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Unintended Consequences of Holding Dollar Assets

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Unintended Consequences of Holding Dollar Assets

Abstract

We examine a novel mechanism whereby the US dollar's global dominance can have a large, unexpected impact on foreign Treasury yields in crisis periods. Non-US institutions hold substantial dollar assets and hedge dollar exposures by selling dollars forward. In crisis periods, the dollar appreciates against other currencies. To meet margin calls on FX hedging positions, traditionally passive institutions sell domestic safe assets, thereby contributing to yield spikes in domestic markets. We show that during the recent COVID crisis, UK institutions with substantial dollar holdings and FX hedging positions sold large amounts of gilts, which contributed to the observed gilt yield spike.

Keywords: dollar assets, currency hedging, variation margin, FX derivatives, gilt yields, global reserve currency, COVID crisis

1 Introduction

Government bonds issued by developed countries (e.g., US, UK, and Germany) are typically viewed as the safest and most liquid financial assets. In crisis periods, these high-quality assets often experience large buying pressure and appreciate in value – a phenomenon referred to as "Flight-to-Safety" (e.g., Vayanos, 2004). In the recent 2020 COVID crisis, however, these traditionally liquid, safe financial assets experienced unprecedented global selloffs and tumbled in value. As shown in Figure 1 (complemented by Figure 14), government bond yields across developed markets rose sharply in the few days after the World Health Organization (WHO) declared the COVID outbreak a global pandemic. For example, the ten-year government bond yields in the US and UK rose by more than 50 basis points (bps) between the 10th and 18th of March 2020, which resulted in unprecedented central bank interventions in both countries.[1]

Given the importance of government bond yields to the functioning of the financial market and the real economy, the March-2020 episode has inspired a volume of academic research.[2] Much of the existing work focuses on the US Treasury market, partly because of its size and global importance, and partly due to data availability. He, Nagel and Song (2022), for example, show that open-end mutual funds experienced large outflows and sold $240bn of US Treasuries in the first quarter of 2020 to meet investor redemptions. In the same quarter, the US Treasury issued $240bn worth of new Treasury securities while foreign investors (including foreign central banks) sold another $270bn to meet liquidity needs. In face of the large sell-off, dealer banks – many of whom were already facing a binding balance sheet constraint – were unable to quickly absorb the selling pressure (e.g., Duffie, 2020; He, Nagel and Song, 2022). As a result, a large disruption rippled through the US Treasury market in mid-March 2020. The market stabilized only after the Federal Reserve's emergency bond-

[1] The Bank of England announced large-scale asset purchases on the 19th of March 2020, inducing a sharp decline in yields following the announcement. We therefore define the seven trading days between March 10th and 18th of 2020 as the main period of interest in the COVID crisis.

[2] See, for example, Haddad, Moreira and Muir (2021); Ma, Xiao and Zeng (2022); He, Nagel and Song (2022).

purchase program, which bought over $700bn of Treasury securities between the 20th and 31st of March 2020.

We contribute to this growing literature by leveraging detailed, granular bond holdings and transaction data from the UK to examine a novel and increasingly important channel of forced trading in non-US markets. Specifically, we argue that due to substantial losses on currency hedging positions (against dollar exposures), large, typically passive non-US institutions are forced to liquidate their holdings of domestic safe assets in crisis periods, thereby driving up the yields of these securities.

The US dollar, as the reserve currency in the international payment and financial systems, serves several important roles: for instance, to clear cross-border transactions and to provide investment opportunities in dollar-denominated assets. As shown by Maggiori, Neiman and Schreger (2019, 2020) and Du and Huber (2023), the share of dollar-denominated cross-border investments by non-US institutions has surged – in some cases, more than tripled – since the 2008 Global Financial Crisis. In our sample, at the end of Q4 2019 (right before the COVID crisis), UK insurers invested more than £250bn in dollar-denominated assets (accounting for roughly half of their foreign asset holdings), mostly in US stocks and corporate bonds. Since their liabilities are mostly in home currencies, non-US institutions naturally hedge (part of) their dollar exposures on the asset side of the balance sheet through foreign exchange (FX) derivatives (more specifically, by selling dollars forward). UK insurers, for example, accumulated over £80bn in short USD positions in Q4 2019.

Just like many previous crises, the COVID episode was also a dollar liquidity crisis, as investors and businesses scrambled for dollars to meet dollar-denominated liabilities (Cesa-Bianchi, Czech and Eguren-Martin, 2023). As a result, USD appreciated significantly against virtually all other major currencies in this episode. For instance, the dollar appreciated by more than 10% against the sterling between March 10th and 18th of 2020. An immediate result of these large exchange rate movements is that non-US institutions with significant FX hedging positions suffered substantial losses on their FX derivative holdings. For instance, large UK asset owners (mainly insurance companies and pension funds) lost £10bn in variation margin (VM) on their FX hedging positions in this nine-day window.

It is worth noting that since the enactment of the leverage ratio rule in 2015, UK institutions have been largely unable to use government bonds as collateral to meet VM calls. Consequently, to meet FX margin calls, UK institutions have to sell their USD risky holdings, GBP risky holdings, and/or their domestic safe assets.[3] As shown in Ma, Xiao and Zeng (2022), institutions often follow a pecking order in their liquidation choice: they sell their safe and liquid assets (which are predominantly long-term gilts in our setting) before risky positions to meet immediate liquidity needs. Furthermore, to the extent that dealer banks and other liquidity providers in the gilt market are constrained in their ability to absorb the selling pressure, this channel of forced liquidation could partially explain the yield spikes in the UK, and more broadly, in other non-US markets during crisis periods.

The goal of our paper is to take this novel channel of FX-margin-induced selling to the data, more specifically, to examine its impact on UK gilt yields during the recent COVID crisis. Unlike recent studies on US Treasury yields in the COVID crisis that utilize low-frequency (monthly or even quarterly) investor holdings and trading data, we exploit granular and comprehensive information on virtually all transactions in the UK gilt and gilt repo markets. The granularity and completeness of the data allow us to delineate and examine exactly what happened in the few days in mid-March 2020.

Our analyses yield a number of interesting findings. First, in the week of the COVID crisis (between March 10th and 18th of 2020), UK insurance companies and pension funds (ICPFs) incurred VM losses of nearly £8bn on their FX derivatives holdings. Second, in response to their massive VM losses, ICPFs – who are typically passive buy-and-hold investors in the gilt market – collectively sold nearly £4bn of gilts and increased gilt repo borrowing by over

[3] Technically, UK institutions can also liquidate their relatively small holdings of US Treasuries. However, selling US Treasuries requires an extra step of converting USD to GBP to meet margin calls in the UK, which takes additional time and tends to be costly in market turmoils.

£2bn.[4] This is in addition to the £4bn gilt issuance by the UK's Debt Management Office (DMO) (which, like US Treasury issuance, was planned and announced months in advance) and the £4.5bn gilt sales by bond mutual funds (driven largely by capital outflows).[5] For reference, the average daily trading volume in the gilt market between dealer banks and their clients was roughly £10bn in 2019 (Czech, Gual-Ricart, Lillis and Worlidge, 2021a).

Third, in the cross-section of ICPFs, a 1% increase in FX variation margin loss is associated with a 42bps (t-statistic = 3.96) increase of gilt sales and a 22bps (t-statistic = 2.14) increase of repo borrowing.[6] To the extent that investors' FX variation margin losses (which are primarily a function of their pre-crisis USD asset holdings) are unrelated to the perceived risk of holding gilts during the COVID crisis, our cross-sectional result lends support to the argument that ICPFs were forced to liquidate their gilt holdings, and is inconsistent with the alternative view that ICPFs sold gilts because they perceived gilts to be particularly risky during the COVID crisis.

Fourth, the sudden influx of £12bn worth of gilts to the market in this short window was entirely absorbed by a handful of dealer and non-dealer banks, as well as a small number of fixed-income hedge funds, all of which were likely facing tight balance sheet and capital constraints themselves. In light of this, we examine whether and the extent to which the selling of gilts by ICPFs contributed to the gilt yield spikes in March 2020. Our analysis reveals that a one-standard-deviation increase in ICPF selling – due to variation margin losses – is associated with a 0.82% decrease in daily long-term gilt returns during the COVID crisis, or over 50% of the total gilt price movement in this period. This price effect is fully reversed

[4] Czech, Huang, Lou and Wang (2021b) show that ICPFs account for 4% of the aggregate gilt trading volume in normal periods. In contrast, mutual funds account for 14% of the aggregate gilt trading volume in the same period.

[5] The pricing implications of the activities of the DMO/Treasury and open-end mutual funds have been the focus of a large body of prior research. It is well-documented that Treasury issuance (e.g., Lou, Yan and Zhang, 2013) and mutual fund flow-induced trading (e.g., Coval and Stafford, 2007; Lou, 2012) can have a large impact on secondary-market security returns. Ma, Xiao and Zeng (2022) and Huang, Jiang, Liu and Liu (2021a) further show that mutual fund flow-induced selling was partly responsible for the US Treasury market turmoil in the COVID crisis.

[6] Consistent with an increase in repo borrowing demand, term repo rates spiked by up to 40bps in this short period (see Figure 13).

in the following month, consistent with the view that ICPFs were forced to liquidate their gilt holdings due to FX VM losses.

A potential concern with our empirical approach – that we take the appreciation of the dollar against sterling as given – is that exchange rate movements are endogenous, which can be affected by ICPFs' trading as well as other confounding factors. We argue that this is not a major concern in our setting, for two reasons. First, UK ICPFs did not increase their dollar asset holdings in the week of the COVID crisis (neither did UK mutual funds), so were unlikely to drive the USD/GBP exchange rate directly. Second, macro factors that are important for exchange rates (e.g., interest differentials, imbalances in dollar demand and supply) are unlikely to account for the strong *cross-sectional* association between FX variation margin losses and trading by individual ICPFs, as well as the *cross-sectional* relation between ICPF trading in individual gilts and gilt yield movements.

Another important concern with our interpretation of the evidence is that rather than being forced to liquidate their gilt holdings due to FX margin calls, UK asset owners *chose* to sell their gilt holdings because they perceived gilts to be risky during the COVID crisis. First, as argued earlier, this risk-based story is unlikely to account for the cross-sectional relation between pre-crisis FX hedging positions of individual ICPFs and their gilt trading during the crisis. Second and more directly, by exploiting the granularity of our transaction data, we show that virtually all of ICPFs' gilt selling – in response to the daily VM – takes place in the last few trading hours of the day (between 3pm and 6pm UK time), so in a tight window around the cutoff time for calculating daily variation margins by most dealer banks (around 4pm UK time). (For reference, the last three trading hours account for only 20% of the total daily trading volume in the gilt market.) This discontinuous jump in intraday-trading is inconsistent with the risk-perception view of the evidence.

In sum, our analyses uncover a novel channel through which the reserve currency status of the US dollar can have a large, unanticipated impact on non-US safe-asset yields during crisis periods. Since the costs of cross-border financing and investment have dropped significantly in the last few decades, non-US investors hold more dollar assets today than at any time in history. These non-US investors also hedge their USD exposures by selling dollars forward. In crisis periods, the dollar appreciates against all other major currencies, resulting in significant losses on these FX hedging positions. Due to the recently enacted leverage ratio rule, most investors are unable to use non-cash collateral to meet VM demand, so have to liquidate their domestic safe assets to meet margin calls, thereby exacerbating yield spikes at home. In other words, by zooming in on a group of large, deep-pocket non-US institutions that are passive in normal times but are forced to liquidate domestic safe assets during crisis periods, we highlight an unintended consequence of the US dollar's global dominance.

Our findings also highlight an unexpected effect of the leverage ratio rule (see also Duffie and Krishnamurthy, 2016; Duffie, 2018; Du, Tepper and Verdelhan, 2018; Cenedese, Della Corte and Wang, 2021). Prior to the new regulation, ICPFs were generally able to post non-cash collateral – such as gilts – to meet their VM demand. However, unlike cash collateral, non-cash collateral does not reduce dealers' derivative leverage exposures.[7] As a result, dealers found themselves unable to meet their ROE targets on these trades and started adjusting derivative contracts' credit support annexes, often removing the option to post non-cash collateral. Since many ICPFs were unable to post gilts as collateral during the COVID crisis, they had to sell these securities at a discount in the secondary market. This dynamic therefore highlights how the leverage ratio regulatory framework – despite its positive impact on dealers' capacities to withstand the crisis – may have exacerbated gilt fire sales by large asset owners during that period.

Our proposed mechanism and empirical results have useful implications for investors and policymakers in all non-US markets, including developed markets. While non-US investors enjoy the diversification benefit of investing in dollar assets, there is a potential downside to this trend – their liquidation of domestic safe assets during crisis periods may exacerbate

[7] In the treatment of derivative exposures for the purpose of the leverage ratio, the cash portion of VM exchanged between counterparties may be viewed as a form of pre-settlement payment. See Basel Committee on Banking Supervision, Leverage Ratio Exposure Measurement, Sections 30.28 and 30.29.

problems at home. Indeed, as shown in Figure 14, there is a strong parallel between exchange rate movements and bond yield changes in many developed countries (e.g., Australia, Japan, Switzerland, and Germany) during the COVID crisis. Although we do not have detailed bond trading data for these markets, the mechanism outlined in this paper is likely to play a role in these other countries as well.[8]

Against this backdrop, a natural question is whether and how policymakers can encourage large asset owners to better manage their liquidity in crisis periods, for example by making margin calls on derivatives more manageable and transparent.[9] One way to achieve this goal is to introduce central clearing to FX derivatives, as central clearing provides improved netting opportunities and better transparency of margin calculations and payments, all of which are handled by the central clearing counterparty (see, e.g., Duffie, 2019, 2020). Such measures may help prevent a similar liquidity drain in future downturns, and reduce the likelihood of an adverse impact of US dollar appreciations on prices and liquidity in non-US government bond markets.

Related Literature Our study contributes to the recent literature on the economic mechanisms underlying the treasury market turmoil in March 2020. For example, Duffie (2020) emphasizes frictions in the market-making mechanisms, whereas Schrimpf, Shin and Sushko (2020) highlight the role of margin spirals. He, Nagel and Song (2022) focus on the interaction between levered investors who obtain financing via repo transactions and dealers who are subject to balance sheet constraints. Ma, Xiao and Zeng (2022) study the liquidity management of fixed-income mutual funds during the COVID pandemic and find that the funds follow a liquidity pecking order when selling their assets to meet capital outflows. Huang, Jiang, Liu and Liu (2021a) further link liquidity management decisions of fixed-income mu-

[8]Our proposed channel is also discussed in recent policy reports from the Eurozone and Norway, where investors were also exposed to large VM losses in the COVID period due to their substantial FX hedging positions (e.g., Rousová et al., 2021; Alstadheim et al., 2021).

[9]In the aftermath of the COVID crisis, policymakers around the globe have indeed started coordinated work on policies that try to mitigate the systemic risks from unexpectedly large margin calls on derivative exposures (see, e.g., Cunliffe, 2022; Financial Stability Board, 2022).

tual funds to excess return comovement of Treasury securities.

We contribute to this strand of literature in at least three aspects. First, we depart from the literature by focusing on UK gilts. Given the global reserve currency status of the US dollar, yield movements of US safe assets in crisis periods may not reflect the experiences of safe assets in other countries. Consequently, a careful examination of investor trading and bond yield patterns of UK gilts during the COVID crisis can provide useful insights into government bond markets in other developed countries.

Second, unlike prior research on the US treasury market that uses low-frequency (monthly or quarterly) investor holdings and trading data (to analyze a high-frequency event), we have access to detailed and granular information on every transaction in the UK gilt market. This allows us to examine and disentangle exactly what happened in the few days between the 10th and 18th of March 2020: who were buying, who were selling, by how much, and the associated price effects.

Third, our granular data allow us to analyze the driving forces behind the trading behavior of different investor types during the COVID crisis. While we also find that mutual funds' selling of gilts was largely driven by investor redemptions, we uncover a novel channel for ICPFs' selling of gilts. As the dollar appreciated against sterling, many ICPFs had to meet large VM calls on their USD hedging positions. This immediate liquidity demand forced large institutions to sell their domestic government bonds, thereby contributing to the yield spike in the UK gilt market. Our study not only provides a detailed anatomy of the turmoil in the gilt market during the COVID crisis, but also uncovers an unintended consequence of dollar asset holdings by large passive institutions.

Our paper is also closely related to recent studies on the unintended consequences of the leverage ratio rule. For example, Du, Tepper and Verdelhan (2018) show that recent violations of the covered interest parity are associated with bank balance sheet costs due to tighter leverage constraints at quarter-ends. Exploiting variation induced by the UK leverage ratio regulatory framework, Cenedese, Della Corte and Wang (2021) find that dealers who are affected by the regulatory change demand an additional premium of about 20bps per annum for synthetic dollar funding relative to unaffected dealers. Our study complements these earlier results by analyzing the impact of the leverage ratio rule on the ability of derivative investors to meet margin calls, and the impact of the associated selling pressure on the prices of safe assets.

