contain customer identities; (2) it only allows us to track the flows so we cannot measure the levels of dealers' MBS holdings accurately.

We consider additional data sources to shed some light on these issues. First, from the Financial Accounts of the United States (Z.1), we find that, of all mortgage investors, mortgage REITs decreased their MBS holdings the most, by about \$120 bns in 2020 Q1 (Figure 5). This decrease is about 37% of their MBS holdings in 2020 Q4. Holdings of other investors like mutual funds, life insurance companies and pension funds, however, did not change much between the same two quarters. Second, we obtain the weekly series of primary dealers' net positions of agency MBSs from the FR2004 data collected by the Federal Reserve Bank of New York.²⁵ The reported series are netted by combining dealers' cash and derivatives positions including forward contracts (Fleming and Rosenberg (2007)), and aggregated across all primary dealers. As

the cash market and hence provide liquidity. Such investors are included as customers in the TRACE data, so our estimate of dealers' cash positions (and forward positions) are net of the amount of customers' liquidity provision.

²⁴One particular issue is that the interest rate change was large and quick, so the moneyness of a coupon cohort had a similar variation, which makes the coupon fixed effect less suitable. Indeed, as reported in Table 9, the statistical significance is stronger when moneyness fixed effects are used.

²⁵For details, see <https://www.newyorkfed.org/markets/gsds/search>.

Table 4. Daily Position Changes during the COVID-19 Crisis

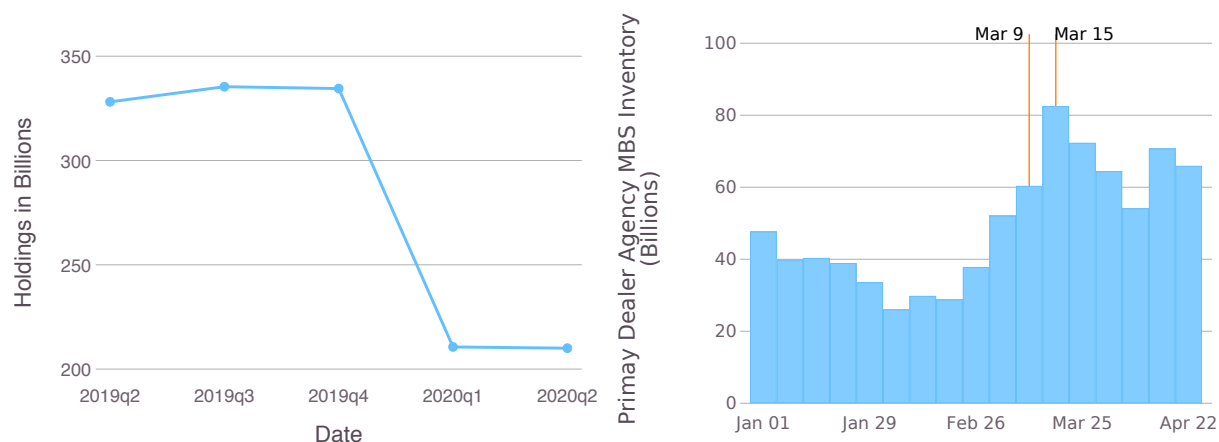
	$Q_{i,t}$	$V_{i,t}^{SP}$	$V_{i,t}^{TBA}$	
	(1)	(2)	(3)	(4)
Pre-COVID Average	0.823** (0.284)	0.158* (0.054)	-0.723* (0.327)	
D_{COVID}	0.654* (0.335)	0.607 (0.354)	-0.145 (0.227)	
$V_{i,t}^{SP}$				-0.574*** (0.126)
Coupon FE	Yes	Yes	Yes	Yes
Obs.	322	322	322	322
Adj. R^2	0.409	0.040	0.232	0.340

Notes: The "Pre-COVID Average" row reports the estimated pre-COVID average of customers' daily gross selling amount $Q_{i,t}$ in column (1), dealers' daily net cash position $V_{i,t}^{SP}$ in column (2), and dealers' daily net forward position $V_{i,t}^{TBA}$ in column (3), all in \$bns, using regressions on D_{COVID} and an intercept but without the coupon fixed effect. The remaining rows report results from the following regressions. Column (1) reports results from the regression of $Q_{i,t}$ on D_{COVID} with the coupon fixed effect but excluding the intercept. Column (2) - (3) report estimates from similar regressions for $V_{i,t}^{SP}$ and $V_{i,t}^{TBA}$. Column (4) reports results from the regression of $V_{i,t}^{TBA}$ on $V_{i,t}^{SP}$. The sample includes 30-year UMBS for cohorts with moneyness in the range of $[-1\%, 4\%]$ over January 1 – March 13, 2020, which covers the pre-COVID and COVID shock periods. Standard errors are clustered at the coupon level and are reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

plotted in the bottom panel of Figure 4, primary dealers' net MBS holdings increased from mid-February and stayed positive, implying that they maintained significant MBS risk exposure in providing liquidity to the market.

Overall, consistent with the economic framework in Section 2.2, our evidence on quantities and prices together shows that investors experience liquidity shocks and sell MBSs to raise cash immediately. Dealers provide liquidity by taking these MBSs into inventory and hedging inventory risk partially using forward contracts, which incur significant costs (as indicated by the long decline in the payout and increase in the OAS). We now turn to provide evidence on how dealers' funding, inventory risk and balance sheet constraints affect their liquidity provision and are then mitigated by the Fed's actions.

