BANK OF ENGLAND

Staff Working Paper No. 977

Central bank swap lines: micro-level evidence

Gerardo Ferrara, Philippe Mueller,
Ganesh Viswanath-Natraj and Junxuan Wang

April 2024
This is an updated version of the Staff Working Paper originally published on 6 May 2022

BANK OF ENGLAND

Staff Working Paper No. 977

Central bank swap lines: micro-level evidence

Gerardo Ferrara,[1] Philippe Mueller,[2] Ganesh Viswanath-Natraj[3] and Junxuan Wang[4]

Abstract

This paper investigates the impact of central bank swap lines during the 2020 pandemic using micro-level data. Institutions relying on these swap lines tend to be better capitalised due to stringent collateral requirements. Combining data on FX derivative contracts with dealers that draw on USD swap lines at the Bank of England, we find that swap line participants engage in more favourable pricing of forward contracts, reduce their gross outstanding FX exposures, and increase their net supply of USD forwards to non-financial institutions. Our findings support the use of swap lines in reducing FX market mispricing and providing cross-border liquidity.

Key words: Swap lines, monetary policy, foreign exchange swaps, covered interest rate parity, central banking.

JEL classification: E44, F30, F31, F32, F41, G11, G12, G15, G18, G20.

(1) Bank of England. Email: gerardo.ferrara@bankofengland.co.uk
(2) Warwick Business School. Email: philippe.mueller@wbs.ac.uk
(3) Warwick Business School. Email: ganesh.viswanath-natraj@wbs.ac.uk
(4) University of Cambridge. Email: j.wang@jbs.cam.ac.uk

For detailed comments,we would like to thank discussants Saleem Bahaj, Benedikt Ballensiefen, Joseph Barunik, Falk Bräuning, Pasquale Della Corte, Phillipp Gnan, Steven Kamin, Jun Pan, Fabiola Ravazzolo, and Andreas Stathopolous. For helpful comments, we would also like to thank Carlos Canon Salazar, Robert Czech, Darrell Duffie, Fernando Eguren-Martin, Eddie Gerba, Arie Gozluklu, Sinem Hacioglu, Edward Kent, Lauren Rana, Matt Roberts-Sklar, Farzad Saidi, Nicholas Sander, David Skeie, Olav Syrstad, John Thannasoulis, Nicholas Vause, Paul Whelan and seminar participants at the ABFER Annual Meeting, Bank of England, BIS-BdI-ECB 12th Workshop on Exchange Rates, Canadian Derivative Institute, CEPR IFM Annual Meeting, IFABS Annual Meeting, Federal Reserve 'Day Ahead' Conference on Financial Markets and Institutions, Finance Management Annual Meeting, MMF Annual Meeting, NY Federal Reserve Inaugural Conference on the International Roles of the USD, New Zealand Finance Meeting, SGF Conference, Annual Financial Market Liquidity Conference, Australasian Banking and Finance Conference, Vienna Foreign Exchange Symposium and the University of Warwick. We are particularly grateful for the assistance given by Melissa Faglia and Stephen Newell in collecting the data. All errors remain those of the authors. The views expressed in this paper are those of the authors and not necessarily those of the Bank of England, University of Warwick, University of Cambridge, or any other institution with which the authors may be affiliated or associated.

The Bank's working paper series can be found at www.bankofengland.co.uk/working-paper/staff-working-papers

Bank of England, Threadneedle Street, London, EC2R 8AH
Email enquiries@bankofengland.co.uk

ISSN 1749-9135 (on-line)

1 Introduction and Motivation

A currency swap line is an agreement between two central banks to exchange currencies. A source central bank exchanges currency for the domicile currency of the counterparty central bank. The counterparty central bank can then auction the source currency they receive to domestic banks. Multiple swap line networks exist, and the focus of this paper is the network of swap lines between the Federal Reserve, Bank of England (BOE), Bank of Canada (BOC), European Central Bank (ECB), Bank of Japan (BOJ) and Swiss National Bank (SNB). [1]

Swap lines have been used as a policy tool by the Federal Reserve in response to the crisis of 2008, and again in response to the international spillovers of Covid in March 2020. The Federal Reserve acts as a source central bank by exchanging USD for the domicile currency of the counterparty central bank. The primary reason for swap lines is to mitigate the financial stability risks of USD shortages, which can impair the functioning of global markets and spill back into domestic markets and have significant negative macroeconomic effects (Cesa-Bianchi et al., 2022; Committee on the Global Financial System, 2020). An emerging literature has focused on the effects of swap lines on pricing, with evidence that swap lines lower the ceiling on Covered Interest Parity (CIP) deviations (Bahaj and Reis, 2022, 2020a; Eren et al., 2020; Goldberg and Ravazzolo, 2021; Choi et al., 2021; Schellekens et al., 2022).

In this paper, we document micro-level evidence on how swap lines affect the pricing and hedging of outstanding FX exposures of market participants. This is an important question for policy makers to understand if central bank lending is an appropriate tool in reducing bank currency exposures during financial crises. Transaction-level data can be used to test if dealers that received the swap line engage in more favorable pricing of forward and swap contracts, improving USD funding conditions in cross-border financial markets. Additionally, it can be used to clarify mechanisms through which swap lines affect demand and supply in the FX swap market. We investigate whether dealers utilize liquidity from central bank swap lines for USD lending and arbitrage activities, or alternatively, are using swap lines as a substitute for USD funding through FX outright forward and swap contracts.

Our analysis is based on two confidential data sets from the Bank of England (BOE). This includes transaction-level data on USD repurchase (repo) auctions made by the BOE to private institutions. We combine this data with a BOE trade repository, which contains

[1] Other swap line networks include the ECB's agreements with Bulgaria, Sweden, Denmark, Croatia and China. China's People's Bank of China (PBOC) has extended a network of swap lines with Asia, Europe and the U.S. with the aim to increase trade invoicing in RMB, see Bahaj and Reis (2020b) for more details.

details on both FX outright forward and swap contracts in which one of the counterparties is based in the UK. To our knowledge, we present the first analysis using confidential transaction-level data on the drawings of swap lines. This allows us to trace individual dealers' access to swap lines, their pricing of FX outright forward and swap contracts, and measure gross outstanding exposures of dealers with different client segments that include commercial banks and non-financial (corporate) institutions.

We outline three contributions. First, our analysis of institutions that access BOE swap lines reveals that they are generally larger and better capitalized, with a greater distance from the minimum leverage ratio requirement. Additionally, these institutions exhibit a lower ratio of risk-weighted assets to total assets. We attribute these findings to the stringent collateral requirements that restrict access to BOE swap lines, which typically discount illiquid and high-risk assets with haircuts that exceed 15% of the collateral value. Consequently, better capitalized institutions are more likely to access the swap line.

Second, we find swap line drawings lead to a reduction in pricing inefficiencies in FX outright forward and swap contracts. The granularity of data allow us to identify FX transaction prices at a dealer-counterparty level. We use a difference-in-difference (DiD) specification to test if dealers that received BOE swap line USD liquidity (treated group) changed their FX pricing relative to dealers that did not receive a swap line (control group). Following Cenedese et al. (2021) and Khwaja and Mian (2008), we use dealer-counterparty and counterparty-time fixed effects to control for idiosyncratic demand for FX hedging by counterparties. We find that treated dealers charged favorable forward rates for FX outright forward and swap contracts at the 1 week and 3 month maturity following announcement of the swap line auctions on March 18, 2020. Our findings are consistent with a decline in the magnitude of CIP violations following the swap line, enhancing market efficiency in FX markets.

Third, we find dealers that access swap lines reduce their gross outstanding FX exposures due to a substitution toward USD liquidity received via swap lines, and increased their net supply of USD to non-financial institutions. The decline in outstanding FX exposures is concentrated in dealer transactions with (non-dealer) commercial banks, and at maturities less than 1 week. Our results are consistent with dealers using swap lines as an alternative to seeking USD funding through FX outright forward and swap contracts. In contrast, we find limited evidence that dealers are using liquidity from the central bank swap line for USD lending and arbitrage activities. Based on our analysis of dealer exposures with respect to non-financial institutions, swap lines also play a role in providing marginal USD liquidity to the non-financial sector.

Related Literature: We contribute to an emerging literature on the macro-financial deter-

minants, price and balance sheet effects of Federal Reserve swap lines (Rose and Spiegel, 2012; Bahaj and Reis, 2022; Goldberg et al., 2011; Bahaj and Reis, 2020a; Goldberg and Ravazzolo, 2021; Aizenman et al., 2022; Choi et al., 2021; Cesa-Bianchi et al., 2021; Bahaj and Reis, 2020a; Eren et al., 2020; Schellekens et al., 2022; Aldasoro et al., 2020; Eren et al., 2020; McCrone et al., 2020), swap lines in emerging markets (Bahaj and Reis, 2020a), theories of the macroeconomic effects of swap lines (Cesa-Bianchi et al., 2022; Bohorquez, 2023), and the effects of lender of last resort lending (Drechsler et al., 2016). Within this literature, our paper relates closely to Bahaj and Reis (2022) which documents how Federal Reserve swap lines can enforce a ceiling on CIP violations. Our contribution is to exploit transaction-level data to understand the balance sheet characteristics, the pricing and FX exposures of dealers that accessed the swap line.

A second strand of literature focus on theories of pricing and balance sheet exposures in the FX market. The primary focus is on understanding the determinants of CIP deviations, which includes dealer balance sheets and regulatory requirements, funding costs in segmented markets, hedging demands, liquidity and counterparty risk, and monetary policy (Cenedese et al., 2021; Du et al., 2018; Liao, 2020; Bräuning and Puria, 2017; Avdjiev et al., 2019; Siriwardane et al., 2024; Rime et al., 2022; Andersen et al., 2019; Viswanath-Natraj, 2020; Baba and Packer, 2009; Mancini Griffoli and Ranaldo, 2009; Borio et al., 2016; Ivashina et al., 2015; Iida et al., 2018; Syrstad, 2020; Zeev and Nathan, 2023).

Additional topics include a discussion of balance sheet exposures of FX derivative positions during quarter-ends (Abbassi and Bräuning, 2020; Kloks et al., 2023), discrimination in derivative pricing with respect to non-financial counterparties (Hau et al., 2021), the role of order flow in price-setting of FX outright forward and swap contracts (Syrstad and Viswanath-Natraj, 2022), and the role of FX hedging in understanding the dynamics of spot rates and spillovers to domestic markets (Liao and Zhang, 2020; Czech et al., 2021; Bräuer and Hau, 2022).

Within this literature, our paper is closely related to Cenedese et al. (2021), which uses transaction-level data on FX derivatives to identify the impact of Basel III capital regulations. They exploit a change in regulatory reporting of the leverage ratio to identify the effects of intermediary constraints on the pricing of forward and swap contracts, and they follow Khwaja and Mian (2008) to control for counterparty related effects.

Our paper is motivated by a similar design, and identifies the effect of swap lines on dealer-level FX outright forward and swap contract pricing. We are the first paper to document that swap lines reduce the magnitude of CIP violations using intra-day trades, and that dealers reduce their outstanding gross FX exposures due to a substitution toward USD liquidity received via swap lines.

The remainder of the paper is structured as follows. In section 2 we summarize the institutional details of swap lines, describe the BOE data sources for our empirical work, and motivate our paper with a set of stylized facts on the price and volatility effects of swap lines using benchmark rates. In section 3 we conduct our empirical analysis on swap line access, FX outright forward and swap pricing and exposures using detailed dealer-level transaction data. Section 4 concludes.

2 Definitions and Data

2.1 Federal Reserve swap line data

The BOC, BOE, BOJ, ECB and the SNB set up a network of bilateral central bank swap lines with the Federal Reserve, which have been in place on a standing basis since 2013. The existence of a swap line allows the counterparty central banks to provide foreign exchange operations to their respective domestic markets. The two central banks can agree bilaterally the terms and conditions of swap line use.

The timing of the swap line auctions and the arrangement between the BOE and the Federal Reserve is provided in Figure 1. The process involves four key steps. Initially, the BOE auctions USD repurchase agreements (repos) to dealers in the UK on the trade date. Subsequently, the Federal Reserve swaps USD for GBP, eliminating exchange rate risk in the swap contract. Following the announcement of the auction results, the BOE then conducts a swap of GBP for USD with the Federal Reserve for the full amount bid by participants. This swap between the central banks is executed on the same day as the BOE swap line operation, with settlement typically occurring on a T+1 basis. On the settlement date, the BOE distributes the USD to dealers who were successful in the auctions, and the Federal Reserve's USD funds are deposited in participant accounts. Finally, upon the maturity of the contract, the currencies are re-exchanged at the initial exchange rate.

Crucially, these swap lines are offered at a penalty rate, with the recipient central bank bearing the counterparty risk of the operation. The penalty rate is generally set as a spread above the US Overnight Index Swap (OIS) rate. In March 2020, significant modifications were made to the operation of these swap lines, including the introduction of auctions for swaps with a 3-month maturity, an increase in the frequency of Federal Reserve auctions to daily, and a reduction in the swap line penalty rate from OIS+50 basis points (bp) to OIS+25bp. All participants that bid in the BOE USD repo auctions are charged the same rate that the BOE pays to the Federal Reserve, which is OIS+25 basis points.

[INSERT FIGURE 1 ABOUT HERE]

Publicly available data from the New York (NY) Federal Reserve contain details on the amount, currency, tenor and counterparty central bank of each auction, and a summary of allotments for the BOE, ECB and BOJ is provided in Appendix A. Using this, we can construct a measure of outstanding swap lines for each currency, which is the total amount of swap lines drawn during the Covid crisis less any swap lines that have matured. Based on Figure 2, outstanding swap lines peaked at 142 Billion USD for EUR/USD, 196 USD Billion for JPY/USD and 38 Billion USD for GBP/USD in May 2020.

