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Does the Diversity and Solvency of Authorized Participants Matter for Bond ETF Arbitrage? Evidence from the Dash for Cash Episode

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Does the Diversity and Solvency of Authorized Participants Matter for Bond ETF Arbitrage? Evidence from the dash for cash episode

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Abstract

Authorized participants' (APs) arbitrage in primary markets for ETF shares plays a key role in limiting dislocation in ETF prices. This paper builds a novel dataset of detailed US bond ETF-AP relationships and shows that high AP leverage played a significant role in weakening this arbitrage during the dash-for-cash episode of March 2020. The strength of the arbitrage relationship linking price signals to primary market activity weakened by 77 percent in ETFs related to more leveraged APs versus 64 percent for ETFs linked to less leveraged APs. This effect was particularly strong among those ETFs focusing on less liquid asset classes, relying on APs engaging in high-frequency trading strategies, and unrelated to banks and bank holding companies. Policy announcements by the Federal Reserve did not have had a strong impact in restoring arbitrage strength. AP leverage constraints operated in parallel to constraints faced by lead-market makers in secondary ETF markets, which were more closely related to regulatory capital limits.

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Introduction

Assets managed by Exchange Traded Funds (ETFs) experienced extremely rapid growth during the last decade, with global net assets going from 1.5 to more than 5 trillion US dollars. At the same time ETFs have expanded into a wide set of underlying asset classes, including equities, bonds, and commodities, and into various investment strategies (active, leveraged, etc.). Bond ETFs have experienced one of the fastest sustained expansions, with global net assets going from 200 billion in 2010 to 1.2 trillion by end 2019. This process has greatly increased the set of low-cost, high-liquidity investment vehicles available for institutional and retail investors (Ben-David et al., 2018, Lettau and Madhavan, 2018, among others).

A key feature behind the attractiveness of ETFs is that they provide intraday liquidity to investors. —In contrast to traditional mutual funds, —ETF shares can be traded in secondary markets at a price that, under normal conditions, should not deviate much from the price of the basket of underlying assets in the ETF portfolio (the ETF Net Asset Value or NAV). Thus, through ETFs, investors can nowadays easily gain exposure to portfolios of bonds and other less liquid assets–whose direct access require significant resources and expertise—and can liquidate their positions whenever necessary at posted prices, obtaining intraday access to liquidity.

The mechanism to guarantee intra-day ETF liquidity and to arbitrage differences between an ETF price and NAV that may arise on secondary markets relies on the actions of Authorized Participants (APs). These are institutions that have the right—but not the obligation—to create or redeem ETF shares in primary markets by transforming ETF shares into the basket of underlying securities and vice-versa.[2] By doing this, APs can balance the supply and demand for ETF shares in secondary markets until any difference between the price and NAV of an ETF becomes negligible. Thus, the willingness and ability of APs to engage in primary market arbitrage in response to the price signals observed in secondary markets is key in mitigating the consequences of shocks to ETF supply or demand.

[2] In practice, creation baskets can differ somewhat from the exact basket of underlying securities.

The mechanics of ETF arbitrage and their expansion into less liquid assets have raised concerns about the robustness of the arbitrage mechanism during stress and the potential consequences of the liquidity transformation conducted by ETFs (Dannhauser and Hoseinzade, 2017; Financial Stability Board, 2011; European Central Bank, 2018). A sudden flight to liquidity by bond ETF investors would require APs to engage in a selloff of illiquid securities that may drive their prices away from fundamentals and propagate to other financial intermediaries exposed to the underlying assets. Having a reduced number of APs or relying on APs with little balance sheet space may impair the arbitrage mechanism and lead to significant deviations of ETF prices from the NAV of underlying assets. There is, however, very little research on the behavior of APs, especially during stress periods, and how their characteristics affect their willingness to engage in arbitrage in response to price signals (Pan and Zeng, 2019). This is partly due to the scarce data linking ETFs and APs that could be exploited to study these phenomena.

This paper provides new evidence that solvency constraints of APs associated with a bond ETF matter for the intensity of the arbitrage relationship linking price signals to the creation and redemption of ETF shares. To this end, it constructs a novel and detailed dataset linking each US bond ETF to its APs from US SEC regulatory filings, which is then linked to APs financial statements data. Using these data, the paper provides several key stylized facts of the AP landscape for US bond ETFs and presents econometric evidence of the relationship between the average characteristics of an ETF's APs and the price dislocations and failures in the primary market arbitrage mechanism observed during the episode of large bond ETF redemptions and severe price dislocations observed during the dash-for-cash episode of March 2020.

The results indicate that the intensity of primary market arbitrage weakened significantly during the dash-for-cash episode, falling by 72 percent on average and only partially recovering after the various announcements made by the Federal Reserve in the second half of March 2020. Importantly, the results show that the weakening of arbitrage activity was especially pronounced for ETFs related to relatively more leveraged APs. While the decline in arbitrage intensity for an ETF with average AP leverage at the 25^{th} percentile was of 64 percent, an ETF with average APs leverage at the 75^{th} percentile saw a 77 percent decline in arbitrage intensity. The number of

APs plays some role in strengthening arbitrage during normal times but does not seem to matter for dampening the decline in arbitrage intensity observed during the dash-for-cash. ETFs related to a larger number of APs did not see a smaller decline in arbitrage intensity than peers with a smaller number of APs. Thus, the findings do not support the idea that diversifying the portfolio of APs by contracting with a large number of them would ensure a more robust arbitrage mechanism during periods of market turmoil. Other AP characteristics, like the stock of securities available in their portfolios—a proxy for their ability to absorb securities when redeeming ETF shares—or the excess regulatory capital (related to SEC rule 13-3) do not seem to have mattered for strengthening ETF arbitrage.

The results support previous findings that arbitrage intensity is weaker for ETFs investing in less liquid assets (Pan and Zeng, 2019). ETFs with higher average bid-ask spreads during normal times have a weaker arbitrage mechanism. Although there is no clear evidence that ETFs with wider bid-ask spreads during normal times experience a further weakening of arbitrage during the dash-for cash, results dividing the sample of bond ETFs by segments that are likely related to liquidity show a less significant weakening of the arbitrage mechanism during the dash for cash for ETFs investing in US Treasuries than for those investing in other type of bonds, especially for those related to more leveraged APs. Thus, AP leverage seem to have been an active constraint mainly for ETFs investing in less liquid asset classes.

Further results show that high AP leverage seemed to have been especially important for the weakening of arbitrage when coinciding with a high prevalence of high-frequency traders among an ETF APs. This is consistent with policymakers concerns about the resilience of liquidity provision by these types of market makers in periods of turmoil. In contrast, AP leverage seemed to have been less of a binding constraint during the dash-for-cash for APs that were ultimately related to a bank or bank holding company.

The findings of this paper are robust to a battery of checks including the use of different measures of primary market activity, price signals, time horizons, and to controlling for many alternative channels for the weakening of primary market arbitrage activity.

This paper contributes to several strands of literature. First, it contributes to the literature on limits to arbitrage and intermediary asset pricing by providing novel evidence of the importance of APs balance sheet constraints for their arbitrage activity and ETF prices. The theoretical literature has noticed that real-world arbitrage is not instantaneous nor risk free, and the financial intermediaries that act as professional arbitrageurs need funding and balance sheet space to engage in it (Shleifer and Vishny, 1997; Gromb and Vayanos, 2002). Financial or regulatory constraints that become active will therefore limit intermediaries' ability to conduct arbitrage and lead to persistent deviations of prices from fundamentals or even result in damaging price spirals (Brunnermeier and Pedersen, 2009). Building on these insights a series of papers have unveiled evidence that the financial health of financial intermediaries is a key determinant of asset prices. Adrian et al. (2014) show that the leverage of securities broker-dealers captures the marginal value of wealth of financial intermediaries and can be used to price a broad set of securities. Lewis et al. (2017) find that increases in the funding costs of dealers of corporate bonds backed by the US government lead to higher mispricing of these instruments. Siriwardane (2019) presents evidence that shocks to the capital of CDS protection sellers has an impact on the spreads observed in CDS markets and Jermann (2018) shows that limits to arbitrage can explain the negative spreads observed between the 30-year swap rate and US treasury bond. Focusing on regulatory constraints, Du et al. (2018) show that the passing of several regulations after the global financial crisis—notably the money market fund reform in the US—led to persistent deviations of covered interest parity (CIP) in major currencies. On the opposite direction, Chu et al. (2020) present evidence that the relaxation of short-selling constraints for a broad set of securities leads to a weakening of the manifestation of 11 price anomalies—documented by Stambaugh et al. (2012)—among those securities. This article is the first one to present evidence that AP leverage becomes a binding constraint for their arbitrage activity during stress periods.

The paper also contributes to the broad literature on ETFs and to the recent part of this literature studying the role of APs in ETF pricing. While the literature has recognized the multiple benefits of ETFs in terms of low-cost access to diversified portfolios for retail investors, it has also noticed that ETFs may pose risks. Ben-David et al. (2018) argue that the intra-day liquidity offered by

ETFs may attract high-frequency capital that would not otherwise invest in the underlying securities in the ETF portfolio. Movements in this high-frequency capital would lead to changes in ETF share prices that would elicit movements in the prices of underlying securities through the primary arbitrage mechanism. Consistent with this mechanism, Ben-David et al. (2018) provide evidence that securities with a higher share of ETF ownership are indeed more volatile. Da and Shive (2018) show that ETF ownership is associated with higher comovement of underlying securities, suggesting the possibility of informational herding or of the exposure to a common risk factor—such as the capital of ETF APs—once assets become part of ETF portfolios. Consistently with this finding, Israeli et al. (2017) argues that ETF ownership leads to higher trading costs (expressed as a higher bid-ask spread) and lower benefits of information acquisition. Looking at the consequences of ETF ownership for the liquidity of underlying assets, Agarwal et al. (2018) find that ETF ownership exacerbate the comovement in the liquidity of underlying stocks because of the arbitrage mechanism.

Although most of the existing literature has focused on the consequences of ETF ownership for the pricing of underlying securities, a recent set of papers have started to study how the arbitrage mechanism behind ETF structures affects the pricing of ETF themselves. Evans et al. (2021) argue that ETF's secondary market dealers trying to arbitrage price deviations and to provide liquidity in ETF markets will engage in operational shorting of ETF shares (selling ETF shares that haven't been created yet). While this may increase liquidity in ETF secondary markets, it may also lead to increases in fail-to-deliver for these trades, which they document in the data. Madhavan and Sobczyk (2016) find that price efficiency—the deviation of ETF prices from NAVs—varies significantly across funds and is systematically related to cross-sectional measures of liquidity, with smaller deviations for ETFs investing in more liquid underlying assets. In their view, the price of ETFs investing in illiquid assets may be a better measure of the value of the basket of underlying assets than their NAVs, which for these assets could quickly be stale. Brown et al., (2020) interpret the creation and redemption of ETF shares by APs as signals of non-fundamental demand shocks and, consistently with this idea, find that ETF flows predict future asset returns in both ETF shares and underlying assets. Pan and Zeng (2019) notice that many corporate bond ETF APs are also dealers of the underlying basket of bonds in the ETF and exploit this dual role to provide evidence that shocks to APs balance sheets resulting from their role as bond dealers affect their arbitrage activity in ETF markets. They find that a positive bond flow shock—e.g. an increase in the bonds that are part of an ETF portfolio where the dealer is an AP—lead to ETF creations and vice versa, which is consistent with dealers using their AP role to offload balance sheet imbalances resulting from their dealer activity. Their evidence suggest that the dual dealer-AP role may weaken the arbitrage mechanism by making ETF creation and redemption less sensitive to price signals, which according to their findings is especially relevant for less liquid funds.

This paper complements this literature on several fronts. First, it is the first to directly study how various AP characteristics, especially their leverage but also their trading strategies and ownership, constraint their arbitrage activity during periods of market turmoil, complementing Pan and Zeng (2019)'s findings of balance sheet constraints arising from the dual role of APs. Second, this is the first paper to study the characteristics of primary market arbitrate in the universe of US bond ETFs, an asset class that has become increasingly relevant in the industry and that differs in many respects from the more widely studied segment of equity ETFs. This broad scope also allows for further exploration of the role of underlying asset liquidity in determining the differential role of leverage constraints across types of bond ETFs. Finally, this article presents new evidence that allows disentangling the differential role played by constraints faced by ETFs secondary market makers and primary market APs.

This paper also contributes to the literature on price pressure resulting from funds' redemption shocks. This literature has mostly focused on redemption shocks hitting open-end mutual funds and how the need to liquidate assets to meet these redemptions may lead to non-fundamental movement in the price of asset held by the fund (Coval and Stafford, 2007; Goldstein et al., 2017; Jotikasthira et al., 2012). The literature has also studied whether funds would react to redemption shocks by selling their most liquid or illiquid assets, depending on their expectation of the persistence of the shocks (Morris et al., 2017). In contrast to open-ended mutual funds, an idiosyncratic demand for liquidity by some ETF investors can be met in secondary markets by other investors willing to buy their shares. However, this mechanism is would not be able to deal with an aggregate preference for liquidity or in conditions of market turmoil that lead to an order imbalance in secondary markets. In these cases, the only way to provide liquidity is through primary market activity, which can put pressure on the prices of underlying assets, much as in a mutual fund. The results of this paper show that in conditions of stress primary market activity can become detached from price signals. While these limits to arbitrage could be seen as dampening the transmission of redemption shocks to underlying markets, the disorderly primary market activity observed during this period could also indicate broader spillovers across asset classes.

Finally, this paper is also related to the recent literature trying to understand the sources and transmission of the dislocations observed across several key markets in March 2020, at the onset of the global COVID-19 pandemic (Schrimpf et al., 2020). The evidence presented in this article shows that limits to AP arbitrage related to leverage constraints were an active impediment to ETF primary market arbitrage and therefore contributed to more persistent price dislocations in ETF prices.

The rest of the paper is structured as follows. Section 2 briefly describes the main data sources, data construction, and presents the main stylized facts of the landscape of US bond ETF APs and the relationship between ETFs and APs. Section 3 discusses the main developments in the US bond ETF market during the dash-for-cash episode, including the policy responses by the Fed. Section 4 presents the main results of the paper and robustness checks. Section 5 provides additional results that further explore the mechanism behind the main results and test for alternative explanations. Section 6 concludes.

1. Data and Stylized Facts

This section describes the main data sources and the matching process used to construct the linked ETF-AP database that is used in the analysis. It also presents a series of summary statistics and stylized facts that characterize the AP landscape for US bond ETFs, and the relationship between APs and ETFs.