Figure 5. MBS Holdings of Mortgage REITs and Primary Dealers in the COVID-19 Crisis



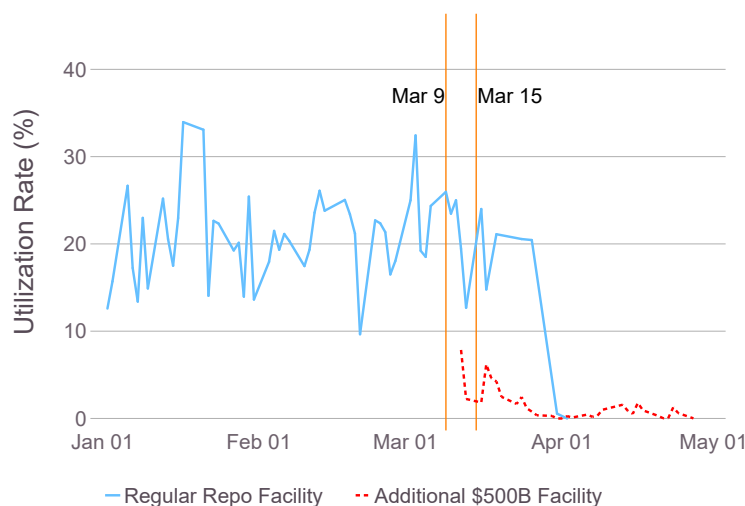
Notes: This figure plots the quarterly holdings of U.S. mortgage REITs from Q2 2019 to Q2 2020 (left panel) and primary dealers' weekly net MBS positions from January 1 to April 22, 2020 (right panel).

4.1.3 The Fed's Provision of Funding Liquidity

Starting with funding liquidity, the costs of funding MBS inventories can potentially limit dealers' liquidity provision (Brunnermeier and Pedersen (2009)). Since the 2008 financial crisis, the Fed has been conducting overnight and term repo operations regularly, which provide funding liquidity to primary dealers directly and support the smooth functioning of short-term funding markets broadly. To address potentially large funding shortages during the COVID-19 market disruptions, the Fed conducted large-sized term repo operations since March 12, offering up to \$500 bns in each operation.

Figure 6 plots the daily series of the repo utilization rate, defined as the aggregate repo amount with agency MBS as collateral awarded to primary dealers divided by the aggregate offering amount. We calculate the utilization rate for the regular repo operations and the newly added large-sized term repo operations separately. We observe that the utilization rate for the regular repo operations is between 10-30% before the COVID pandemic, and importantly, does not show any increase in the COVID shock period – in fact, the utilization rate dropped since mid-March. The take-up in the Fed's offered large-sized term repo funding is particularly low,

Figure 6. The Fed’s Repo Funding Operations during the COVID-19 Crisis



Notes: This figure plots daily series of the utilization rate of the Fed’s repo funding, defined as the aggregate repo amount with agency MBS as collateral awarded to primary dealers divided by the aggregate offering amount. The utilization rate is calculated separately for the regular repo operations and the new large-size term repo operations initiated in March. The sample period is from January 1 through April 27, 2020.

below 10%.²⁶

Overall, primary dealers’ bids in repo operations were mostly accepted 100% of the time at rates close to the minimum bid rates, which are set at attractive values by the Fed in times of market distress.²⁷ This low demand for low-cost funding offered by the Fed suggests that funding costs were not the major constraint on dealers’ liquidity provision.

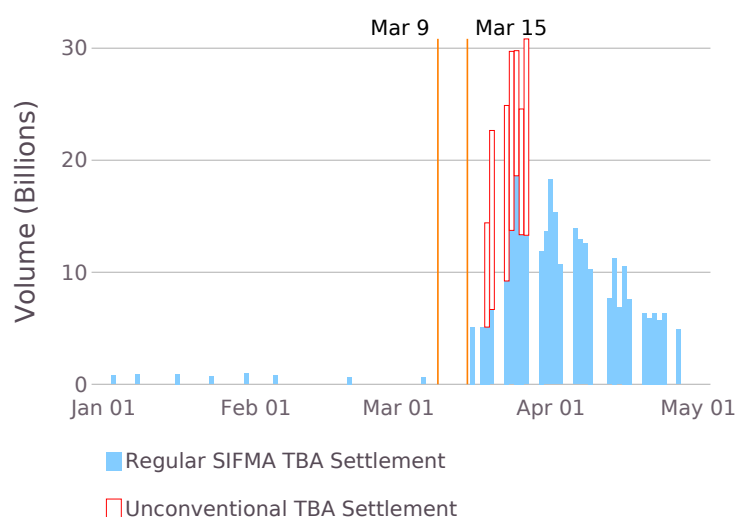
4.2 The Fed’s Market-Functioning Purchases

Turning to the Fed’s MBS purchases, we shall examine changes in prices and positions across the three sub-periods, FED1, FED2, and FED3, as outlined in Section 2.3. Given that we break

²⁶The utilization rate using all collateral securities, including Treasury securities, agency MBSs, and agency debt, shows a similar pattern, except for an increase in early March associated with Treasury securities.

²⁷The minimum bid rate is usually set at the prevailing market rate that reflects market expectations for the path of the federal funds rate over a similar tenor plus a spread, and is announced before the operation. See <https://www.newyorkfed.org/markets/domestic-market-operations/monetary-policy-implementation/repo-reverse-repo-agreements/repurchase-agreement-operational-details> for more details.