[INSERT FIGURE 2 ABOUT HERE]

The NY Federal Reserve data provides us aggregate data on the swap line auctions between the Federal Reserve and the counterparty central bank. To obtain more granular data, we use a confidential dataset from the BOE which contains detailed individual dealer-level drawings on BOE swap line auctions in the months of March to June 2020. Details of the dataset include maturity, amount, announcement and settlement date of the auction, and a dealer identifier, which we can use to link to dealer transactions in FX outright forward and swap contracts. In Appendix A we verify that the BOE dealer-level drawings are consistent with the publicly available data on BOE swap line allotments provided by the NY Federal Reserve.

Institutions eligible for BOE swap lines are outlined in the Sterling Monetary Framework.[2] In order to access the BOE swap line facility, institutions are mandated to provide collateral. Detailed characteristics of the collateral, such as the types, credit ratings and haircuts are summarized in Table 1. Collateral are categorized into buckets A, B, and C, taking into account both credit ratings and asset types. Bucket A encompasses government securities issued by specific countries, while bucket B comprises securities from other advanced economies and the AAA tranches of mortgage/asset-backed securities. Bucket C, on the other hand, includes lower-rated mortgage/asset-backed securities.

[INSERT TABLE 1 ABOUT HERE]

The sterling monetary framework further refines these collateral categories to include haircuts. For instance, collateral in bucket A, representing government securities from countries like the US, UK, Canada, Germany, France, and the Netherlands, is subject to haircuts on short-term debt at 0.5 percent. In bucket B, which includes sovereign government securities from additional advanced economies and the AAA tranches of

[2]See https://www.bankofengland.co.uk/markets/market-notices/2020/consolidated-market-notice-for-usd-repo-operations-march-2020 for more details on eligible institutions.

mortgage and asset-backed securities, the haircuts typically range from 0.5 to 12 percent. Bucket C, comprising mortgage or asset-backed securities with a tranche rating of A3 or above, carries higher haircuts, generally ranging from 15 to 30 percent for riskier assets like mortgage-backed securities. The differentiation in haircuts is not only dependent on the collateral's credit rating and type but also on the maturity period. For instance, in the case of maturities exceeding 30 years, collateral in bucket A incurs a 15 percent haircut for long-term bonds, while bucket C assets face higher haircuts ranging from 27 to 42 percent. The haircuts are effectively costs incurred by institutions in providing risky assets as collateral to access swap lines.

2.2 BOE trade repository data

The 2008 global financial crisis marked an important turning point as G20 leaders put forward in September 2009 an initiative to significantly reform the level of transparency in OTC derivatives markets. As part of this initiative, it was agreed that all derivatives contracts would be reported to trade repositories in order to provide policy makers and regulators access to both high-quality and high-frequency data. Within the European Union (EU), the European Market Infrastructure Regulation (EMIR) was introduced in support of this initiative, requiring large EU firms to report the details of any derivative transaction to a European Securities and Markets Authority (ESMA) approved trade repository by the following business day.

The UK trade repository data contains details on the FX derivative trades for all transactions with at least one counterparty in the UK, with coverage representing over 42% of the entire outstanding global FX derivative contracts (Cenedese et al., 2021).[3] The dataset covers trades in FX forwards, currency swaps, futures and options for all currency pairs. We restrict our analysis to FX forwards and swaps, and focus on major bilateral currency pairs, such as EUR/USD, JPY/USD, GBP/USD. For each transaction, we observe information about counterparties (i.e., legal identifier and corporate sector) and the contract characteristics (e.g., price, notional amount, maturity date, execution date, execution time).

The trade repository data can be broadly divided into two types of reports: a) state reports, which contain trade information on the cumulative outstanding amount of derivative trades between individual counterparties, or stock; and b) activity reports, which contain trade information on new intra-day trades of derivative contracts, or flow. We use the state reports collected within the trade repository data to collect all the outstanding derivative positions in the FX outright forward and swap legs of FX markets at the end

[3]This is based on estimates in Cenedese et al. (2021) that show the sample coverage is approximately 42% of global outstanding trades in FX outright forward and swap markets based on the BIS derivative statistics.

of each month from September 2019 to November 2020. In addition, we use the activity reports to collect all the trades in the FX outright forward and swap legs of FX intra-day trades around the principal swap line announcement on March 18 2020.

We use the dataset to construct outstanding FX exposures of dealers with respect to different client segments. This includes all (non-dealer) counterparty sectors: asset managers, (non-dealer) commercial banks, hedge funds, ICPF and LDI, non-financial and other financial institutions.[4]

For each FX outright forward and swap transaction, we have an identifier which allows us to determine which counterparty is buying and selling USD at the forward leg of the swap. Figure 3 defines Buy and Sell transactions. A dealer purchasing USD at the forward leg while agreeing to sell GBP forward is involved in a Buy transaction. On the other hand, a dealer selling USD at the forward leg and buying GBP forward participates in a Sell transaction. Buy and Sell transactions are used to calculate the gross outstanding exposures between a specific dealer and their counterparty. Additionally, net USD exposures are defined as the USD purchases at the forward leg of all outright forward and swap transactions.

[INSERT FIGURE 3 ABOUT HERE]

2.3 Other Data

2.3.1 Forward prices and CIP deviations

Our measure of CIP deviations $x_{\$,d}$ is expressed as the difference between the local USD borrowing rate less the synthetic USD borrowing rate, where $r^f_{\$}$ is the US interest rate, r^f_d is the base interest rate (eg. GBP), and is expressed in equation (1),

[4]The classification of non-financial counterparties is based on the statistical classification of economic activities in the European Community (NACE) as defined in Regulation (EC) No 1893/2006 of the European Parliament and of the Council. For EMIR reporting purposes the industry classification is: 1 = Agriculture, forestry and fishing, 2 = Mining and quarrying, 3 = Manufacturing, 4 = Electricity, gas, steam and air conditioning supply, 5 = Water supply, sewerage, waste management and remediation activities, 6 = Construction, 7 = Wholesale and retail trade, repair of motor vehicles and motorcycles, 8 = Transportation and storage, 9 = Accommodation and food service activities, 10 = Information and communication, 11 = Financial and insurance activities, 12 = Real estate activities, 13 = Professional, scientific and technical activities, 14 = Administrative and support service activities, 15 = Public administration and defense; compulsory social security, 16 = Education, 17 = Human health and social work activities, 18 = Arts, entertainment and recreation, 19 = Other service activities, 20 = Activities of households as employers; undifferentiated goods – and services – producing activities of households for own use, 21 = Activities of extraterritorial organizations and bodies.

$$x_{\$,d} = \underbrace{1 + r^f_{\$}}_{\text{direct}} - \underbrace{\frac{F}{S}(1 + r^f_d)}_{\text{synthetic}} \tag{1}$$

where S is the spot rate and F is the forward rate, calculated as the mid-point using bid and ask quotes. A negative $x_{\$,d}$ indicates that synthetic USD borrowing costs exceed local borrowing costs. Summary statistics of daily annualized CIP deviations are presented in Table 2. For the stylized facts presented in this section, we use daily spot, forward and OIS benchmark rates for the 1 week, 1 month and 3 month maturities available from Bloomberg. For transaction-level CIP based on intra-day outright forward and swap contracts, we refer readers to the discussion in Section 3.2.

In addition, we determine a measure of realized volatility by analyzing intra-day data on forward rates, specifically at 5-minute intervals, sourced from Reuters Refinitiv. This measure of intra-day volatility is derived by taking the square root of the sum of squared returns for each 5-minute interval, averaged over the course of a day.

2.3.2 Balance sheets

We collect quarterly information on total assets, liabilities, Tier 1 capital, leverage ratios, and risk-weighted assets from Bloomberg. Table 3 presents summary statistics of balance sheet characteristics at the parent company level. To create monthly datasets from the quarterly data, we use the data from the end of a quarter for each month within that quarter. For instance, the balance sheet figures for October and November 2019 are identical to those at the end of the quarter (December 2019). The minimum requirements for Tier 1 Capital and leverage ratios adhere to the banking regulations of the country where the parent firm's headquarters are located. All the data are presented in USD.

[INSERT TABLES 2 and 3 ABOUT HERE]

2.4 Stylized facts: price and volatility effects using benchmark rates

Stylized fact #1:: *The reduction in the penalty rate on Covid swap lines from OIS+50 basis points to OIS+25 basis points lowers the ceiling on CIP deviations.*

Bahaj and Reis (2022, 2020a) establish a no-arbitrage condition, showing that deviations from CIP are determined by the discount rate on USD borrowings from the Federal Reserve. They illustrate a scenario where a dealer borrows USD via the BOE swap line, lends these dollars in the FX swap market by swapping USD for GBP, and then invests the

GBP with the Bank of England at an excess reserve rate, denoted as $i^{GBP}_{reserve}$. The duration of the loan could be one week, one month, or three months, based on the swap auction duration. To hedge against interest rate risks, the dealer buys an Overnight Indexed Swap (OIS) contract. The cost is equal to the spread between the OIS rate and the interbank (LIBOR) rate, expressed as $i^{GBP}_{ois} - i^{GBP}_{interbank}$. The dealer's net profits, Π, can be outlined as follows:

$$\Pi = f - s + i^{GBP}_{reserve} + i^{GBP}_{ois} - i^{GBP}_{interbank} - i_{swapline} \tag{2}$$

Incorporating the swap line interest rate, $i_{swapline} = i^{USD}_{ois} + \delta$, where δ is the borrowing rate penalty, and defining the CIP deviation using OIS interest rates, $x_{ois} = f - s + i^{GBP}_{ois} - i^{US}_{ois}$, we can rewrite the dealer's arbitrage profits as:

$$\Pi = x_{ois} - \delta + i^{GBP}_{reserve} - i^{GBP}_{interbank} \tag{3}$$

Therefore the penalty on the swap line rate sets a maximum limit on CIP deviations. Under no-arbitrage conditions, $\Pi \leq 0$ leads to the following ceiling equation:

$$x_{ois} \leq \delta + i^{GBP}_{interbank} - i^{GBP}_{reserve} \tag{4}$$

This ceiling is determined by two factors: the penalty imposed by the Federal Reserve and frictions in interbank markets. A reduction in the penalty rate lowers the ceiling on CIP deviations, all else equal. Meanwhile, higher costs in hedging interest rate risks, reflected in a larger spread between the interbank rate and the reserve rate, raise this ceiling.

We examine if the penalty rate reduction on March 19, 2020, decreased the likelihood of ceiling breaches. Figure 4 illustrates the ceiling derived from equation (4), with a dotted line marking the penalty rate reduction on March 19, 2020. Our analysis reveals a lowered ceiling on CIP deviations across all examined maturities and currencies post-reduction. Additional findings in Appendix B indicate that reducing the penalty rate from 50 basis points above OIS to 25 points enforces a stricter ceiling on CIP deviations, particularly for the one-week maturity.

[INSERT FIGURE 4 ABOUT HERE]

Stylized fact #2: *There is a reduction in CIP deviations of currencies that accessed the swap line relative to a control group that did not activate the swap line*

Figure 5 presents CIP deviations (benchmark OIS rate) for advanced economies for maturities of 1 week, 1 month and 3 month, and Table 2 presents summary statistics. After an initial spike in CIP deviations in March for the EUR/USD, GBP/USD and JPY/USD, as USD liquidity became scarce, we observe a sharp reversal of CIP deviations following the introduction of swap line arrangements between the Federal Reserve and counterparty central banks.

In Appendix C, we apply a DiD approach to compare the CIP deviations of countries that activated the swap line with the Federal Reserve against those of a control group that did not. The identifying assumption is that swap lines initiated between the Federal Reserve and the BOC, BOE, BOJ, ECB and SNB are permanent, whereas temporary swap arrangements with other advanced economy central banks act as an appropriate control group. Results reveal that the allocation of swap lines in March 2020 led to a reduction in the magnitude of 3 month CIP deviations by approximately 13 basis points compared to the control group.

[INSERT FIGURE 5 ABOUT HERE]

Stylized fact #3: *There is a reduction in the price dispersion of dealer quotes and a decline in the intra-day volatility of CIP deviations*

Figure 6 plots the intra-day forward rate volatility of the EUR/USD, GBP/USD and JPY/USD pairs for the 1 week, 1 month and 3 month maturities. The plots show an increase in volatility in the days preceding the swap lines settled on March 19 2020, and a reversal of volatility shortly after, consistent with the price effects. To more formally test for the reduction in volatility, Appendix D presents a HAR model to measure the effects of swap lines on realized volatility, controlling for COVID-19 variables. The results show that the second day after settlement, there is a significant negative effect on volatility across all currencies and maturities, with the strongest effect on the EUR/USD. Interestingly, we find positive significant effects on volatility on the day of settlement, likely reflecting that swap line auctions occur during periods of increased volatility in the FX market.

[INSERT FIGURE 6 ABOUT HERE]

3 Empirical Evidence

3.1 Predictors of Swap Line Access

H1: *Dealers that use swap lines are highly capitalized and use high quality liquid assets as collateral due to strict collateral requirements.*

To test this hypothesis, we identify potential determinants of swap line usage in equation (5). Outcome variables D_{treat} is a dummy variable for dealers that activated the BOE swap line. Explanatory variables include the distance from the minimum capital (CET1) and leverage ratio, and the share of risk-weighted assets. All balance sheet variables are taken at a snapshot of February 2020.

$$D_{treatment,i} = \beta x_t + \epsilon_{i,j,t} \tag{5}$$

Table 4 presents the results. Interestingly, in columns (I) to (III), BOE swap lines are drawn by institutions that are better capitalized, with a higher distance from the minimum CET1 and leverage ratio, and have higher share of risk weighted assets. We offer a potential explanation of why dealers with a higher distance from the leverage ratio requirements are more likely to draw on BOE swap lines. Mechanically, drawing on BOE swap lines reduces the distance to the leverage ratio requirement as it reduces the ratio of equity to total assets. Therefore dealers that are close to the minimum leverage ratio required cannot borrow USD via BOE swap lines. Alternatively, these institutions are more likely to borrow dollars via outright forward and swap transactions as they are off-balance sheet.