Finally, our study contributes to the large body of literature on the role of institutional trading in generating price impacts and financial fragility. For instance, Coval and Stafford (2007), Edmans, Goldstein and Jiang (2012) and Lou (2012) show that equity mutual funds' flow-induced trading has a significant impact on stock prices.[10] Our paper complements these prior studies by proposing and examining a novel channel of forced institutional trading. Specifically, our documented forced selling by large, passive UK institutions is a result of the increasing global dominance of the US dollar and the enactment of the leverage ratio regulation in the aftermath of the Global Financial Crisis.

2 Institutional Background and Data

2.1 Institutional Background on Derivative Margin Calls

Following the 2007-08 global financial crisis, regulatory reforms resulted in the majority of derivative exposures being backed by collateral. To cover potential counterparty losses in a default event, derivative users post collateral to their counterparties to cover both changes in their current exposure (variation margin, VM) and potential future exposures (initial margin, IM) (e.g., BCBS and IOSCO, 2015). More precisely, IM is posted to cover the loss that could incur between the default of a counterparty and the closing-out of a position, and is recalculated on a regular basis.

[10] Greenwood and Thesmar (2011) link correlated fund flows to stock return comovement. Anton and Polk (2014) further show that common mutual fund ownership leads to negative cross-serial correlations among stocks. Huang, Song and Xiang (2021b) document that correlated mutual fund flows contribute to a large portion of the variance-covariance in anomaly returns.

Moreover, derivative users are required to settle changes in the market value of the trade at least once a day via VM. Hence, VM directly reflects the mark-to-market process, and positions have zero value again after VM payments (BCBS and IOSCO, 2015). Importantly, while some derivative transactions are exempted from the exchange of IM (e.g. physically-settled FX forwards and swaps), the requirement to exchange VM applies to all exposures in the UK, i.e. both cleared and non-cleared trades across all derivative types. Most clearinghouses and dealers issue VM calls predominantly on an end-of-day basis (EoD margin), and the VM demand typically has to be met on the next trading day (BCBS and IOSCO, 2021). During periods of heightened market volatility, clearinghouses also have the option to issue intraday VM calls to account for substantial price movements. To meet these VM calls, counterparties have to use cash for centrally cleared trades. For non-centrally cleared trades, even though it is not a regulatory requirement, in practice VM demand is usually also settled by cash (ISDA, 2017).

In terms of magnitudes, daily VM calls tend to be much larger compared to IM calls. Based on CCPs' Public Quantitative Disclosures, the aggregate VM calls across clearing members are usually several times higher than IM calls. For example, the largest daily aggregate VM call made by SwapClear in 2017 Q4 was 5.3 times higher than its largest aggregate IM call (Bardoscia, Ferrara, Vause and Yoganayagam, 2021). During the COVID crisis (also known as the 'Dash-for-Cash period'), VM calls on non-bank financial intermediaries (NBFIs) amounted to more than £13bn, while NBFIs' IM demand at UK clearinghouses increased by £2.4bn (Czech, Gual-Ricart, Lillis and Worlidge, 2021a). Therefore, VM calls far exceeded IM demand and were therefore the main driver of the liquidity pressure on ICPFs during this period.

2.2 Data Sources

We collect data from several sources. First, we collect supervisory data on the asset and derivative holdings of UK insurers from the Solvency II database. Second, we obtain transaction-level reports on government bond and repo trades from the regulatory MiFID II and Sterling Money Market databases, respectively. Last, we incorporate estimated VM calls based on derivatives data from the regulatory EMIR Trade Repository Data, along with data on mutual fund flows from Morningstar. In what follows, we provide more detailed descriptions of each data source.

We first use granular data on asset and derivative holdings of insurance companies regulated by the UK's Prudential Regulation Authority (PRA) and subject to the Solvency II Directive. Insurers within the scope of the Solvency II Directive are required to submit annual and quarterly returns, with the exception of some smaller firms with quarterly waivers. The data are available from 2016 Q1. The reports include detailed information on the holdings of a given insurer, such as the instrument's ISIN, quantity, currency, issuer country, asset category and rating.

For derivatives holdings, the reports also include information on the the identity of the counterparties, underlying security, notional amount, derivative category (e.g. FX forward), and swap delivered/received currencies. We consider both unit-linked and non-unit-linked portfolios. The asset holdings data cover 83 insurers with a total asset size of around £2tn in 2019 Q4 (see Figure 2). Among these 83 insurers, 37 also provide information on their derivative holdings. These insurers collectively represent 95% of the sector's total assets, hence giving us a comprehensive overview of the sector's asset and derivative holdings. We also have complete information on the daily VM demand and bond trading of 21 insurers, accounting for 87% (£1.73tn) of the sector's total assets (£2tn) in 2019 Q4. Therefore, our sample covers the vast majority of insurers' assets in the UK.

In the empirical analysis of VM demand and bond trading, we identify a total of 41 individual insurer portfolios (based on the legal entity identifiers (LEIs) in the data) held by these 21 insurance companies. Moreover, we expand our analysis to include the pension fund sector, which encompasses Liability-Driven Investment (LDI) funds. Insurance companies and pension funds share many similarities in their business models, risk management practices, and regulatory frameworks. During the COVID crisis, our sample consists of 51 pension funds. For comparison, according to the UK Office for National Statistics, the total net asset value of pension funds amounted to £2.2tn in 2019. The UK insurance and pension fund sectors are therefore similar in size.

To analyze trading in the gilt market, we use the transaction-level MiFID II database, maintained by the UK's Financial Conduct Authority (FCA). The MiFID II data provide detailed reports of all secondary-market trades of UK-regulated firms, or branches of UK firms regulated in the European Economic Area (EEA). Given that all gilt dealers are UK-domiciled and hence FCA-regulated institutions, our data cover virtually all transactions in the gilt market. Each transaction report contains information on the transaction date and time, ISIN, execution price, transaction size, and the legal identities of the buyer and seller.

Third, we use the Bank of England's Sterling Money Market data collection, Form SMMD. This transaction-level dataset covers the sterling unsecured and secured (gilt repo) money markets. The data are obtained from dealers in the respective money markets and have been collected since 2016. The data cover 95% of activity in which a bank or dealer is a counterparty, but the data do not capture the small segment of non-bank to non-bank repo transactions.

Next, we use the EMIR Trade Repository Data on interest rate swaps, inflation swaps, FX forwards, and cross-currency basis swaps to estimate the VM calls of individual insurers, pension funds, hedge funds, and mutual funds for each trading day in March 2020. The estimates are based on the methodology used in Bardoscia, Ferrara, Vause and Yoganayagam (2021). We observe derivatives trades satisfying one of the following conditions: i) one of the counterparties is a UK-regulated entity, ii) any leg of the trade is denominated or paid for in Sterling, iii) the trade is cleared by a UK-supervised CCP, or iv) the underlying reference entity is a UK firm. It is important to reiterate that derivative users are required to settle changes in the market value of the trade at least once a day via the exchange of VM.

Finally, we collect international government bond yields and foreign exchange rates from

Bloomberg. To obtain mutual fund flows, we first use the MiFID II bond transaction data to find the legal identifiers of all asset managers that are active in the gilt market. Out of roughly 2,000 LEIs, we are able to manually match more than 900 LEIs to the corresponding fund ISINs in Morningstar. We then collect daily fund flows for these matched funds from Morningstar.

2.3 Summary Statistics

We present the summary statistics of our sample in Figures 2 to 5 and Table 1. Figure 2 shows that out of their total capital of £2tn in 2019 Q4, UK insurers invested around £1.5tn in domestic sterling assets, roughly £250bn in dollar-denominated assets and another £250bn in non-dollar denominated foreign assets. Figure 3 further shows that over 90% of UK insurers' dollar-denominated investment was in risky assets, including US equity and corporate bonds. UK insurers also hedged against this currency risk: their net short position in USD in the FX derivatives market was over £80bn in 2019 Q4 (Figure 5). In terms of domestic investments, out of the £1.5tn invested in sterling-denominated assets in 2019 Q4, around £300bn was allocated to UK gilts. Figure 4 further shows that more than half of insurers' gilt holdings was concentrated in long-term gilts with a maturity of more than ten years (likely to match the long duration of their liabilities).

We then analyze the magnitude of the estimated variation margins on derivative holdings. As shown in Figure 6, there was a pronounced spike in VM demand during the COVID crisis (March 10th-18th), while in early March (March 1st-9th) most non-bank investors in our sample were net receivers of VM.

Panel A of Table 1 reports summary statistics of the daily VM demand on ICPFs for both periods. The largest share of the VM surge in the COVID period can be attributed to the VM on FX derivatives, with an average VM loss of £16.3m per day per investor, followed by VM on interest rate swaps (with an average daily loss of £11.7m per investor). The VM demand on inflation swaps was relatively small (with an average daily loss of around £1m per investor). We also aggregate the VM demand at the investor type level. As shown in Figure 6, VM losses were largest for insurance companies and pension funds, with an aggregate VM loss of £13.5bn during the COVID crisis. For mutual funds and hedge funds, the VM losses were much smaller. Figure 7 further shows that the largest share of VM losses of ICPFs can be attributed to the VM on FX derivatives (£7.9bn). These findings highlight the varying levels of VM losses associated with different types of derivatives.

Panel B of Table 1 presents summary statistics of the daily ICPF trading in the gilt market. An average ICPF sold £7.5m worth of gilts each day in the COVID crisis period (March 10th-18th). In contrast, ICPFs on average increased their gilt holdings in early March (March 1st-9th) by £2.7m per day. As shown in Figure 9, the total gilt selling by the ICPF sector during the COVID crisis amounted to £3.8bn; in contrast, the ICPF sector bought £1.1bn worth of gilts in early March before the COVID crisis.

Panel C of Table 1 reports the daily gilt returns during the COVID crisis. Gilts experienced a significantly negative average return of -1.23% per day during this period. Longer-maturity gilts (with a remaining time-to-maturity of more than five years) experienced a much larger drop in returns (-1.57% each day) compared to shorter-maturity gilts (with a statistically insignificant -11bps per day). This pattern is also evident in Figure 1, which shows the yield changes of the 2-year and 10-year gilts during March and April 2020. The yield of the highly liquid 10-year gilt reached 80bps on March 18, reflecting a yield jump of over 50bps in just seven trading days since March 10.

3 Main Results

In Section 3.1, we analyze UK insurers' FX hedging behavior as a function of their foreign asset holdings. We then examine the link between insurers' USD FX hedging positions and their VM losses in March 2020 in Section 3.2. In Section 3.3, we delve into the effects of VM demand on ICPFs' gilt trading. Finally, in Section 3.4, we examine the effect of ICPFs' gilt selling on gilt returns in this period.[11]

3.1 USD Asset Holdings and FX Hedging Positions

We start our analysis by examining UK insurers' FX hedging behavior. When foreign institutions invest in dollar assets, they usually hedge their currency exposures on the asset side of the balance sheet through FX derivatives (e.g., by selling USD and buying GBP forward), as their liabilities are often denominated in the domestic currency. For example, the claims against UK insurers tend to be sterling-denominated, as most policyholders are domiciled in the UK. Furthermore, many countries also have regulations that provide guidance on FX hedging and restrict the build-up of currency risks (for a more detailed institutional background, see Liao and Zhang, 2021). In the UK market, insurers are regulated by the UK's Prudential Regulation Authority (PRA) and are subject to the Solvency II Directive (which incentivizes UK insurers to hedge currency risks).

In terms of derivative exposures, UK insurers predominantly hold interest rate swaps and FX derivatives. This is not surprising: insurers use interest rate swaps to manage their portfolio duration with limited upfront payments, while FX derivatives provide hedges against the currency risk of their foreign asset holdings. As shown in Figure 5, UK insurers' dollar hedging positions have increased steadily in recent years, in line with the growing amount of dollar asset holdings shown in Figures 2 and 3.

The aggregate patterns in Figures 2, 3, and 5 suggest that UK insurers frequently use FX derivatives. We now exploit our rich regulatory holdings data and formally examine the extent to which UK insurers hedge the currency risk of their foreign asset holdings. Specifically, we conduct the following panel regression:

$$FX\ Hedging\ Position_{i,j,t} = \beta_0 + \beta_1 \times Foreign\ Asset\ Holdings_{i,j,t} + FE + \varepsilon_{i,j,t}, \quad (1)$$

[11] Since we do not observe the asset holdings of individual pension funds, we conduct our analyses in Sections 3.1 and 3.2 for the insurance sector only. As discussed in Section 2, the UK insurance and pension fund sectors are comparable in size. In Sections 3.3 and 3.4, we exploit our granular transaction-level data to study the trading behavior and price impact of both UK insurers and pension funds.

where $FX\ Hedging\ Position_{i,j,t}$ is insurer i's net FX derivative hedging notional in foreign currency j (to convert to pound sterling) in quarter t, and $Foreign\ Asset\ Holdings_{i,j,t}$ is insurer i's total asset holdings in foreign currency j in quarter t. To mitigate the influence of outliers and for the ease of interpretation, we adjust both $FX\ Hedging\ Position_{i,j,t}$ and $Foreign\ Asset\ Holdings_{i,j,t}$ using the Inverse Hyperbolic Sine (IHS) method. This transformation is similar to taking the natural logarithm of these variables but can be applied to zero or negative values (see, e.g., Burbidge, Magee and Robb, 1988; Bellemare and Wichman, 2020). We further include insurer fixed effects, time fixed effects, or insurer×time fixed effects in the regressions (as in Sialm and Zhu, 2023) to control for unobservable insurer characteristics and common shocks. The standard errors are double-clustered by currency and time.

Table 2 presents the results of the regression. In Columns (1)-(3), we include asset holdings across all foreign currencies, and find that UK insurers hedge a significant portion of the currency risk associated with foreign asset holdings. On average, a 1% change in foreign asset holdings is associated with a 0.44% change in the FX hedging position in the corresponding currency. This result also holds after including insurer fixed effects, time fixed effects, or insurer×time fixed effects. We then zoom in on dollar assets in Column (4): specifically, we repeat the analysis in Equation (1) focusing solely on the subsample of assets denominated in USD. The result suggests that a 1% increase in insurers' dollar asset holdings is associated with a 0.49% increase in their USD hedging positions.[12]

3.2 FX Hedging Positions and Variation Margin Losses

Figure 1 illustrates a significant increase in the 10-year gilt yield within a short window between the 10th and 18th of March 2020. At the same time, the value of the British pound declined substantially against the US dollar. We argue that this surprising correlation

[12]Note that Figures 2 and 5 imply an aggregate hedging ratio of about 0.35 (UK insurers have total USD holdings of £250B and USD hedging positions of slightly over £80B. The difference between the aggregate hedging ratio and the cross-sectional hedging ratio is likely due to the fact that larger insurers have more foreign operations so have weaker incentives to hedge their foreign currency exposures.

between the gilt yield spike and the dollar/pound exchange rate is not a coincidence, but partly arises from FX variation margin-induced trading. Specifically, we argue that UK insurers, who had short FX derivative positions on the US dollar (i.e., by selling dollars forward), incurred substantial losses on their FX hedging positions as the dollar appreciated against the pound. Facing this large liquidity demand, insurers then sold off their gilt holdings to meet the VM calls on their FX derivative hedges.

To confirm the mechanical link between FX hedging positions and VM losses, we start by showing the cumulative FX VM demand on UK insurers in March 2020. To this end, we divide insurance companies into two groups based on their USD FX hedging positions at the end of 2019Q4: Top USD FX derivative hedgers (with above-median short USD exposures) and Bottom USD FX derivative hedgers (below-median). As shown in Figure 8, the FX derivative VM losses of the top group are strongly correlated with the dollar/pound exchange rate. Specifically, in the COVID crisis, the top dollar hedgers incurred substantial losses on their hedging positions as the dollar appreciated against pound sterling; in early March (before the COVID crisis), the top dollar hedgers were net receivers of VM as the dollar slightly depreciated against the pound.

Importantly, we do not observe a similar pattern for the group of insurers with less pronounced dollar hedging positions. The difference in FX VM between the top and the bottom group is statistically significant. While the patterns in Figure 8 are unsurprising given the mechanical link between exchange rate movements and FX derivative VM, they highlight the substantial liquidity pressure on insurers due to VM calls on FX hedging positions.[13]

[13] In Figure A1 of the Internet Appendix, for comparison, we also analyze the dynamics of VM demand on interest rate swaps and inflation swaps separately for the top/bottom group of USD FX hedgers. Unsurprisingly, we find no link between dollar hedging and the VM demand on either instrument. This finding provides further support for our argument that insurers' heightened FX VM demand was not driven by other confounding factors, but can be distinctly attributed to their USD hedging positions.

3.3 Variation Margin Losses and Gilt Trading

After establishing the relation between FX hedging positions and VM losses, we now proceed to investigate the impact of VM demand on gilt trading. We focus on gilt trading by large asset owners (i.e., insurance companies and pension funds, ICPFs). As shown in the previous section, the ICPF sector is a net payer of VM during the COVID crisis with a total VM payment of £13.5bn (Figure 6). In general, ICPFs have various options to fulfill their VM obligations, for example, by using their cash holdings, redeeming money market fund shares, using their revolving bank credit lines, borrowing via repo, or by selling risky or safe assets (e.g., gilts).

We first examine net gilt trading by different types of institutions during the COVID crisis. As shown in Figure 9, while dealers, non-dealer banks and hedge funds were net buyers of gilts during the COVID crisis, ICPFs and mutual funds were net sellers. The ICPF sector alone sold £3.84bn worth of gilts during the crisis.