Figure 7. The Fed's Purchases



Notes: This figure plots the daily amount (in \$bns) of the Fed's purchases of 30-year UMBS aggregated across coupon cohorts, over January 1 – April 27, 2020. The solid blue bars represent the Fed's conventional TBA purchases. The stacked hollow red bars on top of conventional TBA purchases represent the Fed's t+3 TBA purchases, which were implemented from March 19 through March 27.

up the sample period according to whether the Fed conducted the conventional or unconventional t+3 TBA purchases (see Section 2.3 for details), we first provide a summary of these two types of purchase operations in Figure 7. We observe that the Fed conducted some sporadic MBS purchases in the pre-COVID period under the historical purchase programs. In the FED1 period, the Fed only conducted conventional TBA purchases, with an average daily amount of about \$5 bns. In the FED2 period, the Fed conducted t+3 TBA purchases with an average daily amount of about \$13 bns, in addition to conventional TBA purchases with an average daily amount of \$11 bns. On average, the t+3 TBA purchases account for more than half of the Fed's total daily purchase amount in the FED2 period.

4.2.1 Effects of the Fed's MBS Purchases

Columns (1) and (2) of Table 5 report results from regressions of dealers' daily forward positions with non-Fed customers and with both non-Fed customers and the Fed (using only its conven-

tional TBA purchases), respectively, on dummy variables for all the four sub-periods. Moreover, columns (3) and (4) report results from similar regressions of dealers' daily net cash positions with non-Fed customers and with both non-Fed customers and the Fed (treating its t+3 TBA purchases as cash trades), respectively. We note that these dummy variables equal one only in the associated sub-period, so the coefficients capture the changes in that sub-period relative to the pre-COVID period. This approach allows us to track when the variables of interest exhibit reversions. To measure the change from one period to the next, one would need to compute the difference in the relevant coefficients.

We make several important observations on the variations across these sub-periods. First, as shown in columns (1) – (2), dealers' daily net forward positions with non-Fed customers do not exhibit significant changes relative to the pre-COVID period, while the total net forward positions including the Fed's conventional TBA purchases become significantly more negative. That is, in aggregate, only the Fed (and not customers) increased TBA purchases since the COVID shock and facilitated dealers' inventory hedging.²⁸ Second, as reported in columns (3) – (4), dealers' net cash positions with non-Fed customers kept increasing, especially in the FED2 period, while their total net cash positions decreased in the FED2 period, relative to the pre-COVID period. Hence, in the FED2 period, dealers not only fully offload the inventory newly acquired from customers' selling but they also offload previously accumulated inventories to the Fed.

Turning to the price changes, column (6) of [Table 5](#) reports results from the regression of OAS on sub-period dummies. We find that, after its increase in the COVID shock period, the OAS increased further in the FED1 period, but increased less in the FED2 period and finally reverted in the FED3 period. Column (7) reports results from a similar regression for the payup measure. Following the \$0.554 decrease per \$100 face value in the COVID shock period, the payup decreased further and was lower by \$0.924 in the FED1 period relative to the pre-COVID

²⁸It is worth noting that the liquidity distress implies a stronger selling in the cash market than the forward market. If the selling in the forward market was stronger, we would expect an increase in the payup – opposite to the decrease observed in the data.

Table 5. Effects of the Fed's Purchases on Customers' Selling and Dealers' Positions

	Dealers			Customers		MBS Price	
	$V_{i,t}^{TBA}$ (1)	$V_{i,t}^{TBA} - F_{i,t}^{TBA}$ (2)	$V_{i,t}^{SP}$ (3)	$V_{i,t}^{SP} - F_{i,t}^{T+3}$ (4)	$Q_{i,t}$ (5)	OAS (6)	Payup (7)
Pre-COVID Average	-0.723* (0.328)	-0.741* (0.336)	0.158** (0.055)	0.608 (0.355)	0.823** (0.285)	45.098*** (11.185)	0.790** (0.295)
D_{COVID}	-0.142 (0.229)	-0.101 (0.219)	0.611 (0.353)	0.608 (0.355)	0.668* (0.334)	38.394*** (2.445)	-0.554** (0.161)
D_{FED1}	0.197 (0.388)	-0.287 (0.357)	1.076** (0.454)	1.054* (0.454)	1.027** (0.396)	54.543*** (6.106)	-0.924*** (0.224)
D_{FED2}	-0.029 (0.490)	-1.584** (0.546)	1.494** (0.614)	-0.482 (0.282)	1.662* (0.751)	33.243** (10.189)	-1.026** (0.303)
D_{FED3}	0.118 (0.298)	-1.259 (0.698)	0.535*** (0.115)	0.533*** (0.115)	0.238 (0.239)	-14.984 (10.937)	-0.316* (0.139)
Coupon FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Coupon FE×Quality Differential	No	No	No	No	No	No	Yes
Obs.	520	521	520	521	520	528	527
Adj. R^2	0.209	0.414	0.189	0.111	0.343	0.801	0.773