Finally, we examine if a dealer's access to swap lines is influenced by the quality of their collateral assets. According to the findings in column (IV), it appears that dealers generally possess a larger quantity of UK public sector assets. This aligns with the data presented in Table 1 which shows lower haircuts for high-quality collateral, indicating that well-capitalized institutions holding a greater proportion of safe assets incur lower costs when providing collateral to access swap lines.[5]

Our findings regarding the users of central bank swap lines significantly diverge from patterns observed in other forms of central bank lending. For instance, Drechsler et al. (2016) investigate the lender of last resort role during the Euro debt crisis and discover that banks with weaker capitalization are more inclined to borrow from the central bank. We explain these differences by considering the collateral costs of accessing the swap lines.

[5]This uses dealer-level balance sheet data on level 1 tradeable assets, which is defined as UK central or regional government, local authority or public sector entity assets. More information can be found in https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/regulatory-reporting/banking/pra110-instructions.pdf.

Due to considerable haircuts applied to riskier mortgage and asset-backed securities, dealers utilizing the swap lines tend to have a smaller proportion of risk-weighted assets.

While dealers receiving USD may not be distressed firms, we argue that the swap lines may have indirect effects on firms facing significant USD shortages through reducing the extent of mispricing in the FX market. We now turn to these effects using transaction-level FX prices.

[INSERT TABLE 4 ABOUT HERE]

3.2 Intra-day Prices Around the Largest Swap Line Auction

H2: *Dealers that access the BOE swap line charge more favorable forward rates relative to a control group of dealers that did not access the BOE swap line.*

In this analysis, we exploit transaction-level heterogeneity in forward prices charged by dealers. We hypothesize that dealers that access the BOE swap line charge more favorable forward rates relative to a control group of dealers that did not access the swap line. Our hypothesis is that dealers that access the swap line now have additional USD liquidity at their disposal to provide customers in intra-day FX outright forward and swap contracts. Therefore, all else equal, the magnitude of CIP violations should fall for treated dealers relative to control dealers.

For a dealer i and counterparty j, we calculate a transaction-level CIP deviation based on the forward rate quoted by dealer i in the transaction in equation (6). All other variables, including risk-free rates in USD and domestic currency, and the spot rate are based on benchmark rates in Section 2.4.

$$x_{\$,d,i,j} = 1 + r^f_{\$} - \frac{F_{i,j}}{S}(1 + r^f_d) \tag{6}$$

We construct intra-day transaction-level CIP deviations for the dates of March 17 to March 20 2020. We choose these dates as they correspond to the largest allotment of swap line auctions during the pandemic. March 18 is the announcement for the BOE and the ECB, and March 17 is the announcement date for auctions with the Bank of Japan. March 19 is the settlement date of the auctions for all three counterparty central banks. In our analysis, we use all transactions between dealer and non-dealer clients. This includes asset managers, (non-dealer) commercial banks, hedge funds, ICPF and LDI, non-financial and other financial. We subdivide our sample into a control and treated group, where treated dealers access BOE swap lines during the period of 18-20 March 2020.

We estimate a DiD specification in equation (7) to test the effects of swap lines on transaction price CIP deviations for the currency pairs of EUR/USD, GBP/USD and

JPY/USD. Following Cenedese et al. (2021) and Khwaja and Mian (2008), we use both dealer-counterparty and counterparty-time fixed effects to control for idiosyncratic hedging demands of counterparties. The outcome variable is the transaction-level CIP deviation measured at the dealer-counterparty level. D_{treat} is a dummy variable for dealers that activated the BOE swap line. $D_{03/18}$, $D_{03/19}$ and $D_{03/20}$ are dummy variables for March 18, 19 and 20, which correspond to the day of announcement, settlement and the day after settlement.

$$Y_{i,j,t} = \alpha_{i,j} + \alpha_{j,t} + \sum_{j=1}^{3} \delta_j D_{03/17+j} \times D_{treatment,i} + \epsilon_{i,j,t} \tag{7}$$

Table 5 details the results for 1 week and 3 month maturities in transactions involving dealers and all counterparties. For the 1 week maturity, columns (I) to (III) cover EUR/USD, GBP/USD, and JPY/USD, respectively. The analysis extends to 3 month maturity in columns (IV) to (VI). The key variables of interest are the interactions of each day of swap line access (18-20 March 2020) with the indicator for swap line access.

Given that CIP deviations are negative for the EUR/USD, GBP/USD, and JPY/USD, a positive coefficient on the interaction variable suggests a reduction in the magnitude of the CIP deviation. The most significant effect is observed for EUR/USD at 1 week maturity, showing a decrease in CIP deviation magnitude by 112 basis points (annualized) on March 18 and 56 basis points (annualized) on March 19. For 3-month maturity, GBP/USD displays the strongest results, with positive coefficients of 23, 19, and 16 basis points on March 18, 19, and 20, respectively. In summary, dealers that access BOE swap lines experienced a net decline in forward rate mispricing relative to the control group in the days following the announcement.

[INSERT TABLE 5 ABOUT HERE]

3.3 Outstanding Derivative Exposures

H3.1: *Arbitrage: Dealers that access the BOE swap line conduct arbitrage activity by lending USD at the spot leg of FX swap contracts, and purchasing USD forward.*

Dealers have the capacity to obtain USD from a swap line to execute arbitrage transactions in the FX swap market. The arbitrage process encompasses the following steps: (i) borrowing USD from the swap line at a penalty rate relative to the USD risk-free rate, (ii) exchanging borrowed USD for a foreign currency (e.g., GBP) at the spot leg of an FX swap, and (iii) repurchasing USD at the forward leg of the swap. The arbitrageur aims to

make excess profits based on CIP deviations, generating arbitrage profits in excess of the penalty rate applied to the swap line. If dealers primarily employ swap lines for arbitrage, empirical observations should reveal an increase in net USD purchases at the forward leg of FX swap transactions and outright forward contracts.

H3.2: *Substitution: Dealers that access the BOE swap line are anticipated to mitigate both immediate and future USD liquidity needs.*

Consider a scenario where a dealer traditionally relies on borrowing USD for meeting debt obligations or hedging activities. Such liquidity needs are typically fulfilled through borrowing USD in money markets or by borrowing USD through FX outright forward and swap transactions with other market participants. Dealers may use swap lines as a substitute source of USD liquidity as an alternative to FX markets. This translates to a reduction in the dealer supply of USD at the forward leg of outright FX outright forward and swap contracts.

Furthermore, dealers may anticipate swap lines reduce their future demand for USD liquidity, driven, for instance, by the extended maturity of swap lines to 3 months and the potential for rolling over BOE swap lines. This anticipated reduction in future USD liquidity demand results in a corresponding decrease in demand for USD at the forward leg.

H3.3: *Dealers that access the BOE swap sell USD forward to non-financial institutions that have net dollar liabilities and use outright forward contracts to hedge their positions.*

Dealers that access the BOE swap line are anticipated to supply USD liquidity to institutions with net dollar liabilities. Consider an institution with dollar liabilities necessitating hedging through outright forward contracts. This category may include non-financial and corporate institutions that lack direct access to swap lines. Elevated uncertainty, particularly during the pandemic, has amplified the demand for hedging among non-financial entities. Consequently, we hypothesize an increase in dealer net sales of USD forward to non-financial firms in the UK seeking to hedge their net USD liabilities. We summarize these predictions in the table below.

Hypothesis	**Instrument**	**Buy**	**Sell**	**Net**
Arbitrage	FX swap and outright forward	(+)	0	(+)
Substitution (immediate)	FX swap	0	(−)	(+)
Substitution (future)	FX swap	(−)	0	(−)
Hedging Corporates	Outright forward	0	(+)	(−)

3.3.1 Outstanding FX exposures in March 2020

As a starting point, we plot the gross outstanding FX exposures for different counterparty segments and maturities for the initial period in March 2020. Figure 7 presents gross outstanding positions of dealers with respect to the following 6 counterparty sectors: asset managers, (non-dealer) commercial banks, hedge funds, ICPF, non-financial and other financial. We exclude inter-dealer transactions from our analysis. Outstanding FX exposures are aggregated across all maturities and are the outstanding positions at the end of each day. The top panel of each Figure reports Buy positions, and the bottom panel reports Sell positions. A Buy position is when the dealer buys USD and sells GBP, EUR or JPY at the forward leg of the FX outright forward and swap contract. Sell positions are recorded when the dealer sells USD and buys GBP, EUR or JPY at the forward leg.

The aggregate gross outstanding Buy and Sell positions are approximately 1.25 Trillion USD each day for the EUR/USD pair, and is closer to 1 Trillion and 0.5 Trillion USD each day for the GBP/USD and JPY/USD pairs. The largest counterparty segment is commercial banks, accounting for over half of the gross outstanding exposures for the EUR/USD and JPY/USD pairs. A dotted line in each the Figure indicates the date of March 18, 2020, which is the trade date for the swap line auctions. The key pattern is a decline in the gross outstanding positions on March 18, 2020 for dealers trading in all currency pairs. Examining maturities in Figure 8, we note that most of the decline in Buy and Sell positions is coming from maturities less than 1 week.

[INSERT FIGURES 7 and 8 ABOUT HERE]

Table 6 summarizes gross outstanding Buy and Sell exposures by counterparty sector during the period from March 17 to March 20, 2020. Panel A presents the aggregate exposures for all dealers, indicating changes in exposures from March 17 to the average over March 18-20. Panel B focuses on the difference in exposures between treated dealers (those activating the BOE swap line on March 18) and control dealers. In general, most sectors see a decline in both outstanding Buy and Sell exposures during this period. Dealer exposures with hedge Funds saw a 108 USD Billion decrease in Buy exposures and a 107 USD Billion decrease in Sell exposures. Dealer exposures with (non-dealer) commercial banks decreased by 25 USD Billion in Buy exposures and 36 USD Billion in Sell exposures. Non-financials showed minimal changes, with a 1 USD Billion decrease in Buy exposures and a 1 USD Billion decrease in Sell exposures. Panel B reports the results for exposures of treated dealers less control dealers. Treated dealers that activated the BOE swap line on March 18 exhibited a relative decline in outstanding Buy and Sell exposures for all counterparty sectors.

[INSERT TABLE 6 ABOUT HERE]

Table 7 provides a breakdown of dealer outstanding Buy and Sell exposures by maturity during the period from March 17 to March 20, 2020. For exposures with a maturity less than 1 week, Buy exposures decreased by 218 USD Billion, while Sell exposures decreased by 203 USD Billion from March 17 to the average over March 18-20. For maturities between 1 month and 3 months, we observe a 18 USD Billion decrease in Buy exposures and a 4 USD Billion decrease in Sell exposures. In panel B, we can dis-aggregate total exposures by treated and control dealers. For treated dealers that activated the BOE swap lines on March 18, there was a notable decrease in outstanding Buy and Sell exposures across the 1 week maturity compared to control dealers. Exposures with a maturity less or equal to 7 days saw a decrease of 168 USD Billion in Buy exposures and 158 USD Billion in Sell exposures. This suggests most of the decline in Buy and Sell exposures for the 1 week maturity is reflected in treated dealer exposures.

[INSERT TABLE 7 ABOUT HERE]

Taken together, the snapshot of outstanding FX exposures during the days of 17-20 March supports the substitution channel outlined in Hypothesis H3.2, with a decline in gross outstanding Buy and Sell exposures, in particular for dealer exposures with counterparty sector hedge funds and (non-dealer) commercial banks. Turning to maturities, the decline in exposures are driven primarily by the short-term maturities of less than 1 week. This is intuitive as the pandemic led to a shortage of short-term USD liquidity, and the swap line allotments were largest for the 1 week maturity followed by the 3 month maturity on March 18, 2020.[6] Interestingly, we find little support for hypothesis H3.1, in which dealers use swap lines to lend USD and conduct arbitrage activities in FX outright forward and swap contracts. In the aggregate, dealers do not report an increase in the net purchase of USD forward. This suggests they are not using BOE swap lines to lend in FX swap markets.

3.3.2 Long term effects on outstanding FX exposures

A limitation of our previous analysis is that by aggregating outstanding FX exposures at the dealer level, we cannot appropriately control for the idiosyncratic hedging demands of counterparties. We therefore identify the effect of outstanding FX exposures of dealers that received a swap line relative to dealers that did not receive a swap line, using a similar DiD framework to our analysis using transaction-level prices.

[6] See Appendix A for more details on BOE swap line amounts.

We compute outstanding FX derivative exposures at the end of month, from September 2019 to November 2020. We include maturities less than or equal to 95 days, consistent with swap lines being extended from the 1 week to 3 month maturity. Dealers that have drawn on the BOE swap line are classified as "treated", and the remaining set of dealers are the control group. Figures 9 and 10 plot aggregate Buy, Sell and Net exposures for each set of dealers with respect to all counterparties and non-financial counterparties respectively. The dotted line indicates March 2020 which is when Covid swap lines were activated.