1.1 Data sources and construction

The analysis relies on detailed daily information on the price of the universe of US domiciled bond ETFs, net asset values (NAVs), primary market activity (captured by changes in the shares outstanding and the net inflows), secondary market activity (turnover), and other fund characteristics (identifiers, domicile, segment, etc.) between March 2019 and May 2020 from Refinitiv. This timespan includes one year of data before the dash-for-cash episode of March 2020 and two months following the implementation of various support measures aimed at stabilizing bond markets—including bond ETFs—by the Federal Reserve in late March and early April 2020. The universe of US domiciled bond ETFs also comes from Refinitiv-Lipper and was obtained by filtering from the universe of Lipper funds all US domiciled ETFs with an asset type corresponding to bonds to obtain a sample of 407 ETFs after dropping a few cases of dual series of the same ETF and cases where the Lipper identifiers did not match with Refinitiv price and NAV data.

This information is complemented with hand-gathered data from ETFs NCEN regulatory filings with the US Securities and Exchange Commission (SEC). Since 2018, all funds registered with SEC under the Investment Company Act of 1940 have to file an annual report where they provide detailed information on various aspects of the fund's functioning, such as the directors of the fund, managers, brokers, data providers, etc.[3] In particular, ETFs are required to identify their Authorized Participants and also list the amount (in US dollars) of creation and redemption of ETF shares conducted by each of them during the previous year. The analysis of this paper focuses on the ETF-AP relationships as of March 2020, which are sourced from the 2020 NCEN filings—usually filed during the first quarter of each year. In a few cases where the 2020 filing was not available, the latest available filing was used.

Data on APs' financial statements as of end 2019 was sourced from Refinitiv and SNL. These data come mostly from regulatory filings that registered broker dealers have to file with the SEC (form X-17A-5). While NCEN identifies the APs by their Legal Entity Identifier (LEI), in many

[3] The new filing forms are form N-PORT and NCEN, which were introduced as part of a modernization plan of reporting forms started by the SEC in 2015 and completed in 2017.

cases this information is incomplete, includes LEIs that are no longer active, or refers to LEIs that do not correspond to the institution named in the corresponding entry. Thus, the matching of data from NCEN forms and SNL relied on a combination of criteria plus a visual verification of the resulting matches. A similar process was required to merge the ETF data from NCEN with that from Refinitiv because the match of the tickers reported in the two sources was incomplete or incorrect. Data on ultimate ownership of APs, used to identify those APs related to a bank or bank-holding company, also come from SNL. APs were classified as having a business model that relied on high frequency trading (HFT) based on industry publications listing the most important names in the HFT landscape.[4]

The final dataset of linked ETFs and APs covers 379 US bond ETFs and 79 APs (69 with balance sheet information), and the matched dataset of ETF daily prices and AP characteristics includes 371 US bond ETFs, representing 91 percent of the Lipper universe and 99 percent of the universe's AUM.

1.2 The landscape of Authorized Participants

Almost all firms named as APs by US domiciled ETFs are investment banks, broker dealers, and capital market firms.[5] Many important names are subsidiaries of US bank holding companies (BHCs), or of large international banks, but there are many relevant BHC-unaffiliated firms that provide broad investment bank services for clients and engage in AP activity. This section presents the main characteristic of these firms.

The average value of APs total assets is about \$75 billion, although it is highly influenced by a few large, bank affiliated APs, since the median assets is much lower at \$25 billion, and the 75$^{\text{th}}$ percentile is at \$60 billion (Table 1, Panel A). As specialized firms, securities are the main AP asset, representing on average about 65 percent of total assets. The share of unpledged securities—

[4] See, for instance https://blog.grainstonelee.com/insight/top-50-hft-firms-and-their-history, https://www.planetcompliance.com/2017/03/26/introduction-hft-industry-top-20-hft-firms-world/, https://www.quora.com/What-are-the-top-high-frequency-trading-firms

[5] Evans et al. (2021) notice that APs are typically market makers, broker dealers or banks. Pan and Zeng, 2019 also emphasize that oftentimes corporate bond ETFs APs are also market makers in the bonds that are targeted by the ETF.

excluding segregated securities or securities pledged as collateral—is about 20 percent, but exhibits important variation, with the interquartile range going from 2 to 24 percent.[6] Average leverage—measured by the debt to equity ratio—is about 15 times but is also highly influenced by some highly leveraged APs, as seen from an interquartile range between 0.8 and 17 times.[7] The final column of the table shows the excess capital ratio, computed as the excess regulatory net capital under SEC rule 15-C3 as a ratio of the minimum required capital.[8] The high level of this ratio is surprising, with average excess capital being about 200 times the regulatory minimum and a median of 28 times. This suggests that this capital requirement is unlikely to be a binding constraint for the action of APs.

Looking at raw correlations, there is no apparent relationship between size and either unpledged securities holdings or leverage across APs (Table 1, Panel B) except for the correlation between unpledged securities holdings and leverage. However, this lack of correlation is mainly driven by the behavior of entities with extreme values for total assets. Indeed, when looking at rank correlations, there is a clear and significant relationship between size and leverage (as in Adrian and Shin, 2014), size and securities holdings, and securities holdings and leverage. Thus, the data suggest that larger APs tend to be more leveraged and have a larger fraction of their overall assets in securities.

1.3 The linked network of ETFs and APs

The network of US bond ETFs and APs obtained from the data is composed of 371 bond ETFs linked to a total of 69 APs. For the typical bond ETF, the average characteristics of the APs with which it relates are reported in Table 2. An entry in this table is obtained by first computing, for

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[6] Total securities include securities purchased to resell, securities borrowed, and securities pledged as collateral. Unpledged securities consider only the securities owned by the dealer, including all securities in the trading, available for sale, held to maturity and other securities categories, but not segregated securities or securities pledged as collateral for broker-dealers and asset managers.

[7] To include all types of non-equity liabilities, leverage is computed as the inverse of the equity to asset ratio minus one.

[8] Specifically, the excess net capital is the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3). This rule requires broker dealers to have enough liquid assets—after applying a proper haircut—to cover their liabilities, plus an extra cushion of additional liquid assets to ensure repayment under additional contingencies, which constitute the net capital.

each ETF, the average of the corresponding characteristic across all its APs, and then taking another average across bond ETFs. This is done for the universe of all bond ETFs and for several segments defined by sector, geographic scope, credit risk, and investment strategy.

The average ETF maintains relationships with 30 APs, although only 4 of them conducted primary trading (creation or redemption of ETF shares) in 2019 (Table 2).[9] The variation in the number of AP relationships across segments is inconsistent with the idea that ETFs investing in illiquid assets enlist more APs to raise the chance that one of them would be able to engage in arbitrage. For instance, ETFs focused on government-issued securities tend to have more APs—and more active APs—than those investing in corporate bonds, which are relatively more illiquid. ETFs that explicitly focus on high-yield bonds also have a smaller number of APs than those with a broader focus. Only when looking at the geographic scope it is the case that funds focused on US bonds have less APs than those focused on emerging market bonds, although the patter reverses when looking at the number of active APs.

For the typical ETF, the leverage of the APs with which it is related is around 21 times, with little variation and no clear pattern across segments. The same applies to the holding of securities, with an average of total securities of around 72 percent of assets and a share of unpledged securities of 16 percent of assets. The excess capital ratio is about 116 and again does not show a clear pattern across segments. For instance, ETFs investing in government bonds have relationships with APs that, on average, have larger excess capital than those APs related to ETFs investing in corporate bonds, although this could be due to the lower and more stable expected haircuts for US Treasuries.

There is, nonetheless, important variation across individual ETFs in all these dimensions (Figure 1). The average leverage of APs across ETFs has a twin peak distribution, with two modes at around 20 and 25 times (Panel A). In contrast, the distribution of the total number of securities is concentrated in a range between 0.6 and 0.8 (Panel B), similarly to the distribution of unpledged securities, which fluctuates between 0.1 and 0.2 (Panel C). Nonetheless, where the distribution of

[9] This is similar to Antoniewicz and Heinrichs (2014) which reports that an ETF has around 5 active APs.

total securities has a fat left tail, the distribution of unpledged securities has a long right tail. The excess capital ratio also has a twin peak distribution with modes around 60 and 220 times (Panel D), as it does the distribution of the total number of APs, with peaks at around 20 and 45 (Panel E). On the other hand, the distribution of active APs—which depends on the decision of APs to engage in primary market arbitrage—is compressed, with most of its mass concentrated below 5 (Panel F). Overall, the figure shows that the distributions of several average AP characteristics across ETFs exhibit a twin-peak shape, which suggests the presence of two clusters of bond ETFs following different strategies in their relation to APs.

2. The dash-for-cash episode and bond ETFs

As news from the global spread of COVID 19 sunk in during late February and early March 2020, firms started drawing on credit lines and investors started exiting all type of risky assets and shifting not only to relatively safe assets but into cash. The underlying causes of the turmoil in fixed income markets has been linked to the forced selling of treasuries by leveraged investors receiving margin calls coupled with the inability of traditional broker-dealers to absorb this unwinding of positions (Schrimpf et al., 2020; International Monetary Fund, 2020) and also to the liquidation of the most liquid assets (usually US Treasuries) by bond mutual funds experiencing large redemptions (Ma et al., 2020). In early March (between March 5$^{\text{th}}$ and 9$^{\text{th}}$ depending on the threshold used) this large-scale unravelling of positions was associated with the breaking of longstanding arbitrage relationships, including in highly liquid US Treasury markets, large price declines in stock markets, withdrawals from mutual funds and ETFs, and a rotation into US government money market funds and out of prime funds.

In this scenario, the US Federal Reserve announced a series of measures aimed at restoring normal market functioning, especially in the US Treasury market, which was severely impacted despite being one of the deepest and most liquid fixed-income markets worldwide. On March 17, the Fed announced the commercial paper fund facility (CPFF), a special-purpose vehicle aimed at backstopping the issuance of commercial paper by eligible issuers, and on March 18 the money market liquidity facility (MMLF), aimed at assisting money market funds meeting withdrawal requests. Policy announcements continued on March 23, when the Fed announced the Term Asset-Backed Securities Loan Facility (TALF), to enable the issuance of asset-backed securities, the Primary Market Corporate Credit Facility (PMCCF) aimed at purchasing new loans and bonds issued by large investment-grade US corporations (including those that had recently lost their investment grade), and the Secondary Market Corporate Credit Facility (SMCCF), to support the PMCCF through secondary markets operations. The SMCCF explicitly allowed for the purchase of shares of ETFs investing in the assets covered by the PMCCF, including a limited fraction of shares of ETFs that target high-yield bonds. These facilities were expanded on April 9, together with the announcement of the Municipal Liquidity Facility. Finally, on March 31, 2020 the Federal Reserve introduced a change to the Supplementary Leverage Ratio (SLR), allowing banks to exclude their holdings of US Treasury securities and reserve deposits at the Federal Reserve from their assets for the purpose of the calculation of their regulatory leverage ratio. This measure had the goal of freeing balance-sheet space and facilitating the intermediation of US Treasuries by banks and primary dealers.

Bond ETFs were severely hit by this episode. Turnover increased importantly, showing widespread activity in secondary markets (Figure 2, Panel A). The gap between bond ETF prices and NAVs widened significantly, reaching a median across ETFs of minus 120 basis points at its trough on March 20 and a weekly average of minus 90 basis points during the same week (Figure 2, Panel B).[10] These are very relevant magnitudes in a market of $1 trillion. Outflows from bond ETFs were very pronounced for some funds, reaching a daily average of almost 2 percent of total net assets the week ending in March 20 in some cases (Figure 2, Panel C). Nonetheless, the figure also shows that median flow across ETFs during that week was zero. A similar picture emerges when looking at the evolution of the growth in ETF shares, where there is a significant destruction of shares for a fraction of ETFs while the median ETF sees no primary market activity (Figure 2, Panel D). These trends only started to reverse after the Federal Reserve announcements of March 23, 2020 and returned to relatively normal levels by early April 2020. These patterns hint that

[10] See also Aramonte and Avalos (2020) for an account of the developments in US and European corporate bond ETFs.

the degree of secondary market activity—reflected in widespread increases in turnover and in the widening of price-NAV gaps—was not followed by a similarly sweeping shifts in primary market activity. The formal econometric results described next will confirm this intuition and the cross-sectional dispersion observed in the various panels of Figure 2 will be key for identifying the role of AP characteristics in explaining these trends.

3. AP characteristics and primary market arbitrage in US bond ETFs during the dash-for-cash

This section studies whether the characteristics of APs and their relationship with ETFs played a role in explaining the dislocations observed in the pricing of bond ETFs during the dash-for-cash episode of March 2020 and following the introduction of relief measures by the US Federal Reserve. To this end, the section presents the results of a series of econometric exercises that rely on a difference-in-difference strategy to test whether AP characteristics affect the strength of ETF primary market arbitrage across three sub-periods:

- Normal times (*Normal*): comprising the six-month period between September 1st, 2019 and March 4, 2020.
- Dash for Cash (*D4C*): between March 5, which is the first day when median price-NAV deviations turn negative and persistent outflows from US bond ETFs start, and March 31, 2020, when the median price-NAV deviation returns to nearly zero.
- Post-Intervention (*Post-int*): between April 1st and May 30th, 2020.

Since these sub-periods are arbitrarily defined, the analysis will study the sensitivity of the main findings to changes in these specific dates, as well as to using broad indicators of market stress, like the CBOE VIX or the 30-year US Treasury swap spread (a more specific measure of stress in US bond markets) instead of period dummies.