Notes: The "Pre-COVID Average" row reports the estimated pre-COVID average using regressions on D_{COVID} with an intercept but without the coupon fixed effect and the sample of January 1 to March 13, 2020. The remaining rows report results from regressions on dummy variables D_{COVID} , D_{FED1} , D_{FED2} , and D_{FED3} that equal 1 in the respective sub-periods COVID, FED1, FED2 and FED3, using the sample of January 1 – April 27, 2020. The dependent variables are the dealers' daily net forward purchase amount with customers in column (1), dealers' daily net forward purchase amount with both customers and the Fed in column (2), dealers' daily net cash purchase amount with customers in column (3), dealers' daily net cash purchase amount with both customers and the Fed in column (4), customers' daily gross cash selling amount in column (5), the OAS of TBA contracts in column (6), and the payup in column (7). In the OAS and payup regressions, the observations are weighted by the logarithm of gross TBA and SP trading volume, while quality differential controls are included only in the payup regressions. The sample consists of 30-year UMBS with moneyness in the range of [-1%, 4%]. Standard errors are clustered at the coupon level and reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

period. The decline seemed to slow down towards the end of the FED2 period, so even though the payup declined by \$1.026 in the FED2 period overall, the decline reverted to \$0.316 in the FED3 period.²⁹

We further look into daily changes of the OAS spread and the payup. Specifically, we consider the regression of $OAS_{i,t}$ on daily dummies for each trading date s :

$$OAS_{i,t} = \sum_s \beta_s \times D_{t=s} + FE_{coupon} + \epsilon_{i,t}, \quad (5)$$

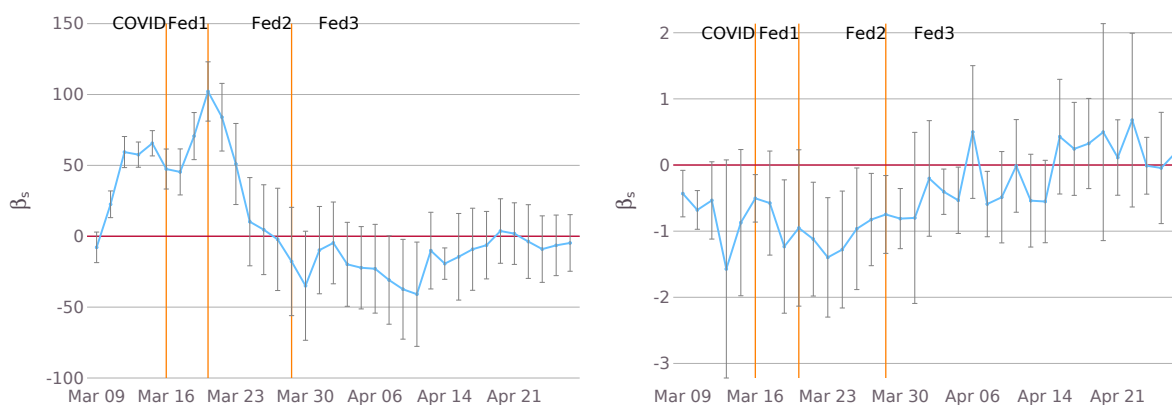
where $D_{t=s}$ is the dummy for day s that equals 1 if the date t coincides with s and 0 otherwise, which captures the change in day- s OAS relative to the pre-COVID average. We also consider the same regression for $Payup_{i,t}$. Figure 8 plots estimates of the daily dummy coefficients with 95% confidence intervals for the OAS (left panel) and the payup (right panel). Consistent with Table 5, the OAS increased since the COVID shock, and began to revert at the beginning of the FED2 period immediately when the Fed started its t+3 TBA purchases. Meanwhile, the payup declined beginning with the COVID shock but started to revert only during the middle of the FED2 period. Both the OAS and the payup fully reverted to their pre-COVID levels and then stabilized in the FED3 period.³⁰

In summary, the Fed's MBS purchases first facilitated dealers' inventory hedging with conventional TBA trades and then directly reduced dealers' holdings with t+3 TBA trades. The latter action played an important role in reverting increases in the OAS and the cash-forward price divergence. Given that the OAS is mainly associated with inventory risk premium and the cash-forward price difference is mainly associated with balance sheet costs, as shown in equations (2) and (3), the slower reversion of the latter suggests that dealers' balance sheet constraints are

²⁹We observe that the pre-COVID average payup is \$0.790, which is slightly different from that reported in column (3) of Table 3 (\$0.825). The reason is that the regression used to estimate the pre-COVID average payup depends on the estimated effects of quality differential controls on payup, which can be different when different samples are used. In Table 3, the sample used includes the pre-COVID and COVID shock periods, while the sample for Table 5 includes the whole sample period.

³⁰In unreported analyses, we study changes in the micro-structure measures of transaction costs. Similar to dynamics of the payup and the OAS, transaction costs rose substantially when the COVID-19 pandemic started, before slowing down towards the end of FED2 period.

Figure 8. Daily regressions: OAS and Payup



Notes: The left panel plots the estimated coefficients from a regression of OAS on day dummy variables. The right panel plots estimates from a similar regression of the payup measure. Each day dummy equals 1 on a specific day between March 9 to April 27, 2020, and 0 otherwise. The 95% confidence intervals of the estimates are also shown. The sample period is from January 1 through April 27 2020.