We then conduct a panel regression to pin down the cross-sectional relation between VM demand and gilt trading with the following specification:

$$Net\ Trading_{i,t} = \beta_0 + \beta_1 \times VM_{i,t} + FE + \epsilon_{i,t}. \tag{2}$$

The dependent variable is the daily gilt trading by institution i on day t. The main independent variable is the VM call on the same day, which includes VM demand on all derivative contracts (including FX derivatives, interest rate swaps, inflation swaps, etc.). We focus on the same-day gilt trading because investors have to settle the VM payment by the next day (most gilt transactions are cleared the next morning).

A positive (negative) VM value means that the investor was a net payer (receiver) of VM. We focus on the period between March 1st to 18th, but also run the regression separately for early March (March 1st-9th) and the COVID period (March 10th-18th). The indicator variable $COVID\ crisis$ is equal to one if the date of the observation is between March 10th to 18th, and zero otherwise. VM(>0) truncates the independent variable, VM, at zero, and equals the original value when VM is positive, and zero otherwise. VM(<0) is equal to the original value when VM is negative, and zero otherwise. Both the net gilt trading and variation margin payment are adjusted using the Inverse Hyperbolic Sine (IHS) method. We include time fixed effects and report bootstrapped standard errors in all specifications.

Table 3 reports the results of these regressions. Panel A shows the results for the entire period (March 1st to 18th), and also separately for early March (March 1st-9th) and the COVID crisis period (March 10th-18th). Across all specifications, VM has a significant negative effect on gilt trading in the COVID crisis. In other words, ICPFs sell government bonds when they have to meet VM calls.[14] For example, as shown in Panel A, during the COVID crisis, the VM coefficient estimate of -0.16 (t-statistic = -2.22) implies that a 1% increase in VM is associated with a 16bps increase of gilt sales by ICPFs. For comparison, the coefficient is positive but insignificant for early March, when ICPFs' VM demand is negative (i.e., they were net receivers of VM). Furthermore, we explore the asymmetric effect of VM demand. To this end, we split the sample based on the sign of the VM demand (VM payers (VM>0) vs. VM receivers (VM<0)), and find that ICPFs sell government bonds when they have to pay VM, but do not buy government bonds when they are net receivers of VM. Importantly, the observed selling pressure may have been further aggravated by ICPFs trying to replenish their liquidity buffers in anticipation of future margin calls.[15]

3.3.1 Variation Margin and Gilt Trading across Different Hours

The results so far are consistent with our hypothesis that VM losses induced ICPFs to sell gilts during the COVID crisis. But there may exist unobserved factors that simultaneously

[14] We acknowledge that ICPFs may not always need to sell gilts immediately to meet VM demand, hence we also examine how VM affects ICPFs' gilt trading on the next day. Table A1 of the Internet Appendix shows that VM calls also induce ICPFs to sell gilts on the following trading day.

[15] In Table A2 of the Internet Appendix, we analyze the impact of VM demand on gilt trading of mutual funds and hedge funds. There is no significant relation between VM demand and the gilt trading of these two investor types. Therefore, the VM channel is not the main driver of gilt selling by mutual funds, which is consistent with the small magnitude of the sector's VM losses shown in Figures 6 and 7.

drive VM losses and gilt sales. For example, investors may have perceived gilts as particularly risky during the COVID period, and this perception may have contributed to the heightened selling pressure in the gilt market. However, this risk-based argument fails to explain the cross-sectional relation between VM demand (arising from pre-crisis FX hedging positions) on individual ICPFs and their gilt trading, nor does it elucidate why such a relation exists exclusively in the case of ICPFs.

To provide further evidence for our hypothesis, we take advantage of the granularity of our data and exploit the timing of variation margin calls. Specifically, clearinghouses and dealers issue VM calls predominantly on an end-of-day basis (BCBS and IOSCO, 2021), usually around 4pm London time. Therefore, if ICPFs sold gilts to meet VM calls during the COVID crisis, VM should have a more pronounced impact on ICPFs' gilt trading around closing hours of the same day. If on the other hand, ICPFs sold gilts because they perceived gilts to be risk and their risk perception is correlated with their dollar hedging positions, then the 4pm cutoff time should not matter for their trading activity. To differentiate between the two hypotheses, we decompose gilt trading of ICPFs into trading before closing hours (from 8am to 3pm) and trading around closing hours (from 3pm to 6pm).[16]

As shown in Panel B of Table 3, the relation between VM and the same-day ICPFs' gilt trading is statistically significant only around closing hours. In contrast, the regression coefficients are small and insignificant during earlier trading hours. Furthermore, the link between VM demand and ICPFs' gilt trading during closing hours is nonexistent in the early March period (March 1st-9th), when ICPFs were receiving VM payments. Next, we go even further and measure ICPFs' trading activities hour by hour. Specifically, we use the hourly gilt trading of ICPFs as the dependent variable in regression Eq. (2). As shown in Figure 10, the relation between VM and ICPFs' gilt trading only starts to be statistically detectable after 3pm.

There are two potential concerns with these findings. First, One may be concerned that

[16]ICPFs can also trade during non-conventional trading hours (before 8am or after 6pm). We do not, however, observe any overnight trading by ICPFs in the COVID period.

there is higher overall liquidity in the gilt market during closing hours than in earlier hours. However, as shown in Figure 11, the closing hours account for roughly 20% of the total daily volume in the the gilt market, so our results are unlikely driven by variation in market liquidity. Second, it is possible that there is more cross-sectional variation in ICPFs' trading around closing hours – which may mechanically lead to larger responses to VM – than in earlier trading hours. However, we find that the standard deviation of ICPFs' gilt trading is comparable before and around closing hours (1.96 vs. 1.73).

In sum, the results in this subsection – that ICPFs' trading around closing hours (3-6pm) is much more responsive to variation margin calls than their trading in earlier hours (8am-3pm) – provide perhaps the cleanest evidence for our hypothesis that ICPFs' selling of gilts during the COVID crisis was induced by variation margin losses on their derivative holdings, rather than other confounding factors such as the perceived risk of holding gilts.

3.3.2 Variation Margin on Different Derivative Types

We next examine the differential impact of VM losses from different derivative instruments on investors' gilt trading during the COVID crisis. We examine three types of derivatives: FX derivatives, interest rate swaps (IRS), and inflation swaps. As shown in Table 4, VM on FX derivatives has the largest impact on ICPF gilt trading, with a negative coefficient of -0.42 and a t-statistic of -3.96. In contrast, the effect of VM on interest rate swaps on ICPF gilt trading is only marginally negative, with a coefficient of -0.13 and a t-statistic of -1.94 . The coefficient estimate on VM on inflation swaps is statistically insignificant; this is unsurprising given the small magnitude of VM losses from inflation swaps (see Figure 7). These results highlight the importance of FX hedging positions and the associated VM losses in inducing gilt selling during the COVID crisis.

There are a few factors that may contribute to the heterogeneous impact of variation margin losses from different derivative instruments on ICPFs' gilt trading. First, during the COVID period, ICPFs' VM on FX derivatives spiraled to a substantially larger amount

(£8bn) compared to those on interest rate swaps (£5bn) and inflation swaps (£0.6bn). Any convexity in ICPFs' response to VM losses would imply a larger average effect on ICPF gilt trading for VM on FX derivatives than VM on interest rate swaps or inflation swaps. Second, and more importantly, while most interest rate derivatives are centrally cleared, less than 5% of FX derivatives are centrally cleared (with the remaining 95% bilaterally cleared).[17] Central clearing offers many advantages, including enhanced netting opportunities, and greater transparency in margin calculations and payments (see, e.g., Duffie, 2019, 2020). All these factors – the netting of margin gains/losses plus the certainty in the timing and amount of margin payments – may prompt ICPFs to raise cash more aggressively in response to VM losses on FX derivatives than to VM losses on interest rate swaps.

3.3.3 FX Derivatives Holdings and Gilt Trading

To alleviate the concern that part of the relation we document in the previous section between VM on FX derivatives and ICPF trading is due to movements in exchange rates, we next explore the relation between pre-COVID FX derivative holdings and gilt trading during the COVID crisis. To this end, we conduct the following panel regression:

$$Net\ Trading_{i,t} = \beta_0 + \beta_1 \times FX\ Derivative\ Holding_{i,t-1} + FE + \epsilon_{i,t}. \tag{3}$$

Panel B of Table 4 reports the results. Across all specifications, pre-crisis FX derivative holdings are significantly negatively associated with ICPFs' gilt trading in the crisis period. In contrast, the coefficients are statistically zero for the pre-COVID period (March 1st-9th). Given the unforeseen nature of the COVID crisis, the pre-crisis FX derivative holdings are largely exogenous to the perceived risk of holding gilts during the crisis. Thus, the results lend further support to the view that ICPFs' gilt trading during the COVID period is driven by their VM losses on FX derivatives and not by heightened risk perceptions.

[17] See summary statistics in the BIS derivatives report at https://www.bis.org/statistics/derstats.html.

3.3.4 Variation Margin and Gilt Trading: Bond Level Analysis

We further examine the impact of VM demand on gilt trading at the investor-bond level, which enables us to exploit the heterogeneity across gilts. Specifically, we conduct the following panel regression:

$$Net\ Trading_{i,j,t} = \beta_0 + \beta_1 \times VM_{i,t} + \beta_2 \times VM_{i,t} \times Liquid\ Bond_j + FE + \epsilon_{i,j,t}, \quad (4)$$

where the dependent variable is the daily gilt trading at the ICPF (i)–bond (j) level, and the main independent variable is the investor's daily VM demand. The indicator variable $Liquid\ Bond_j$ is equal to one if the gilt's pre-crisis turnover is above the sample median, and zero otherwise. We include time and bond fixed effects in the regression and report bootstrapped standard errors.

As shown in Table 5 (and consistent with the results in Table 3), VM demand significantly increases an ICPF's gilt sales during the COVID period. In the cross-section of gilts, the effect is more pronounced for more liquid bonds. For instance, in Column (4) of Panel A, the coefficient estimate on VM is -0.036 (t-statistic = -2.86), and that on the interaction term between VM and *Liquid Bond* is -0.049 (t-statistic = -2.10). In other words, the effect of VM on bond trading for liquid bonds is more than twice as large as that for illiquid bonds. These results are consistent with the view in Ma, Xiao and Zeng (2022) and Huang, Jiang, Liu and Liu (2021a) that institutions follow a liquidity pecking order whereby they sell their most liquid assets first to meet immediate obligations.

We also examine the differential impact on ICPFs' gilts trading of VM losses from different types of derivative contracts (FX vs. interest rate swaps vs. inflation swaps). As can be seen in Panel B of Table 5, the effect is the largest for VM on FX derivatives. Moreover, consistent with the results in Panel A, ICPFs' selling in response to VM on FX derivatives is more pronounced for more liquid gilts.

3.3.5 Gilt Repo Transactions

In addition to selling gilts, ICPFs can also borrow cash in the gilt repo market to meet VM calls. Figure 12 provides an overview of the total borrowing and lending activities of ICPFs and other investor groups during the COVID crisis. From March 10th-18th, ICPFs increased their net repo borrowing by approximately £2bn. Hedge funds and mutual funds also increased their net borrowing during this period (by roughly £4bn and £2.5bn, respectively).

By using a variant of the regression model in Eq. (2), we examine the cross-sectional relation between VM losses and ICPFs' repo borrowing. More precisely, we test whether variation margins on FX derivatives, interest rate swaps, and inflation swaps have an impact on their repo (i.e., cash borrowing) and reverse repo (i.e., cash lending) transactions.

Table 6 reports the regression results. Panel A focuses on ICPFs' repo transactions, and Panel B on their reverse repo activities. Across all specifications, we observe a significantly positive association between VM on FX derivatives and repo borrowing during the COVID crisis. For instance, as shown in Column (4) of Panel A, the coefficient estimate on VM on FX derivatives is a statistically significant 0.22 (t-statistic = 2.14). In other words, a 1% increase in FX variation margin loss is associated with a 22bps increase in repo borrowing.

As can be seen from Panel B, VM on FX derivatives does not have a significant impact on ICPFs' reverse repo transactions during the COVID period. In other words, ICPFs do not adjust their repo lending in response to VM calls on their FX derivatives. Interestingly, ICPFs reduce repo lending in response to VM losses on their interest-rate-swap positions. It is important to note that ICPFs' repo lending is much smaller in magnitude than their repo borrowing (Czech, Gual-Ricart, Lillis and Worlidge, 2021a).

To understand why ICPFs chose to sell gilts to meet VM calls during the COVID crisis despite having the option to borrow cash through the gilt repo market, we take a closer look at the dynamics of gilt repo rates. As shown in Figure 13, repo rates experienced a significant spike during this period, suggesting that repo borrowing became considerably more costly for ICPFs. This applied to both the overnight and longer-term segments of the repo market (e.g., the three-month repo rate spiked by nearly 40bbps in the COVID week). A large part of this rate spike is also due to dealers' balance-sheet constraints, so limited ability and willingness to intermediate repo transactions, as a result of the Basel III requirements, in particular the leverage ratio rule (Kotidis and van Horen, 2018).

3.4 Gilt Trading and Bond Returns

To shed light on the drivers of yield spikes during the COVID crisis, we next analyze – in the cross-section of gilts – the impact of ICPFs' selling on gilt yields. An obvious concern with this exercise is that ICPFs' selling of gilts may be driven by many factors, including private information. To isolate the impact of VM demand on ICPF trading and, in turn, on gilt yield movements, we construct a measure of "variation margin-induced trading" (VMIT) in the spirit of "flow-induced trading" proposed by Coval and Stafford (2007) and Lou (2012). Specifically, we calculate ICPF i's variation margin-induced trading in bond b assuming that each ICPF proportionally scales up or down its holdings in response to variation margin changes.

Due to the lack of complete information on bond holdings of individual pension funds, we approximate the weight of bond b ($w_{i,b}$) in ICPF i's portfolio using the ICPF's trading volume in bond b over the past year. Variation margin-induced trading (VMIT) in bond b on day t is then defined as:

$$VMIT_{b,t} = -\frac{\Sigma_i VM_{i,t} \times w_{i,b}}{Amount\ Outstanding_{b,t}}, \tag{5}$$

where $Amount\ Outstanding_{b,t}$ is bond b's amount outstanding at time t. To facilitate the interpretation of the coefficients, we add a minus sign since a positive VM value indicates that the investor incurs VM losses, which are associated with gilt sales. To further reduce noise in our estimation, we divide all gilts into several maturity buckets, and calculate value-weighted gilt returns and VMIT for each maturity bucket (<1 year, 1-3 years, 3-5 years, 5-7 years, 7-10 years, 10-15 years, 15-20 years, 20-25 years, 25-30 years, 30+ years and short-term / medium-term / long-term index-linked bonds).[18] We construct VMIT based on the total VM demand across all derivative types, as well as separately for VM on each derivative type. The VMIT variables are standardized to a unit standard deviation. We then examine the extent to which VMIT affects gilt returns with the following regression:

$$Return_{j,t} = \beta_0 + \beta_1 \times VMIT_{j,t} + Controls + FE + \epsilon_{j,t}. \tag{6}$$

We focus on the COVID crisis period, given that we only observe a significant link between VM demand and gilt trading in these seven trading days (see Table 3). We include time-fixed effects to control for common shocks, as well as to highlight the variation in the cross section. We also control for total trading volume, mutual fund flow-induced trading (following Lou (2012)), and the contemporaneous return of US Treasuries with the same maturity. We report bootstrapped standard errors in all specifications.

Table 7 reports the regression results. As shown in Columns (1) and (2), there is a positive contemporaneous association between variation margin-induced trading of ICPFs and gilt returns. The coefficient estimate on VMIT is economically large: a one-standard-deviation decrease in VMIT (i.e., a one-standard-deviation increase in ICPF selling due to variation margin losses) corresponds to a 72.8bps reduction in gilt returns per day. For reference, the average daily gilt return is -1.23% during the COVID crisis, so a one-standard-deviation move in VMIT accounts for over 50% of the average daily gilt price movement. The results are unchanged after we control for other confounding factors (Column 3). In Columns 4-6, we separately analyze VMIT based on the three derivative types and find that only VMIT based on FX derivatives significantly impacts gilt returns. For example, in the full specification with all the controls (Column 6), the coefficient on VMIT(FX) is a statistically significant 0.535. These results suggest that VM losses on FX derivatives contributed to the gilt yield

[18] The results are similar if we use bonds' trading volume as the denominator (Internet Appendix Table A3), or if we use equal-weighted average returns and VMIT for each maturity basket (Internet Appendix Table A4).

spikes during the COVID crisis.

3.4.1 Short-term vs. Long-term Gilts

As shown in Figure 4, the ICPF sector mainly holds long-term gilts. In this subsection, we examine the effect of VMIT on bond returns separately for short-term and long-term gilts. To this end, we split all gilts into two groups: those with remaining time-to-maturity of less than or equal to five years (short-term gilts), and those with remaining time-to-maturity of more than five years (long-term gilts).