[INSERT FIGURES 9 and 10 ABOUT HERE]

Our specification is in equation (8). For a dealer i and counterparty j at the end of month t, we measure the outstanding Buy and Sell positions of USD at the forward leg of FX forwards and swap contracts. The outcome variables include gross outstanding Buy, Sell and Net exposures of dealer i and counterparty j in month t. Counterparty sectors include: asset managers, (non-dealer) commercial banks, hedge funds, ICPF and LDI, non-financial and other financial. $D_{swapline,t}$ takes a value of 1 during months of March, April and May, 2020. $D_{treatment,i}$ takes value of 1 for dealers that draw on BOE swap lines during the months of March, April and May 2020. The variable of interest is the interaction term $D_{swapline,t} \times D_{treatment,i}$

$$Y_{i,j,t} = \alpha_{i,j} + \alpha_{j,t} + \gamma D_{swapline,t} + \delta D_{swapline,t} \times D_{treatment,i} + \text{controls}_{i,t} + \epsilon_{i,j,t} \quad (8)$$

Tables 8 and 9 present the results for all counterparty sectors and non-financial sector respectively. In each Table, columns (I), (III) and (V) test for effects on gross outstanding FX exposures (Buy, Sell and Net) without controls, and the remaining columns test for effects with controls, which include dealer-level balance sheet characteristics such as the leverage ratio and share of risk-weighted assets. Our estimates in Table 8 suggest that gross Buy and Sell exposures of treated dealers decline by 71 USD Million relative to dealers that did not access BOE swap line. We find no significant change in net exposures. In summary, our findings support the role of swap lines in substituting the demand for dollar liquidity in the FX swap market (H3.2). In contrast, we find no evidence of an increase in lending USD in the FX swap market to increase arbitrage activity (H3.1).

[INSERT TABLE 8 ABOUT HERE]

In Table 9, we focus on dealer transactions with respect to non-financial counterparties. We find a significant decline in gross Buy exposures with respect to non-financial

institutions, with an estimated decline in 75 USD Million relative to dealers that did not access BOE swap lines. However, we find an insignificant effect on gross Sell exposures. The USD net exposures significantly decreased by 57 USD Million. This is consistent with dealers using swap lines to provide net USD liquidity to hedge the USD net liabilities of corporates, by supplying USD at the forward leg of FX outright forward and swap contracts. This supports the research hypothesis regarding the use of FX outright forwards (H3.3) to supply USD to non-financial counterparties.

Finally, Appendix E provides evidence for other counterparty sectors. The findings of a decline in dealer Buy and Sell exposures with respect to all counterparties are mainly driven by the response of exposures with (non-dealer) commercial banks. In contrast, we find limited effect on dealer Buy and Sell exposures with hedge funds, asset managers and ICPF and LDI.

[INSERT TABLE 9 ABOUT HERE]

4 Conclusion

In this paper, we provide micro-level evidence on how swap lines influence the pricing and trading behavior of financial market participants. We combine BOE swap line drawings during the Covid pandemic of 2020 with transaction-level data on FX outright forward and swap contracts. Using this data, we make three contributions to understanding the pricing and trading behavior of market participants during the provision of swap line liquidity.

First, we document that institutions utilizing swap lines tend to be larger and better capitalized, with a lower share of risk-weighted assets and higher quality collateral. We attribute these findings to the stringent collateral requirements that restrict access to BOE swap lines and favor better capitalized institutions.

Second, we find swap line drawings led to a reduction in pricing inefficiencies in the FX market. Using a DiD framework, we find that dealers that accessed the swap line charged more favorable forward rates relative to the control group, and is consistent with a decline in the magnitude of CIP violations following the swap line, enhancing market efficiency.

Third, in response to swap line drawings, dealers reduce their gross outstanding FX exposures, and increased their net supply of USD at the forward leg of contracts to non-financial institutions. Our results are consistent with dealers using swap lines as a substitute source of USD funding to FX outright forward and swap contracts. Interestingly, we find limited evidence that swap lines are being used to lend USD and pursue arbitrage activities.

Our work has several policy implications. We point to collateral requirements being important in determining access to swap lines. Swap lines achieve the intended goal of alleviating USD liquidity in FX outright forward and swap contracts through lowering the ceiling on CIP deviations, and can be used as a tool to reduce bank currency exposures and mitigate dollar shortages during financial crises.

Finally, we point to future areas of research. For instance, what are the incentives for particular dealers to bid in swap line auctions? Do the reduction in outstanding FX exposures and net supply of USD to non-financial institutions led to further lending in the economy? More research using dealer-level swap line data can provide insights into the macroeconomic and financial stability effects of swap lines, the risk-taking behavior and the lending and funding of bank balance sheets.

References

Abbassi, Puriya and Falk Bräuning, "Demand Effects in the FX Forward Market: Micro Evidence from Banksâ Dollar Hedging," *Review of Financial Studies, forthcoming*, 2020.

Aizenman, Joshua, Hiro Ito, and Gurnain Kaur Pasricha, "Central bank swap arrangements in the covid-19 crisis," *Journal of International Money and Finance*, 2022, *122*, 102555.

Aldasoro, Iñaki, Christian Cabanilla, Pitti Disyatat, Torsten Ehlers, Patrick McGuire, and Goetz von Peter, "BIS Bulletin," 2020.

Andersen, Leif, Darrell Duffie, and Yang Song, "Funding value adjustments," *The Journal of Finance*, 2019, *74* (1), 145–192.

Avdjiev, Stefan, Wenxin Du, Catherine Koch, and Hyun Song Shin, "The dollar, bank leverage, and deviations from covered interest parity," *American Economic Review: Insights*, 2019, *1* (2), 193–208.

Baba, Naohiko and Frank Packer, "Interpreting deviations from covered interest parity during the financial market turmoil of 2007–08," *Journal of Banking & Finance*, 2009, *33* (11), 1953–1962.

Bahaj, Saleem and Ricardo Reis, "Central bank swap lines during the covid-19 pandemic," *Covid Economics*, 2020, *2*.

_ **and** _ , "Jumpstarting an International Currency," 2020.

_ **and** _ , "Central bank swap lines: Evidence on the effects of the lender of last resort," *The Review of Economic Studies*, 2022, *89* (4), 1654–1693.

Bohorquez, Diego, "The United States as the International Lender of Last Resort," November 2023. Job Market Paper.

Borio, Claudio EV, Robert N McCauley, Patrick McGuire, and Vladyslav Sushko, "Covered interest parity lost: understanding the cross-currency basis," *BIS Quarterly Review September*, 2016.

Bräuer, Leonie and Harald Hau, "Can Time-Varying Currency Risk Hedging Explain Exchange Rates?," *Swiss Finance Institute Research Paper*, 2022, (22-77).

Bräuning, Falk and Kovid Puria, "Uncovering covered interest parity: The role of bank regulation and monetary policy," *Federal Reserve Bank of Boston Research Paper Series Current Policy Perspectives Paper*, 2017, (17-3).

Bruno, Valentina and Hyun Song Shin, "Capital flows and the risk-taking channel of monetary policy," *Journal of Monetary Economics*, 2015, *71*, 119–132.

Carvalho, Carlos, Ricardo Masini, and Marcelo C Medeiros, "Arco: an artificial counterfactual approach for high-dimensional panel time-series data," *Journal of econometrics*, 2018, *207* (2), 352–380.

Cenedese, Gino, Pasquale Della Corte, and Tianyu Wang, "Currency mispricing and dealer balance sheets," *The Journal of Finance*, 2021, *76* (6), 2763–2803.

Cerutti, Eugenio M, Maurice Obstfeld, and Haonan Zhou, "Covered Interest Parity Deviations: Macrofinancial Determinants," Technical Report, National Bureau of Economic Research 2019.

Cesa-Bianchi, Ambrogio, Fernando Eguren Martin, and Andrea Ferrero, "Dollar shortages and central bank swap lines," 2022.

_ , Robert Czech, and Fernando Eguren-Martin, "Staff Working Paper No. 932 Dash for dollars," 2021.

Choi, Mark, Linda S Goldberg, Robert Irving Lerman, and Fabiola Ravazzolo, "The Fed's central bank swap lines and FIMA repo facility," Technical Report, Staff Report 2021.

Committee on the Global Financial System, "US dollar funding: an international perspective," Technical Report, Bank for International Settlements 2020.

Corsi, Fulvio, "A simple approximate long-memory model of realized volatility," *Journal of Financial Econometrics*, 2009, *7* (2), 174–196.

Czech, Robert, Shiyang Huang, Dong Lou, Tianyu Wang et al., "An unintended consequence of holding dollar assets," *Bank of England Staff Working Paper*, 2021, (953).

Drechsler, Itamar, Thomas Drechsel, David Marques-Ibanez, and Philipp Schnabl, "Who borrows from the lender of last resort?," *The Journal of Finance*, 2016, *71* (5), 1933–1974.

Du, Wenxin, Alexander Tepper, and Adrien Verdelhan, "Deviations from covered interest rate parity," *The Journal of Finance*, 2018, *73* (3), 915–957.

Eren, Egemen, Andreas Schrimpf, and Vladyslav Sushko, "BIS Bulletin," 2020.

Ferrara, Gerardo, Maria Flora, and Roberto Renò, "The COVID-19 Auction Premium," Technical Report, Working paper 2021.

Goldberg, Linda, Craig Kennedy, and Jason Miu, "Central bank dollar swap lines and overseas dollar funding costs," *Economic Policy Review*, 2011, (May), 3–20.

Goldberg, Linda S and Fabiola Ravazzolo, "The Fed's International Dollar Liquidity Facilities: New Evidence on Effects," *FRB of New York Staff Report*, 2021, (997).

Griffoli, T Mancini and A Ranaldo, "Deviations from Covered Interest Parity during the crisis: A story of funding liquidity constraint," Technical Report, Working Paper, Swiss National Bank 2009.

Hau, Harald, Peter Hoffmann, Sam Langfield, and Yannick Timmer, "Discriminatory pricing of over-the-counter derivatives," *Management Science*, 2021, *67* (11), 6660–6677.

He, Zhiguo, Bryan Kelly, and Asaf Manela, "Intermediary asset pricing: New evidence from many asset classes," *Journal of Financial Economics*, 2017, *126* (1), 1–35.

Iida, Tomoyuki, Takeshi Kimura, and Nao Sudo, "Deviations from covered interest rate parity and the dollar funding of global banks," *55th issue (September 2018) of the International Journal of Central Banking*, 2018.

Ivashina, Victoria, David S Scharfstein, and Jeremy C Stein, "Dollar Funding and the Lending Behavior of Global Banks," *The Quarterly Journal of Economics*, 2015, *130* (3), 1241–1281.

Khwaja, Asim Ijaz and Atif Mian, "Tracing the impact of bank liquidity shocks: Evidence from an emerging market," *American Economic Review*, 2008, *98* (4), 1413–42.

Kloks, Peteris, Edouard Mattille, and Angelo Ranaldo, "Foreign Exchange Swap Liquidity," *Swiss Finance Institute Research Paper*, 2023, (23-22).

Liao, Gordon and Tony Zhang, "The Hedging Channel of Exchange Rate Determination," *Available at SSRN 3612395*, 2020.

Liao, Gordon Y, "Credit migration and covered interest rate parity," *Journal of Financial Economics*, 2020.

McCrone, Annie, Ralf Meisenzahl, Friederike Niepmann, and Tim Schmidt-Eisenlohr, "How central bank swap lines affect the leveraged loan market," *Chicago Fed Letter*, 2020, *446*.

Newey, Whitney K. and Kenneth D. West, "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 1987, *55* (3), 703–708.

Rime, Dagfinn, Andreas Schrimpf, and Olav Syrstad, "Covered interest parity arbitrage," *Review of Financial Studies, Forthcoming*, 2022.

Rose, Andrew K and Mark M Spiegel, "Dollar illiquidity and central bank swap arrangements during the global financial crisis," *Journal of International Economics*, 2012, *88* (2), 326–340.

Schellekens, Kai, Patty Duijm et al., "Effectiveness of Central Bank Swap Lines in Alleviating the Mispricing of FX Swaps at the Start of the COVID-19 Pandemic," Technical Report 2022.

Siriwardane, Emil, Adi Sunderam, and Jonathan L Wallen, "Segmented arbitrage," Technical Report 2024.

Syrstad, Olav, "Covered Interest Parity in long-dated securities," *Available at SSRN 3611635*, 2020.

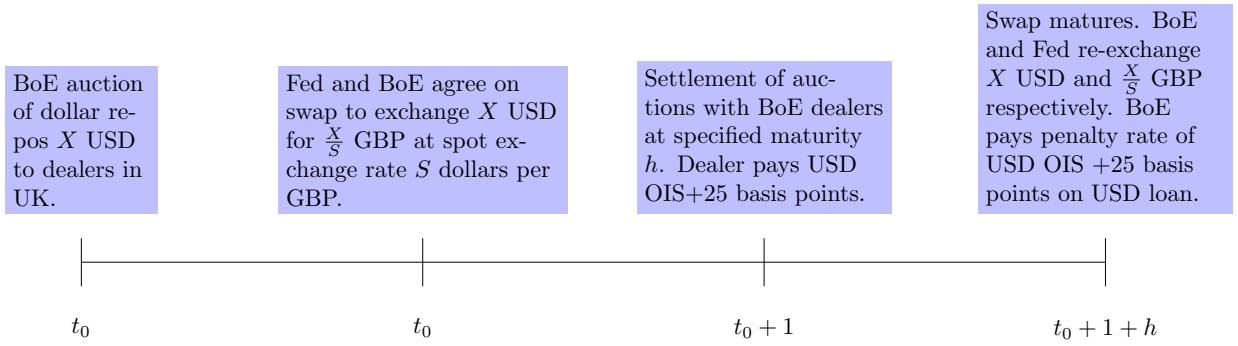
_ **and Ganesh Viswanath-Natraj**, "Price-setting in the foreign exchange swap market: Evidence from order flow," *Journal of Financial Economics*, 2022, *146* (1), 119–142.