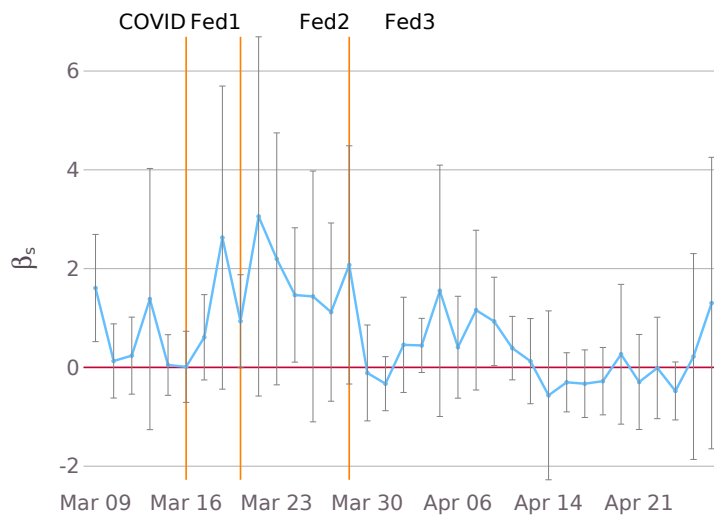
particularly severe.

One may wonder whether the Fed's interventions weakened customers' selling. The regression of customers' gross selling amount $Q_{i,t}$ in the cash market, as reported in column (5) of [Table 5](#), shows that customers' gross selling kept increasing into the FED2 period. [Figure 9](#) plots estimates from a regression of $Q_{i,t}$ on daily dummy variables, along with 95% confidence intervals. We find that customers sold more at the beginning of the FED2 period even as the Fed's t+3 TBA purchases reverted the OAS increase. However, like the payup, customers' gross selling amount also began to revert during the middle of the FED2 period. Hence, the Fed's MBS purchases had observable effects in weakening customers' selling towards the end of COVID-19 market disruptions.

4.2.2 Primary Dealers' Selling Prices and Balance Sheet Costs

Given the documented severity of balance sheet constraints, we conduct further analyses to quantify balance sheet costs in this section. Specifically, although decline in the payup captures this cost in theory, as expressed in (3), empirical measurement issues exist. For example,

Figure 9. Daily regressions: Customers' Gross Selling



Notes: This figure plots the estimated coefficients from a regression of customers' gross selling amount on day dummy variables. Each day dummy equals 1 on a specific day between March 9 to April 27, 2020, and 0 otherwise. The 95% confidence intervals are also shown. The sample period is from January 1 through April 27 2020.

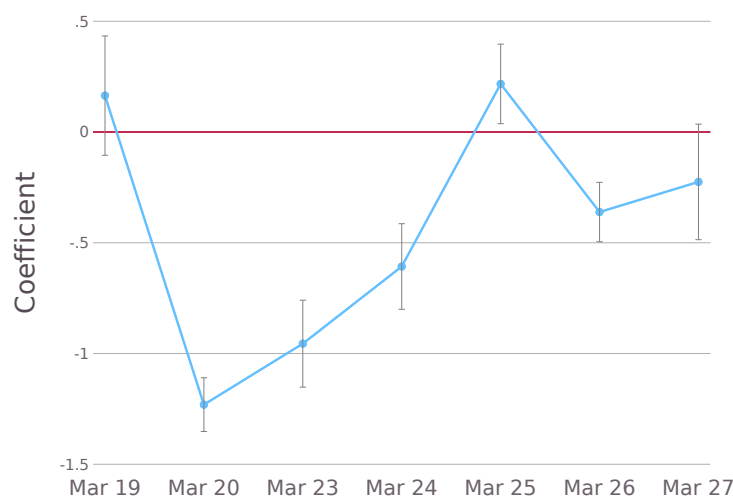
because customers are anonymous in the TRACE data, the TBA and SP prices used in computing the payup measure may involve different customers.

We take advantage of the prices at which primary dealers sell to the Fed, for both the conventional TBA trades and the t+3 TBA trades. As the latter are essentially cash trades, the difference between the prices of these two types of trades is equivalent to the cash-forward price difference, but with both legs tied to the same counterparty — the Fed. Hence, it measures primary dealers' balance sheet costs: how much of a discount primary dealers are willing to accept in immediately unloading the MBS inventory to the Fed relative to holding them until a future TBA settlement date.

For each day in the FED2 period (from March 19 to 27), we run the following regression:

$$P_{i,j} = \beta \times D_{t+3} + \log(F_{i,j}) + D_{back} + FE_i + \epsilon_{i,j} \quad (6)$$

Figure 10. Primary Dealers' Selling Prices to the Fed



Notes: This figure plots the estimated coefficient from a regression of the Fed's daily purchases on a dummy variable that equals 1 for a t+3 TBA trade and 0 for a conventional TBA trade. This regression is estimated for each day in the FED2 period of March 19 – March 27, 2020. The 95% confidence intervals for the estimated coefficients are also shown.

$P_{i,j}$ and $F_{i,j}$ are the price and amount, respectively, of the j -th purchase trade by the Fed for the coupon cohort i . Each purchase trade is either a t+3 TBA trade or a conventional TBA trade. The latter either settles in April (front-month) or May (back-month). The main variable of interest is the dummy variable D_{t+3} that equals 1 for a t+3 TBA trade and is zero otherwise. It captures the price discount primary dealers are willing to accept for unloading MBSs to the Fed immediately rather than holding them until the next monthly settlement date. The dummy variable D_{back} equals 1 for the conventional TBA trade settling in May, and controls for the potential price difference in the April and May TBA contracts.