Table 8 reports the regression results of Equation (6) separately for long-term and short-term gilts. Variation margin-induced trading (VMIT) has a much stronger price impact on long-term gilts than on short-term gilts. Specifically, VMIT does not impact the returns of short-term gilts (Columns 1-3). In contrast, for long-term gilts, the price impact is both statistically significant and economically large: the coefficient on VMIT of 0.573 (Column 6) implies that a one-standard-deviation decrease in VMIT corresponds to an 57.3bps decrease in long-term gilt returns per day.

3.4.2 Bond Returns over a Longer Horizon

We next analyze whether the impact of ICPFs' variation margin-induced trading on gilt returns is temporary or permanent. If ICPFs' selling of gilts was driven by short-term liquidity needs (e.g., meeting VM calls), we expect a full reversal of the price impact over time. On the other hand, if ICPFs' selling was driven by fundamental reasons, we expect a persistent effect on gilt prices (e.g., Czech, Huang, Lou and Wang, 2021b). To shed light on this issue, we conduct regressions of future gilt returns on ICPFs' variation margin-induced trading:

$$Return_{j,t\_t+k} = \beta_0 + \beta_1 \times VMIT_{j,t} + Controls + \epsilon_{j,t\_t+k}. \tag{7}$$

where the dependent variable, $Return_{j,t\_t+k}$, is the cumulative return of gilts in maturity bucket j from days t to $t+k$, with k=1, 5, 10, 15, 21 (one day, one week, two weeks, three weeks, up to one month). As shown in Table 9, there is a complete reversal within the first month. More specifically, the coefficient on VMIT is statistically positive for just one day, and becomes statistically indistinguishable from zero by day five, and turns slightly negative after that. These results suggest that ICPFs' gilt trading during the COVID period was unlikely motivated by fundamental reasons, and is more likely driven by liquidity needs (due to VM calls) in that period.

4 Additional Analyses

4.1 Global Evidence

Our analysis so far has focused on the unintended consequences of UK ICPFs' holdings of dollar-denominated assets – and the associated currency hedging activities – for UK gilts. Specifically, UK ICPFs maintain substantial investments in dollar-denominated assets and hedge their dollar exposures through FX derivatives. During the COVID period, the US dollar appreciated against pound sterling, so UK ICPFs faced substantial VM losses on their FX hedging positions. Consequently, they were forced to sell gilts to meet VM payments, which contributed to the rapid spike of gilt yields during this period.

Given the global trend of increasing investments in dollar-denominated assets by large financial institutions – including but not limited to insurance companies and pension funds – it is plausible that many non-US, non-UK institutions also held substantial dollar investments and encountered significant losses on their FX hedging positions during the COVID crisis, just like their UK counterparts. These non-US, non-UK institutions may have also resorted to selling their domestic assets, particularly domestic government bonds, to meet their VM demand.

To explore this possibility, we examine the dynamics of exchange rates and government bond yields in other G10 countries. Figure 14 depicts the exchange rate between the US dollar and the respective domestic currency, alongside the yields of the domestic 2-year and

10-year government bonds. There is a strong correlation between the exchange rate and government bond yields in other G10 countries that mimics the pattern observed in the UK: as the local currency depreciated against the US dollar in the COVID crisis, domestic government bond yields spiked. While many economic mechanisms may have contributed to the pattern in Figure 14, the resemblance to Figure 1 suggests that some common economic forces might be at play. Our proposed mechanism is further supported by complementary evidence from the Eurozone: for example, in the ECB financial stability review, Rousová et al. (2021) argue that euro-denominated money market funds (MMFs) experienced large outflows in March 2020, which was likely related to the VM losses on derivative holdings of Dutch ICPFs.

4.2 Mutual Fund Trading during the COVID Period

As shown in Figure 9, mutual funds were also net sellers of gilts (by £4.5bn) during the COVID crisis. While it is not the focus of our paper, we also examine the drivers of mutual fund selling in this period. There could be two potential drivers: VM demand on derivative holdings (like ICPFs) and capital outflows (more unique to mutual funds). As shown in Figure 6, mutual funds did not incur substantial VM losses on derivative holdings in the COVID period – therefore, VM demand is unlikely to be an important driver of mutual funds' gilt trading (see Table A2 in the Internet Appendix for a formal test). This is perhaps unsurprising given the limited use of derivatives by mutual funds.

We next analyze capital outflows experienced by UK mutual funds during the COVID period, and find that fund outflows played a major role in driving their' selling of gilts. Internet Appendix Figure A2 shows that UK mutual funds faced substantial outflows in the COVID period. In line with the findings of Ma, Xiao and Zeng (2022) and Huang, Jiang, Liu and Liu (2021a), Internet Appendix Table A5 shows that, in the cross-section of funds, capital outflows are significantly correlated with gilt selling by individual funds in that period.

5 Conclusion

In this paper, we investigate the trading patterns and yield dynamics of UK government bonds during the recent COVID crisis. Our analyses uncover several intriguing results. First, we observe a significant increase in the 10-year gilt yield – of over 50bps – between the 10th and 18th of March 2020. Second, this surge in gilt yields coincided with the selling of gilts by three distinct groups of market participants: the UK Debt Management Office (DMO) conducted auctions and issued over £4bn of gilts, mutual funds divested more than £4.5bn worth of gilts, and ICPFs sold an additional £3.8bn of gilts.

We hypothesize and provide corroborating evidence for a novel mechanism that highlights an unintended consequence of the dollar's reserve currency status for the yields of non-US government bonds. With about half of all global financial assets denominated in dollars, non-US institutions allocate a substantial portion of their capital to dollar-denominated assets. These institutions then hedge their dollar exposures by selling dollars forward through FX derivatives. During crisis periods, the dollar typically appreciates against many other currencies. As a result, these non-US institutions, who are passive investors in normal times, face margin calls on their currency hedging positions and are forced to sell off their holdings of domestic safe assets. This selling pressure then contributes to substantial yield spikes in domestic government bond markets.

Our findings and the proposed mechanism carry significant implications for both investors and policymakers across virtually all non-US countries – to the extent that investors in these countries hold dollar-denominated assets and hedge their dollar exposures through FX derivatives. Understanding and addressing the dynamics outlined in our paper can help guide investment strategies and inform policy decisions in a wide range of jurisdictions.

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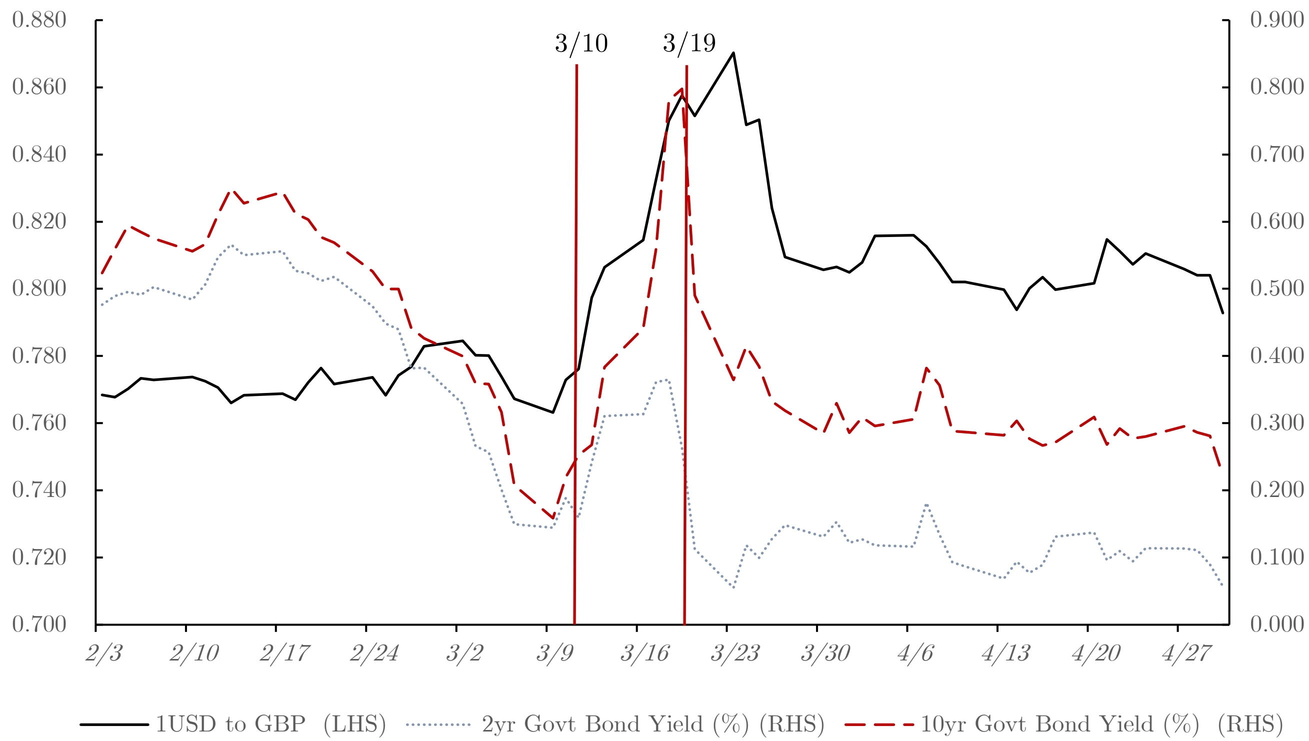


Figure 1: The USD/GBP Exchange Rate and UK Government Bond Yields

This figure shows the dynamics of the USD/GBP exchange rate (left axis) and UK gilt yields (right axis) from February 3 to April 30, 2020. On March 19 the Bank of England voted to cut the Bank rate to 0.1% and to increase its holdings of UK government and corporate bonds by £200 billion. Gilt yields are in percentage points.

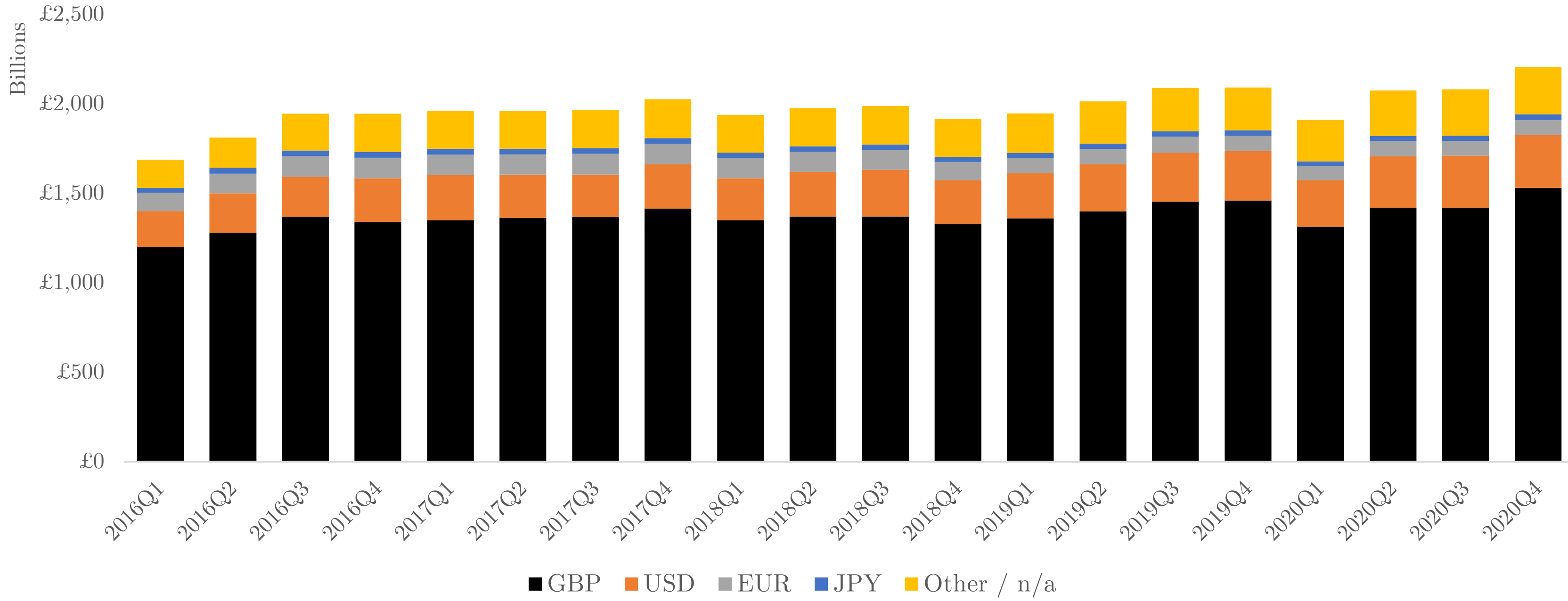


Figure 2: Asset Holdings of UK Insurance Companies

This figure shows the total asset holdings of UK insurance companies by currency. The sample period is from 2016Q1 to 2020Q4. Asset holdings are measured in £ billion.

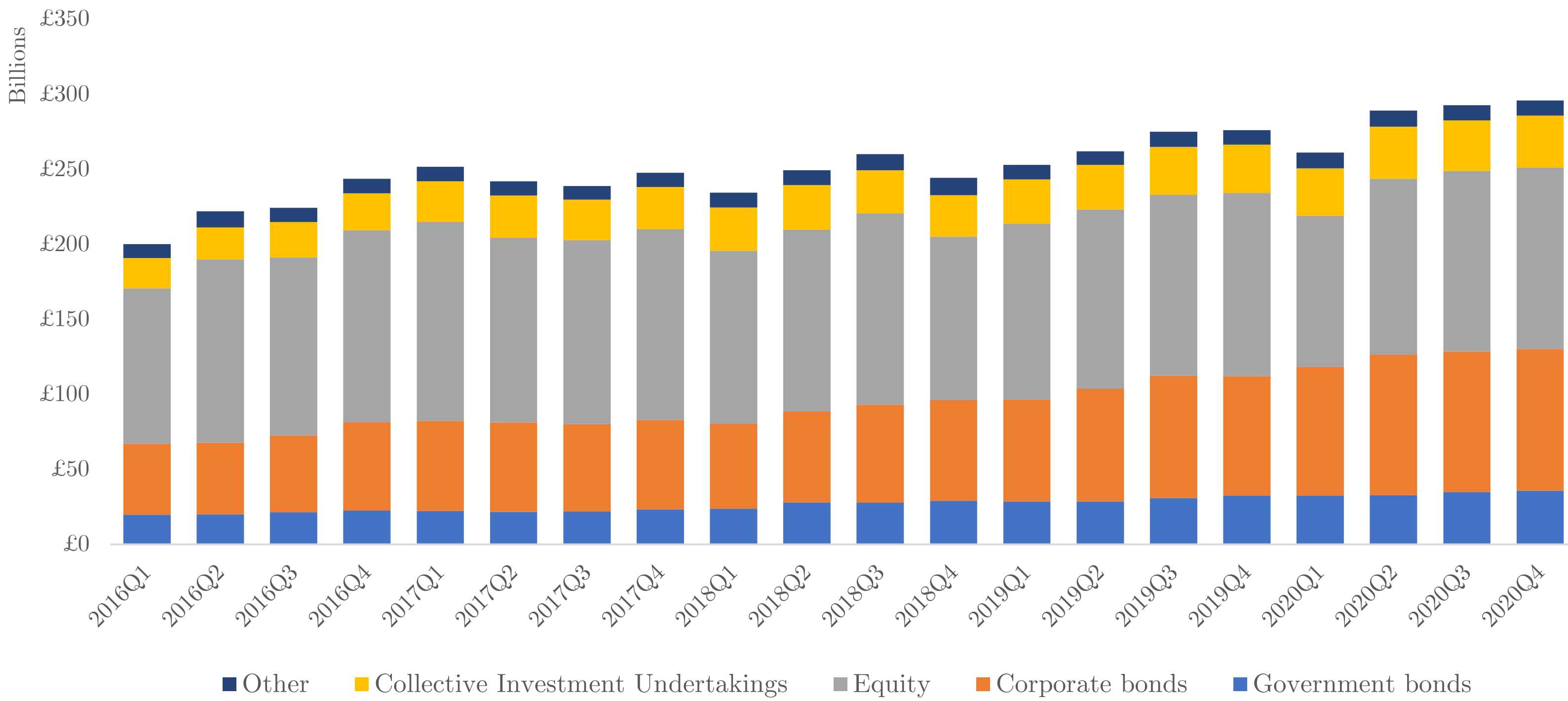


Figure 3: USD Asset Holdings of UK Insurance Companies

This figure shows the US dollar asset holdings of UK insurance companies by asset class. The sample period is from 2016Q1 to 2020Q4. Asset holdings are measured in £ billion.