3.1 Econometric Approach

The following econometric specification will be used to test for the differential impact of AP characteristics on ETF arbitrage intensity during distress times:

$$
\begin{aligned}
&Primary\ Activity_{i,t} \\
&\quad = \theta_0 + \theta_i + \theta_t + \beta_0 PNAV_{i,t} + \beta_D PNAV_{i,t} \times D4C_t + \beta_P PNAV_{i,t} \times PostInt_t \\
&\quad + \gamma_D AP_i \times D4C_t + \gamma_P AP_i \times PostInt_t + \delta_o PNAV_{i,t} \times AP_i \\
&\quad + \delta_D PNAV_{i,t} \times AP_i \times D4C_t + \delta_P PNAV_{i,t} \times AP_i \times PostInt_t + \epsilon_{i,t}
\end{aligned} \tag{1}
$$

Where $Primary\ Activity_{i,t}$ is a measure of the primary market activity experienced by ETF i in day t. $PNAV_{i,t}$ is the difference between the price and the NAV of ETF i at time t (expressed as a fraction of the contemporaneous NAV). In the baseline specification, primary market activity will be captured by the net flows into the ETF between day t—when the price signal is observed and the creation or redemption of shares could be ordered by an AP—and day $t + h$ when the ETF shares are effectively created or redeemed. As discussed in detail below, $h = 2$ will be used as benchmark because of standard industry practice but other horizons will be reported for robustness. Further analysis will use the growth in the number of shares an alternative measure of primary market activity.[11] The variables $D4C_t$ and $PostInt_t$ are dummy variables that take the value 1 when t falls within the dash-for-cash and post-intervention periods, respectively, as defined above. The characteristics of ETF's i authorized participants, such as their number, average leverage, etc. are captured in the variable(s) AP_i. The specification includes fund and time fixed effects that absorb non-parametrically the potential effect of unobserved fund characteristics and of common shocks affecting all bond ETFs. Thus, the identification of the key coefficients comes exclusively from the within fund, cross-sectional variation of the data. Errors will be clustered at the ETF level to allow for arbitrary serial correlation within an ETF.[12]

In this specification, the coefficient β_0 captures the strength of the primary market arbitrage mechanism as it measures whether an ETF with price above its NAV experiences net inflows associated with the creation of ETF shares and vice-versa, and the coefficients β_D and β_P test

[11] There are pros and cons of using flows and growth rates. Flows as a share of TNAs seem to be less affected by outliers, with some extreme values observed for growth rates of outstanding shares even after winsorization. The main drawback of flows is that they are influenced by prices. The literature is split on what measure to use as an indicator of primary market activity. For instance, Pan and Zeng (2019) use the growth rate of outstanding shares and Brown et al., (2020) the net flows.

[12] Relaxing this assumption to use Driscoll and Kraay (1998) standard errors yields higher statistical significance.

whether the strength of this relationship changes during the dash-for-cash and post-intervention periods. The γ coefficients controls for ETF-AP matching—such as the possibility that growing ETFs could select APs with certain characteristics—including for the chance that such matching could be cyclical. The key parameters of interest are the δs, which captures how AP characteristics affect the strength of the arbitrage mechanism and whether this relationship varies across periods. In particular, the coefficient δ_D tests whether a higher value of an AP characteristic leads to a strengthening or weakening of the arbitrage relationship during a period of stress, like the dash-for-cash. The coefficient δ_P would test whether the announcements of the Fed led to a normalization of the arbitrage relationship relative to normal times.

The use of a difference-in-difference strategy and the saturation with fixed effects permit a causal interpretation of the key coefficients under relatively mild assumptions. There are two types of concerns about the causal interpretation of the relationships obtained by estimating equation (1). The first concern is that the price-NAV deviation observed for an ETF could be exogenous to the growth in its shares, and the second is whether the endogenous selection of APs into ETFs could be driving the observed results for the role of AP characteristics.

The timing of the ETF arbitrage mechanism and the difference-in-difference approach help ease the endogeneity concerns. There is no mechanic simultaneity bias in Equation (1), since the analysis relates the secondary market ETF price signals with the adjustments in the supply of ETF shares in primary markets, which take place with a lag. There is no clear consensus in the literature on the length of this lag with some industry publications suggesting a lag of two to three days (Antoniewicz and Heinrichs, 2014) and Brown et al. (2020) arguing for a T to T+1 but acknowledging that this varies across ETFs and that industry practice allows for belated settlement.[13] This study follows the ETF timeline as described by the DTCC, where most US traded ETFs are settled and cleared, which specifies a T+2 settlement date for ETFs cleared

[13] In 2017 the SEC shortened the settlement period for ETF trades from three to two days (T+2). While this is not directly related to primary market creation/redemption of ETF shares, it puts a constraint on the ability of market makers to rely on AP future creation or destruction of units for contemporaneous trading of ETF shares not yet available.

through the NSCC.[14] Regardless, the mechanics of the process are such that the price signal precedes the creation or redemption of ETF shares. Of course, it could still be the case that the expected future creation or destruction of shares could lead to a contemporaneous price correction. However, the focus of this paper is not in identifying whether a change in PNAV causes a change in ETF flows but on whether changes in the strength of arbitrage between normal times and stress periods depend on AP characteristics. This identification simply requires that any potential forward-looking endogeneity problem is constant across periods and unrelated to AP characteristics. The relation with AP characteristics is unlikely as the relation between future creation/destruction of shares and contemporaneous price is determined in secondary markets where APs do not play a central role. Furthermore, even if this were an issue, identifying how AP characteristics affect the arbitrage relationship across periods, only requires that any endogenous deviation from the assumption of parallel trends across characteristics be constant across periods. Thus, while it is not possible to fully rule out the possibility of endogeneity the key coefficient has a causal interpretation under mild assumptions.

The econometric approach, which saturates the model with fixed effects, also eases concerns about the consequences that the non-random matching of APs to ETFs could have on the coefficients capturing the role of AP characteristics. For instance, if more leveraged APs matched with expanding ETFs the data would show a positive association between ETF inflows and AP leverage that is fully driven by the matching process. The inclusion of ETF fixed effects in the econometric specification would fully address this concern by absorbing the average relationship between leverage and flows. The possibility of a more complex form of matching on an AP characteristic that affects its average response to price signals is addressed by the differences-in-differences approach. Following with the previous example, suppose that more leveraged APs use their balance sheet very efficiently and have high-risk tolerance, so they respond strongly to a price signal by quickly creating or redeeming shares. In this case, it would be possible to find that a higher leverage is associated with a stronger arbitrage mechanism (a positive δ_0 coefficient) and

[14] The complete process is described in detail at https://dtcclearning.com/content/220-equities-clearing/exchange-traded-fund-etf/about-etf/3610-etf-lifecycle-video-etf-timeline.html

conclude that leverage is not a constrain to AP arbitrage. By focusing the analysis on the differential role of a given AP characteristic in explaining ETF arbitrage in conditions of market stress relative to normal times (δ_D), the econometric approach controls for this form of matching if any non-random matching related to AP willingness to arbitrage does not change across states.

3.2 Results

3.2.1 Baseline Specification

Before turning to the detailed econometric results, Figure 3 gives a first look at the data that helps understanding the source of the main finding of the paper. Each of the panels shows a scatterplot of the cumulative flows into ETFs between t and $t+2$ against the price-NAV deviation observed at time t for different groups of bond ETFs and time periods. Instead of reporting the full scatterplots, the figures group all funds into 40 equally sized ordered bins across price-NAV deviations and reports the average cumulative flows within each bin.[15]

Panel A of Figure 3 shows the relationship between these two variables for ETFs related to high-leverage APs across the three subperiods of analysis.[16] It clearly shows that the slope of the relationship between the price signal and the primary market activity measure flattens importantly during the dash-for-cash period—relative to normal times—and remains flat in the period following the Federal Reserve announcements. This is consistent with a weakening of the arbitrage mechanism during this period for this type of ETFs. In contrast, the slope of the arbitrage relationship remains largely unaltered across periods for ETFs related to APs with relatively low leverage (Panel B). It is this change in the slope of the relationship between the price signal and primary market activity across funds differentially exposed to leveraged APs and across periods that is at the core of the main findings of this paper.

Table 3 presents the results obtained for the baseline model for four different horizons of net inflows going from $t+1$ to $t+4$, corresponding to alternative timings of the settlement of creation and redemption orders. Although, as explained above, the standard timing for settlement should

[15] This was done using Stata's binscatter function.

[16] High leverage AP ETFs are those whose average AP leverage is above the 75th percentile across ETFs and low leverage those below the corresponding 25th percentile.

be around $t + 2$, these results help dispel concerns about the sensitivity of findings to this particular assumption.[17] For space reasons, the table only reports the coefficients related to the level or interactions with $PNAV$, which are the coefficients of interest of this paper. Nonetheless, all the other coefficients (for instance those of the interaction between AP characteristics and the different sub-periods) are included in the regressions.

The first column of each panel presents a simple regression that tests for the change of the strength of the arbitrage relationship across periods. These columns show that, regardless of the specific horizon, there is a significant weakening of the arbitrage relationship during the dash for cash period. While in normal times a 1 percent difference between an ETF price and NAV—as a share of the NAV—is associated with flows of about 0.5 percent of total net assets, during the dash for cash this difference results in flows of less than 0.2 percent of total net assets. This represents a 66 to 73 percent, statistically significant decline in the slope of the arbitrage relationship, depending on the specification. This situation experiences only a minor reverse after the announcements made by the Federal Reserve in the second half of March and early April 2020. While the announcements seem to clearly have stabilized markets—leading for instance to a closing of price-NAV gaps—the results suggest that they did not achieve this by significantly jumpstarting ETF arbitrage.

Columns (2) to (5) of each panel show the results of our baseline regressions that allow the strength of the arbitrage relationship to vary with AP characteristics. Each of the columns reports results for a different characteristic, starting with leverage (column (2)), number of authorized participants (column (3)), the amount of unpledged securities as a share of total assets (column (4)), and the excess regulatory capital (column (5)).

The results suggest that primary market activity of more levered funds tend to respond more strongly to price signals during normal times, which could be the result of endogenous matching.[18] However, ETFs related to more leveraged APs saw their arbitrage relationship weakening

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[17] Results with contemporaneous variables are similar and exhibit stronger significance (unreported).

[18] It should be noticed that this is not driven by a purely mechanical relationship where higher primary market activity results in higher AP leverage because the leverage of APs is measured using balance sheet data as of December 2019.

substantially and significantly more than their peers related to less leveraged funds during the dash for cash distress. While during normal times the difference in the slope of the arbitrage relationship between high leverage (percentile 75 of leverage) and low leverage (percentile 25) was of 0.32 and statistically significant, during the dash for cash that difference fell to 0.01 and became statistically insignificant. Another way of looking at this is that the strength of the arbitrage relationship fell in 64 percent for an ETF with low AP leverage and in 77 percent for an ETF with high AP leverage. Thus, these results indicate that a higher leverage of the APs related to an ETF resulted in a significantly larger weakening of the arbitrage mechanism during distress.[19] During the period following the announcements of the Fed there is a slight recovery of the strength of arbitrage, but it remains subdued and related to AP leverage.

Other AP characteristics do not seem to matter much for the strength of primary arbitrage. Having a higher number of APs seem to strengthen the arbitrage relationship during normal times—albeit not at standard levels of statistical significance—but not during stress periods (Column (2)).[20] In fact, the interaction coefficient is in this case negative, suggesting that the arbitrage relationship weakened relatively more for ETFs with a larger number of APs. Nonetheless, the latter result is also not statistically significant. Something similar happens with a higher excess capital of authorized participants (Column (5)), which is associated with a stronger arbitrage during normal times but results in significantly weaker arbitrage during stress at the baseline horizon (T+2). However, the significance of this latter result disappears at longer horizons. The share of unpledged securities seems to play no role whatsoever in mediating the strength of the arbitrage relationship.[21]

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[19] This finding is consistent with Adrian et al. (2017) who document that bonds traded by more leveraged dealers were more liquid during normal times but that this relationship reverses during stress.

[20] The result for the relationship during normal times turns significant when using the growth in the number of shares, as it is shown in Table 7 below.

[21] Additional results in Table 7 show that the number of APs and excess capital have a significant relationship to arbitrage activity during normal times when activity is measured by the growth in the number of outstanding shares. The interaction terms with the dummies for dash for cash and post-interventions are not significant in most periods, nonetheless (unreported).

Overall, the baseline results show an economic and statistically significant effect of the average leverage of the APs related to a bond ETF on the strength of the arbitrage mechanism of that fund during periods of distress. This effect is present and statistically significant at different horizons—covering uncertainty on the specific timing of the creation or destruction of ETF shares—and seems distinctly related to AP leverage, being largely absent for other AP characteristics. These results are consistent with APs facing limits to arbitrage related to their overall balance sheet space rather than specific dimensions, like the availability of regulatory capital to cover margin calls that is captured in the excess capital measure.

3.2.2 Is it Truly AP Leverage?

A first concern with the baseline results is that the average characteristics of the APs serving a given bond ETF are likely correlated, and considering each one in isolation—as in Table 3—could lead to misleading conclusions. To ease these concerns, regressions in Table 4 horserace the various dimensions of AP characteristics. The table only reports results for the baseline timing of T+2, but results are similar at other horizons. Columns (1) to (3) sequentially horserace AP leverage against the other three dimensions of AP characteristics and columns (5) and (6) do so against two and three of them simultaneously. The results clearly show that AP leverage is the only characteristic that significantly affects the strength of arbitrage during market stress periods, regardless of the specific measure or combination of measures against which it is compared.

As discussed above, a potential concern with the causal interpretation of the coefficients of the triple interaction between $PNAV$, $AP\ Characteristic$, and $D4C$ is the endogenous matching. While the empirical strategy controls for time-invariant endogenous matching, it does not control for the possibility that the matching of more leveraged APs to certain ETFs could take place conditional on a characteristic that weakens the arbitrage mechanism during periods of distress. This could be the case, for instance, if more leveraged APs matched with more illiquid ETFs, since these are more likely to experience a weakened arbitrage during distress episodes (Dannhauser and Hoseinzade, 2017; Pan and Zeng, 2019). Although this type of matching would go against the standard belief that, being more conscious of their limited balance sheet space, more leveraged APs serve more liquid ETFs, it is important to check that this is not spuriously driving the results.

Another reason to control for the illiquidity of the assets is that some authors have emphasized that, in illiquid assets, price-NAV deviations may reflect stale NAVs rather than non-fundamental arbitrage opportunities (Madhavan and Sobczyk, 2014; Aramonte and Avalos, 2020). Thus, to the extent that more leveraged APs are matched to ETFs trading in less liquid assets, the weakened arbitrage during the dash-for-cash may simply reflect the lack of arbitrage opportunities in those assets because of the stale NAVs. To this end, regressions presented in Table 5 add to the baseline specification a series of interactions between the price signal and a proxy for the illiquidity of each ETF across subperiods. The illiquidity of each ETF is captured by its average bid-ask spread during the six-month period ahead of the beginning of the estimation sample (i.e. from March 1, 2019 to September 1, 2019) and is therefore considered as a constant characteristic for each ETF. The results indicate that, on average, the arbitrage mechanism is weaker for less liquid ETFs, consistently with previous findings in the literature (Ben-David et al., 2018; Pan and Zeng, 2019). However, these funds experience no further weakening of arbitrage during the dash for cash episode, which goes somewhat against those findings to the extent that the dash for cash triggered a tightening of arbitrage constraints. Most importantly, the findings regarding the relationship between AP leverage and the strength of the arbitrage during stress remain unaltered both statistically and economically.