Figure 10 plots the estimated coefficient on D_{t+3} and the associated 95% confidence interval, for each day in the FED2 period. Across this period, the coefficient is mostly significantly negative, implying that primary dealers are indeed willing to accept a discount in clearing MBSs off their balance sheets sooner than later. Analogous to the declining payup reported in the right panel of Figure 8, the discount becomes larger in the earlier half of the period, in a range of \$0.6 – \$1.2 per \$100 face value. The discount shrinks to less than \$0.4 in the latter half of

the period, and becomes insignificantly different from zero on March 27. The average price discount for t+3 TBA purchases is about \$0.89 during this period, slightly lower than the payup decrease of \$1.042 reported in Table 5.³¹

5 Additional Results and Robustness Checks

In this section, we conduct a number of additional analyses and robustness checks.

First, the cutoff date for the COVID shock period, March 9, happens to be one day before the March TBA notification date. Hence, one may be concerned that the change in the payup documented in Table 3 arises from the TBA settlement cycle mechanically. We conduct a placebo test using the historical sample over May 2011 – December 2018 of Fannie Mae 30-year MBSs. In particular, for each TBA settlement month cycle, we keep 7 calendar days before and after the notification day, and run the following regression of MBS prices:

$$\text{Price}_{i,t} = \beta_1 \times D_{\text{PostNotification}} + \beta_2 \times D_{SP} + \beta_3 \times D_{\text{PostNotification}} \times D_{SP} + FE_{\text{Coupon}} + \epsilon_{i,t} \quad (7)$$

where $\text{Price}_{i,t}$ is $P_{i,t}^{TBA}$ or $P_{i,t}^{SP}$, $D_{\text{PostNotification}}$ is a dummy that equals one if day t falls after the notification day in a month and zero otherwise, and D_{SP} is a dummy to indicate the SP trade price. Table 6 reports results from the regression with the coupon fixed effect in column (1) and further adding the interaction term between the coupon fixed effect and quality differential controls in column (2). We observe that the negative coefficient on the interaction term $D_{\text{PostNotification}} \times D_{SP}$ implies that the payup drops after a notification day, but only by about \$0.035 with weak statistical significance (as compared to a significant decrease in the payup of 0.535 in the COVID shock period reported in Table 3).

Second, our baseline results use dealers' cash and forward positions aggregated across all

³¹We do not observe significant price movements associated with the April 1st announcement of the temporary exemption of Treasury securities and reserve bank deposits from the SLR calculation. There are two possible reasons. First, the liquidity distress had already greatly retreated by April 1. Second, this policy action did not involve agency MBSs. He, Nagel, and Song (2021) show that the April 1st announcement did not have significant effects on the Treasury market either, consistent with the former reason.

Table 6. Placebo Test on TBA Settlement Cycle

	(1)	(2)
$D_{\text{PostNotification}}$	-0.081*** (0.025)	-0.069** (0.025)
D_{SP}	0.325*** (0.071)	0.191 (0.321)
$D_{SP} \times D_{\text{PostNotification}}$	-0.024 (0.017)	-0.035 (0.028)
Coupon FE	Yes	Yes
Coupon FE \times Quality Differential	No	Yes
Obs.	14730	14676
Adj. R^2	0.796	0.806

Notes: This table reports results from regressions of TBA and SP prices of 30-year Fannie Mae MBSs, controlling for the coupon fixed effect in column (1) and further adding the interaction term between the coupon fixed effect and quality differential controls in column (2). The sample contains coupon cohorts with the moneyness range $[-1\%, 4\%]$ during the sample period of May 2011 – December 2018. We keep 7 calendar days before and after the notification day for each TBA settlement month cycle. D_{SP} is a dummy that equals 1 for the SP price and 0 for the TBA price, while $D_{\text{PostNotification}}$ is a dummy that equals 0 if the date is more than one day ahead of the notification date. Observations are weighted by the logarithm of gross TBA and SP trading volume. Standard errors are clustered at the coupon level and are reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

broker-dealers. As mentioned in Section 2.3, the Fed implemented its MBS purchases with primary dealers who are recognized by the Federal Reserve Bank of New York as its exclusive direct trading counterparties. Table 7 reports results from regressions of primary dealers' cash and forward positions, and they are similar to those reported for all dealers in columns (1) – (4) of Table 5.

Third, although we control for the potential change in MBS characteristics due to the COVID-19 shock in the baseline analysis, the shock may also lead to a rapid change in investors' risk appetite, causing the dependence of MBS prices on characteristics to change after the shock. We address this issue using trade-level regressions that allow us to control for such time-varying dependence. In particular, we consider the following regression:

$$\text{Price}_{i,j,t} = \beta_1 \times D_{SP} + \beta_2 D_{SP} \times D_{\text{COVID}} + FE_{\text{Coupon} \times t} + FE_{\text{Coupon} \times t} \times \text{Characteristics}_{i,j,t} + \epsilon_{i,j,t} \quad (8)$$