Viswanath-Natraj, Ganesh, "Unconventional Monetary Policy and Covered Interest Rate Parity Deviations: is there a Link?," 2020.

Zeev, Nadav Ben and Daniel Nathan, "The persistent widening of cross-currency basis: When increased FX swap demand meets limits of arbitrage," Technical Report, Working Paper 2023.

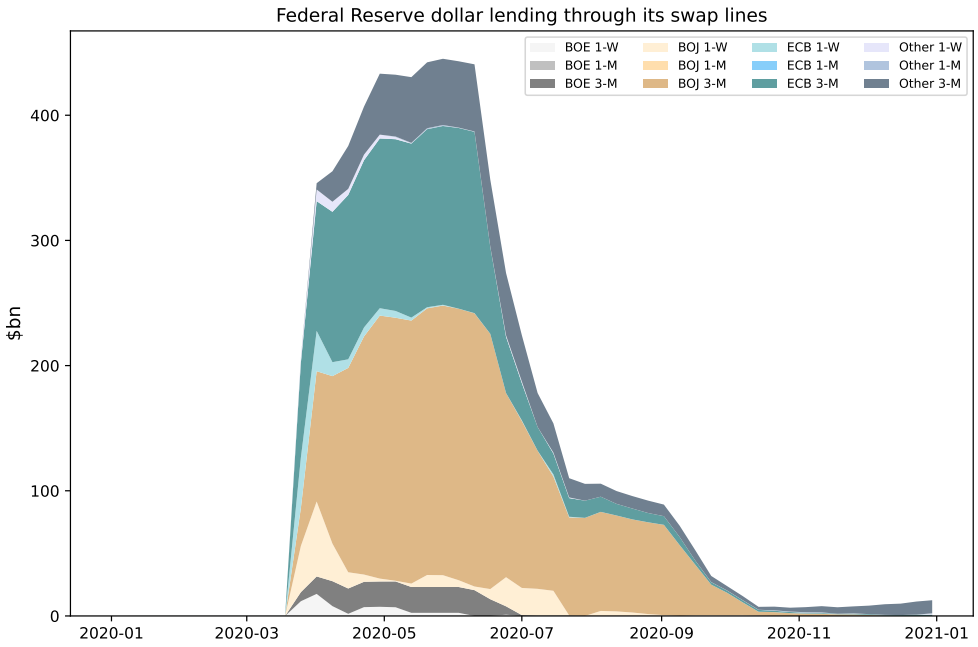
Figures

Figure 1: Swap Line Auctions Timeline



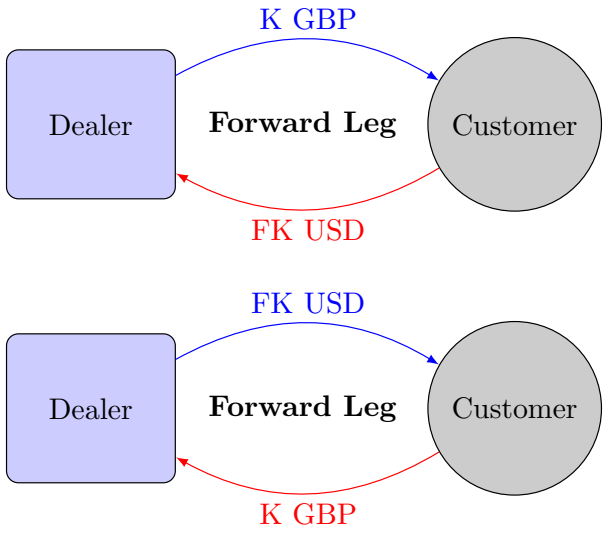
Note: Figure presents timeline of swap line auctions between the Federal Reserve and Bank of England. t_0 is the date of the auctions between the BOE and dealers in the UK, and is also the date of agreement between the Federal Reserve and BOE. $t_0 + 1$ is the day of settlement of auctions. $t_0 + 1 + h$ is the date of expiry.

Figure 2: Swap Line Allotments during Covid



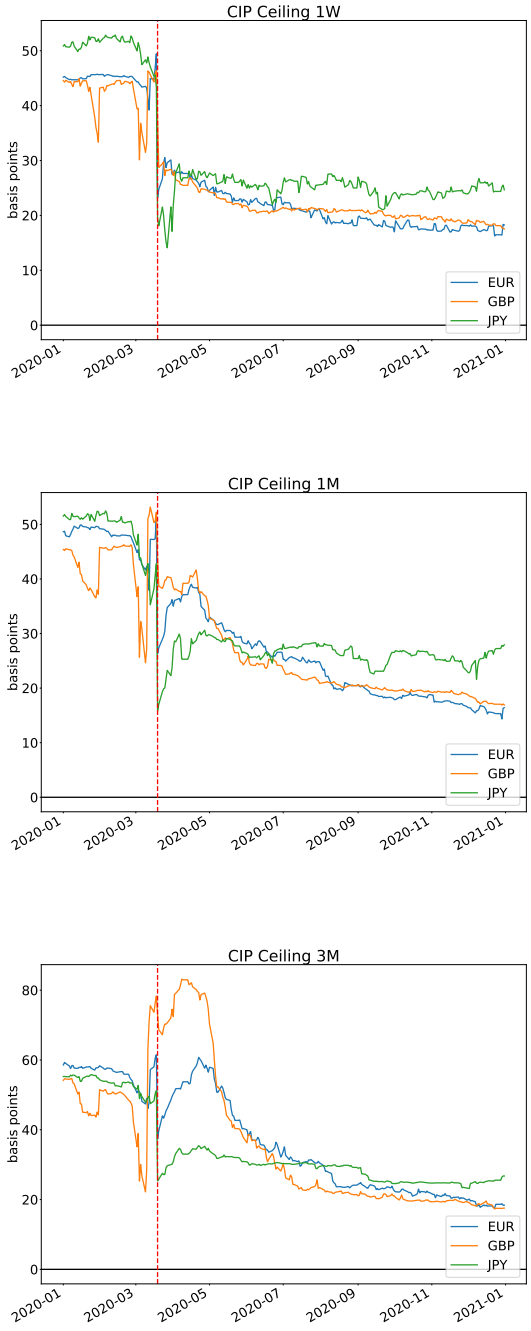
Note: Figure presents outstanding Federal Reserve Swap Lines made to Bank of Japan, Bank of England, European Central Bank and other central banks during 2020. Maturities are 1 week, 1 month and 3 month. Data is taken from the NY Federal Reserve.

Figure 3: Outstanding FX exposures, Top panel: dealer transactions of buying USD at forward leg Bottom panel: dealer transactions of selling USD at forward leg.



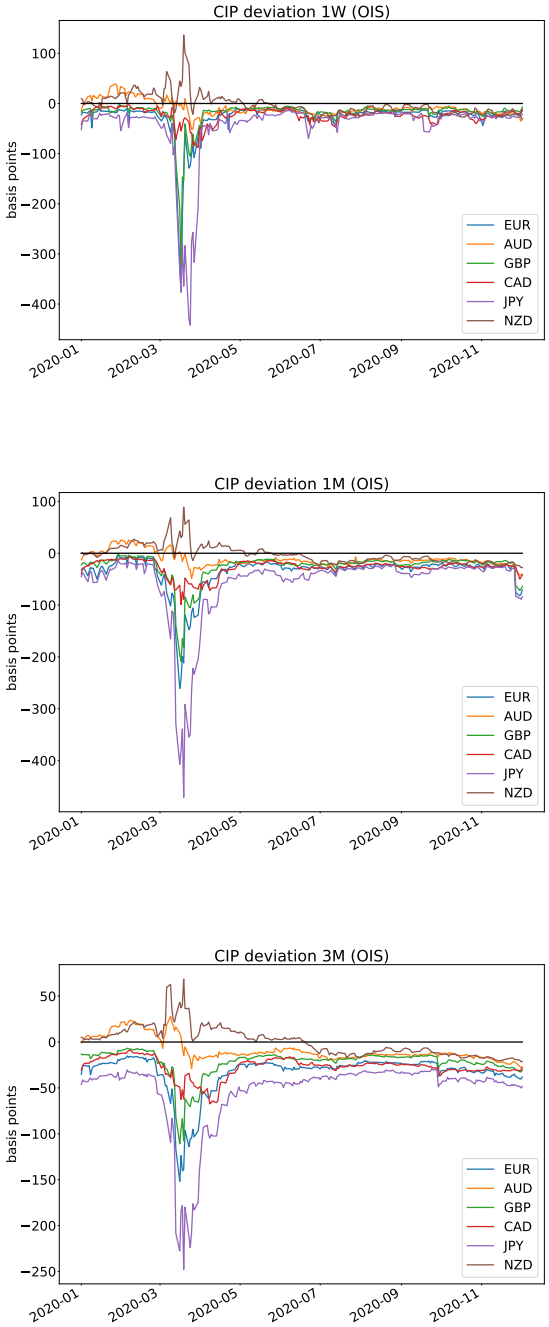
Note: Figure schematic shows how outstanding FX exposures Buy and Sell transactions are measured. In the top panel, a dealer that buys USD at the forward leg and sells GBP forward is recorded as a Buy transaction. In the bottom panel, a dealer that buys GBP at forward leg and sells USD forward is recorded as a Sell transaction.

Figure 4: CIP Deviations during Covid: Ceiling Tests



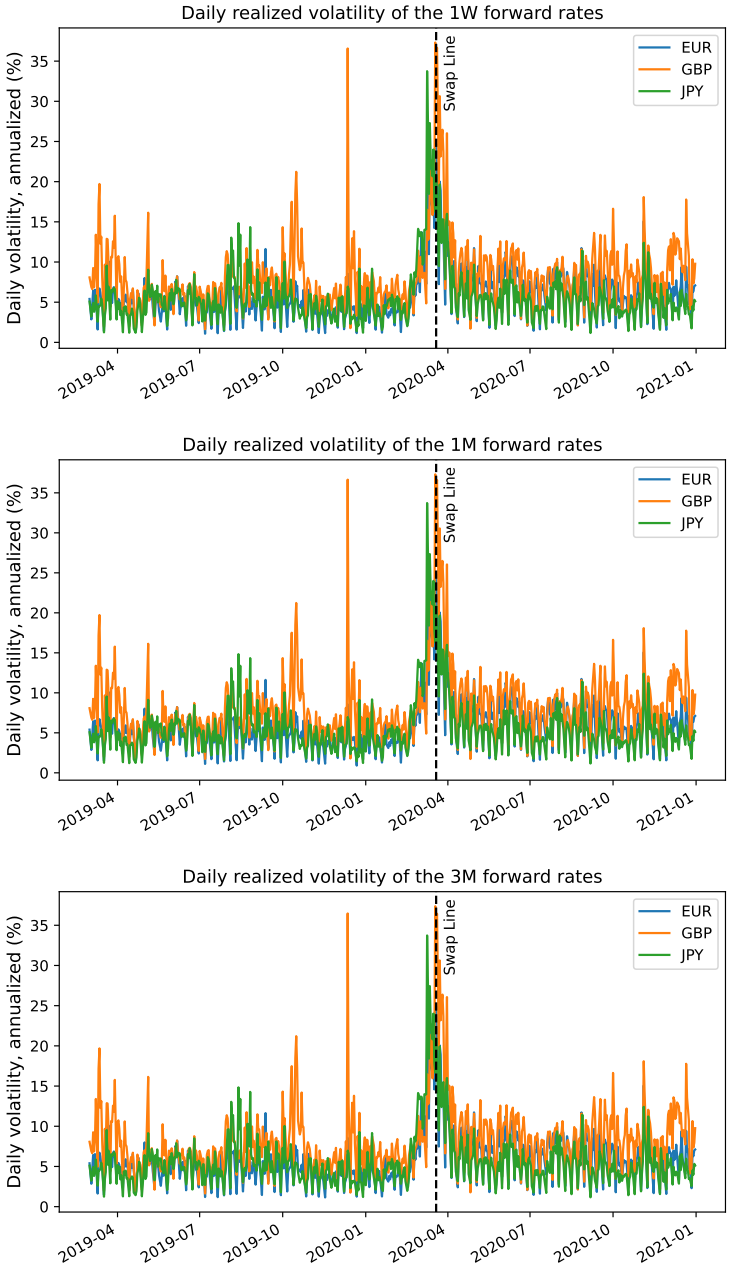
Note: Figure presents the ceiling on CIP deviations for advanced economies for maturities of 1 week, 1 month and 3 month. Data is daily and sample period is from January 1 2020 to December 31 2020. Data for OIS rates, forward and spot rates and interbank and policy rates used to construct the ceiling are taken from Bloomberg.