The stylized facts reported in section 2 showed that although most ETFs have a large number of AP relationships, only a few APs actively engage in primary arbitrage in a given year. This raises the question of whether the average characteristics of the overall set of APs to which an ETF is related that matter for the strength of arbitrage or only the average characteristics of those APs that have been active in the past, perhaps signaling a stronger commitment to arbitrage in that market. Results in Table 6 show that there is no significant relationship of the strength of AP arbitrage with the average characteristic of active APs. This indicates that having been active in the past does not signal a stronger willingness to arbitrage in the future and that it is the overall pool of APs that is relevant for the maintenance of primary arbitrage.

3.3 Robustness

Although the variables chosen to proxy for the key variables of the econometric approach—primary market activity and price signal—are reasonable and have been used in the literature, they are still arbitrary choices. The regressions reported in this sub-section check the robustness of the main results to the consideration of alternative and equally reasonable proxies for these variables.

The baseline measure of primary activity is the net inflow of money into an ETF. This measure has the advantage of comparability across ETFs, since all flows are expressed in US dollars before being normalized by lagged total net assets. Its main disadvantage is that it is influenced by movements in the prices at which the flows take place. To check for the relevance of this issue, Panel A of Table 7 reproduces the same regressions reported in baseline Table 3 for a T+2 horizon but using a quantity-based measure of primary market activity, namely the average annual growth in ETF shares at different horizons. The results are very similar to those reported in the baseline table. The average leverage of the APs related to an ETF is an economically and statistically significant determinant of the strength of the arbitrage mechanism during distress. Results at other horizons are also in line with those reported in the baseline regressions (unreported).

The use of price-NAV deviations as a price signal for primary market arbitrage is simple and standard in the literature (Madhavan and Sobczyk, 2016; Evans et al., 2021; Pan and Zeng, 2019; Aramonte and Avalos, 2020). Its simplicity, however, has its drawbacks. Perhaps the main one is whether it adequately captures the prices at which trades would be actually executed. In fact, this measure assumes that the buying or selling of ETF shares takes place at the closing price observed at end of the day and that the purchasing or selling of the underlying basket would take place at the end-of-day NAV. Both assumptions could deviate from reality. For instance, APs may respond to price signals observed during the day that may differ from the closing price and may buy or sell at bid and ask prices that differ from the mid-price captured in $PNAV$. Similarly, they may have to incur in spreads when buying or selling the basket of underlying securities, or the NAV of the creation or redemption basket may differ from the NAV of the portfolio because of basket management conducted by ETF sponsors (Todorov, 2021). To check for these possibilities, the regressions reported in Panel B of Table 7 use a different measure of price signal that can be constructed based on the daily information used in this paper. The measure—labeled Price-NAV arbitrage—considers the case when the AP buys ETF shares at the Ask price and sells at the Buy price, and when the trading of the underlying basket is subject to a spread that is proportional to the average spread of the ETF during normal times. Thus, the measure corresponds to:

$$Price - NAV\ Arbitrage = \begin{cases} PNAV\ Buy & if\ PNAV\ Buy \geq 0 \\ PNAV\ Sell & if\ PNAV\ Sell \leq 0 \end{cases},$$

where

$$PNAV\ Buy = \frac{Ask\ Price\ -\ NAV(1 - NBAspread)}{NAV},$$

and

$$PNAV\ Sell = \frac{Bid\ Price -\ NAV(1 + NBAspread)}{NAV},$$

with $NBAspread$ been the average bid-ask spread of the ETF during normal times. Thus, this price recognizes that some arbitrages that appear profitable assuming that the AP buys and sells ETFs at the closing price and the underlying basket at NAV may not be profitable and therefore not trigger primary market activity. The measure assumes that APs may have to trade at the most unfavorable conditions on both ends of the trade (based on end of day prices). Of course, APs are oftentimes also lead market makers and may be able to trade at better conditions that those reflected in $PNAV$, or respond to intraday prices, but checking for those possibilities requires data that are not available for this study.

Results based on price-NAV arbitrage, presented in Panel B of Table 7, are somewhat stronger in terms of statistical significance than the baseline results. They confirm the importance of AP leverage in weakening the arbitrage relationship during stress periods, although some of the counterintuitive results for the number of APs and excess capital now turn statistically significant.[22]

In sum, the results reported in this subsection show that the main finding of this paper regarding the role of AP leverage in weakening the ETF arbitrage relationship is not crucially driven by the specific choice of variables used in the baseline specification and is robust to reasonable

[22] The significance of the coefficients associated with excess capital disappears in regressions including both leverage and excess regulatory capital.

modifications in the measures of primary market activity and price signals. The next section, which presents additional results that explore the mechanism behind the baseline findings and will also offer additional robustness results to alternative explanations.

4. Exploring the mechanism

Having documented the robustness of the main findings, the analysis now turns to explore different dimensions of the ETF arbitrage mechanism that can shed some further light on the limits to arbitrage faced by APs during distress periods. In particular, it studies whether the weaker relationship between price signals and primary market activity during periods of distress could be driven by faster price signal corrections or NAV adjustments and how the strength of the arbitrage relationship varies across additional dimensions of market stress, ETF segments, and further characteristics of APs and ETF lead market makers.

4.1 Is equilibrium restored through NAV adjustment?

The baseline results show that the response of flows or the growth of shares to price signals was weakened during the turmoil associated with the dash for cash episode, especially for ETFs whose APs were relatively more leveraged, which is interpreted as a sign of impaired arbitrage. An alternative explanation of the finding could be that, during this period, successful arbitrage required a smaller quantity response for those ETFs. This could happen if, for instance, NAVs reacted faster and more strongly to ETF price deviations. If this were the case, a given price-NAV deviation would correct by adjustments in NAV rather than changes in the overall quantity of ETF shares, thus requiring less creation or redemption of shares and an observed lower elasticity of primary market activity to prices.

If the lower elasticity of primary market activity to price signals were the outcome of a secondary market that does require smaller adjustments in quantities to regain equilibrium, once should observe that the persistence of price-NAV deviations should decline during this period, reflecting the restauration of equilibrium despite the smaller quantity response resulting from the initial price signal. Results in Panel A of Table 8, which estimate the persistence of price-NAV deviations at T+2 show that, on the contrary, the persistence of dislocations increased overall during the dash-for-cash episode: the coefficient associated with the interaction of the lagged price signal and the dash for cash dummy is positive and significant. There is also no significant evidence of a relatively lower persistence for ETFs with more leveraged APs.

It is also possible to look directly at the response of future NAV adjustments to price signals. Results in Panel B of Table 8 show that, overall, the average growth in NAVs between T and T+2 is positively related to price-NAV deviations, indicating that usually part of the adjustments take place through NAVs. However there is no significant difference in the response of NAVs to price signals during the dash for cash, and it is significantly smaller during the post-intervention period. Furthermore, the coefficients that capture the differential response of NAVs to price signals during these periods for ETFs with relatively more leveraged APs are negative—indicating a smaller response—and not statistically significant (although the coefficient for the post-intervention interaction is very close to be significant at the 10% level).

The evidence, therefore, indicates that the lower elasticity of primary market activity to price signals, especially among ETFs with more leveraged APs, was not the result of a secondary market that regained equilibrium through a faster NAV reaction. Nonetheless, the lack of a differentially larger persistence of price-NAV deviations for those funds suggests that, at least in relative terms, other force counterbalanced their smaller quantity response to result in a similar degree of persistence. While it is not possible to show it directly, this is likely related to a relatively larger rebound in demand among these funds.

4.2 The timing of the dash for cash and the impact of policies

The analysis has relied on the timing of the dislocations observed in bond ETFs and the announcement of the measures implemented by the Federal Reserve to identify broad periods of stress. This assumption can be relaxed in two ways. First, allowing for more granularity in the segmenting of the stress period. Second, by using continuous measures of stress in the US markets like the VIX or the MOVE.

The results reported in Panel A of Table 9 segment the dash for cash episode in four different ways: (i) allowing the period to start on February 20, the first day where there is a significant increase in the VIX (column (1)); (ii) starting the dash-for-cash on March 9, mentioned by some authors as the beginning of major disturbances in US fixed income markets (Schrimpf et al., 2020); (iii) ending the dash-for-cash episode on March 17, which is the date when the primary dealer credit facility was announced (PDCF), followed next day by the mutual fund liquidity facility (MMLF); and (iv) ending the dash-for-cash period on March 23rd, when the primary and secondary market credit facilities were announced (PMCCF and SMCCF, respectively). The results show that regardless of the exact timing considered for the beginning or ending of the dash for cash episode, AP leverage remains a significant driver of the strength of the arbitrage relationship. The weakening of arbitrage related to AP leverage was more intense in early March, as the results with a late start of the dash-for-cash episode (March 9) have a somewhat smaller coefficient. As in the baseline case, the coefficient for the interaction of the price signal and AP leverage is slightly smaller in magnitude in the post-intervention period, although in most specifications it is not significantly different from the interaction coefficient during the dash for cash. The only exception occurs when the end of the dash for cash (and hence the beginning of the post intervention period) is set at March 23, the day in which the primary and secondary corporate credit facility were announced. This indicates that among all the measures announced by the Federal Reserve, this is the only one that seems to have a measurable impact in strengthening the arbitrage of the leveraged APs. Nonetheless, as in all cases, the improvement is not enough to bring the strength of the arbitrage back to its normal levels.

Panel B of Table 9 reports the results obtained when using four different continuous measures of market distress instead of relying on period dummies: (i) the CBOE VIX—a widely used measure of risk appetite and market turmoil; (ii) the yield spread between the 30 year US treasury bond and the corresponding swap rate, which captures dislocation in US Treasury markets (see (Schrimpf et al., 2020)); (iii) the Merrill Lynch MOVE bond market volatility index, a simile of the VIX for bond markets, and (iv) the Chicago Fed National Financial Condition Index (NFCI), a broad gauge of conditions in US financial markets. Across the different measures, the results confirm the role of AP leverage in weakening the arbitrage mechanism during periods of heightened market turmoil. In most cases, there is also a clear negative relation between market turmoil and an overall weakening of arbitrage—regardless of AP leverage, with the only exception occurring for the case of the MOVE, where the coefficient has the opposite sign.

The evolving role of AP leverage in altering the strength of the arbitrage relationship during the market turmoil of March, captured in the previous set of regressions, can also be visualized using a non-parametric approach. To this end, a purely cross-sectional version of Equation (1) can be estimated for each day of the period, obtaining each time two estimated coefficients: one for the cross-sectional relation between the price signal and primary market activity, and another for the interaction of the price signal and leverage in the cross-section. The two panels of Figure 4 plot the time series of these two coefficients—along with their cross-sectional confidence bands—and show how the strength of the arbitrage relationship and the amplifying role of leverage varied throughout this period. The top panel shows that the overall strength of the arbitrage relationship collapsed in early March and since then had a gradual recovery, but to a level that is much lower than the initial. The bottom panel shows that this weakening was especially pronounced for funds with relatively leveraged APs, as the decline in early March in the interaction coefficient is especially pronounced—even becoming significantly negative in the cross section. The recovery is also gradual and doesn't seem to be especially influenced by the measures announced by the Federal Reserve, except for a small discrete jump following the announcement of the PMCCF and the SMCCF, which is consistent with the results obtained when ending the dash for cash episode on that particular day. The two figures also show the evolution of the VIX during this period, which is negatively correlated with the coefficients capturing the strength of arbitrage. This evolution can also explain the persistent weakening of arbitrage even after the announcements of the Federal Reserve, since the VIX declined importantly following its spike observed in early March but moved to a level that was much higher than that seen in mid-February.

4.3 Is the relation similar across segments of the bond ETF ecosystem?

The analysis so far has looked at the set of US domiciled bond ETFs as a whole. Nonetheless, various types of ETFs coexist within this ecosystem and the extent to which AP characteristics limit arbitrage may vary across these types. For instance, a number of ETF specialize in bonds issued by the US Treasury, which tend to trade in large and deep markets, while other focus on Municipal bond ETFs or in corporate and emerging market bonds which are much more illiquid. To the extent that these more illiquid categories require more use of balance sheet space, the constraints posed by AP leverage may be more binding for the latter than the former. On the other hand, as previously discussed, the dash-for-cash episode was unusual in resulting in dislocations in US Treasury markets, such as the widening of spreads between US Treasury cash and future markets yields or between US Treasuries and swap yields (swap spread), so the higher liquidity usually seen for US government bonds during normal times might have been absent during this episode.

Results reported in Table 10 show that AP leverage constraints seem to have been binding mainly for ETFs investing in US Municipal bonds and other non-US-government bonds. Panel A shows that AP leverage does not play a significant role in weakening arbitrage among ETFs focused on US Treasury bonds. In contrast, the number of APs and the degree of excess capital seem to matter and to do it in the direction one would have expected: US Treasury ETFs with a larger number of APs and with larger amounts of excess regulatory capital had a relatively stronger arbitrage during the dash for cash episode and post Fed announcements. Results for US Municipal bond ETFs and for ETFs with a balanced mandate or investing in other type of bonds (corporate bonds and non-US sovereign bonds), are similar to those reported for the whole sample. In particular, the role of leverage seems especially pronounced for US Municipal bond ETFs, as well as the counterintuitive results for the number of APs and excess capital. The last two characteristics seem to play no role in the weakening of the ETF arbitrage for the rest of ETFs (Panel C).

4.4 Whose constraints matter the most? APs versus Market Makers

APs play a crucial role in the ETF ecosystem. However, they are not the only players. In addition to the ETF sponsors, which effectively run the fund, most ETF count with lead market makers (LLM) or designated liquidity providers. These are also usually investment banks and security markets firms that have a commitment to make markets and offer quotes in the secondary markets where the funds are traded. Oftentimes, the same firms acting as APs are also market makers for ETFs and for the underlying securities that constitute the ETF portfolio (Pan and Zeng, 2019).

While market makers do not directly operate in primary ETF markets, they frequently engage with APs and use their services for the creation or redemption of ETF shares by bringing either the ETF shares or the underlying securities, depending on the action. They can also actively engage in arbitrage by filling the order imbalance in the ETF market and creating a short interest in the hope of being able to create or redeem the traded shares by the time of settlement (Evans et al., 2021). Thus, a stressed or constrained market maker may also impair the arbitrage mechanism.

The role played by the financial health of lead market makers can be assessed by allowing the strength of arbitrage to depend on various characteristics of these institutions and testing if they significantly affect the strength of the arbitrage relationship. This exercise would also shed light on whether the role identified for AP characteristics may be simply capturing the role of LMMs, since there is some overlap between the two roles.