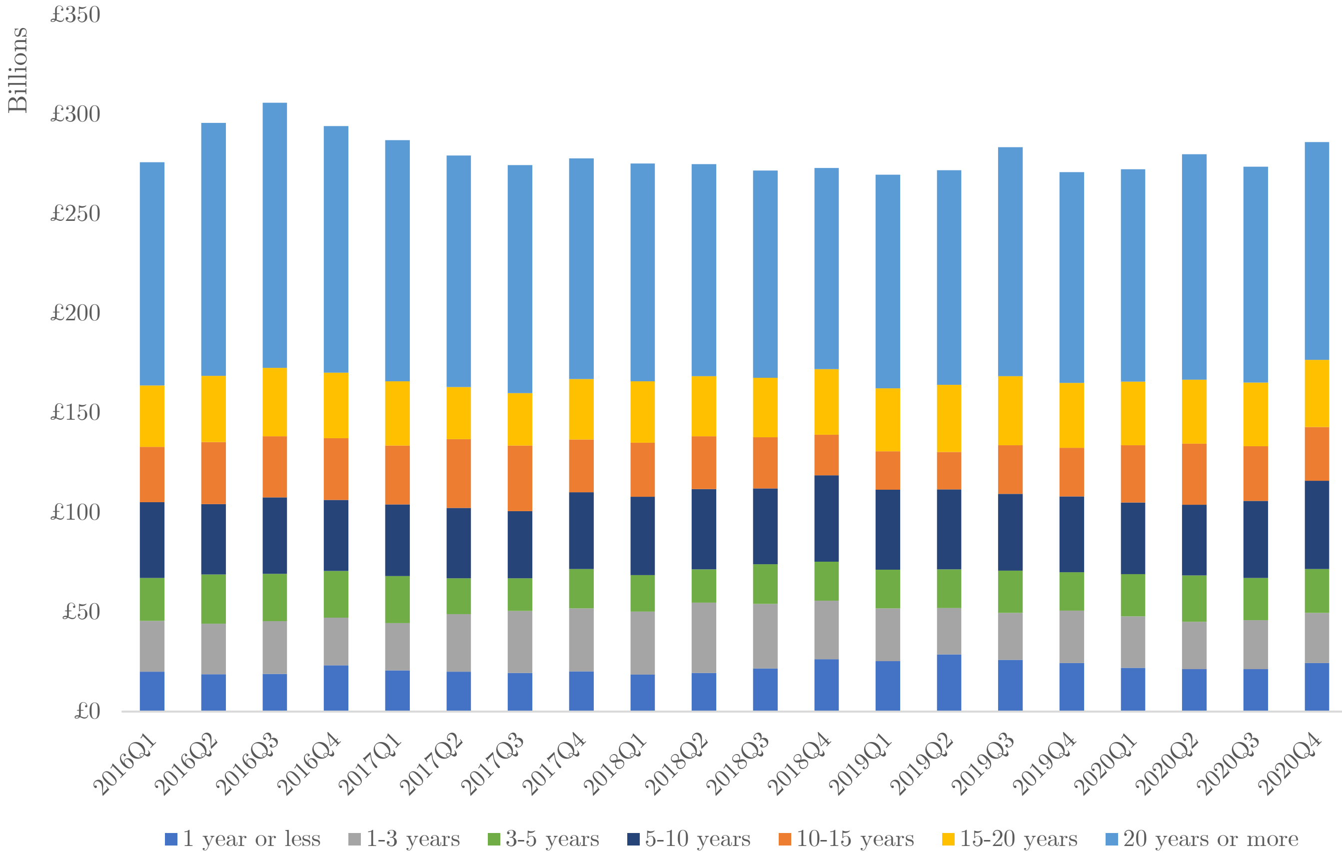


Figure 4: Composition of UK Government Bond Holdings of UK Insurance Companies

This figure shows the composition of UK government bond holdings of UK insurance companies. Government bonds are grouped based on their time-to-maturity. The sample period is from 2016Q1 to 2020Q4. Asset holdings are measured in £ billion.

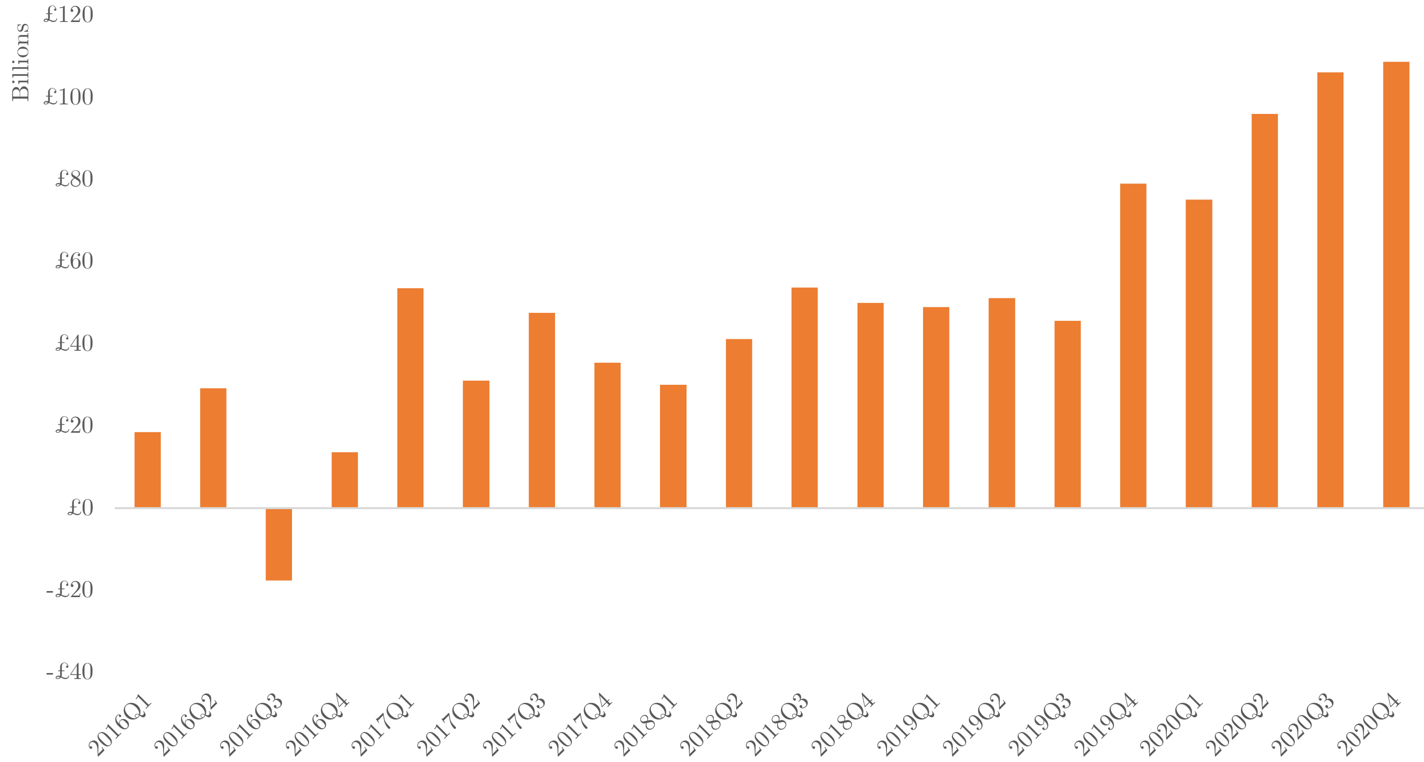


Figure 5: USD FX Derivatives Net Exposures of UK Insurance Companies

This figure shows the USD FX derivative net exposures of UK insurance companies. Positive values indicate that insurers deliver more USD than they receive through FX derivatives, i.e., a net hedging position. The sample period is from 2016Q1 to 2020Q4. FX positions are measured in £ billion.

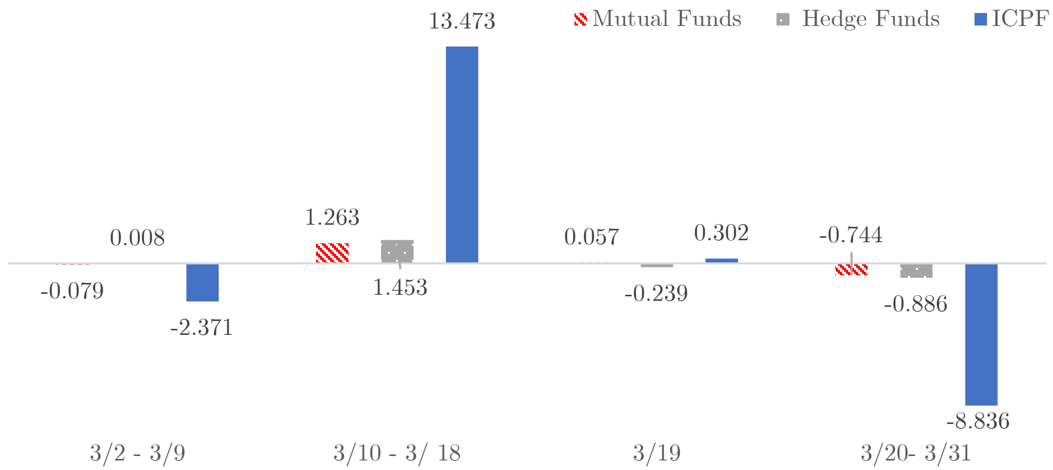


Figure 6: Variation Margin Demand by Investor Type

This figure shows the dynamics of the total variation margin (VM) demand on derivatives held by different investor types (i.e., mutual funds, hedge funds, and insurance companies and pension funds (ICPFs)) during different time windows in March 2020. VM calls are estimated using the EMIR Trade Repository Data on FX derivatives (FX forwards & cross-currency basis swaps), interest rate swaps, and inflation swaps. Positive (negative) values mean that the investor group was a net payer (receiver) of VM. The estimates are based on the methodology used in Bardoscia et al (2020). The variation margin demand is measured in £ billion.

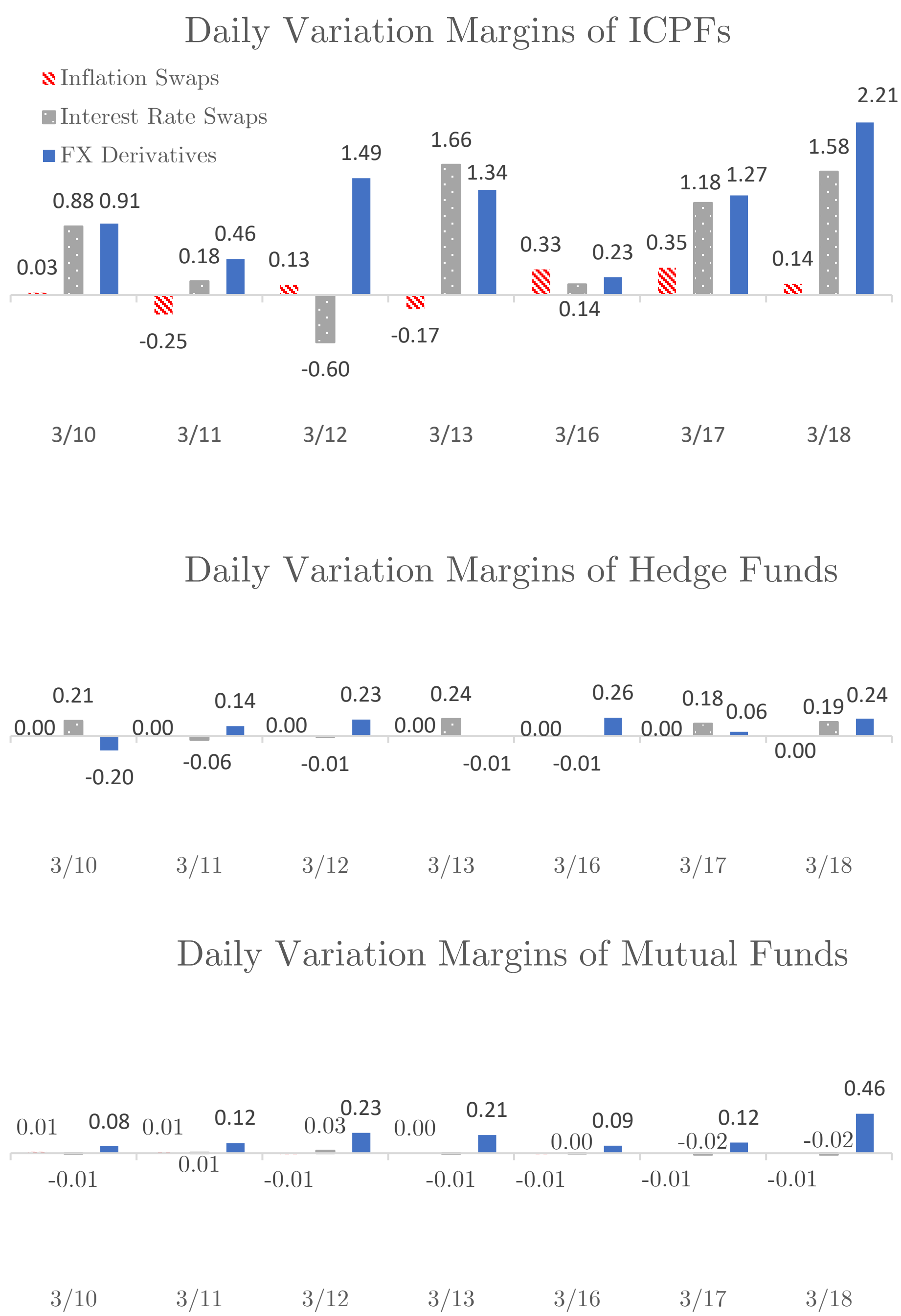


Figure 7: Daily Variation Margin Demand by Investor Type

This figure shows the dynamics of the total variation margin demand on different derivative types held by insurance companies and pension funds (ICPFs), hedge funds and mutual funds from March 10$^{\text{th}}$ to 18$^{\text{th}}$ 2020. VMs are estimated using the EMIR Trade Repository Data on FX derivatives (FX forwards & cross-currency basis swaps), interest rate swaps, and inflation swaps. Positive (negative) values mean that the investor group was a net payer (receiver) of VM. The variation margin demand is measured in £ billion.

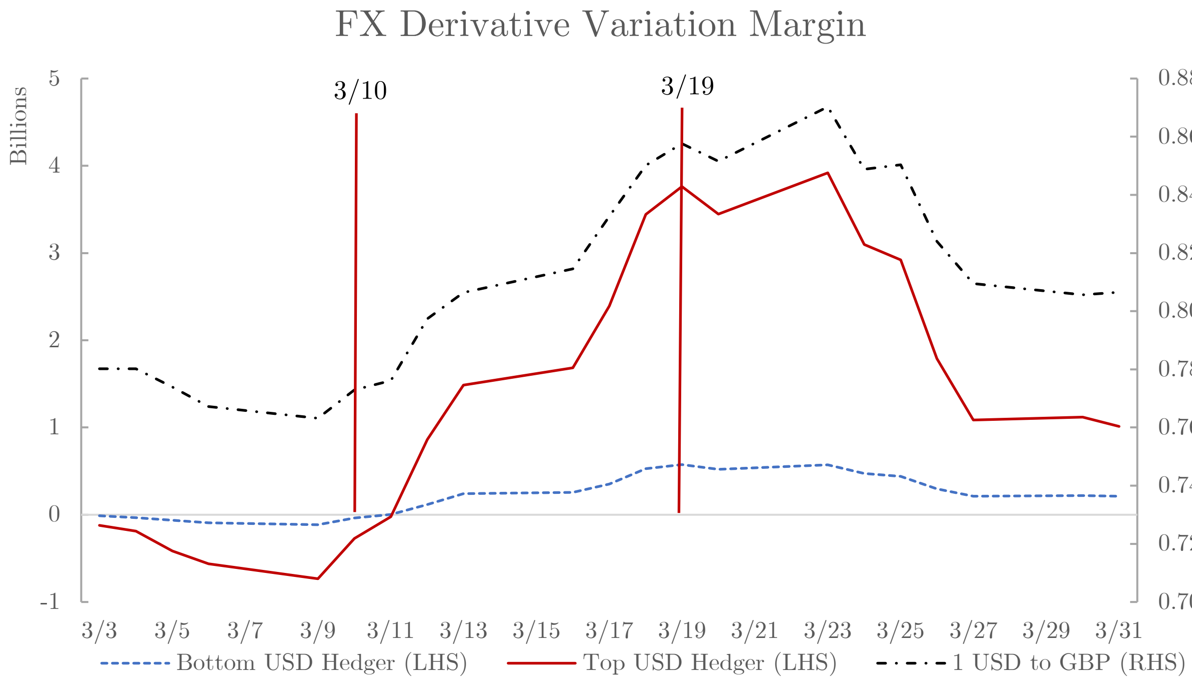


Figure 8: FX Variation Margin Demand of Top and Bottom USD FX Derivatives Hedgers

This figure shows the cumulative FX variation margin demand on insurance companies (left axis) and the dynamics of the USD/GBP exchange rate (right axis) in March 2020. We divide insurance companies into two groups based on their net USD FX hedging positions at the end of 2019Q4: Top USD FX derivative hedgers (with above-average net USD exposure) and Bottom USD FX derivative hedgers. The variation margin demand is measured in £ billion.