Figure 5: CIP Deviations during Covid: Control and Treatment Currencies



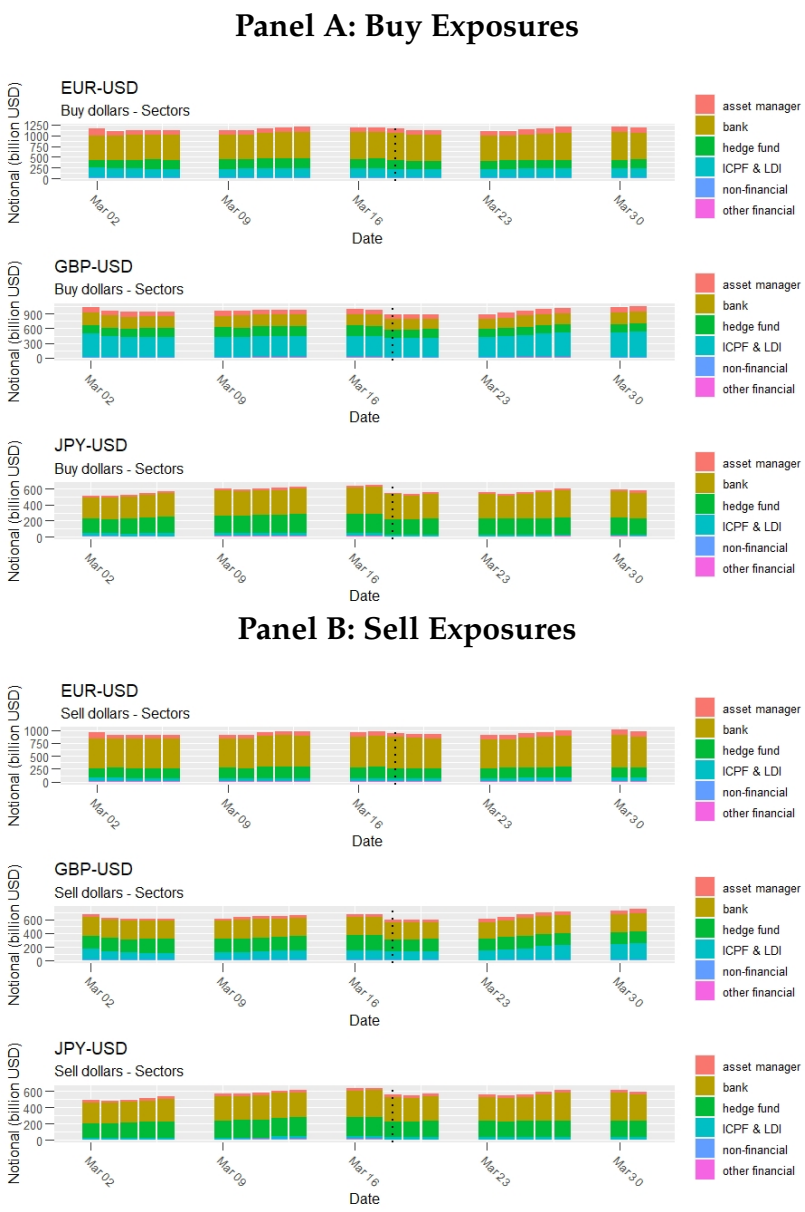
Note: Figure presents CIP deviations (benchmark OIS rate) for advanced economies for maturities of 1 week, 1 month and 3 month. Data is daily and sample period is from January 1 2020 to November 20 2020. Data for OIS rates, forward and spot rates are taken from Bloomberg.

Figure 6: Forward Rate Volatility: 1 Week, 1 Month and 3 Month



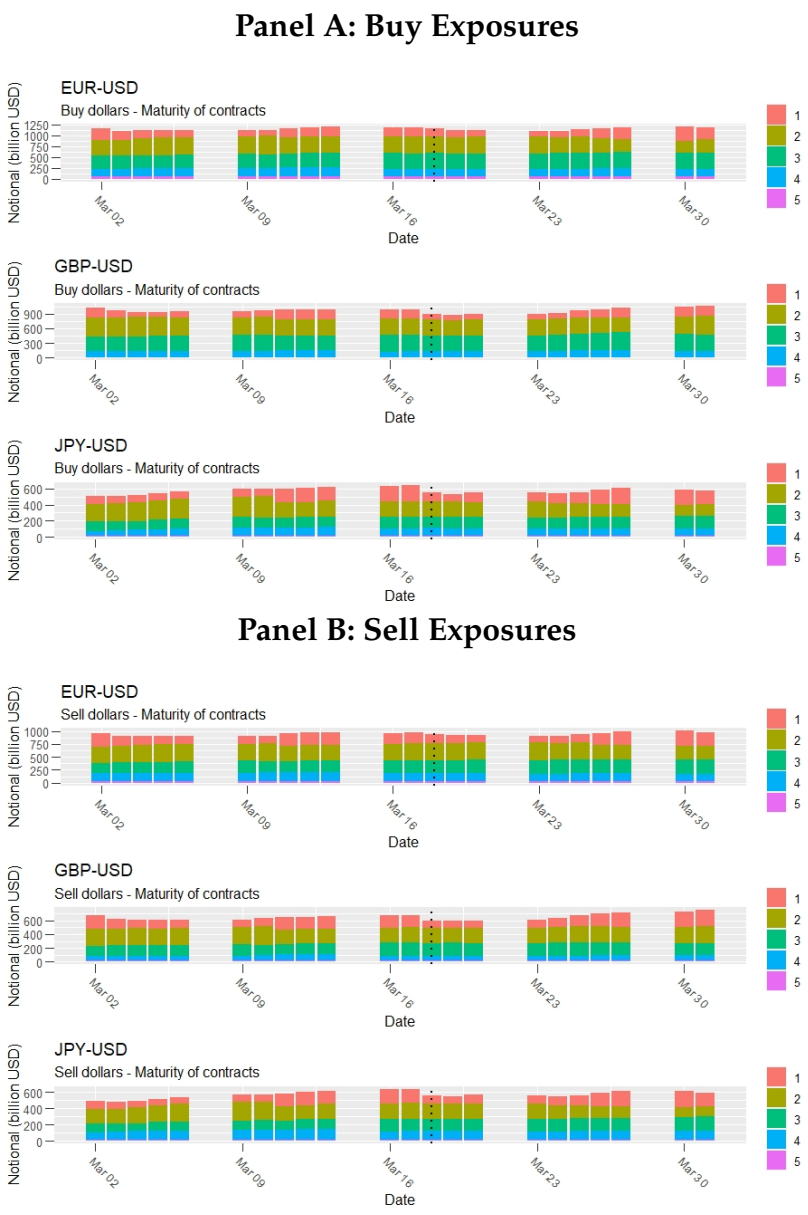
Note: Figure presents daily realized volatility of the EUR/USD, GBP/USD and JPY/USD forward rate for 1 week, 1 month and 3 month maturities. It is calculated using intra-day data taken from Thomson Reuters tick history. Dotted line indicates Federal Reserve settlement date of March 19, 2020.

Figure 7: outstanding FX exposures (Gross Notional) by Sector: Buy USD (Top Panel) and Sell USD (Bottom Panel)



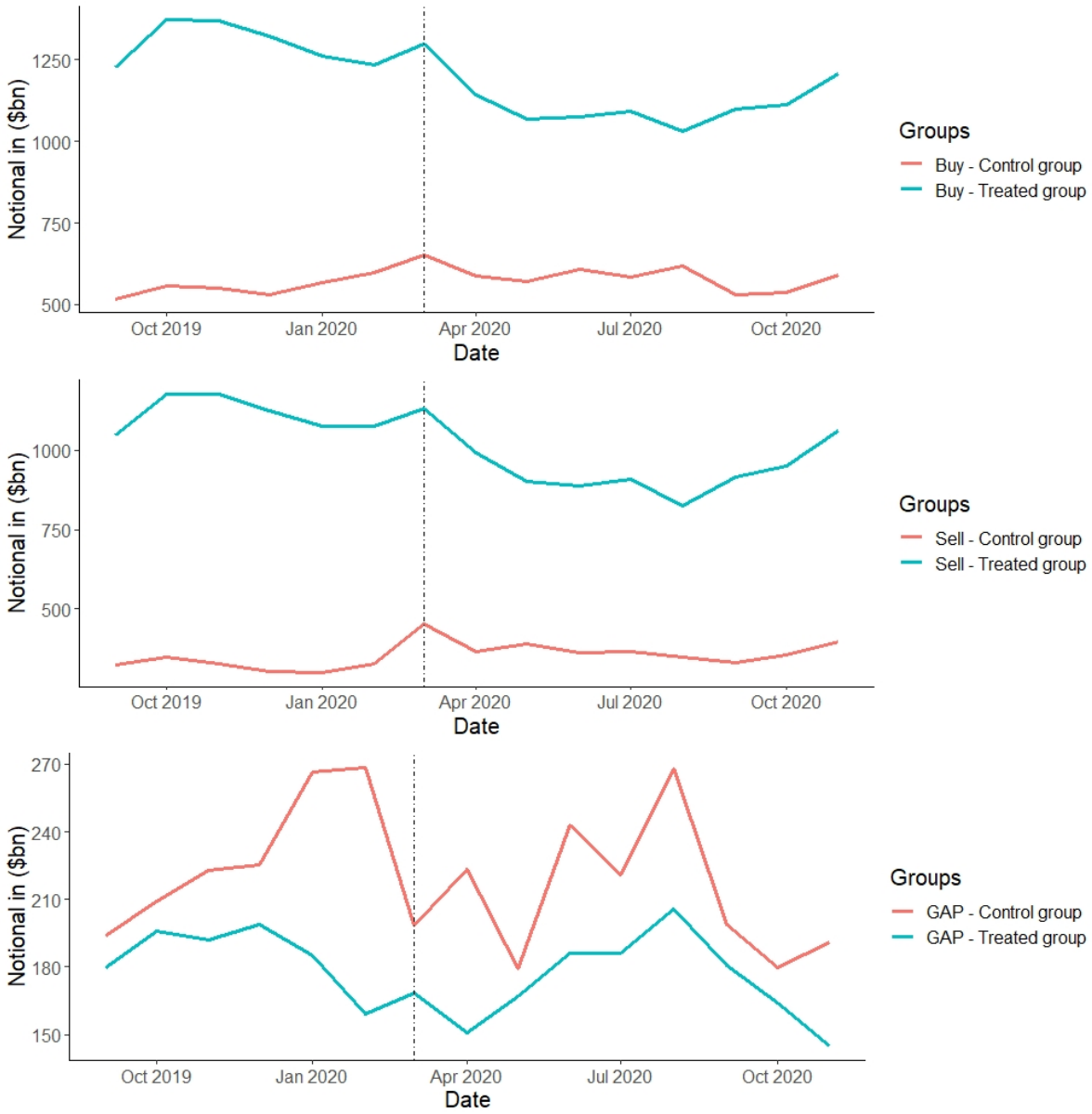
Note: Figure presents aggregate Buy and Sell positions for dealers with respect to the following 6 counterparty sectors: asset managers, (non-dealer) commercial banks, hedge funds, ICPF, and Non-Financial. Outstanding FX exposures are aggregated across all maturities and are the outstanding notional positions at the end of each day. The top panel shows outstanding notional positions in which dealers buy USD and sell EUR, GBP, and JPY at the forward leg. The bottom panel shows outstanding notional positions in which dealers sell USD and buy EUR, GBP, and JPY at the forward leg. The sample period is from March 1 to March 31, 2020. The dotted line indicates March 18, 2020, which is when Covid swap lines were activated.

Figure 8: outstanding FX exposures (Gross Notional) by Maturity: Buy USD (Top Panel) and Sell USD (Bottom Panel)



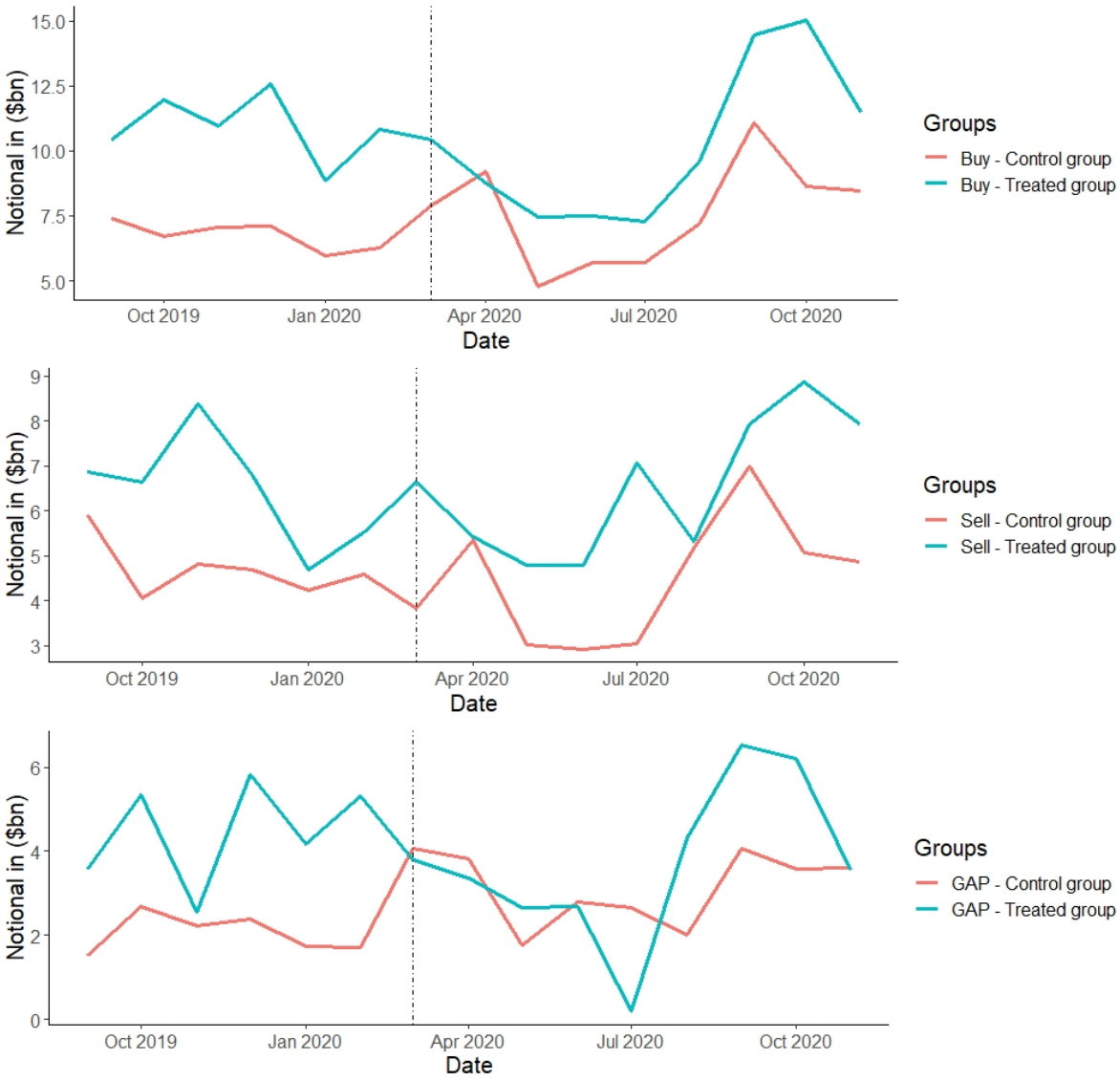
Note: Figure presents aggregate Buy and Sell positions for dealers with respect to the following 5 maturity groups: (1) less or equal to 1 week, (2) greater than 1 week and less than 1 month, (3) greater than 1 month and less than 3 months, (4) greater than 3 months and less than 1 year, (5) greater than 1 year. Outstanding FX exposures are aggregated across all maturities and are the outstanding notional positions at the end of each day. The top panel shows outstanding notional positions in which dealers buy USD and sell EUR, GBP, and JPY at the forward leg. The bottom panel shows outstanding notional positions in which dealers sell USD and buy EUR, GBP, and JPY at the forward leg. The sample period is from March 1 to March 31, 2020. The dotted line indicates March 18, 2020, which is when Covid swap lines were first announced.