Table 7. Primary Dealers' Positions

	$V_{i,t}^{TBA}$ (1)	$V_{i,t}^{TBA} - F_{i,t}^{TBA}$ (2)	$V_{i,t}^{SP}$ (3)	$V_{i,t}^{SP} - F_{i,t}^{T+3}$ (4)
Pre-COVID Average	-0.435 (0.251)	-0.453 (0.257)		0.254** (0.091)
D_{COVID}	0.330 (0.256)	0.353 (0.241)	0.538 (0.312)	0.542 (0.315)
D_{FED1}	0.401 (0.348)	-0.075 (0.356)	0.941* (0.398)	0.921* (0.398)
D_{FED2}	0.016 (0.554)	-1.531** (0.572)	1.563* (0.662)	-0.410 (0.311)
D_{FED3}	0.382 (0.203)	-0.983 (0.534)	0.477*** (0.128)	0.475*** (0.127)
Coupon FE	Yes	Yes	Yes	Yes
Obs.	521	522	521	522
Adj. R^2	0.084	0.293	0.200	0.105

Notes: The "Pre-COVID Average" row reports the estimated pre-COVID average using regressions on D_{COVID} with an intercept but without the coupon fixed effect and the sample of January 1 to March 13, 2020. The remaining rows show results from regressions on dummy variables corresponding to the four sub-periods over January 1 – April 27, 2020 (D_{COVID} , D_{FED1} , D_{FED2} , and D_{FED3}) that equal 1 in the respective sub-period. The dependent variables are primary dealers' daily net forward purchase amount with customers in column (1), primary dealers' daily net forward purchase amount with both customers and the Fed in column (2), primary dealers' daily net cash purchase amount with customers in column (3), and primary dealers' daily net cash purchase amount with both customers and the Fed in column (4). The sample includes 30-year UMBS with moneyness in the range of [-1%, 4%]. Standard errors are clustered at the coupon level and are reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

where $Price_{i,j,t}$ is either $P_{i,j,t}^{TBA}$ or $P_{i,j,t}^{SP}$, and is the price of the j th transaction for cohort i on date t , while D_{SP} and D_{COVID} are dummies for the SP transaction and the COVID shock period, respectively. The interaction term of the coupon-day fixed effect with the MBS characteristics (for TBA and SP trades separately) captures the potentially time-varying loadings of MBS prices on these characteristics. Column (1) of Table 8 reports results from regression (8) with the interaction term of the coupon fixed effect and MBS characteristics, as before. The coefficient on $D_{SP} \times D_{COVID}$ implies that the payoff drops by about \$0.713 per \$100 face value. In column (2), we allow for time-varying interactions between MBS prices and characteristics through the term $FE_{Coupon \times t} \times Characteristics_{i,j,t}$. The coefficient on $D_{SP} \times D_{COVID}$ is still significantly neg-

ative, with an even larger magnitude.

Table 8. Trade-Level Regressions of SP and TBA Prices in the COVID-19 Crisis

	(1)	(2)
D_{SP}	0.868*** (0.116)	0.888*** (0.112)
$D_{SP} \times D_{COVID}$	-0.713*** (0.127)	-0.948*** (0.098)
Coupon \times Trade Date FE	Yes	Yes
Coupon FE \times MBS Quality	Yes	No
Coupon \times Trade Date FE \times MBS Quality	No	Yes
Obs.	255,035	255,035
Adj. R^2	0.902	0.913

Notes: Column (1) reports results from a regression of the price of each (TBA and SP) trade for each coupon cohort on each day, controlling for the Coupon \times Trade Date fixed effect, as well as the interaction term of the coupon fixed effect with MBS characteristics. Column (2) adds the triple interaction term of the coupon fixed effect, trade date fixed effect, and MBS characteristics, which subsumes the interaction term of the coupon fixed effect with MBS characteristics. The sample includes 30-year UMBS with moneyness in the range of $[-1\%, 4\%]$ over the sample period of January 1 – March 13, 2020. D_{SP} is a dummy that equals 1 if the price is for an SP trade and 0 for a TBA trade. D_{COVID} is a dummy that equals 1 if the trade date is in the COVID shock period, and zero otherwise. Observations are weighted by the logarithm of trade size. Standard errors are clustered at the coupon level and are reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Fourth, our baseline analysis uses coupon fixed effects. Table 9 reports regressions similar to those in Table 5 but using moneyness fixed effects. We observe that all the main findings on changes in prices and positions remain similar and even more statistically significant.

Fifth, our baseline analysis uses only the most liquid front-month TBA contracts. Table 10 reports the baseline results like those in Table 5 but using both front-month and back-month TBA contracts. Note that this affects not only the TBA position measures but also the SP position measures because certain coupon cohorts only show up in the back-month TBA contracts. We find that the main findings on changes in positions are similar to our earlier results.

Table 9. Moneyness Fixed Effect

	Dealers			Customers		MBS Price	
	$V_{i,t}^{TBA}$ (1)	$V_{i,t}^{TBA} - F_{i,t}^{TBA}$ (2)	$V_{i,t}^{SP}$ (3)	$V_{i,t}^{SP} - F_{i,t}^{T+3}$ (4)	$Q_{i,t}$ (5)	OAS (6)	Payup (7)
D_{COVID}	-0.355** (0.125)	-0.471** (0.145)	0.718** (0.237)	0.666** (0.252)	0.865*** (0.195)	24.119** (9.882)	-0.915*** (0.224)
D_{FED1}	0.079 (0.260)	-0.470 (0.253)	1.121** (0.428)	1.081** (0.438)	1.114** (0.381)	48.323*** (3.169)	-1.132*** (0.256)
D_{FED2}	-0.230 (0.444)	-1.884*** (0.475)	1.541** (0.470)	-0.466 (0.359)	1.808** (0.653)	22.021*** (5.765)	-1.178*** (0.250)
D_{FED3}	-0.199 (0.344)	-1.720* (0.799)	0.618*** (0.141)	0.561*** (0.150)	0.479 (0.282)	-32.966*** (8.348)	-0.740*** (0.145)
Moneyness FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Moneyness FE × Quality Differential	No	No	No	No	No	No	Yes
Obs.	520	521	520	521	520	529	528
Adj. R^2	0.180	0.363	0.175	0.119	0.223	0.707	0.727