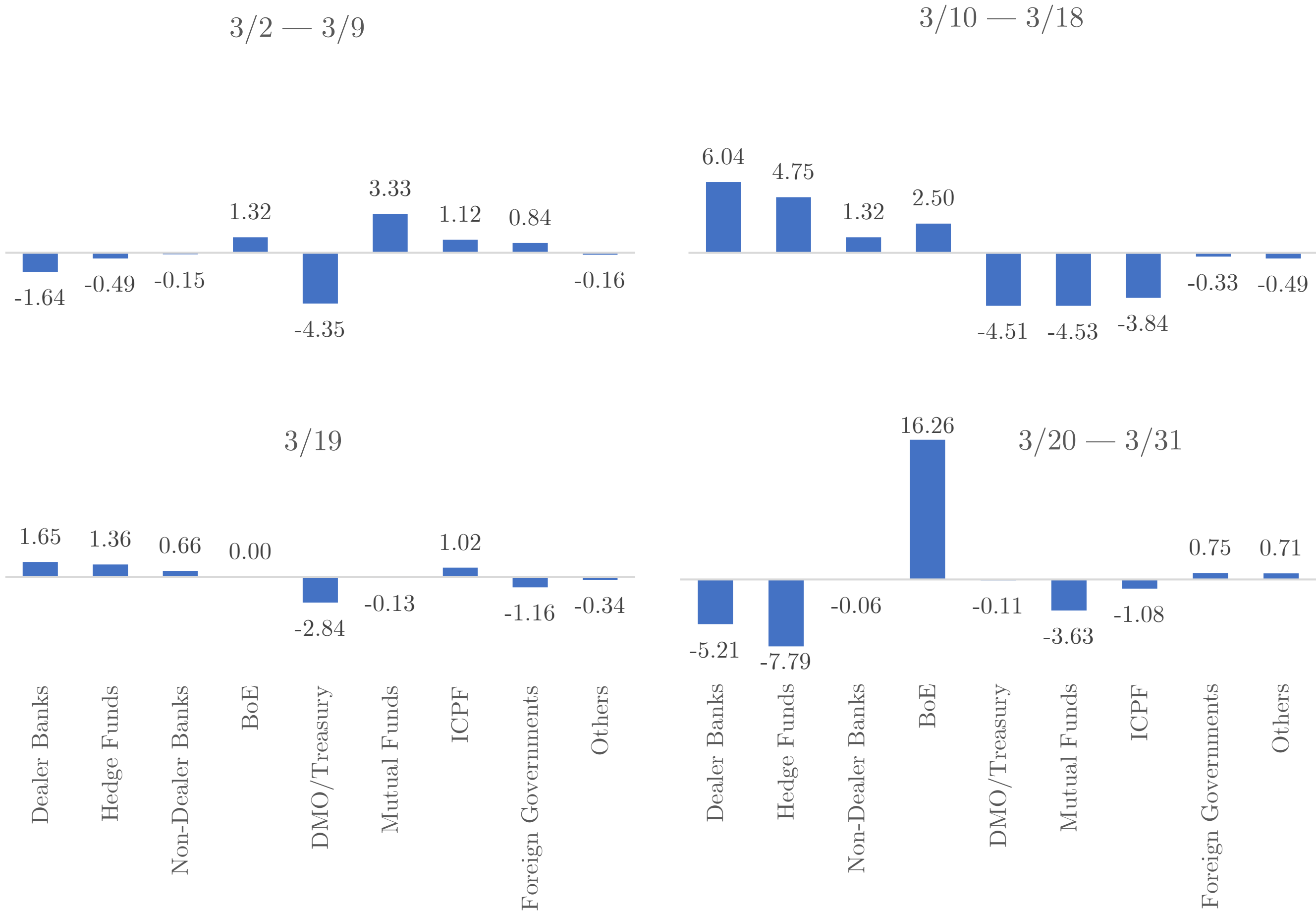


Figure 9: Net Gilt Trading by Investor Type

This figure shows the total gilt net trading volumes of different investor types in March 2020. The investor types include dealer banks, hedge funds, non-dealer banks, Bank of England (BoE), UK Debt Management Office (DMO), mutual funds, insurance companies and pension funds (ICPFs), and foreign governments. Gilt trading volumes are measured in £ billion.

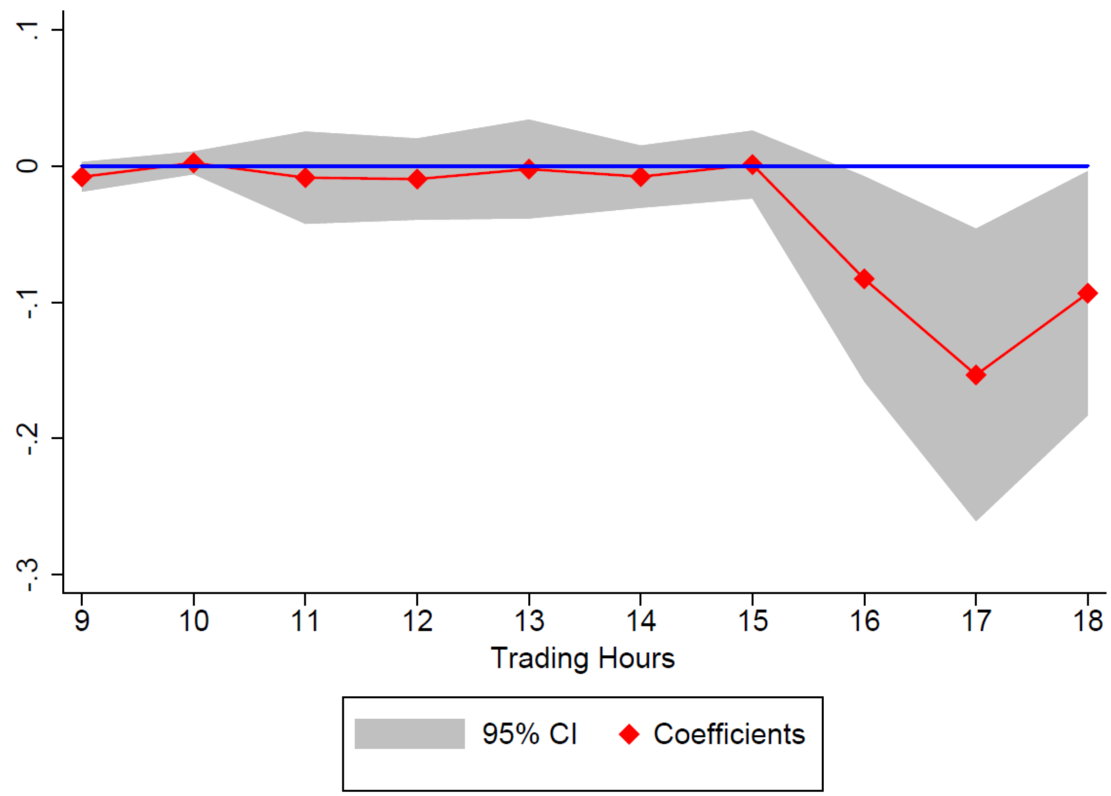


Figure 10: Variation Margin and Gilt Trading Across Trading Hours

This figure reports the coefficients (and the corresponding 95% confidence intervals) from regressions of hourly gilt net trading volumes of ICPFs on their variation margin demand during the conventional trading hours from 9am to 6pm, for the period of March 10^{th} to 18^{th} 2020.

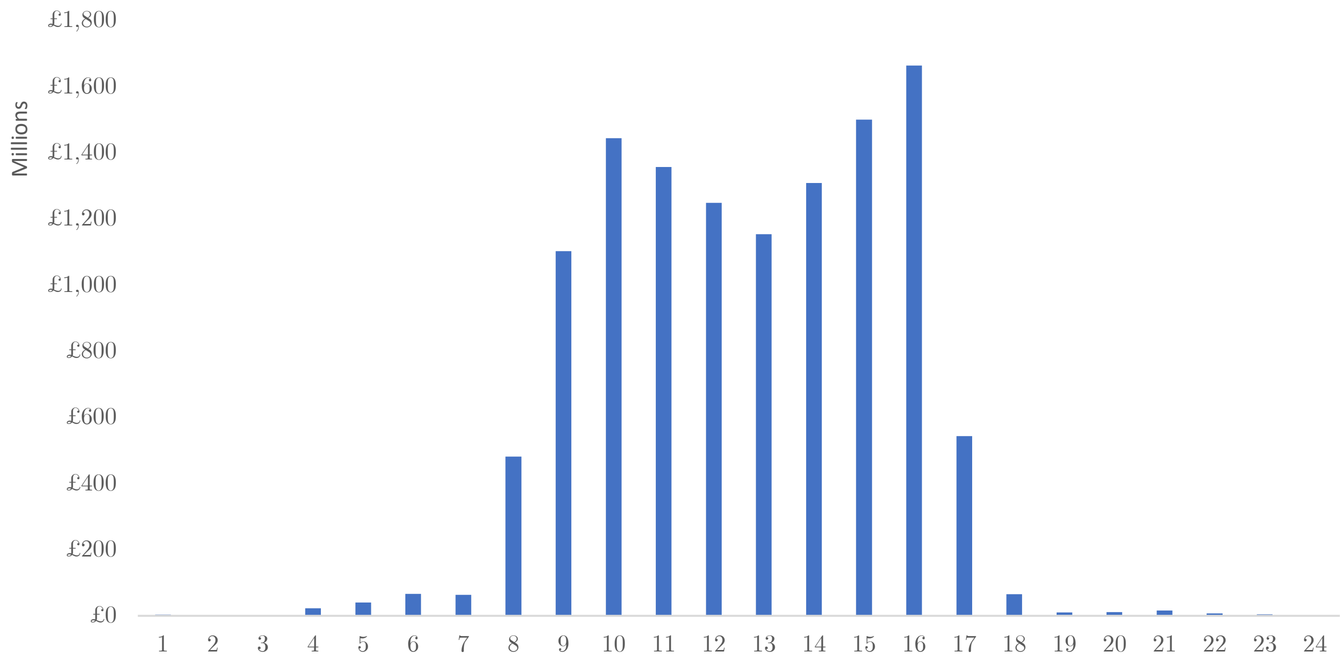


Figure 11: Gilt Trading Volume Across Trading Hours

This figure shows the gilt trading volumes by hour (from 12am to 12pm) of all client sectors. Gilt trading volumes is measured in £ million. The sample covers the period from January 2018 to December 2019.

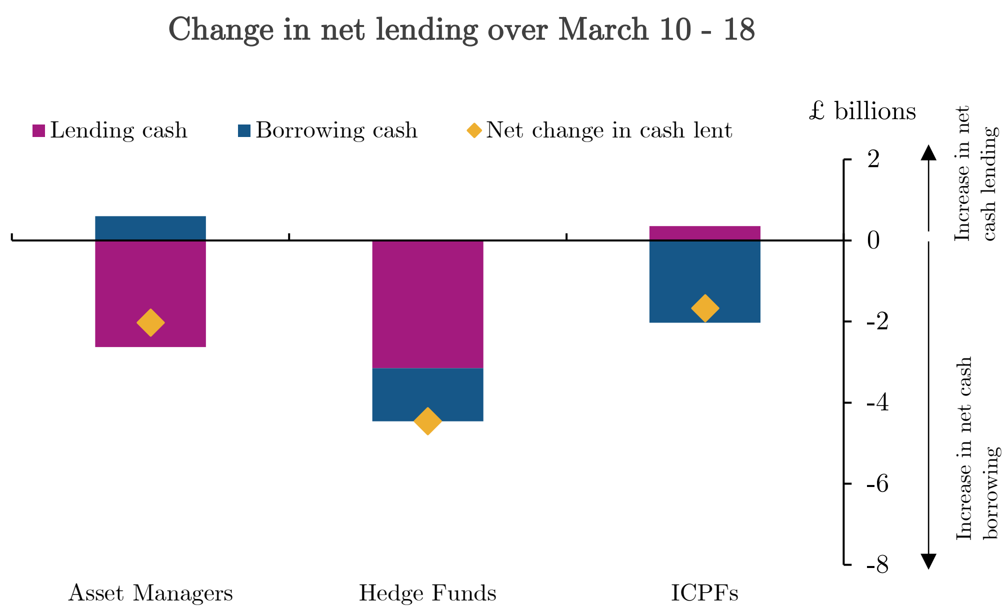


Figure 12: Repo Activity of Mutual Funds, Hedge Funds, and ICPFs

This figure shows the repo trading activity of mutual funds, hedge funds, and ICPFs from March 10^{th} to 18^{th} 2020. Positive (negative) values in the net change in cash lent (yellow diamond) indicate that the investor group decreased (increased) their net repo borrowing. Repo trading volumes are measured in £ billion.

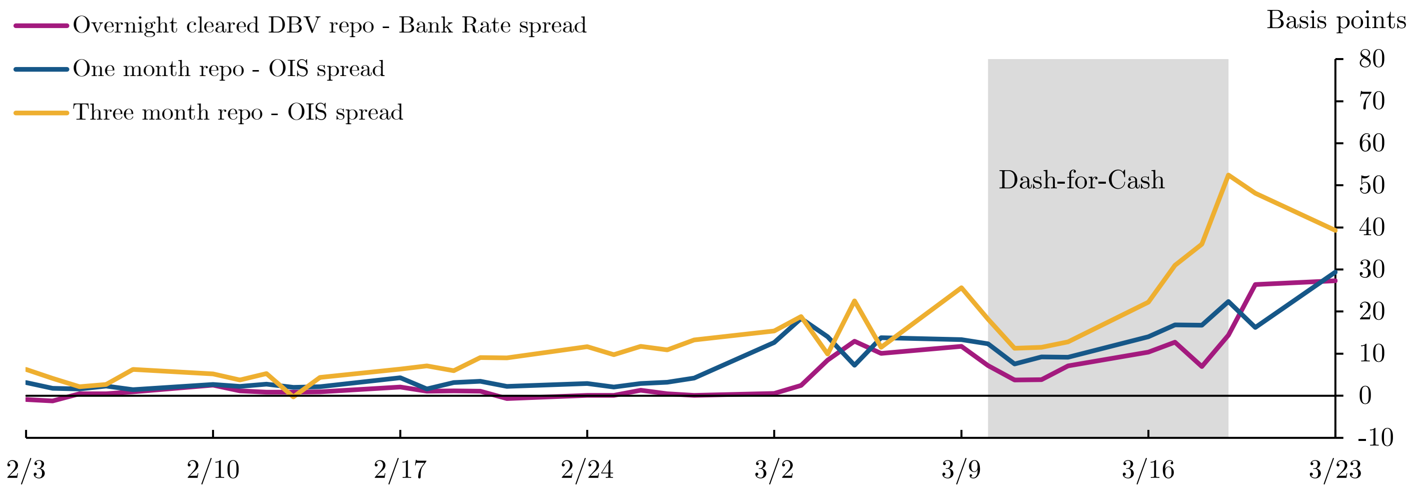


Figure 13: UK Repo Rates in February and March 2020

This figure shows the dynamics of UK repo rates between February 3rd and March 23rd 2020. The overnight cleared DBV repo – Bank Rate spread is a volume-weighted average of cleared DBV (general collateral) repo and reverse repo trades as a spread to Bank Rate. One-month/three-month repo – OIS spreads are volume-weighted averages of repo rates (from the perspective of clients borrowing cash; including all DBV types) as a spread to the corresponding OIS rates.

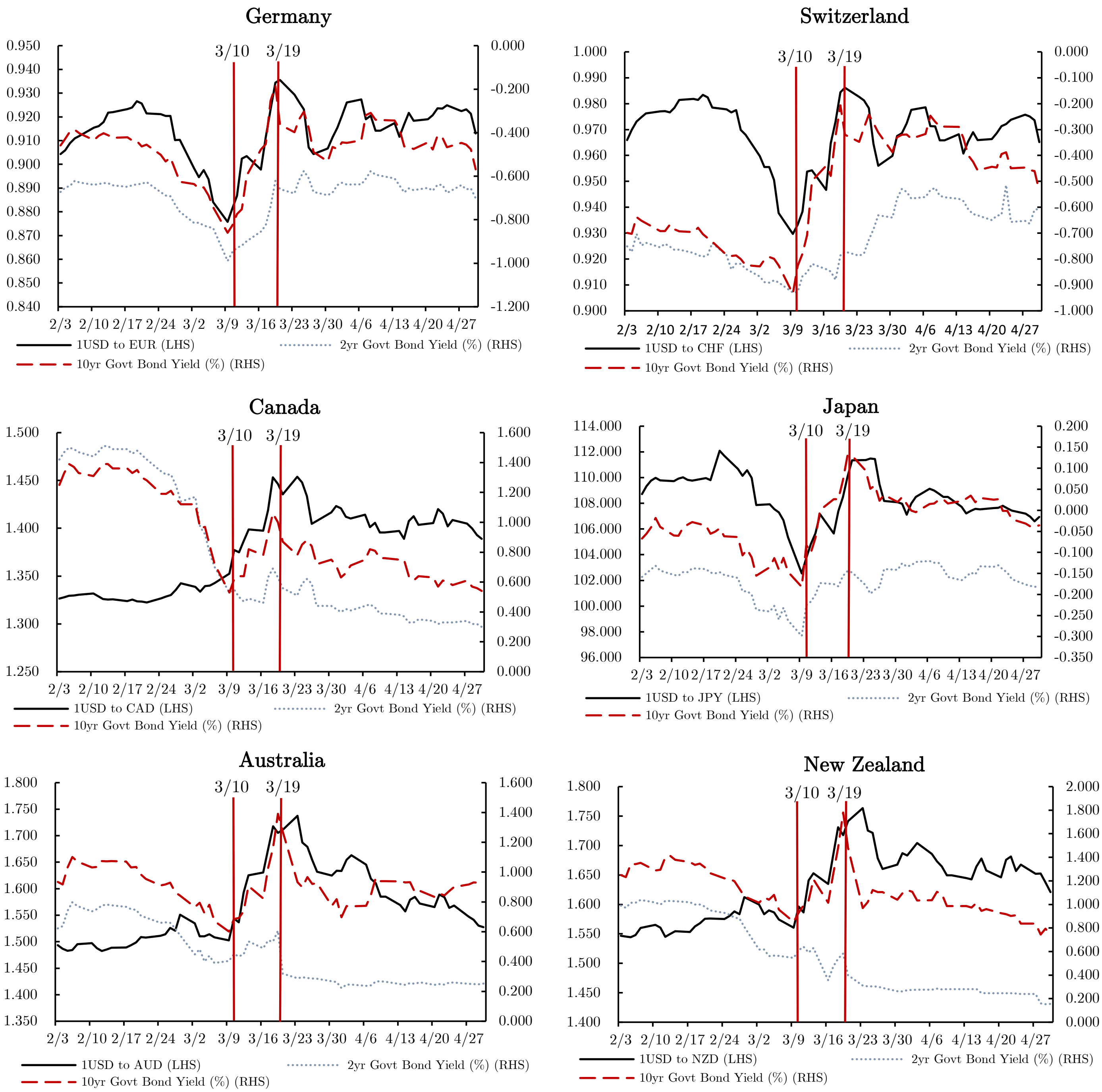


Figure 14: Exchange Rates and Government Bond Yields

This figure shows the dynamics of the exchange rate of USD against the domestic currency (left axis) and the domestic government bond yields (right axis) across different countries from February to April 2020. The yield is in percentage points.