The regressions reported in Table 11 control for the role of LMM characteristics in two ways. First, results presented in columns (1) to (3) add to the baseline specification the interaction of various LMM balance sheet ratios with the price signal across sub-periods. The selected ratios are the same used for the characteristics of APs: leverage, the ratio of unpledged securities to assets, and the regulatory excess capital ratio. Data on the institution acting as LMM for each AP come from NYSE ARCA. Data on the balance sheets of these institutions are sourced from SNL and correspond to the X-17A-5 filing as of December 2019. Second, results reported in Column (4) capture the time varying health of LMM balance sheet using the contemporaneous bid-ask spread of the ETF in secondary markets. Although there is no publicly available high-frequency information on balance sheet constraints of LMM, a constrained and stressed market maker will tend to charge wider spreads (Comerton-Forde et al., 2010; Adrian et al., 2013; Adrian et al., 2017). Thus, the width of the bid-ask spread for an ETF could be used as a proxy for the stress of the market maker for that particular ETF on a given date. Of course, this is an imperfect measure, as the spreads can widen for other reasons, such as increased uncertainty or increased illiquidity in the underlying assets in the ETF portfolio, but nonetheless, it can shed some light on the relevance of this channel.

The results show that several LMM characteristics matter for the strength of the arbitrage mechanism. In contrast to the findings for AP characteristics, LMM leverage does not seem to play a role in weakening ETF arbitrage. However, both a higher share of unpledged securities and a higher excess regulatory capital ratio strengthen arbitrage during stress periods. In contrast, during normal times a higher excess capital ratio weakens arbitrage, somewhat similar to the result obtained for higher AP leverage, which is consistent with previous findings that assets intermediated by more leveraged dealers are more liquid during normal times but not during stress (Adrian et al., 2017). Results using the contemporaneous bid-ask spread as a gauge of LMM health confirm that a higher spread is related to weakened arbitrage, but there is no significant additional impact during stress. Importantly, the key result of AP leverage weakening arbitrage during distress remains significant across specifications, confirming that it is not capturing LMM characteristics nor trivially driven by events taking place in secondary markets.

4.5 Does the type of AP matter?

Results have so far documented the importance of AP leverage in the weakening of the arbitrage mechanism during stress periods. However, they document the role of high leverage for the average bond ETF and average AP related to that ETF. The regressions reported in this section turn to the question of whether high leverage is especially harmful for arbitrage for certain types of APs. They explore five dimensions of AP heterogeneity. First, firms relying on high-frequency trading strategies (HFT) have become increasingly relevant players in the bond ETF space, with the average share of APs engaging in HFT raising from 12 to 16 percent in the last three years for the typical bond ETF. HFT firms tend to use sophisticated algorithms to arbitrage and to follow a business model with little inventory and limited balance sheet space (Deutshe Bank, 2011), which has raised concerns among policymakers about the ability or willingness of these players to step in to provide liquidity under stressed conditions. Second, many APs are firms that are ultimately owned by a bank or part of a bank holding company. These APs might be able to obtain support from their parent when facing balance sheet constraints to arbitrage, making AP leverage a less relevant constraint for primary arbitrage. Third, one of the markets that experienced the largest dislocations during the dash for cash was the US Municipal bond market, where secondary market liquidity mostly disappeared. It is thus possible that leverage constraints were especially important for APs operating in this segment—as documented in Table 10. Since a given AP typically offers services to many ETFs, ETFs whose APs had an important role in the US Muni bond market could have also experienced important distress, especially when highly leveraged. Finally, the ETF-AP relationships can be summarized in a network where APs importance would depend on their position in the network (how many ETFs they relate to and how closely related are those to other APs and ETFs). An AP linked to many ETFs and also highly leveraged could have had to choose where to deploy its balance sheet space and leave other ETFs with a more limited primary market arbitrage. The analysis considers two measures of AP network importance: its degree and its betweenness centrality.[23]

Regressions reported in Table 12 explore each of these channels by adding to the baseline specification not only the interaction of $PNAV$ and the average value of each of these characteristics across the APs serving an ETF across sub-periods, but also the quadruple interaction between those and AP leverage. This last set of terms provides information on whether the weakening effect of AP leverage for primary arbitrage in normal times and across stress periods, is especially pronounced for ETFs relying on APs that also score high on those characteristics.

Column (1) shows that high AP leverage seems especially relevant in weakening arbitrage for ETFs that also have a high exposure to APs relying on HFT strategies. This is consistent with the view that leveraged HFT APs might be the less able or willing to engage in primary arbitrage. The opposite is true for bank affiliation. In this case, high AP leverage becomes less relevant during stress periods (Column (2)), supporting the view that parents can help override leverage constraints. The role of AP leverage does not seem to vary among ETFs with differential exposure to APs with large presence in US Muni bond funds (Column (3)), indicating that there were limited negative spillovers from this asset class to the rest of bond ETFs. Finally, results in columns (4) and (5), which use two different measures of AP centrality in the ETF-AP network, show that leverage was less of a constraint to arbitrage during stress for ETFs related to APs

[23] An AP's degree is the number of ETFs with which an AP is linked, and its betweenness centrality is the number of shortest paths linking any pair of nodes (ETFs) in the network that go through that AP. For a comprehensive description of various network centrality measures see Jackson (2008)

with a higher degree of centrality in the network. These centrally positioned APs seem to have been able to successfully navigate arbitrage constraints.

5. Conclusion

The correct functioning of ETF markets relies on the willingness and ability of APs to engage in the creation and destruction of ETF shares in response to price signals. This paper has presented new evidence that AP's leverage may limit their ability to engage in arbitrage trades during periods of market turmoil, when balance sheet space is scarcer and costlier because of Value-at-Risk or other risk management constraints, contributing to the persistence of price dislocations. Interestingly, the results indicate that regulatory constraints imposed on broker dealers to ensure their ability to meet haircuts did not seem to have played a significant role in weakening AP arbitrage, except for ETFs focused on US Treasuries. A possible explanation of this finding could be that APs serving US Treasury ETFs operate with slimmer excess capital because of the relative stability in the price and low spreads of these instruments. The unusual market dislocations observed for US Treasuries in March 2020 could have made these constraints suddenly and unexpectedly tight.

Other dimensions of the ETF-AP relationship don't play a significant role in preserving arbitrage during distress. Having a large number of APs does not ensure stronger arbitrage, especially for funds investing in riskier and more illiquid assets, such as US Municipal bonds and other non-Treasury securities. The view that having many APs would ensure someone would step in does not seem to be valid, at least during distress periods. The findings that the characteristics of the few APs that had been active in the creation or destruction during the previous year do not seem to matter for the preservation of arbitrage also suggest little persistence in the ETF-AP relationship. What seems crucial during distress is whether the average AP with which an ETF has a relationship has sufficient balance sheet space, regardless of whether this average AP was or not active in the past. Nonetheless, other characteristics of APs do seem to matter in making leverage constraints a relatively more important limit to arbitrage. These constraints seem to have been especially important for APs relying on high-frequency trading strategies, and less so for those related to bank-holding companies.

The results also shed light on the differential and complementary role of APs and market makers in ensuring a proper functioning of the arbitrage mechanism. The correct operation of both types of entities is crucial for the microstructure of ETF markets and the results show that both seemed to have faced balance sheet constraints that weaken arbitrage during the turmoil of the dash for cash. The nature of the constraints seems different nonetheless, with leverage being a more active constraint for APs and regulatory capital for lead market makers.

The findings of this paper also offer an interesting perspective on how the policy measures taken during this episode helped restore proper market functioning. While the econometric analysis shows a small recovery in arbitrage strength in the post-intervention period, this recovery was not enough to restore arbitrage strength to its normal time levels, especially for ETFs related to more leverage APs. Despite that some of these announcements should have had a direct impact in easing balance sheet constraints, such as the temporary exemption of Treasury securities from the calculation of the supplementary leverage ratio, the relevance of AP leverage in dampening arbitrage did not improve much following these announcements. This could be explained by the persistent increase in measures of uncertainty, such as the VIX and the MOVE, which declined importantly following these announcements but remained elevated relative to the pre-COVID 19 period. This is not to say that the measures were ineffective, as in fact they led to an important closing of price dislocations in ETF markets. But this closing doesn't seem to have been related to a restored strength of APs ability to engage in arbitrage in the direction suggested by price signals. Further understanding the manner in which the announcements largely closed dislocations in ETF markets in an important research question that could shed further light on how ETF markets operate.

While these results offer valuable insights on the role of the ETF-AP relationship and the way limits to arbitrage operate in this market during distress, they are limited by the characteristics of the publicly available data used. Further analysis relying on higher frequency information on the balance sheet space of APs and their individual arbitrage activity could contribute importantly to pin down the detailed manner in which these limits operate. Other dimensions of interest that are part of ongoing work is to better understand the matching of ETFs and APs and the reasons why, facing similar arbitrage opportunities, only a handful of APs engage in primary trading, even in normal times when arbitrage constraints should be less relevant.

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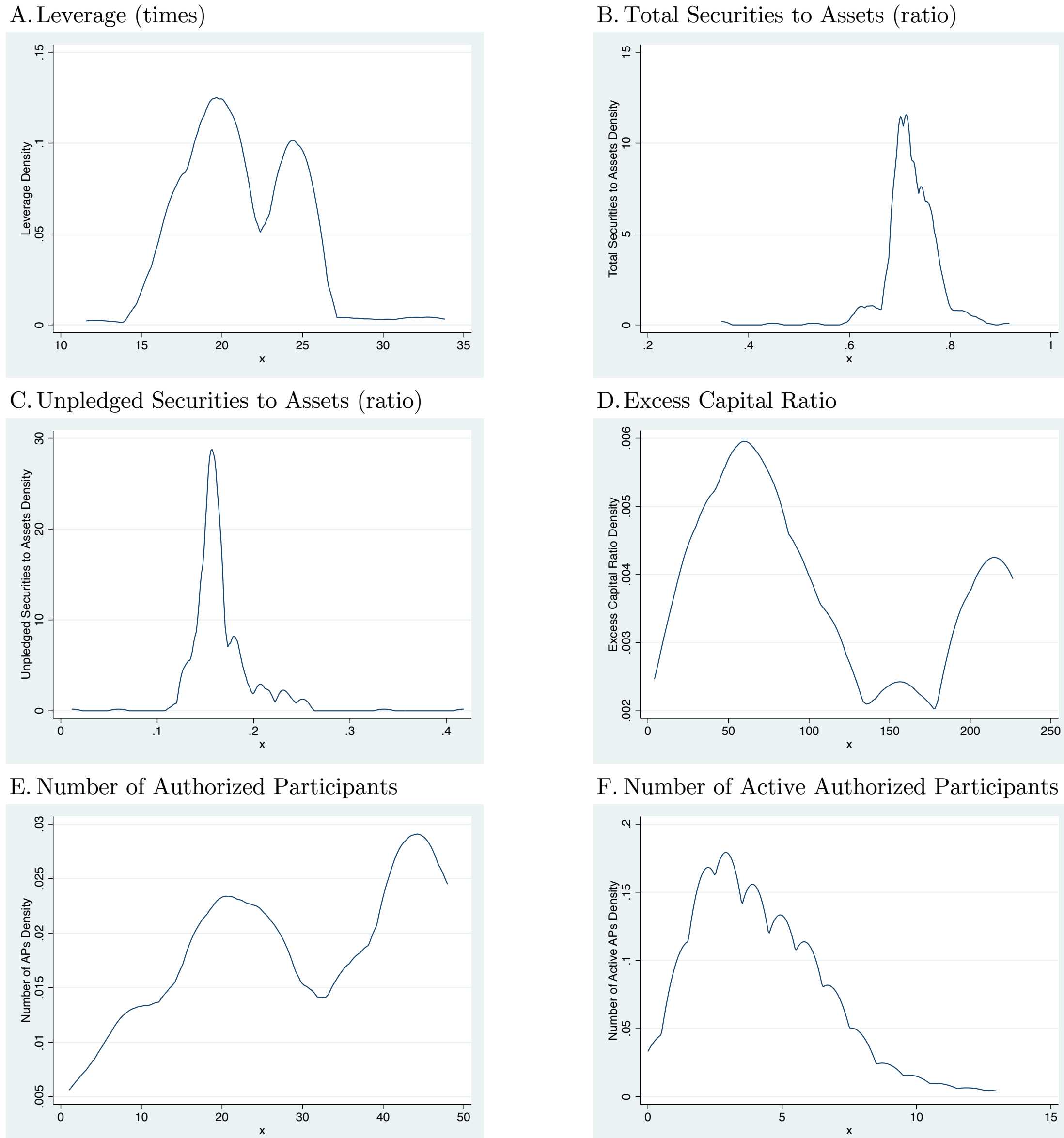
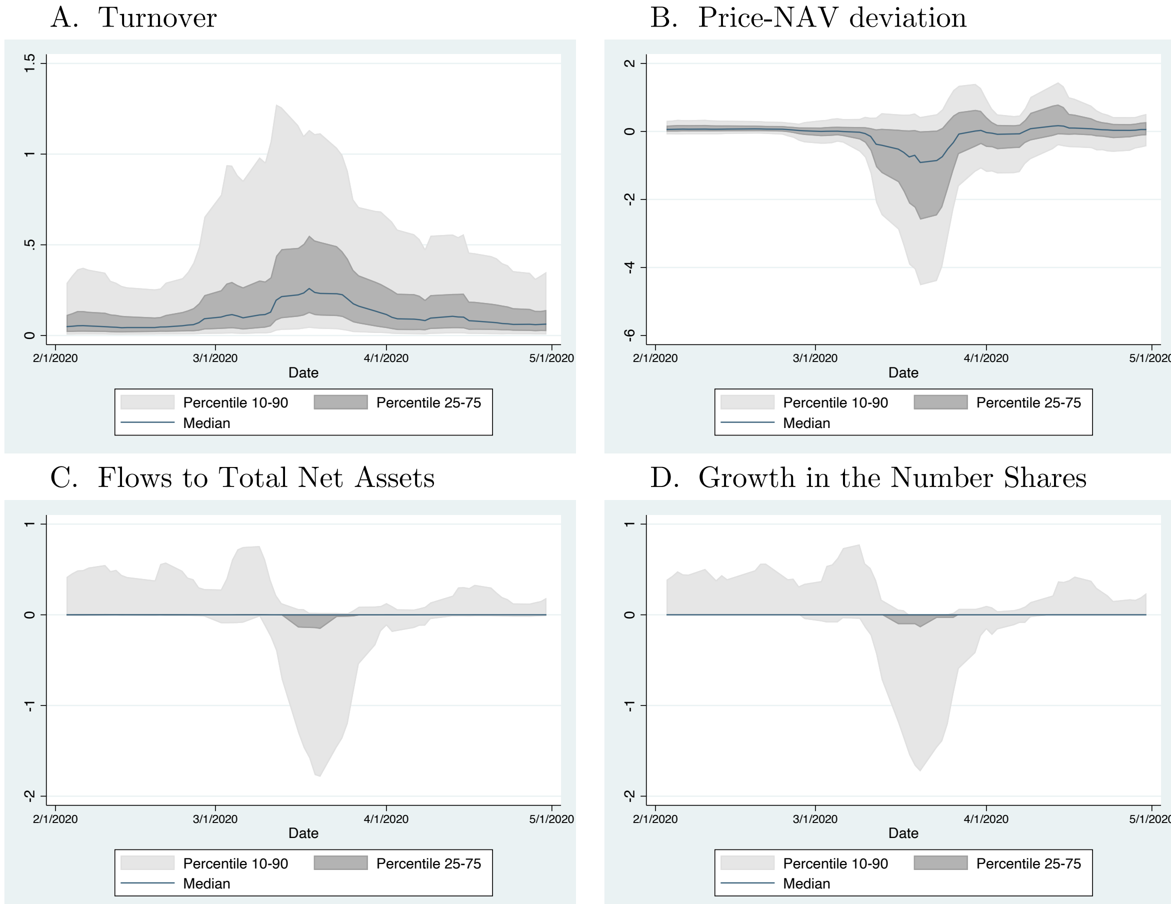
Figure 1: The distribution of average AP characteristics across US Bond ETFs



The various panels of the figure show the kernel densities of different average characteristics of authorized participants across US domiciled bond ETFs. The unit of observation is the ETF and each observation corresponds to the average of each characteristic across all the authorized participants of that ETF. Leverage is the ratio of non-equity liabilities to assets. Total Securities is the sum of securities purchased to resell, securities borrowed, and securities pledged as collateral. Unpledged securities consider only the securities owned by the dealer. Excess Capital Ratio is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. Number of Authorized Participants is the total number of designated authorized participants for an ETF, and the Number of Active Authorized Participants corresponds to those that engaged in the creation or redemption of ETF shares in 2019.