Figure 9: Dealer outstanding FX exposures: all counterparties



Note: Figure presents aggregate Buy, Sell and Net FX (Gap) exposures for dealers with respect to all (non-dealer) counterparty sectors: asset managers, (non-dealer) commercial banks, hedge funds, ICPF and LDI, non-financial and other financial. Dealers that have drawn on BOE swap lines are classified as "treated", and the set of dealers that did not draw on BOE swap lines are "control". Outstanding FX exposures at a maturities less than or equal to 95 days are aggregated across the two groups and are the outstanding notional positions at end of month. Sample period is from September 2019 to November 2020. Dotted line indicates March 2020 which is when Covid swap lines were activated.

Figure 10: Dealer outstanding FX exposures with non-Financial counterparties



Note: Figure presents aggregate Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty non-financial. Dealers that have drawn on BOE swap lines are classified as "treated", and the set of dealers that did not draw on BOE swap lines are "control". Outstanding FX exposures at a maturities less than or equal to 95 days are aggregated across the two groups and are the outstanding notional positions at end of month. Sample period is from September 2019 to November 2020. Dotted line indicates March 2020 which is when Covid swap lines were activated.

Tables

Table 1: BOE Repo Collateral requirements

Collateral Bucket	Eligible Securities	Credit Rating	Haircut (< 1yr)	Haircut (> 30y)
A	Sterling, euro, US dollar and Canadian dollar denominated securities issued by the governments and central banks of the UK, Canada, France, Germany, the Netherlands and the United States.	AAA	0.5 %	15 %
B	Sovereign and central bank debt of Australia, Austria, Belgium, Denmark, Finland, Ireland, Italy, Japan, Luxembourg, New Zealand, Norway, Portugal, Spain, Sweden and Switzerland, issued in either the domestic currency or in sterling, euro or US dollar. Debt issued by Federal Home Loan Mortgage Corporation (Freddie Mac), the Federal National Mortgage Corporation (Fannie Mae) and the Federal Home Loan Banks, UK and EEA residential mortgage-backed securities (RMBS), credit cards, consumer loans and student loans	AAA	0.5-12%	15-24%
C	UK, US and EEA residential mortgage-backed securities (RMBS), credit cards, consumer loans and student loans. Can also include US, UK and EEA senior tranches of Asset-Backed Commercial Paper, listed senior corporate bonds, and mortgage, consumer, corporate loans to a non-bank.	A3/A- or above	15-30%	27-42%

Note: Table presents collateral requirements of BOE repos. Based on the Sterling monetary framework, collateral is listed in three buckets, with varying credit rating and haircuts. Information is consolidated from Bank of England statements on collateral. See https://www.bankofengland.co.uk/markets/eligible-collateral for more details on collateral types. Details on haircuts for specific collateral types can be found on https://www.bankofengland.co.uk/-/media/boe/files/markets/eligible-collateral/summary-tables-of-haircuts-for-bank-lending-operations.pdf.

Table 2: Summary Statistics CIP Deviations

ticker	maturity	count	mean	std	min	25%	50%	75%	max
AUD	1M	241.0	-11.6336	13.3709	-48.9205	-19.2562	-14.1811	-10.7404	25.6246
	1W	241.0	-9.6211	14.8024	-51.7389	-17.8174	-12.8280	-7.1070	39.2151
	3M	241.0	-8.5968	12.4008	-28.8911	-15.8186	-13.3068	-6.9131	27.9645
CAD	1M	241.0	-27.8233	15.3231	-98.9089	-29.5292	-24.9021	-19.4680	-7.2059
	1W	241.0	-23.5510	13.9235	-87.7985	-28.7256	-20.9109	-14.8276	2.3307
	3M	241.0	-27.5181	11.1793	-67.4104	-30.8768	-25.3747	-21.6974	-8.6429
EUR	1M	241.0	-35.4576	34.7870	-260.8301	-31.0260	-25.9459	-21.7743	-1.1150
	1W	241.0	-27.1465	37.3687	-376.3558	-23.9274	-17.8493	-15.2576	-9.4049
	3M	241.0	-33.4913	21.8315	-151.7875	-33.3120	-27.3625	-23.1721	-15.1927
GBP	1M	241.0	-25.4783	28.0707	-208.4684	-22.4256	-18.0506	-14.6971	-0.5657
	1W	241.0	-19.6559	30.1869	-329.0601	-17.0460	-13.0853	-10.2204	-0.9319
	3M	241.0	-22.0334	15.1014	-111.0227	-23.2635	-18.3410	-15.0092	-6.7289
JPY	1M	241.0	-56.3742	67.9096	-470.7259	-47.9777	-34.9833	-28.4677	-12.4672
	1W	241.0	-44.5181	64.9019	-442.1727	-35.0796	-27.2906	-22.5068	-14.0107
	3M	241.0	-53.2375	38.4388	-247.7134	-46.9396	-41.1928	-35.3749	-28.9152
NZD	1M	241.0	-2.6283	17.1728	-27.5873	-15.7704	-5.7870	7.4376	89.0939
	1W	241.0	-3.2889	21.2507	-38.4681	-18.4023	-7.7653	7.7899	136.5972
	3M	241.0	0.1465	15.7790	-21.4597	-12.5235	0.8074	9.7328	68.5067

Note: Table presents summary statistics on CIP deviations (benchmark OIS rate) for advanced economies for maturities of 1 week, 1 month and 3 month. Data is daily and sample period is from January 1st 2020 to November 20th 2020. Data for OIS rates, forward and spot rates are taken from Bloomberg.

Table 3: Summary Statistics Balance Sheet Variables

	count	mean	std	min	25%	50%	75%	max
Total_Asset (USD Billion)	496	1344280	797289	182286	725686	1101276	1900303	3386071
$\frac{Loan}{Asset}$	496	0.43	0.16	0.08	0.33	0.40	0.52	0.81
$\frac{RWA}{Asset}$	496	0.36	0.13	0.12	0.27	0.35	0.47	0.65
$\text{distance}_{\text{CET1 Ratio}}$ (%)	496	9.48	3.97	5.88	7.31	8.30	10.20	30.00
$\text{distance}_{\text{Leverage Ratio}}$ (%)	496	2.14	1.05	0.90	1.40	1.90	2.55	8.40

Note: Table presents summary statistics on balance sheet variables: total assets (USD Billion), the share of loans to total assets, the share of risk-weighted assets, and the distance to the leverage ratio and CET1 ratio. Sample is monthly from September 2019 to December 2020. Data source is Bloomberg.

Table 4: Determinants of Swap Line Access

	I	II	III	IV
	$\mathbb{D}_{\text{treat}}$	$\mathbb{D}_{\text{treat}}$	$\mathbb{D}_{\text{treat}}$	$\mathbb{D}_{\text{treat}}$
$\text{distance}_{\text{CET1 Ratio}}$	0.1885*			
	(0.094)			
$\text{distance}_{\text{Leverage Ratio}}$		0.1973***		
		(0.004)		
$\frac{RWA}{Assets}$			-5.1272**	
			(0.017)	
UK Government Bonds				0.0002*
				(0.079)
constant	-1.8805*	-0.5585*	1.5292**	-0.8150
	(0.078)	(0.067)	(0.046)	(0.133)
N	36	36	36	19

Note: Table estimates a panel probit specification to test the determinants of access to BoE Repos. Outcome variables D_{treat} is a dummy variable for dealers that activated the BoE dollar repo in March or April 2020. Explanatory variables include the distance from the leverage ratio and CET1 ratio, and the share of risk-weighted assets. All balance sheet variables are taken from March and April 2020. UK government bonds held by dealers is defined as UK central or regional government, local authority or public sector entity assets, and are denominated in GBP Million. Standard errors are White Heteroscedasticity robust. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 5: Transaction-Level CIP Deviations for EUR/USD, GBP/USD and JPY/USD: All counterparties

	I EUR 1W	II GBP 1W	III JPY 1W	IV EUR 3M	V GBP 3M	VI JPY 3M
$D_{treat} \times D_{03/18}$	111.6139***	-55.7294	7.3914	4.0338	22.2930***	13.6564*
	(13.8764)	(36.8631)	(19.2569)	(11.7480)	(4.8319)	(7.7213)
$D_{treat} \times D_{03/19}$	56.3292***	20.8513		-2.8982	18.8637**	-4.0425
	(17.7520)	(45.3687)		(7.2352)	(9.2552)	(8.2560)
$D_{treat} \times D_{03/20}$				-2.7758	16.8283*	14.3046
				(10.1976)	(9.0860)	(15.0707)
constant	-91.0513***	-93.8882***	-25.5267***	-132.1824***	-104.7267***	-202.6335***
	(3.9662)	(8.2738)	(2.1868)	(2.0531)	(2.2173)	(2.4876)
R-sq	0.267	0.194	0.199	0.328	0.226	0.473
N	1034	567	590	2155	1383	1097

Note: Table estimates a difference-in-difference specification to test the effects of swap lines on transaction price CIP violations for the currency pairs of EUR/USD, GBP/USD and JPY/USD. Transactions are between dealers and all counterparty sectors: asset managers, commercial banks, hedge funds, ICPF and LDI, non-financial and other financial. Outcome variables include individual currency CIP deviations measured using transaction level data at the dealer-counterparty level. For columns (I) to (III), the maturity is 5 days, which corresponds to a 1 week forward or FX swap contract. For columns (IV) to (VI), the maturity is 85-95 days, which corresponds to the 3 month maturity. D_{treat} is a dummy variable for dealers that activated the BoE dollar repo. $D_{03/18}$, $D_{03/19}$ and $D_{03/20}$ are dummy variables for the March 18, 19 and 20 respectively. March 18 corresponds to the day in which the Federal Reserve announced the swap line auctions, which is known as the trade date, and March 19 is the settlement date of the auctions. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level. Missing coefficients in columns (I), (II) and (III) are due to small sample selection and insufficient data on 1W forward contracts for the select dealer-counterparty pairs.

Table 6: Buy and Sell Exposures by Counterparty Sector: 17th-20th March 2020

Panel A: Counterparty - All Dealers						
		Buy			**Sell**	
	17 March	18-20 March	Δ	17 March	18-20 March	Δ
Asset Managers	$246B	$220B	-$26B	$165B	$141B	-$24B
Commercial Banks	$1178B	$1153B	-$25B	$1191B	$1156B	-$36B
Hedge Funds	$673B	$565B	-$108B	$670B	$563B	-$107B
ICPF and LDI	$660B	$599B	-$61B	$223B	$200B	-$23B
Non-financials	$34B	$33B	-$1B	$18B	$18B	-$1B
Other financials	$29B	$17B	-$12B	$27B	$16B	-$11B
Panel B: Counterparty - Treated minus Control						
		Buy			**Sell**	
	17 March	18-20 March	Δ	17 March	18-20 March	Δ
Asset Managers	$96B	$93B	-$3B	$66B	$64B	-$1B
Commercial Banks	$517B	$492B	-$25B	$548B	$512B	-$36B
Hedge Funds	$541B	$435B	-$106B	$558B	$450B	-$108B
ICPF and LDI	$107B	$81B	-$26B	$40B	$26B	-$15B
Non-financials	$9.6B	$9.2B	-$0.4B	$2.5B	$2.4B	-$0.1B
Other Financials	$20B	$11B	-$9B	$15B	$6B	-$9B

Note: Table presents Buy and Sell exposures by counterparty sector. Buy and sell exposures are aggregated across all maturities, and are between dealers and the following counterparty sectors: asset managers, commercial banks, hedge funds, ICPF and LDI, Non-Financial and Other Financial. Buy and Sell exposures are aggregated across all maturities, for the days of the March 17, and the average over March 18-20. March 18 corresponds to the day in which the Federal Reserve announced the swap line auctions, which is known as the trade date, and March 19 is the settlement date of the auctions. We record the difference Δ between the exposures on the 18-20 March and the 17 March for each counterparty sector. In panel A, we record the aggregate Buy and Sell Exposures for all dealers. In panel B, we record the aggregate Buy and Sell Exposures for treated dealers less control dealers, where treated dealers are those that activated the BoE dollar repo on the March 18, 2020.