Table 1: Summary Statistics

This table reports the summary statistics for our sample. Panels A and B report the daily variation margin (in £ million) and gilt net trading per investor (in £ million) in our ICPF sample from the 1st to 18th of March 2020. Panel C reports the daily gilt returns from the 10th to 18th of March 2020. The short-term gilt sample includes gilts with a time-to-maturity of five years or less; the long-term gilt sample includes the remaining gilts.

Panel A: Variation Margin					
	Mean	Std.Dev	Q25	Q50	Q75
March 1 – 18	16.02	165.06	-1.63	0.23	5.79
March 1 – 9	-3.40	161.01	-4.83	-0.12	1.62
March 10 – 18	28.97	166.76	-0.36	1.15	14.94
March 10 – 18 (FX)	16.29	55.07	0.00	0.00	2.17
March 10 – 18 (IRS)	11.66	157.63	-0.37	0.00	0.32
March 10 – 18 (Inflation)	1.03	12.46	-0.19	0.00	1.05
Panel B: Net Gilt Trading					
	Mean	Std.Dev	Q25	Q50	Q75
March 1 – 18	-3.40	40.18	-7.94	-0.59	2.41
March 1 – 9	2.67	40.92	-6.74	-0.80	1.95
March 10 – 18	-7.45	39.23	-8.50	-0.43	2.41
Panel C: Gilt Returns					
	Mean	Std.Dev	Q25	Q50	Q75
Return (%)	-1.23	1.90	-2.22	-0.56	-0.02
Return (%) (Long-term)	-1.57	2.06	-3.03	-1.19	-0.25
Return (%) (Short-term)	-0.11	0.17	-0.14	-0.05	-0.00

Table 2: Foreign Asset Holdings and Derivative Hedging Positions

This table reports the results of regressions of UK insurance companies' net FX hedging positions on asset holdings in the corresponding currency. The sample period is 2016Q1 to 2020Q4, and the observations are at the insurer-currency-quarter level. The dependent variable is an insurer's net FX notional in a foreign currency in each quarter. The key independent variable is the total asset holdings in the given foreign currency. Columns (1)-(3) include insurance companies' asset holdings and FX derivative hedging positions across all currencies excluding USD, column (4) only includes insurers' asset holdings and FX derivative hedging positions in USD. The dependent and independent variables are adjusted using the Inverse Hyperbolic Sine (IHS) method. *T*-statistics in columns (1)-(3) are reported in parentheses and are based on standard errors double clustered by currency and time. *T*-statistics in columns (4) are reported in parentheses and are based on standard errors clustered by time. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	All Currencies			USD
	(1)	(2)	(3)	(4)
DepVar:	Derivative Hedging Positions			
Foreign Asset Holdings	0.443***	0.444***	0.455***	0.491**
	(7.76)	(7.67)	(7.90)	(2.14)
Insurer FE	Yes	Yes	No	Yes
Time FE	No	Yes	No	Yes
Insurer × Time FE	No	No	Yes	No
No. of Obs.	16,510	16,510	16,297	1,665
Adj. R^2	0.363	0.364	0.364	0.698

Table 3: Variation Margin and Government Bond Trading

This table reports the results of regressions of the gilt net trading of insurance companies and pension funds (ICPFs) on their variation margin (VM) demand. The sample period is March 1st to 18th 2020, and the observations are at the ICPF-day level. We conduct our analysis for different time windows: March 1st – 9th (column (1)), March 10th – 18th (column (2)), and March 1st – 18th (columns (3)-(4)). We refer to the window of March 10th – 18th as the COVID crisis period. The dependent variable is the daily gilt net trading volume (in £ million) of a particular ICPF. In Panel A, the main independent variable is the daily variation margin (in £ million) of a given ICPF, and this variable is denoted as VM. Positive (negative) VM values indicate that the investor was a net payer (receiver) of VM. The indicator variable *COVID Crisis* is equal to one if the observation date falls between March 10th to 18th, and zero otherwise. VM (>0) truncates the independent variable, VM, at zero, and is equal to the original value when VM is positive and zero otherwise. VM (<0) is equal to the original value when VM is negative and zero otherwise. In Panel B, we decompose the gilt net trading of insurance companies and pension funds (ICPFs) into the trading before closing hours (from 8am to 3pm) and the trading around closing hours (from 3pm to 6pm). The dependent variables and the variation margins are adjusted using the Inverse Hyperbolic Sine (IHS) method. We also control for time fixed effects. *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Variation Margin (VM) and Net Gilt Trading				
	(1)	(2)	(3)	(4)
	March 1 – 9	March 10 – 18	March 1 – 18	
DepVar:	Net Gilt Trading			
VM	0.110	-0.163**	0.110	
	(1.246)	(-2.220)	(1.265)	
$VM \times COVID\ Crisis$			-0.273**	
			(-2.514)	
$VM(>0)$				0.181
				(1.059)
$VM(<0)$				0.050
				(0.383)
$VM(>0) \times COVID\ Crisis$				-0.619***
				(-3.166)
$VM(<0) \times COVID\ Crisis$				0.212
				(1.128)
Time FE	Yes	Yes	Yes	Yes
No. of Obs.	174	261	435	435
Adj. R^2	0.016	0.020	0.017	0.051

Panel B: Variation Margin (VM) and Net Gilt Trading Across Different Hours				
	(1)	(2)	(3)	(4)
	March 10 – 18	March 1 – 18	March 10 – 18	March 1 – 18
	Before Closing Hours (8am – 3pm)		Around Closing Hours (3pm – 6pm)	
DepVar:	Net Gilt Trading			
VM	-0.019	-0.014	-0.164***	0.077
	(-0.346)	(-0.189)	(-2.993)	(1.620)
$VM \times COVID\ Crisis$		-0.005		-0.241***
		(-0.050)		(-3.405)
Time FE	Yes	Yes	Yes	Yes
No. of Obs.	261	435	261	435
Adj. R^2	-0.007	0.012	0.040	0.062

Table 4: Variation Margin on Different Derivative Types and Government Bond Trading

This table uses the same regression specifications as Table 3 (Equation 2 in the text), but we now decompose variation margin into VM on FX derivatives, VM on interest rate swaps, and VM on inflation swaps. In Panel A, the sample period is March 10th to 18th 2020, and the observations are at the ICPF-day level. The dependent variable is the daily gilt net trading volume (in £ million) of a particular ICPF. The main independent variable is the daily variation margin (in £ million) of the given ICPF on one of three different types of derivatives (FX derivatives, interest rate swaps, and inflation swaps), and this variable is denoted as VM. Positive (negative) VM values indicate that the investor was a net payer (receiver) of VM. Panel B focuses on the FX derivatives and examines the impact of FX derivative holdings (immune from the exchange rate changes) on the gilt net trading of ICPFs. The independent variable in Panel B is the FX derivative holding of a given ICPF at the end of February 2020. The dependent variable and the variation margins are adjusted using the Inverse Hyperbolic Sine (IHS) method. We also control for time fixed effects. *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Variation Margin on Different Derivatives and Net Gilt Trading

	(1)	(2)	(3)	(4)
DepVar:	Net Gilt Trading			
VM on FX Derivatives	-0.386***			-0.420***
	(-3.684)			(-3.961)
VM on Interest Rate Swaps		-0.106		-0.132*
		(-1.451)		(-1.937)
VM on Inflation Swaps			0.043	0.092
			(0.310)	(0.736)
Time FE	Yes	Yes	Yes	Yes
No. of Obs.	261	261	261	261
Adj. R^2	0.057	0.003	-0.010	0.074

Panel B: FX Derivative Holdings and Net Gilt Trading

	(1)	(2)	(3)
	March 1 – 9	March 10 – 18	March 1 – 18
DepVar:	Net Gilt Trading		
FX Derivative Holdings	0.068	-0.151***	0.068
	(1.220)	(-3.671)	(1.226)
FX Derivative Holdings × COVID Crisis			-0.219***
			(-3.122)
Time FE	Yes	Yes	Yes
No. of Obs.	174	261	435
Adj. R^2	0.012	0.047	0.032

Table 5: Variation Margin and Government Bond Trading: Bond-Level Analysis

This table reports the results of regressions of the gilt net trading volume of insurance companies and pension funds (ICPFs) on their variation margin (VM) demand. The sample period is March 10th to 18th 2020, and the observations are at the ICPF-bond-day level. The dependent variable is the daily net trading volume (in £ million) of a given ICPF in a particular gilt. In Panel A, the main independent variable is the daily variation margin (in £ million) of the given ICPF, and this variable is denoted as VM. Positive (negative) VM values indicate that the investor was a net payer (receiver) of VM. In Panel B, the main independent variables include a given ICPF's daily variation margin demand separately for FX derivatives, interest rate swaps, and inflation swaps. The indicator variable *Liquid Bond*, takes a value of one if the particular gilt's turnover ratio in January - February 2020 is above the sample median, and zero otherwise. The dependent variable and the variation margins are adjusted using the Inverse Hyperbolic Sine (IHS) method. We also control for time and bond fixed effects. *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Variation Margin (VM) and Net Gilt Trading				
	(1)	(2)	(3)	(4)
DepVar:	Net Gilt Trading			
VM	-0.054***	-0.058***	-0.034***	-0.036***
	(-4.964)	(-5.166)	(-2.992)	(-2.859)
VM × *Liquid Bond*			-0.046**	-0.049**
			(-2.084)	(-2.097)
Liquid Bond			-0.011	
			(-0.116)	
Time FE	Yes	Yes	Yes	Yes
Bond FE	No	Yes	No	Yes
No. of Obs.	1,596	1,596	1,596	1,596
Adj. R^2	0.028	0.065	0.030	0.068

Panel B: Variation Margin (VM) on Different Derivative Types and Net Gilt Trading				
	(1)	(2)	(3)	(4)
DepVar:	Net Gilt Trading			
VM on FX Derivatives	-0.098***	-0.094***	-0.041*	-0.037
	(-4.498)	(-4.030)	(-1.693)	(-1.413)
VM on Interest Rate Swaps	-0.044***	-0.047***	-0.020*	-0.019
	(-4.046)	(-4.153)	(-1.691)	(-1.611)
VM on Inflation Swaps	0.058	0.056	0.134	0.016
	(1.275)	(1.292)	(0.302)	(0.336)
VM on FX Derivatives × Liquid Bond			-0.149***	-0.141***
			(-3.759)	(-3.282)
VM on Interest Rate Swaps × Liquid Bond			-0.064***	-0.069***
			(-2.710)	(-2.910)
VM on Inflation Swaps × Liquid Bond			0.098*	0.091
			(1.624)	(1.534)
Liquid Bond			0.176	
			(1.482)	
Time FE	Yes	Yes	Yes	Yes
Bond FE	No	Yes	No	Yes
No. of Obs.	1,596	1,596	1,596	1,596
Adj. R^2	0.035	0.069	0.047	0.081

Table 6: Variation Margin and Repo Transactions

This table reports the results of regressions of the repo (cash borrowing) and reverse repo (cash lending) transactions of insurance companies and pension funds (ICPFs) on their variation margin (VM) demand. The sample period is March 10^{th} to 18^{th} 2020, and the observations are at the ICPF-day level. In Panel A, the dependent variable is the daily repo transactions (in £ million) of a particular ICPF. In Panel B, the dependent variable is the ICPF's daily reverse repo transactions (in £ million). The main independent variable is the daily variation margin (in £ million) of the given ICPF, and this variable is denoted as VM. Positive (negative) VM values indicate that the investor was a net payer (receiver) of VM. The dependent variable and the variation margins are adjusted using the Inverse Hyperbolic Sine (IHS) method. We also control for time fixed effects. *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Panel A: Repo Transactions				
	(1)	(2)	(3)	(4)
DepVar:	Repo Transactions			
VM on FX Derivatives	0.236**			0.216**
	(2.558)			(2.144)
VM on Interest Rate Swaps		-0.118*		-0.093
		(-1.671)		(-1.392)
VM on Inflation Swaps			-0.034	-0.103
			(-0.173)	(-0.511)
Time FE	Yes	Yes	Yes	Yes
No. of Obs.	146	146	146	146
Adj. R^2	0.036	0.023	-0.004	0.040

Panel B: Reverse Repo Transactions				
	(1)	(2)	(3)	(4)
DepVar:	Reverse Repo Transactions			
VM on FX Derivatives	0.065			0.013
	(0.445)			(0.056)
VM on Interest Rate Swaps		-0.218***		-0.251**
		(-2.685)		(-2.134)
VM on Inflation Swaps			-0.026	-0.149
			(-0.161)	(-0.666)
Time FE	Yes	Yes	Yes	Yes
No. of Obs.	34	34	34	34
Adj. R^2	0.006	0.194	-0.002	0.168

Table 7: Variation Margin-Induced Trading and Government Bond Returns

This table reports the results of regressions of contemporaneous gilt returns on variation margin-induced trading (VMIT) for insurance companies and pension funds (ICPFs). The sample period is March 10th to 18th 2020. Gilt returns are measured in percentage points. Variation margin-induced trading (VMIT) is measured according to Equation (5) in text. We calculate value-weighted gilt returns and VMIT across all gilts in each maturity bucket (<1 year, 1-3 years, 3-5 years, 5-7 years, 7-10 years, 10-15 years, 15-20 years, 20-25 years, 25-30 years, 30+ years and short-term / medium-term / long-term index-linked bonds). VMIT is calculated for total VM, VM on FX derivatives, VM on interest rate swaps, and VM on inflation swaps, respectively. To enhance interpretability, all VMIT variables are standardized (with standard deviation of one). Control variables include mutual fund flow-induced trading (FIT) (with standard deviation of one), the logarithm of total client volume (denoted as $Volume$), and the returns of Treasuries with the same maturities as the gilts (denoted as $USret$). T-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
DepVar:	Government Bond Returns (%)					
$VMIT$	0.728***	0.494**	0.547***			
	(4.126)	(2.281)	(2.728)			
$VMIT(FX)$				0.743***	0.624***	0.535***
				(3.582)	(2.807)	(2.312)
$VMIT(IRS)$				0.229	0.177	0.281
				(1.338)	(1.041)	(1.559)
$VMIT(Inflation)$				-0.018	0.057	-0.023
				(-0.092)	(0.183)	(-0.081)
FIT			0.366			0.398
			(1.342)			(1.469)
$Volume$			0.206			0.187
			(0.794)			(0.731)
$USret$			0.235**			0.215**
			(2.359)			(2.051)
Time FE	No	Yes	Yes	No	Yes	Yes
No. of Obs.	91	91	91	91	91	91
Adj.R^2	0.136	0.218	0.311	0.163	0.236	0.310

Table 8: Variation Margin-Induced Trading and Government Bond Returns: Short- and Long-Term Bonds

This table reports the results of regressions of gilt returns on variation margin-induced trading (VMIT) for insurance companies and pension funds (ICPFs) in short-term and long-term gilts. The sample period is March 10th to 18th 2020. Gilt returns are measured in percentage points. Variation margin-induced trading (VMIT) is measured according to Equation (5) in text. The short-term gilt subsample includes gilts with a time-to-maturity of five years or less (see columns (1)-(3)); the long-term gilt subsample includes the remaining gilts (see columns (4)-(6)). We calculate value-weighted gilt returns and VMIT across all gilts in each maturity bucket (<1 year, 1-3 years, 3-5 years, 5-7 years, 7-10 years, 10-15 years, 15-20 years, 20-25 years, 25-30 years, 30+ years and short-term / medium-term / long-term index-linked bonds). VMIT is standardized (with standard deviation of one). Control variables include mutual fund flow-induced trading (FIT) (with standard deviation of one), the logarithm of total client volume (denoted as $Volume$) and the returns of US Treasuries with the same maturities as the gilts (denoted as $USret$). *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