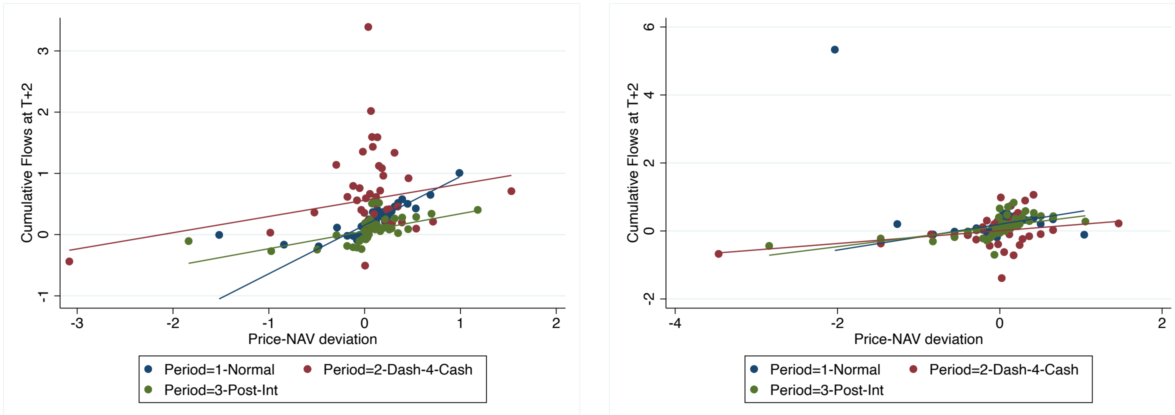
Figure 2. The Evolution of Secondary and Primary Market US Bond ETF Prices and Activity During the Dash for Cash



The panels report the evolution of different indicators of secondary and primary market activity across the sample of US bond ETFs used in this paper during February 1^{st} and April 30^{th}, 2020. The blue lines report for each day in the period the 5-day moving average of the median of each indicator across ETFs, and the dark- and light-gray bands show the similarly smoothed series for the interquartile range and the 10-90 percentile range for that variable across ETFs. Turnover is the total value traded of an ETF in secondary markets. Price-NAV deviation is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. Flows to Total Net Assets is the ratio of the net flows into an ETF divided by its one-day lagged total net assets (reported as 5-day moving average). The growth in the number of shares is the 5-day average growth in the number of ETF shares outstanding.

Figure 3: The Relation Between Price-NAV Deviations and Cumulative Flows

A. ETFs with Highly Leveraged APs B. ETFs with Low Leverage APs

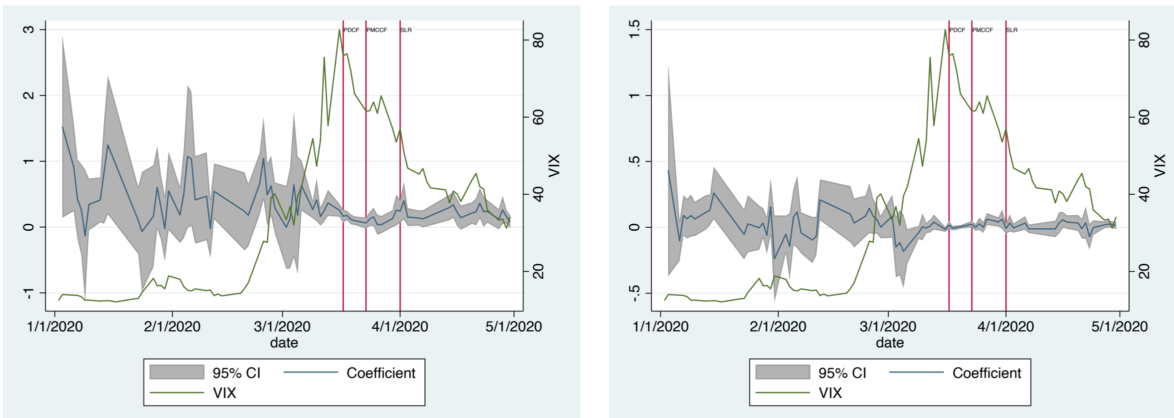


Each panel reports the binned scatterplot of the relationship between bond ETFs price NAV deviations at time T and the cumulative flows into the fund at time T+2 for each of the three subperiods corresponding to normal times (September 1, 2019 to March 3, 2020), dash for cash (March 3 to March 28, 2020) and post intervention (March 29 to May 30 2020). Panel A presents the scatterplots for those ETFs whose average AP leverage is in the top quartile across funds, and Panel B reports the scatterplots for ETFs whose average AP leverage is in bottom quartile across funds.

Figure 4: The Evolution of the Coefficients Capturing Arbitrage Intensity

A. Coefficient on Price Signal

B. Coefficient on the Interaction of Price Signal and AP Leverage



The figures report the time series of estimated cross-sectional coefficients of the relationship between the cumulative flows into each US bond ETF and the price-NAV deviation (Panel A) and the interaction between price-NAV deviation and average AP leverage (Panel B). The blue lines report the estimated cross-sectional coefficient for each date and the gray bands the 95 percent cross-sectional confidence interval. The vertical lines mark the announcement of the Primary Dealer Credit Facility (PDCF) on March 17, 2020 (which was followed by the Money Market Mutual Fund Liquidity Facility on March 18, 2020), the Primary and Secondary Market Corporate Credit Facilities (PMCCF and SMCCF) on March 23, and the temporary change to the Supplemental Leverage Ratio (SLR) on April 1st, 2020. The green line shows the evolution of the CBOE VIX during the same period.

Table 1. Characteristics of Bond ETFs Authorized Participants

A. Summary Statistics	Total Assets	Securities to Assets	Unpledged Securities to Assets	Leverage	Excess Capital Ratio
Average	74,122	0.64	0.19	15.3	190.73
Std. Dev	166,492	0.33	0.25	36.01	396.36
Median	24,683	0.8	0.07	4.25	28.35
Percentile 25	3,392	0.34	0.02	0.48	6.56
Percentile 75	60,395	0.9	0.24	14.68	160.94

B. Correlations	Total Assets	Securities to Assets	Securities to Assets	Leverage	Excess Capital Ratio
Raw correlations					
Total Assets	1				
Securities to Assets	0.252	1			
Securities to Assets	0.219	0.284*	1		
Leverage	-0.0152	0.298*	-0.181	1	
Excess Capital Ratio	-0.201	0.112	0.0918	-0.0502	1
Rank Correlations					
Total Assets	1				
Securities to Assets	0.404**	1			
Securities to Assets	0.0992	0.248	1		
Leverage	0.533***	0.560***	-0.183	1	
Excess Capital Ratio	-0.539***	0.219	0.189	-0.221	1

The table provides summary statistics (Panel A) and correlations (Panel B) for the main characteristics of bond-ETF authorized participants (APs) used in the analysis. The unit of observation is the authorized participant, and the figures reported come from their latest financial statement ahead of March 2020 (in almost all cases corresponding to end 2019). Total assets are the AP total assets in millions of US dollars. Leverage is the ratio of non-equity liabilities to assets. Total Securities is the sum of securities purchased to resell, securities borrowed, and securities pledged as collateral. Unpledged securities consider only the securities owned by the dealer. Excess Capital Ratio is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. In Panel B, the upper half reports the raw correlations across these variables, and the bottom half the rank correlations. In both cases *, **, and *** denote statistical significance at 10, 5, and 1 percent level, respectively.

Table 2: Average AP Characteristics Across Segments of US Bond ETFs

	Number of ETFs	AP Leverage	Total Securities	Unpleadge d securities	Excess Capital Ratio	Number of APs	Number of Active APs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Overall							
	371	21.1	0.72	0.166	117.4	29.9	4.2
B. Sector							
Corporate	77	21.7	0.72	0.163	133.8	33.8	4.6
Government	31	21.5	0.70	0.165	153.5	38.1	5.1
Muni	48	21.7	0.73	0.165	128.7	29.7	4.1
Other	215	20.7	0.72	0.167	103.8	27.4	3.9
C. Geographic Scope							
Cty EME	2	19.9	0.75	0.150	87.1	27.5	1.0
Div EME	20	20.5	0.73	0.163	121.6	30.9	3.1
Global	63	21.8	0.71	0.166	130.7	32.9	3.9
USA	286	21.0	0.72	0.166	114.4	29.2	4.3
D. Credit Risk							
High-Yield	58	20.9	0.72	0.160	111.8	30.3	3.6
No HY	313	21.2	0.72	0.167	118.4	29.9	4.3
E. Type							
Exotic	21	20.2	0.72	0.166	98.4	28.8	3.5
Traditional	350	21.2	0.72	0.166	118.5	30.0	4.2

The table reports summary statistics of the average value of various characteristics of authorized participants across US domiciled bond ETFs, grouped by segments. The unit of observation is the ETF, and each data point corresponds to the average of each characteristic across all the authorized participants related to that ETF. Leverage is the ratio of non-equity liabilities to assets. Total Securities is the sum of securities purchased to resell, securities borrowed, and securities pledged as collateral. Unpledged securities consider only the securities owned by the dealer. Excess Capital Ratio is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. Number of Authorized Participants is the total number of designated authorized participants for an ETF, and the Number of Active Authorized Participants corresponds to those that engaged in the creation or redemption of ETF shares in 2019. ETFs are classified in different non-exclusive segments according to the Lipper Global Classification and Geographical Focus. In Panel B, Muni refers to ETFs investing exclusively on US Municipal bonds and Other includes balanced funds that invest across corporate and government sectors. In Panel C, Cty EME are funds that invest in single name emerging markets, and Div. EME are funds that broadly invest in this segment. In Panel D, High-Yield include only funds whose Lipper Global Classification explicitly mentions High-Yield or HY. In Panel E, Exotic include leveraged and short (inverse) ETFs.

Table 3. AP Characteristics and the Strength of the ETF Arbitrage Mechanism

	Cumulative Flows between T and T+1					Cumulative Flows between T and T+2				
	None	Leverage	Number of APs	Unpledged Securities	Excess Capital	None	Leverage	Number of APs	Unpledged Securities	Excess Capital
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Price-NAV dev.	0.515***	0.575***	0.542***	0.543***	0.559***	0.531***	0.591***	0.554***	0.555***	0.571***
	(0.067)	(0.066)	(0.068)	(0.072)	(0.066)	(0.072)	(0.070)	(0.073)	(0.077)	(0.069)
Dash-4-Cash X Price-NAV dev.	-0.342***	-0.417***	-0.381***	-0.379***	-0.400***	-0.351***	-0.426***	-0.384***	-0.385***	-0.404***
	(0.068)	(0.068)	(0.071)	(0.073)	(0.067)	(0.073)	(0.070)	(0.075)	(0.078)	(0.070)
Post-Int X Price-NAV dev.	-0.331***	-0.384***	-0.353***	-0.358***	-0.370***	-0.350***	-0.395***	-0.363***	-0.369***	-0.379***
	(0.067)	(0.067)	(0.067)	(0.070)	(0.064)	(0.075)	(0.075)	(0.075)	(0.079)	(0.072)
Price-NAV dev. X AP Charact.		0.048***	0.007	-0.828	0.002**		0.055***	0.007	-1.131	0.002**
		(0.015)	(0.004)	(2.216)	(0.001)		(0.016)	(0.004)	(2.144)	(0.001)
Dash-4-Cash X Price-NAV dev. X AP Charact.		-0.046***	-0.005	0.862	-0.002*		-0.052***	-0.005	0.946	-0.002*
		(0.016)	(0.004)	(2.201)	(0.001)		(0.016)	(0.004)	(2.039)	(0.001)
Post-Int X Price-NAV dev. X AP Charact.		-0.042**	-0.004	0.498	-0.001		-0.047***	-0.004	0.984	-0.001
		(0.017)	(0.004)	(2.221)	(0.001)		(0.017)	(0.004)	(2.051)	(0.001)
Observations	61832	57615	57615	56812	57615	58844	54856	54856	54093	54856
R-squared	0.053	0.048	0.048	0.047	0.048	0.070	0.060	0.059	0.059	0.060
Adjusted R-squared	0.044	0.039	0.039	0.039	0.039	0.062	0.051	0.050	0.050	0.051
	Cumulative Flows between T and T+3					Cumulative Flows between T and T+4				
Price-NAV dev.	0.509***	0.584***	0.546***	0.547***	0.560***	0.527***	0.590***	0.548***	0.549***	0.561***
	(0.072)	(0.071)	(0.072)	(0.076)	(0.069)	(0.076)	(0.074)	(0.075)	(0.079)	(0.072)
Dash-4-Cash X Price-NAV dev.	-0.338***	-0.431***	-0.388***	-0.389***	-0.404***	-0.377***	-0.454***	-0.406***	-0.409***	-0.422***
	(0.073)	(0.071)	(0.074)	(0.077)	(0.070)	(0.076)	(0.075)	(0.076)	(0.080)	(0.073)
Post-Int X Price-NAV dev.	-0.350***	-0.405***	-0.373***	-0.380***	-0.384***	-0.387***	-0.429***	-0.391***	-0.397***	-0.401***
	(0.080)	(0.083)	(0.080)	(0.084)	(0.077)	(0.092)	(0.098)	(0.092)	(0.096)	(0.089)
Price-NAV dev. X AP Charact.		0.051***	0.005	-2.686	0.001		0.054***	0.004	-3.288	0.001
		(0.015)	(0.004)	(2.285)	(0.001)		(0.016)	(0.005)	(2.518)	(0.001)
Dash-4-Cash X Price-NAV dev. X AP Charact.		-0.046***	-0.003	2.337	-0.001		-0.048***	-0.003	2.573	-0.001
		(0.015)	(0.004)	(2.048)	(0.001)		(0.016)	(0.004)	(2.253)	(0.001)
Post-Int X Price-NAV dev. X AP Charact.		-0.043**	-0.002	2.593	-0.001		-0.050**	-0.002	3.554	-0.001
		(0.017)	(0.004)	(2.098)	(0.001)		(0.019)	(0.005)	(2.387)	(0.001)
Observations	55854	52095	52095	51372	52095	53610	50021	50021	49328	50021
R-squared	0.086	0.070	0.069	0.068	0.069	0.101	0.078	0.077	0.077	0.078
Adjusted R-squared	0.077	0.060	0.060	0.059	0.060	0.093	0.069	0.068	0.067	0.068