Notes: The "Pre-COVID Average" row reports the estimated pre-COVID average using regressions on D_{COVID} with an intercept but without the coupon fixed effect and the sample of January 1 to March 13, 2020. The remaining rows report results from regressions on dummy variables for the four sub-periods over January 1 – April 27, 2020 (D_{COVID} , D_{FED1} , D_{FED2} , and D_{FED3}) that equal 1 in the respective sub-period. The dependent variables are dealers' daily net forward purchase amount with customers in column (1), dealers' daily net forward purchase amount with both customers and the Fed in column (2), dealers' daily net cash purchase amount with customers in column (3), dealers' daily net cash purchase amount with both customers and the Fed in column (4), customers' daily gross cash selling amount in column (5), OAS of TBA contracts in column (6), and the payoff in column (7). In the regressions of the OAS and the payoff, the observations are weighted by the logarithm of gross TBA and SP trading volume, while quality differential controls are included only in the payoff regressions. The sample consists of 30-year UMBS with moneyness in the range of [-1%, 4%]. Standard errors are clustered at the moneyness cohort level and reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 10. Including Back-Month TBA Trades

	Dealers				Customers
	$V_{i,t}^{TBA}$ (1)	$V_{i,t}^{TBA} - F_{i,t}^{TBA}$ (2)	$V_{i,t}^{SP}$ (3)	$V_{i,t}^{SP} - F_{i,t}^{T+3}$ (4)	$Q_{i,t}$ (5)
Pre-COVID Average	-0.155* (0.078)	-0.173* (0.086)		0.155** (0.053)	0.808** (0.280)
D_{COVID}	-0.573 (0.419)	-0.561 (0.412)	0.559 (0.333)	0.557 (0.333)	0.597 (0.323)
D_{FED1}	0.221 (0.293)	-0.256* (0.128)	1.075** (0.454)	1.057* (0.454)	1.031** (0.396)
D_{FED2}	0.249 (0.768)	-1.299** (0.541)	1.494** (0.616)	-0.479 (0.283)	1.666* (0.754)
D_{FED3}	0.140 (0.157)	-1.207* (0.563)	0.528*** (0.120)	0.523*** (0.120)	0.242 (0.235)
Coupon FE	Yes	Yes	Yes	Yes	Yes
Obs.	537	537	537	537	537
Adj. R^2	0.005	0.166	0.189	0.110	0.346

Notes: The “Pre-COVID Average” row reports the estimated pre-COVID average using regressions on D_{COVID} with an intercept but without the coupon fixed effect and the sample of January 1 to March 13, 2020. The remaining rows report results from regressions on dummy variables for the four sub-periods over January 1 – April 27, 2020 (D_{COVID} , D_{FED1} , D_{FED2} , and D_{FED3}) that equal 1 in the respective sub-period. The dependent variables are dealers’ daily net forward purchase amount with customers in column (1), dealers’ daily net forward purchase amount with both customers and the Fed in column (2), dealers’ daily net cash purchase amount with customers in column (3), dealers’ daily net cash purchase amount with both customers and the Fed in column (4), and customers’ daily gross cash selling amount in column (5). The sample consists of 30-year UMBS with moneyness in the range of $[-1\%, 4\%]$. Both front-month and back-month TBA contracts and related SP trades are included. Standard errors are clustered at the moneyness cohort level and are reported in parentheses. Significance: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6 Conclusion

The COVID-19 pandemic caused substantial disruptions in most fixed-income markets in March 2020, including MBSs, corporate bonds, municipal bonds, and even Treasuries. In this paper, we provide empirical evidence on the economic channels underlying these market disruptions. Our specific focus is the role of broker-dealers as the key liquidity providers and the Fed as the “dealer of last resort” through its novel implementation of asset purchases to support market functioning. Because dealers usually hedge inventory risk using derivative contracts in the process of liquidity provision, we study both the cash and forward markets of agency MBSs, taking advantage of the institutional structure and data available for this market.

We show that amid customers’ selling to “scramble-for-cash”, dealers provided liquidity by taking inventory in the cash market and hedging inventory risk in the forward market. But the MBS yield spread increased and the cash and forward prices diverged significantly, pointing to substantial constraints and costs associated with dealers’ liquidity provision. The Fed first facilitated dealers’ inventory hedging and then took holdings off dealers’ inventory directly through a novel settlement practice. The latter action had strong effects in reverting the price dislocation. The MBS yield spread dropped immediately, followed by a reversion in the cash-forward price divergence.

Our results not only shed light on COVID-19 market disruptions but also provide the basic facts for the evaluation and potential optimal design of the market-functioning-driven-asset-purchase as the Fed’s new policy tool going forward. A rigorous theoretical framework would be needed to analyze the interactions between dealers and the Fed’s liquidity provision. Cross-market interactions would also be an important extension.

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