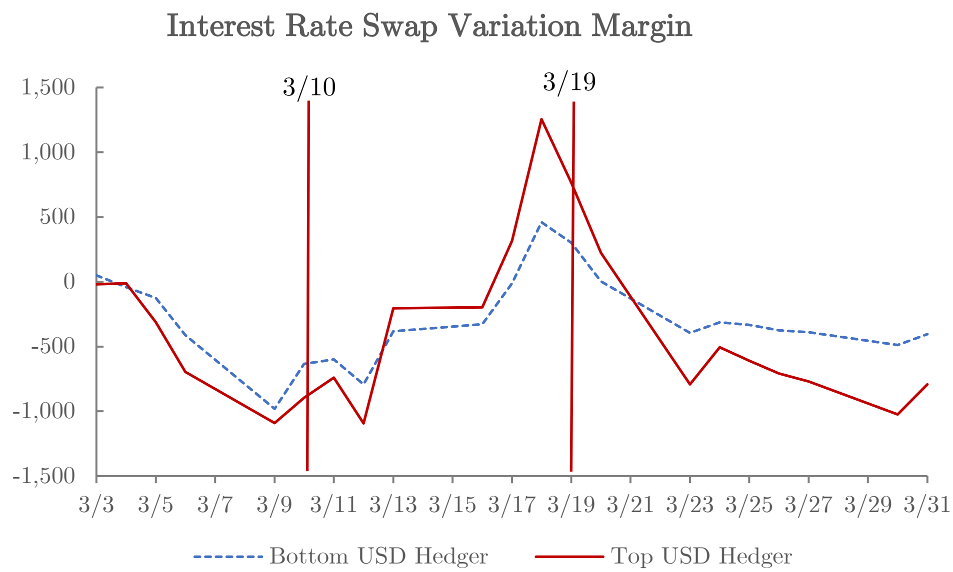
	(1)	(2)	(3)	(4)	(5)	(6)
	Short-Term Government Bonds			Long-Term Government Bonds		
Dep Var:	Government Bond Returns (%)					
$VMIT$	0.133	0.034	0.047	0.824***	0.543*	0.573**
	(1.180)	(0.257)	(0.418)	(3.767)	(1.932)	(2.061)
FIT			0.172			0.204
			(1.359)			(0.478)
$Volume$			0.235			0.237
			(1.607)			(0.748)
$USret$			0.391			0.204
			(1.375)			(1.506)
Time FE	No	Yes	Yes	No	Yes	Yes
No. of Obs.	28	28	28	63	63	63
Adj.R^2	0.074	-0.008	0.439	0.145	0.316	0.362

Table 9: Variation Margin-Induced Trading and Future Government Bond Returns

This table reports the results of regressions of future gilt returns (for the 1-day, 5-days, 10-days, 3-weeks, and 1-month horizons) on variation margin-induced trading of insurance companies and pension funds (ICPFs). The sample period is March 10th to 18th 2020. Gilt returns are measured in percentage points. Variation margin-induced trading (VMIT) is measured according to Equation (5) in text. *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)
DepVar:	$ret(t, t+1)$	$ret(t, t+5)$	$ret(t, t+10)$	$ret(t, t+15)$	$ret(t, t+21)$
$VMIT$	1.097***	0.355	-0.127	-0.250	-0.248
	(4.420)	(1.015)	(-0.440)	(-0.979)	(-0.897)
No. of Obs.	91	91	91	91	91
Adj.R^2	0.170	-0.004	-0.008	0.003	0.001

Online Appendix



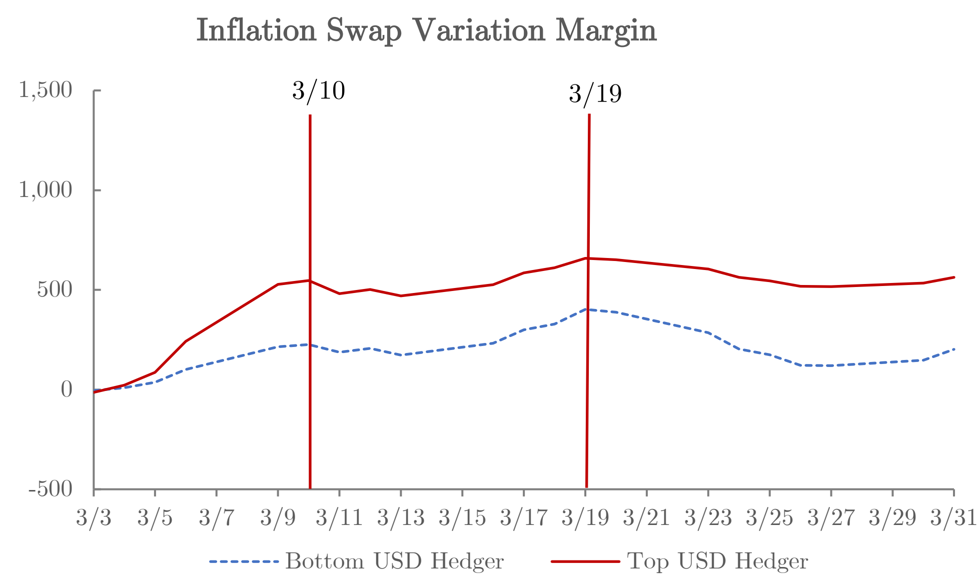


Figure A1: Variation Margin Demand on Top and Bottom USD FX Derivative Hedgers

This figure shows the cumulative interest rate swap and inflation swap variation margin demand on insurance companies from March 10th to 18th 2020. We divide insurance companies equally into two groups based on their net USD FX hedging positions at the end of 2019Q4: Top USD FX derivative hedgers (with an above-average net USD exposure) and Bottom USD FX derivative hedgers. The variation margin is measured in £ million.

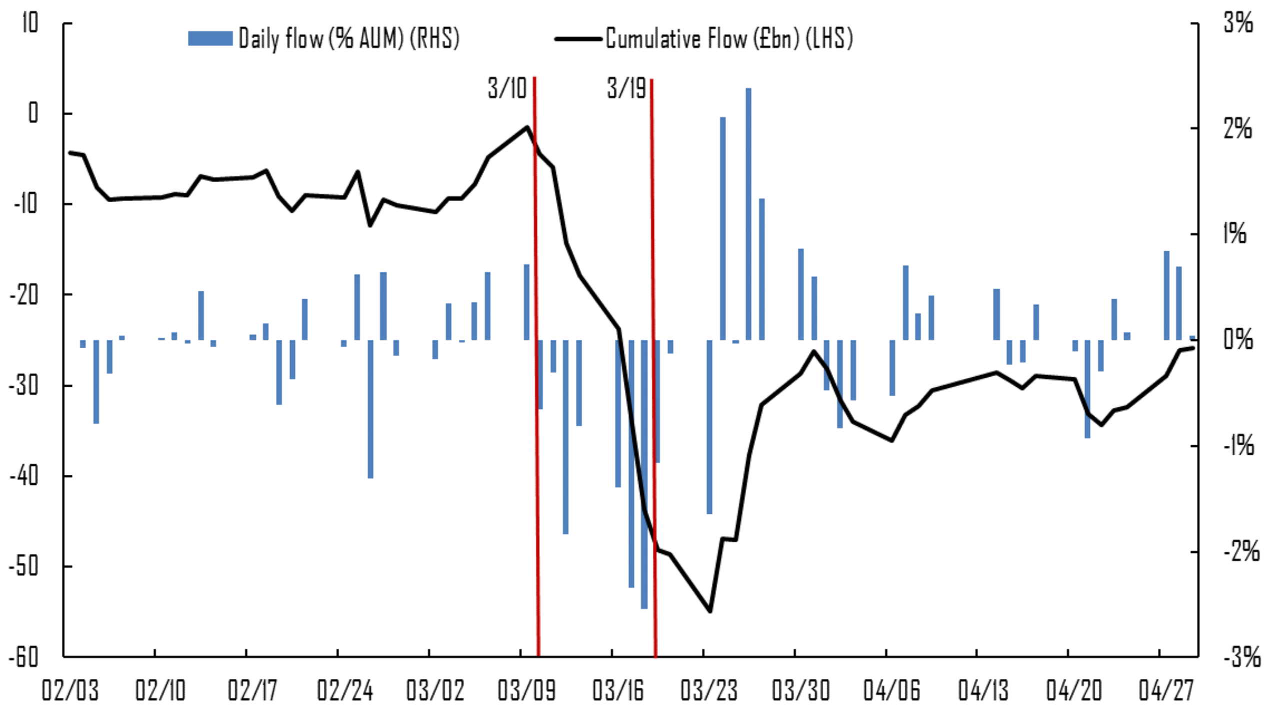


Figure A2: Mutual Fund Flows

This figure shows the dynamics of mutual fund flows from February 3rd to April 30th 2020. The solid line represents the cumulative mutual fund flow in £ billion, and the bars represent daily fund flows in percentage points. The sample of mutual funds includes around 900 funds that trade in the gilt market.

Table A1: Variation Margin and Next Day Government Bond Trading

This table reports the results of regressions of the gilt net trading of insurance companies and pension funds (ICPFs) on lagged variation margin (VM) demand. The sample period is March 10th to 18th 2020, and the observations are at the ICPF-day level. The dependent variable is the daily gilt net trading volume (in £ million) of a particular ICPF. The main independent variables include a given ICPF's lagged daily variation margin, separately for FX derivatives, interest rate swaps, and inflation swaps. Positive (negative) values mean that the investor was a net payer (receiver) of VM. The dependent variable and the variation margins are adjusted using the Inverse Hyperbolic Sine (IHS) method. We also control for time fixed effects. *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)
DepVar:	Next Day's Net Gilt Trading			
VM on FX Derivatives	-0.388***			-0.404***
	(-3.364)			(-3.547)
VM on Interest Rate Swaps		-0.037		-0.086
		(-0.482)		(-1.122)
VM on Inflation Swaps			-0.129	-0.109
			(-0.789)	(-0.743)
Time FE	Yes	Yes	Yes	Yes
No. of Obs.	198	198	198	198
Adj. R^2	0.080	0.010	0.013	0.081

Table A2: Variation Margin and Mutual Fund & Hedge Fund Trading

This table reports the results of regressions of the gilt net trading volumes of mutual funds and hedge funds on their variation margin (VM) demand. The sample period is March 10^{th} to 18^{th} 2020, and the observations are at the investor-day level. The dependent variable is the daily gilt net trading volume of a given mutual fund or hedge fund. In columns (1)-(2), the main independent variable is the daily variation margin of the given mutual fund, and this variable is denoted as VM. In column (3), the main independent variables include the given mutual fund's daily variation margin on FX derivatives, interest rate swaps, and inflation swaps, respectively. In columns (4)-(5), the main independent variable is the daily variation margin of the given hedge fund. In column (6), the main independent variables include the given hedge fund's daily variation margin on FX derivatives, interest rate swaps, and inflation swaps, respectively. Positive (negative) VM values indicate that the investor was a net payer (receiver) of VM. The dependent variable and the variation margins are adjusted using the Inverse Hyperbolic Sine (IHS) method. We also control for time and bond fixed effects. *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	Mutual Funds			Hedge Funds		
	(1)	(2)	(3)	(4)	(5)	(6)
DepVar:	Net Gilt Trading			Net Gilt Trading		
VM	-0.047	-0.056		0.009	-0.019	
	(-1.100)	(-1.290)		(0.216)	(-0.374)	
VM *on FX Derivatives*			-0.044			0.004
			(-0.539)			(0.075)
VM *on Interest Rate Swaps*			-0.064			-0.060
			(-0.991)			(-0.656)
VM *on Inflation Swaps*			0.157			0.112
			(1.196)			(0.439)
Time FE	No	Yes	Yes	No	Yes	Yes
Bond FE	No	Yes	Yes	No	Yes	Yes
No. of Obs.	545	539	539	958	954	954
Adj. R^2	0.003	-0.035	-0.023	-0.001	0.049	0.048

Table A3: Variation Margin-Induced Trading and Government Bond Returns: Alternative Scaling Method

This table reports the results of regressions of contemporaneous gilt returns on variation margin-induced trading (VMIT) for insurance companies and pension funds (ICPFs). The sample period is March 10th to 18th 2020. Gilt returns are measured in percentage points. Variation margin-induced trading (VMIT) is measured according to Equation (5) in the text, but we now use gilts' total trading volume as the denominator. We calculate value-weighted gilt returns and VMIT across all gilts in each maturity bucket (<1 year, 1-3 years, 3-5 years, 5-7 years, 7-10 years, 10-15 years, 15-20 years, 20-25 years, 25-30 years, 30+ years and short-term / medium-term / long-term index-linked bonds). VMIT is calculated for total VM, VM on FX derivatives, VM on interest rate swaps, and VM on inflation swaps, respectively. To enhance interpretability, all VMIT variables are standardized (with standard deviation of one). Control variables include mutual fund flow-induced trading (FIT) (with standard deviation of one), the logarithm of total client volume (denoted as $Volume$) and the returns of Treasuries with the same maturities as the gilts (denoted as $USret$). *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
DepVar:	Government Bond Returns					
$VMIT$	0.779***	0.612***	0.524**			
	(3.245)	(2.662)	(2.368)			
$VMIT(FX)$				0.807***	0.673**	0.659**
				(3.212)	(2.347)	(2.071)
$VMIT(IRS)$				0.341	0.320	0.361
				(1.672)	(1.483)	(1.720)
$VMIT(Inflation)$				0.104	0.210	0.180
				(0.462)	(0.058)	(0.502)
FIT			0.364			0.435
			(1.362)			(1.712)
$Volume$			-0.012			-0.177
			(-0.041)			(-0.672)
$USret$			0.213**			0.187**
			(2.151)			(2.091)
Time FE	No	Yes	Yes	No	Yes	Yes
No. of Obs.	91	91	91	91	91	91
Adj.R^2	0.157	0.254	0.307	0.236	0.326	0.374

Table A4: Variation Margin-Induced Trading and Government Bond Returns: Equal-Weighted Approach

This table reports the results of regressions of contemporaneous gilt returns on variation margin-induced trading (VMIT) for insurance companies and pension funds (ICPFs). The sample period is March 10th to 18th 2020. Gilt returns are measured in percentage points. Variation margin-induced trading (VMIT) is measured according to Equation (5) in text. We calculate equal-weighted gilt returns and VMIT across all gilts in each maturity bucket (<1 year, 1-3 years, 3-5 years, 5-7 years, 7-10 years, 10-15 years, 15-20 years, 20-25 years, 25-30 years, 30+ years and short-term / medium-term / long-term index-linked bonds). VMIT is calculated for total VM, VM on FX derivatives, VM on interest rate swaps, and VM on inflation swaps, respectively. To enhance interpretability, all VMIT variables are standardized (with standard deviation of one). Control variables include mutual fund flow-induced trading (FIT) (with standard deviation of one), the logarithm of total client volume and the returns of Treasuries with the same maturities as the gilts (denoted as $USret$). *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
DepVar:	Government Bond Returns					
$VMIT$	0.707***	0.468**	0.508**			
	(3.772)	(2.092)	(2.290)			
$VMIT(FX)$				0.679***	0.559**	0.464**
				(3.142)	(2.332)	(1.982)
$VMIT(IRS)$				0.286	0.214	0.342*
				(1.534)	(1.242)	(1.831)
$VMIT(Inflation)$				0.004	0.099	0.016
				(0.021)	(0.312)	(0.052)
FIT			0.364			0.404
			(1.372)			(1.472)
$Volume$			0.202			0.216
			(0.746)			(0.841)
$USret$			0.232**			0.219**
			(2.252)			(2.201)
Time FE	No	Yes	Yes	No	Yes	Yes
No. of Obs.	91	91	91	91	91	91
Adj.R^2	0.128	0.213	0.303	0.155	0.230	0.311

Table A5: Mutual Fund Flows and Government Bond Trading

This table reports the results of regressions of gilt net trading volumes of mutual funds on their fund flows. The sample period is March 1st to 18th 2020, and the observations are at the fund-day level. The dependent variable is the gilt net trading volume of a particular mutual fund on day t, and the independent variables are the fund flows of the given mutual fund on day t and lagged fund flows from day $t-1$ to day $t-3$. Both dependent and independent variables are adjusted using the Inverse Hyperbolic Sine transformation method. In columns (1)-(2), the sample includes observations from March 1st to 18th. In columns (3)-(4), the sample includes observations from March 1st to 9th. In columns (5)-(6), the sample includes observations from March 10th to 18th. *T*-statistics are based on bootstrapped standard errors and are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

	March 1 – 18		March 1 – 9		March 10 – 18	
	(1)	(2)	(3)	(4)	(5)	(6)
DepVar:	Net Gilt Trading					
$Flow_t$	0.253***	0.220***	0.152***	0.119**	0.311***	0.293***
	(9.039)	(6.959)	(3.498)	(2.464)	(8.927)	(6.695)
$Flow_{t-1}$		0.083**		0.083*		0.060
		(2.441)		(1.717)		(1.201)
$Flow_{t-2}$		-0.051		-0.022		-0.086*
		(-1.521)		(-0.461)		(-1.825)
$Flow_{t-3}$		0.030		0.002		0.078*
		(0.978)		(0.040)		(1.879)
No. of Obs.	4,026	4,003	1,752	1,745	2,274	2,258
Adj. R^2	0.070	0.074	0.023	0.025	0.091	0.098