In all regressions, the dependent variable is an ETF's average cumulative flows between period t and a horizon that, depending on the panel, goes from t+1 to t+4, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price-NAV dev.* is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. *AP Charact.* corresponds to the average characteristic of an ETF authorized participants (APs) described in each of columns (2)-(5) and (7)-(10). For each horizon, regressions in columns (1) and (6) report results without considering AP characteristics as a baseline. *Leverage* is the ratio of non-equity liabilities to assets. *Number of APs* is the total number of designated authorized participants for an ETF. *Unpledged securities* include only the securities owned by the dealer, expressed as a ratio of total assets. *Excess Capital* is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** p<0.01; ** p<0.05; *p<0.1

Table 4. Comparing the Role of AP Characteristics for the Strength of the ETF Arbitrage Mechanism

	Cumulative Flows between T and T+2				
	(1)	(2)	(3)	(4)	(5)
Price-NAV deviation	0.589***	0.592***	0.601***	0.591***	0.598***
	(0.070)	(0.069)	(0.071)	(0.068)	(0.069)
Dash-4-Cash X Price-NAV deviation	-0.423***	-0.428***	-0.435***	-0.426***	-0.432***
	(0.071)	(0.069)	(0.070)	(0.068)	(0.069)
Post-Int X Price-NAV deviation	-0.392***	-0.395***	-0.404***	-0.397***	-0.396***
	(0.073)	(0.072)	(0.075)	(0.072)	(0.071)
Price-NAV deviation X AP Leverage	0.053***	0.050**	0.068***	0.050**	0.074**
	(0.017)	(0.020)	(0.020)	(0.022)	(0.030)
Dash-4-Cash X Price-NAV deviation X AP Leverage	-0.052***	-0.051***	-0.066***	-0.050**	-0.077**
	(0.017)	(0.019)	(0.021)	(0.021)	(0.030)
Post-Int X Price-NAV deviation X AP Leverage	-0.049***	-0.047**	-0.058***	-0.045**	-0.060**
	(0.018)	(0.020)	(0.020)	(0.021)	(0.027)
Price-NAV deviation X Number of AP	0.002			0.000	0.008
	(0.005)			(0.010)	(0.011)
Dash-4-Cash X Price-NAV deviation X Number of AP	-0.001			-0.000	-0.008
	(0.004)			(0.010)	(0.012)
Post-Int X Price-NAV deviation X Number of AP	0.000			0.003	-0.000
	(0.004)			(0.010)	(0.011)
Price-NAV deviation X AP Excess Capital		0.000		0.000	-0.001
		(0.001)		(0.002)	(0.003)
Dash-4-Cash X Price-NAV deviation X AP Excess Capital		-0.000		-0.000	0.002
		(0.001)		(0.002)	(0.003)
Post-Int X Price-NAV deviation X AP Excess Capital		-0.000		-0.001	0.000
		(0.001)		(0.002)	(0.003)
Price-NAV deviation X AP Unpledged Sec.			2.146		2.723
			(2.278)		(2.460)
Dash-4-Cash X Price-NAV deviation X AP Unpledged Sec.			-2.377		-2.997
			(2.295)		(2.481)
Post-Int X Price-NAV deviation X AP Unpledged Sec.			-1.976		-1.404
			(2.192)		(2.553)
Observations	54856	54856	54093	54856	54093
R-squared	0.060	0.060	0.060	0.060	0.060
Adjusted R-squared	0.051	0.051	0.051	0.051	0.051

The dependent variable is an ETF's average cumulative flows between period t and t+2, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price-NAV deviation* is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. *AP Leverage* is the ratio of non-equity liabilities to assets. *Number of AP* is the total number of designated authorized participants for an ETF. *Unpledged Sec.* are the securities owned by the dealer, expressed as a ratio of total assets. *Excess Capital* is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** p<0.01; ** p<0.05; *p<0.1

Table 5. Is it AP Characteristics or ETF Liquidity?

	Cumulative Flows between T and T+2			
	Leverage	Number of APs	Unpledged Securities	Excess Capital
	(1)	(2)	(3)	(4)
Price-NAV deviation	0.648***	0.611***	0.620***	0.624***
	(0.090)	(0.100)	(0.103)	(0.094)
Dash-4-Cash X Price-NAV deviation	-0.472***	-0.426***	-0.436***	-0.444***
	(0.090)	(0.102)	(0.104)	(0.096)
Post-Int X Price-NAV deviation	-0.391***	-0.357***	-0.352***	-0.366***
	(0.088)	(0.096)	(0.098)	(0.091)
Price-NAV deviation X AP Characteristic	0.053***	0.004	-0.152	0.002*
	(0.018)	(0.005)	(2.316)	(0.001)
Dash-4-Cash X Price-NAV deviation X AP Characteristic	-0.052***	-0.005	0.605	-0.002
	(0.019)	(0.005)	(2.132)	(0.001)
Post-Int X Price-NAV deviation X AP Characteristic	-0.053***	-0.005	1.509	-0.002*
	(0.020)	(0.005)	(2.313)	(0.001)
Price-NAV deviation X ETF Iliquidity	-0.171**	-0.181*	-0.196**	-0.170*
	(0.085)	(0.094)	(0.091)	(0.093)
Dash-4-Cash X Price-NAV deviation X ETF Iliquidity	0.104	0.114	0.127	0.103
	(0.086)	(0.096)	(0.091)	(0.096)
Post-Int X Price-NAV deviation X ETF Iliquidity	0.046	0.051	0.051	0.034
	(0.087)	(0.095)	(0.092)	(0.094)
Observations	53878	53878	53239	53878
R-squared	0.056	0.055	0.054	0.056
Adjusted R-squared	0.047	0.046	0.045	0.047

The dependent variable is an ETF's average cumulative flows between period t and t+4, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price-NAV deviation* is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. *AP Characteristic* corresponds to the average characteristic of an ETF authorized participants (APs) described at the top of each column. *Leverage* is the ratio of non-equity liabilities to assets. *Number of APs* is the total number of designated authorized participants for an ETF. *Unpledged securities* are the securities owned by the AP as a fraction of total assets. *Excess Capital* is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. *ETF Illiquidity* is the average bid-ask spread of the ETF computed between March 1, 2019 and August 31, 2019, ahead of the estimation period. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** $p<0.01$; ** $p<0.05$; *$p<0.1$

Table 6. Do the Characteristics of Active APs Matter?

	Cumulative Flows between T and T+2			
	Leverage	Number of APs	Unpledged Securities	Excess Capital
	(1)	(2)	(3)	(4)
Price-NAV dev.	0.545***	0.577***	0.559***	0.551***
	(0.079)	(0.080)	(0.078)	(0.072)
Dash-4-Cash X Price-NAV dev.	-0.372***	-0.416***	-0.381***	-0.378***
	(0.081)	(0.081)	(0.078)	(0.072)
Post-Int X Price-NAV dev.	-0.358***	-0.373***	-0.323***	-0.343***
	(0.091)	(0.081)	(0.077)	(0.073)
Price-NAV dev. X AP Charact.	0.000	0.067*	-0.099	0.000
	(0.011)	(0.039)	(0.546)	(0.001)
Dash-4-Cash X Price-NAV dev. X AP Charact.	-0.004	-0.050	0.295	0.000
	(0.011)	(0.038)	(0.530)	(0.001)
Post-Int X Price-NAV dev. X AP Charact.	0.001	-0.017	0.397	0.000
	(0.014)	(0.037)	(0.555)	(0.001)
Observations	53890	54856	50477	53890
R-squared	0.059	0.060	0.061	0.059
Adjusted R-squared	0.050	0.051	0.052	0.050

The dependent variable is an ETF's average cumulative flows between period t and t+2, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price-NAV dev.* is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. *AP Characteristic* corresponds to the average characteristic of an ETF active authorized participants (active APs)—those that engaged in the creation or destruction of ETF shares in 2019—described at the top of each column. *Leverage* is the ratio of non-equity liabilities to assets. *Number of APs* is the total number of active designated authorized participants for an ETF. *Unpledged securities* are the securities owned by the active APs as a fraction of total assets. *Excess Capital* is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** $p<0.01$; ** $p<0.05$; *$p<0.1$

Table 7. Robustness to the use of Alternative Measures of Primary Market Activity and Price Signal

	A. Growth in Shares between T and T+2 Price signal is PNAV					B. Cumulative Flows between T and T+2 Price signal is PNAV Arbitrage				
	None	Leverage	Number of APs	Unpledged Securities	Excess Capital	None	Leverage	Number of APs	Unpledged Securities	Excess Capital
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Price Signal	0.497***	0.528***	0.508***	0.502***	0.524***	0.718***	0.835***	0.677***	0.716***	0.713***
	(0.064)	(0.064)	(0.065)	(0.067)	(0.064)	(0.174)	(0.146)	(0.169)	(0.181)	(0.159)
Dash-4-Cash X Price Signal	-0.342***	-0.379***	-0.356***	-0.350***	-0.374***	-0.441**	-0.558***	-0.397**	-0.434**	-0.434***
	(0.062)	(0.063)	(0.064)	(0.066)	(0.063)	(0.177)	(0.148)	(0.175)	(0.183)	(0.164)
Post-Int X Price Signal	-0.291***	-0.315***	-0.301***	-0.302***	-0.315***	-0.460***	-0.554***	-0.412**	-0.461***	-0.439***
	(0.064)	(0.064)	(0.064)	(0.067)	(0.063)	(0.172)	(0.141)	(0.168)	(0.177)	(0.157)
Price Signal X AP Charact.		0.043**	0.008*	-0.989	0.002*		0.139***	0.028***	-5.157	0.005***
		(0.017)	(0.004)	(2.110)	(0.001)		(0.044)	(0.009)	(6.333)	(0.002)
Dash-4-Cash X Price Signal X AP Charact.		-0.040**	-0.006	0.930	-0.001		-0.132***	-0.025**	4.732	-0.005**
		(0.017)	(0.004)	(1.851)	(0.001)		(0.046)	(0.010)	(6.114)	(0.002)
Post-Int X Price Signal X AP Charact.		-0.034**	-0.004	-0.366	-0.001		-0.124***	-0.023**	4.115	-0.004**
		(0.017)	(0.004)	(1.985)	(0.001)		(0.045)	(0.009)	(5.908)	(0.002)
Observations	66462	62252	62252	61586	62252	55001	53878	53878	53239	53878
R-squared	0.054	0.050	0.050	0.049	0.050	0.051	0.053	0.052	0.051	0.053
Adjusted R-squared	0.045	0.041	0.041	0.041	0.042	0.042	0.044	0.043	0.042	0.044

In Panel A, the dependent variable is an ETF's average growth in outstanding shares between period t and t+2, and in Panel B is an ETF's average cumulative flows between period t and t+2, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price Signal* corresponds to the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV (*PNAV*) in Panel A, and to the difference between an ETF's bid or ask closing price, depending on the side of the trade, and net asset value (NAV) amplified or diminished by a factor capturing spreads in secondary markets for underlying assets in Panel B. Both are expressed as a percentage of the NAV. *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. *AP Charact.* corresponds to the average characteristic of an ETF authorized participants (APs) described at the top of each column. *Leverage* is the ratio of non-equity liabilities to assets. *Number of APs* is the total number of designated authorized participants for an ETF. *Unpledged securities* are the securities owned by the APs as a fraction of total assets. *Excess Capital* is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** $p<0.01$; ** $p<0.05$; *$p<0.1$

Table 8. Is Equilibrium Restored Through NAV Adjustment?

	A: Average Price-NAV deviation between T and T+2					B: Average growth in NAV between T and T+2				
	None	Leverage	Number of APs	Unpledged Securities	Excess Capital	None	Leverage	Number of APs	Unpledged Securities	Excess Capital
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Price-NAV dev.	0.384***	0.389***	0.385***	0.365***	0.388***	0.075***	0.078***	0.076***	0.074***	0.081***
	(0.039)	(0.036)	(0.038)	(0.035)	(0.037)	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)
Dash-4-Cash X Price-NAV dev.	0.222***	0.216***	0.215***	0.237***	0.216***	-0.002	-0.009	-0.008	-0.006	-0.011
	(0.042)	(0.039)	(0.042)	(0.039)	(0.041)	(0.017)	(0.018)	(0.018)	(0.018)	(0.018)
Post-Int X Price-NAV dev.	0.286***	0.274***	0.282***	0.305***	0.277***	-0.053***	-0.056***	-0.055***	-0.051***	-0.059***
	(0.056)	(0.052)	(0.049)	(0.054)	(0.050)	(0.011)	(0.012)	(0.012)	(0.012)	(0.012)
Price-NAV dev. X AP Charact.		-0.001	0.001	-2.051*	0.037		0.005	0.002*	-0.247	0.046**
		(0.012)	(0.003)	(1.110)	(0.051)		(0.004)	(0.001)	(0.441)	(0.021)
Dash-4-Cash X Price-NAV dev. X AP Charact.		-0.003	0.000	2.384**	-0.010		-0.006	-0.001	-0.187	-0.044*
		(0.012)	(0.003)	(1.114)	(0.054)		(0.004)	(0.001)	(0.471)	(0.023)
Post-Int X Price-NAV dev. X AP Charact.		-0.014	-0.004	2.316	-0.089		-0.005	-0.002***	0.221	-0.052***
		(0.012)	(0.004)	(1.610)	(0.068)		(0.003)	(0.001)	(0.346)	(0.014)
Observations	65983	61835	61835	61042	61835	66279	62044	62044	61241	62044
R-squared	0.646	0.657	0.658	0.656	0.657	0.363	0.380	0.380	0.379	0.380
Adjusted R-squared	0.643	0.654	0.655	0.653	0.654	0.357	0.374	0.374	0.373	0.374

In Panel A, the dependent variable is an ETF's average price-NAV deviation (*PNAV*) in periods t+1 and t+2, and in Panel B is an ETF's average growth in NAV between t and t+2. *Price-NAV dev.* corresponds to the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV (*PNAV*). *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. *AP Charact.* corresponds to the average characteristic of an ETF authorized participants (APs) described at the top of each column. *Leverage* is the ratio of non-equity liabilities to assets. *Number of APs* is the total number of designated authorized participants for an ETF. *Unpledged securities* are the securities owned by the APs as a fraction of total assets. *Excess Capital* is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** $p<0.01$; ** $p<0.05$; * $p<0.1$

Table 9: Robustness. Market Distress Captured by Subperiods.

A. Different timing for the Dash for Cash	Dash for Cash Period			
	Start Feb. 20th	Start March 9th	End March 17th	End March 23rd
	(1)	(2)	(3)	(4)
Price-NAV dev.	0.617***	0.600***	0.582***	0.588***
	(0.069)	(0.068)	(0.070)	(0.070)
Dash-4-Cash X Price-NAV dev.	-0.446***	-0.442***	-0.348***	-0.410***
	(0.069)	(0.068)	(0.078)	(0.075)
Post-Int X Price-NAV dev.	-0.421***	-0.403***	-0.446***	-0.416***
	(0.075)	(0.073)	(0.069)	(0.070)
Price-NAV dev. X AP Leverage	0.055***	0.045***	0.056***	0.057***
	(0.016)	(0.014)	(0.016)	(0.016)
Dash-4-Cash X Price-NAV dev. X AP Leverage	-0.054***	-0.040***	-0.059***	-0.059***
	(0.017)	(0.015)	(0.019)	(0.018)
Post-Int X Price-NAV dev. X AP Leverage	-0.048***	-0.038**	-0.052***	-0.043***
	(0.018)	(0.015)	(0.015)	(0.016)
Observations	54856	54512	54512	54512
R-squared	0.059	0.060	0.060	0.060
Dash-4-Cash - Post-Int	-0.006	-0.002	-0.007	-0.016*

B. Using continuous measures of distress	Distress captured by			
	VIX	Swap Spread	MOVE 3M	NFCI
	(1)	(2)	(3)	(4)
Price-NAV deviation	0.986***	1.312***	0.738**	0.232***
	(0.159)	(0.278)	(0.285)	(0.022)
Price-NAV deviation X AP Leverage	0.138***	0.117*	-0.120*	0.007
	(0.035)	(0.060)	(0.062)	(0.005)
Price-NAV deviation X Distress	-0.198***	-0.278***	0.179***	-0.470***
	(0.038)	(0.068)	(0.065)	(0.070)
Price-NAV deviation X AP Leverage X Distress	-0.033***	-0.027*	-0.038***	-0.035**
	(0.008)	(0.014)	(0.014)	(0.015)
Observations	54856	53170	54856	54856
R-squared	0.059	0.059	0.058	0.059
Adjusted R-squared	0.050	0.050	0.049	0.050

The dependent variable is an ETF's average cumulative flows between period t and t+2, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price-NAV dev.* is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. In Panel A, the beginning and ending of the *Dash-4-Cash* dummies are defined as indicated at the top of each column. *AP Charact.* corresponds to the average characteristic of an ETF authorized participants (APs) described at the top of each column. In Panel B, the degree of market stress is captured by the continuous evolution of the variables indicated in each column. *VIX* is the (log) CBOE VIX index. *Swap Spread* is the difference between the yield of a 30-year US Treasury bond and the corresponding swap rate at the same maturity. *MOVE 3M* is the Merrill Lynch 3-month Bond Volatility Index, and *NFCI* is the National Financial Condition Index produced by the Chicago Fed. *Leverage* is the ratio of non-equity liabilities to assets. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** $p<0.01$; ** $p<0.05$; *$p<0.1$

Table 10: AP Characteristics and the Strength of ETF Arbitrage across ETF Segments

	US Treasury Bonds ETFs				US Muni Bond ETFs				Other US Domiciled Bond ETFs			
	Leverage	Number of APs	Unpledged Securities	Excess Capital	Leverage	Number of APs	Unpledged Securities	Excess Capital	Leverage	Number of APs	Unpledged Securities	Excess Capital
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Price-NAV dev.	3.281*	2.912***	3.210*	2.977**	0.818***	0.655***	0.469**	0.780***	0.525***	0.494***	0.495***	0.509***
	(1.656)	(1.015)	(1.815)	(1.093)	(0.189)	(0.169)	(0.217)	(0.181)	(0.069)	(0.072)	(0.075)	(0.069)
Dash-4-Cash X Price-NAV dev.	-2.426	-2.084*	-2.358	-2.125*	-0.743***	-0.534***	-0.323	-0.694***	-0.368***	-0.333***	-0.332***	-0.349***
	(1.717)	(1.077)	(1.892)	(1.132)	(0.198)	(0.175)	(0.238)	(0.184)	(0.070)	(0.075)	(0.077)	(0.071)
Post-Int X Price-NAV dev.	-1.943	-0.635	-2.489	-1.382	-0.670***	-0.481***	-0.316	-0.627***	-0.328***	-0.296***	-0.308***	-0.309***
	(2.309)	(1.931)	(2.547)	(1.722)	(0.204)	(0.177)	(0.250)	(0.188)	(0.078)	(0.076)	(0.082)	(0.074)
Price-NAV dev. X AP Charact.	-0.274	-0.246*	3.748	-0.032	0.193**	0.030**	-5.467	0.008***	0.047***	0.006	-1.905	0.002*
	(0.339)	(0.131)	(22.620)	(0.019)	(0.093)	(0.013)	(7.872)	(0.003)	(0.016)	(0.004)	(2.190)	(0.001)
Dash-4-Cash X Price-NAV dev. X AP Charact.	0.378	0.260*	-3.908	0.038**	-0.183*	-0.036**	7.816	-0.009***	-0.045***	-0.004	1.092	-0.001
	(0.325)	(0.135)	(23.407)	(0.018)	(0.091)	(0.014)	(8.361)	(0.003)	(0.016)	(0.004)	(2.144)	(0.001)
Post-Int X Price-NAV dev. X AP Charact.	0.645	0.371**	-52.669	0.041*	-0.173*	-0.038***	6.818	-0.010***	-0.041**	-0.003	1.387	-0.001
	(0.491)	(0.156)	(55.092)	(0.024)	(0.096)	(0.013)	(7.842)	(0.003)	(0.017)	(0.004)	(2.386)	(0.001)
Observations	3601	3601	3601	3601	7057	7057	6901	7057	44198	44198	43591	44198
R-squared	0.135	0.145	0.133	0.142	0.101	0.102	0.097	0.103	0.061	0.060	0.060	0.061
Adjusted R-squared	0.087	0.097	0.085	0.094	0.073	0.074	0.069	0.075	0.051	0.051	0.050	0.051

The dependent variable is an ETF's average cumulative flows between period t and t+2, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price-NAV dev.* is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. *AP Charact.* corresponds to the average characteristic of an ETF authorized participants (APs) described at the top of each column. *Leverage* is the ratio of non-equity liabilities to assets. *Number of APs* is the total number of designated authorized participants for an ETF. *Unpledged securities* are the securities owned by the AP, expressed as a share of total assets. *Excess Capital* is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. Panel A presents results for ETFs investing in US Treasury bonds, Panel B for ETFs focused on US Muni bonds, and Panel C considers all other US bond ETFs. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** $p<0.01$; ** $p<0.05$; * $p<0.1$

Table 11: AP Characteristics or Market Maker Stress?

	Lead Market. Maker Charact. Captured by			
	Leverage	Unpledged Securities	Excess Capital	Contemp. B-A Spread
	(1)	(2)	(3)	(4)
Price-NAV dev.	0.632***	0.620***	0.621***	0.619***
	(0.066)	(0.064)	(0.065)	(0.075)
Dash-4-Cash X Price-NAV dev.	0.036**	0.043***	0.040***	0.055***
	(0.015)	(0.015)	(0.015)	(0.016)
Post-Int X Price-NAV dev.	-0.460***	-0.448***	-0.447***	-0.391***
	(0.062)	(0.061)	(0.061)	(0.076)
Price-NAV dev. X AP Charact.	-0.430***	-0.419***	-0.432***	-0.322***
	(0.066)	(0.066)	(0.069)	(0.074)
Dash-4-Cash X Price-NAV dev. X AP Charact.	-0.036**	-0.043***	-0.039***	-0.054***
	(0.015)	(0.015)	(0.015)	(0.017)
Post-Int X Price-NAV dev. X AP Charact.	-0.035*	-0.043**	-0.038**	-0.053***
	(0.018)	(0.019)	(0.018)	(0.019)
Price-NAV dev. X Lead MM Char.	-0.003	-0.267	-0.034**	-0.114*
	(0.003)	(0.165)	(0.017)	(0.064)
Dash-4-Cash X Price-NAV dev. X Lead MM Char.	0.002	0.285*	0.032**	0.073
	(0.003)	(0.160)	(0.016)	(0.060)
Post-Int X Price-NAV dev. X Lead MM Char.	-0.001	0.337*	0.033**	0.026
	(0.005)	(0.184)	(0.016)	(0.070)
Observations	42506	42506	41540	54856
R-squared	0.059	0.059	0.060	0.062
Adjusted R-squared	0.049	0.049	0.050	0.053

The dependent variable is an ETF's average cumulative flows between period t and t+2, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price-NAV dev.* is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. In columns (1)-(3) *Lead MM Char.* corresponds to the characteristic of an ETF lead market maker (LMM) described at the top of each column. *Leverage* is the ratio of non-equity liabilities to assets. *Unpledged securities* are the securities owned by the AP as a fraction of total assets. *Excess Capital* is the ratio of the regulatory net capital over and above the required minimum net capital as defined by SEC's Uniform Net Capital Rule (Rule 15c3) relative to that required minimum. In Column (4) *Lead MM Char* is the log bid-ask spread of the ETF. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** $p<0.01$; ** $p<0.05$; *$p<0.1$

Table 12. Is AP Leverage Most Relevant in Tandem with Other AP Characteristics?

	AP Characteristic				
	Use of HFT Strategies	Bank Affiliation	Serves Muni Bond Funds	Degree in ETF Bond Network	Centrality in ETF Bond Network
	(1)	(2)	(3)	(4)	(5)
Price-NAV dev.	0.601***	0.580***	0.591***	0.583***	0.584***
	(0.070)	(0.069)	(0.076)	(0.069)	(0.069)
Dash-4-Cash X Price-NAV dev.	-0.438***	-0.416***	-0.425***	-0.422***	-0.421***
	(0.070)	(0.069)	(0.077)	(0.070)	(0.069)
Post-Int X Price-NAV dev.	-0.406***	-0.388***	-0.389***	-0.385***	-0.384***
	(0.074)	(0.074)	(0.082)	(0.072)	(0.073)
Price-NAV dev. X AP Leverage	0.070***	0.058***	0.052**	0.055***	0.070***
	(0.019)	(0.017)	(0.021)	(0.015)	(0.020)
Dash-4-Cash X Price-NAV dev. X AP Leverage	-0.067***	-0.056***	-0.051**	-0.051***	-0.066***
	(0.020)	(0.018)	(0.022)	(0.016)	(0.020)
Post-Int X Price-NAV dev. X AP Leverage	-0.060***	-0.052***	-0.032	-0.050***	-0.068***
	(0.020)	(0.018)	(0.021)	(0.016)	(0.020)
Price-NAV dev. X AP Charact.	0.062	-1.054*	1.285	-0.150	-0.008
	(1.184)	(0.581)	(8.981)	(0.254)	(0.115)
Dash-4-Cash X Price-NAV dev. X AP Charact.	0.542	0.927	1.032	0.087	-0.027
	(1.272)	(0.609)	(8.853)	(0.262)	(0.112)
Post-Int X Price-NAV dev. X AP Charact.	0.022	1.308**	-5.330	-0.041	-0.063
	(1.280)	(0.601)	(8.351)	(0.265)	(0.107)
Price-NAV dev. X AP Leverage X AP Charact.	0.343*	-0.179***	-0.414	-0.050	-0.045**
	(0.193)	(0.067)	(1.734)	(0.034)	(0.018)
Dash-4-Cash X Price-NAV dev. X AP Leverage X AP Charact.	-0.376*	0.194***	0.213	0.028	0.041**
	(0.208)	(0.074)	(1.863)	(0.036)	(0.018)
Post-Int X Price-NAV dev. X AP Leverage X AP Charact.	-0.348*	0.202***	0.682	0.051	0.050***
	(0.207)	(0.073)	(1.929)	(0.038)	(0.018)
Observations	54856	54856	54856	54856	54856
R-squared	0.060	0.060	0.060	0.061	0.061
Adjusted R-squared	0.051	0.051	0.051	0.052	0.052

The dependent variable is an ETF's average cumulative flows between period t and t+4, expressed as a percentage of the fund's lagged total net assets (as of t-1). *Price-NAV dev.* is the difference between an ETF's closing price and net asset value (NAV), expressed as a percentage of the NAV. *Dash-4-Cash* and *Post-Int* are dummy variables that take the value 1 between March 5 and March 31, 2020, and April 1 to May 30, 2020, respectively. *AP Leverage* is the ratio of non-equity liabilities to assets. *AP Charact.* corresponds to the average characteristic of an ETF authorized participants (APs) described at the top of each column. *Use of HFT Strategies* is the share of an ETF's authorized participants that use high frequency trading strategies. *Bank Affiliation* is the share of an ETF's authorized participants whose ultimate parent is a bank or bank holding company and *Serves Muni Funds* is the share of an ETF APs that also act as an AP for Municipal bond ETFs. *Degree in ETF Bond Network* and *Centrality in ETF Bond Network* correspond to the average of the corresponding network statistic across an ETF's APs. The *X* symbol denotes an interaction of two variables. All regressions include fund and day fixed effects and also include terms for the interaction between dummy variables and AP characteristics. Standard errors clustered at the ETF level are shown in parentheses. *** $p<0.01$; ** $p<0.05$; *$p<0.1$