Table 7: Buy and Sell Exposures by Maturity: 17th-20th March 2020

Panel A: Maturity - All Dealers

	Buy			Sell		
	17 March	18-20 March	Δ	17 March	18-20 March	Δ
≤ 7 days	$606B	$389B	-$218B	$575B	$372B	-$203B
≥ 8 days ≤ 30 days	$912B	$906B	-$6B	$738B	$741B	$3B
≥ 31 days ≤ 90 days	$837B	$819B	-$18B	$592B	$587B	-$4B
≥ 91 days ≤ 360 days	$393B	$402B	$9B	$333B	$337B	$4B
> 360 days	$71.8B	$71.4B	-$0.4B	$56.9B	$57.2B	$0.3B

Panel B: Maturity Treated minus Control

	Buy			Sell		
	17 March	18-20 March	Δ	17 March	18-20 March	Δ
≤ 7 days	$365B	$197B	-$168B	$323B	$164B	-$158B
≥ 8 days ≤ 30 days	$382B	$380B	-$2B	$359B	$351B	-$9B
≥ 31 days ≤ 90 days	$335B	$335.4B	-$0.4B	$350B	$346B	-$4B
≥ 91 days ≤ 360 days	$178.7B	$178.5B	-$0.2B	$187B	$188B	$2B
> 360 days	$30.1B	$30B	-$0.1B	$10.5B	$10.6B	$0.1B

Note: Table presents Buy and Sell exposures by maturity. Buy and Sell exposures are aggregated across all counterparty sectors (asset managers, commercial banks, hedge funds, ICPF and LDI, Non-Financial and other financial), for the days of the 17 of March, and the average over 18-20 of March. March 18 corresponds to the day in which the Federal Reserve announced the swap line auctions, which is known as the trade date, and March 19 is the settlement date of the auctions. We record the difference Δ between the exposures on the 18-20 March and the 17 March for each counterparty sector. In panel A, we record the aggregate Buy and Sell Exposures for all dealers. In panel B, we record the aggregate Buy and Sell Exposures for treated dealers less control dealers, where treated dealers are those that activated the BoE dollar repo on March 18, 2020.

Table 8: Dealer FX Exposures for maturities ≤ 95 days: all counterparties

	I	II	III	IV	V	VI
	Buy	Buy	Sell	Sell	Net	Net
D_{treat}	199.33***	432.94***	212.31***	422.64***	-12.99	10.30
	(63.06)	(111.25)	(68.93)	(116.53)	(19.52)	(37.09)
$D_{swap\ line} \times D_{treat}$	-99.01***	-71.10**	-93.34***	-71.25**	-5.67	0.16
	(33.09)	(32.13)	(35.20)	(34.31)	(17.40)	(16.18)
$\frac{RWA}{Assets}$		969.68***		670.07***		299.60***
		(224.63)		(183.51)		(96.75)
$distance_{CET1\ Ratio}$		-4.81		-23.28		18.48***
		(14.50)		(14.37)		(5.82)
$distance_{Leverage\ Ratio}$		-90.48***		-61.77***		-28.71***
		(25.21)		(23.52)		(10.37)
constant	262.32***	-7.02	171.60***	147.76	90.71***	-154.78**
	(30.76)	(137.17)	(33.52)	(105.52)	(9.25)	(68.57)
R2	0.42	0.42	0.38	0.38	0.44	0.44
N	71099	71093	71099	71093	71099	71093

Note: Table estimates a difference-in-difference specification to test the effects of swap lines on FX exposures for maturities less or equal to 95 days. Outcome variables include Buy, Sell and Net FX exposures for dealers with respect to all (non-dealer) counterparty sectors: asset managers, commercial banks, hedge funds, ICPF and LDI, non-financial and other financial. D_{treat} is a dummy variable for dealers that activated the BoE dollar repo. $D_{swapline}$ is a dummy variable for the months of March, April and May 2020 in which the BoE repo lines were drawn. Controls include the distance from the leverage ratio and CET1 requirements, and the ratio of risk-weighted assets to total assets. Sample is monthly from September 2019 to November 2020, and aggregates GBP/USD, EUR/USD and JPY/USD FX swaps for maturities less than 3 months. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 9: Dealer FX Exposures for maturities ≤ 95 days: non-financial counterparties

	I	II	III	IV	V	VI
	Buy	Buy	Sell	Sell	Net	Net
D_{treat}	65.77	94.47	27.77	68.63**	37.99	25.84
	(52.75)	(61.39)	(19.67)	(31.41)	(34.87)	(36.47)
$D_{swap\ line} \times D_{treat}$	-74.44*	-74.98*	-19.33	-17.35	-55.11*	-57.63*
	(39.47)	(39.79)	(14.38)	(13.61)	(27.61)	(29.50)
$\frac{RWA}{Assets}$		339.43		389.46*		-50.02
		(199.89)		(204.06)		(79.90)
$distance_{CET1\ Ratio}$		9.72		12.82		-3.11
		(9.16)		(10.92)		(3.83)
$distance_{Leverage\ Ratio}$		-0.03		-22.04*		22.01**
		(4.89)		(10.87)		(9.28)
constant	117.92***	-108.81	79.00***	-158.76	38.92**	49.95
	(24.75)	(180.58)	(9.44)	(170.47)	(16.30)	(50.43)
R2	0.31	0.32	0.28	0.29	0.35	0.35
N	1783	1783	1783	1783	1783	1783

Note: Table estimates a difference-in-difference specification to test the effects of swap lines on FX exposures for maturities less or equal to 3 months. Outcome variables include Buy, Sell and Net FX exposures for dealers with respect to counterparty non-financial. D_{treat} is a dummy variable for dealers that activated the BoE dollar repo. $D_{swapline}$ is a dummy variable for the months of March, April and May 2020 in which the BoE repo lines were drawn. Controls include the distance from the leverage ratio and CET1 requirements, and the ratio of risk-weighted assets to total assets. Sample is monthly from September 2019 to November 2020, and aggregates GBP/USD, EUR/USD and JPY/USD FX swaps for maturities less than 3 months. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Online Appendix to

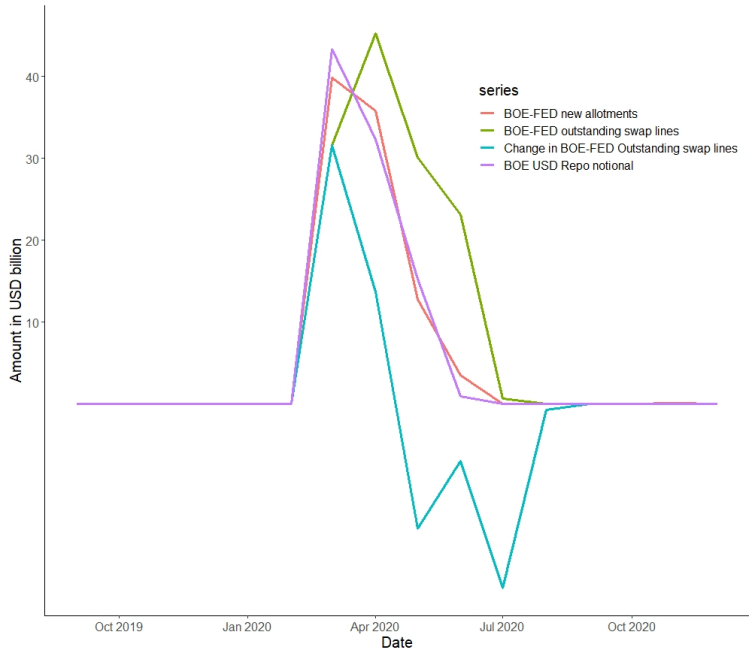
"Central Bank Swap Lines: Micro-Level Evidence"

(Not for publication)

Appendix A: Swap line drawings

To test the validity of our BOE swap line data, we can construct an aggregate measure of BOE all auctions of USD repos across all dealers for all maturities. This aggregate measure should in principle be equal to the outstanding swap lines between the Federal Reserve and the Bank of England.

Figure A1: Validity test: BOE swap line drawings and NY Fed auctions



Note: Figure presents different measures of the outstanding Federal Reserve Swap Lines made to Bank of England. BOE auctions of USD to dealers are aggregated and defined as BOE USD Repo notional in the Figure. This is compared to the aggregate auctions of funds from the Federal Reserve to the BOE based on publicly available New York Federal Reserve data on swap lines made to counterparty central banks. Changes in allotments are measured as the first difference in outstanding swap lines based on New York Federal Reserve data on swap line drawings to the BOE. Data is aggregated for swaps of maturities 1 week, 1 month and 3 month, at a monthly frequency.

In Figure A1, the BOE swap line drawings are compared to the aggregate auctions of funds from the Federal Reserve to the BOE based on New York Federal Reserve data, which are provided in Table A1. We find that the BOE Repo USD Notional, which is the aggregate USD amount bid at dealer auctions for swap lines at the BOE, is consistent with the level of Federal Reserve swap line allotments made to the BOE. This suggests the confidential BOE swap line data that we have matches publicly available aggregate data provided by the Federal Reserve.

The following tables A1, A2 and A3 present the allotment details of central bank swap

lines by the Bank of England, European Central Bank and Bank of Japan respectively. This includes the trade date, settlement date, maturity date, term in days, amount in USD million, and interest rate at which funds are lent to the counterparty central bank, which is typically a spread (25 basis points) above the USD OIS rate.

Table A1: Central Bank Swap Lines Allotments to the Bank of England

Counterparty	Trade Date	Settlement Date	Maturity Date	Term (Days)	Amount (USD mil)	Interest Rate (%)
Bank of England	03/18/2020	03/19/2020	06/11/2020	84	7245.00	0.38
Bank of England	03/18/2020	03/19/2020	03/26/2020	7	8210.00	0.45
Bank of England	03/23/2020	03/24/2020	03/31/2020	7	5.00	0.38
Bank of England	03/24/2020	03/25/2020	04/01/2020	7	3555.00	0.38
Bank of England	03/25/2020	03/26/2020	06/18/2020	84	6685.00	0.35
Bank of England	03/25/2020	03/26/2020	04/02/2020	7	7705.00	0.36
Bank of England	03/26/2020	03/27/2020	04/03/2020	7	905.00	0.34
Bank of England	03/27/2020	03/30/2020	04/06/2020	7	500.00	0.32
Bank of England	03/30/2020	03/31/2020	04/07/2020	7	5005.00	0.32
Bank of England	03/31/2020	04/01/2020	04/08/2020	7	3505.00	0.33
Bank of England	04/01/2020	04/02/2020	06/25/2020	84	6000.00	0.32
Bank of England	04/01/2020	04/02/2020	04/09/2020	7	7850.00	0.32
Bank of England	04/06/2020	04/07/2020	04/14/2020	7	5.00	0.31
Bank of England	04/08/2020	04/09/2020	07/02/2020	84	300.00	0.33
Bank of England	04/08/2020	04/09/2020	04/16/2020	7	1700.00	0.30
Bank of England	04/09/2020	04/14/2020	04/21/2020	7	5.00	0.31
Bank of England	04/15/2020	04/16/2020	04/23/2020	7	2045.00	0.30
Bank of England	04/17/2020	04/20/2020	04/27/2020	7	5000.00	0.30
Bank of England	04/20/2020	04/21/2020	04/28/2020	7	5.00	0.30
Bank of England	04/22/2020	04/23/2020	04/30/2020	7	2045.00	0.29
Bank of England	04/24/2020	04/27/2020	05/04/2020	7	5250.00	0.31
Bank of England	04/27/2020	04/28/2020	05/05/2020	7	15.00	0.32
Bank of England	04/28/2020	04/29/2020	05/06/2020	7	5.00	0.32
Bank of England	04/29/2020	04/30/2020	07/23/2020	84	395.00	0.32
Bank of England	04/29/2020	04/30/2020	05/07/2020	7	1700.00	0.32
Bank of England	05/04/2020	05/05/2020	05/12/2020	7	5255.00	0.30
Bank of England	05/11/2020	05/12/2020	05/19/2020	7	2500.00	0.30
Bank of England	05/18/2020	05/19/2020	05/26/2020	7	2500.00	0.30
Bank of England	05/22/2020	05/26/2020	06/02/2020	7	2500.00	0.30
Bank of England	05/29/2020	06/02/2020	06/09/2020	7	2500.00	0.30

Table A2: Summary of Swap Line Allotments to the European Central Bank

Counterparty	Trade Date	Settlement Date	Maturity Date	Term (Days)	Amount (USD mil)	Interest Rate (%)
European Central Bank	03/04/2020	03/05/2020	03/12/2020	7	58.00	1.58
European Central Bank	03/11/2020	03/12/2020	03/19/2020	7	45.00	1.24
European Central Bank	03/18/2020	03/19/2020	03/26/2020	7	36265.00	0.45
European Central Bank	03/18/2020	03/19/2020	06/11/2020	84	75820.00	0.38
European Central Bank	03/23/2020	03/24/2020	03/31/2020	7	20.00	0.38
European Central Bank	03/24/2020	03/25/2020	04/01/2020	7	4115.00	0.38
European Central Bank	03/25/2020	03/26/2020	04/02/2020	7	17267.00	0.36
European Central Bank	03/25/2020	03/26/2020	06/18/2020	84	27810.00	0.35
European Central Bank	03/26/2020	03/27/2020	04/03/2020	7	3205.00	0.34
European Central Bank	03/27/2020	03/30/2020	04/06/2020	7	2165.00	0.32
European Central Bank	03/30/2020	03/31/2020	04/07/2020	7	6650.00	0.32
European Central Bank	03/31/2020	04/01/2020	04/08/2020	7	2950.00	0.33
European Central Bank	04/01/2020	04/02/2020	04/09/2020	7	6850.20	0.32
European Central Bank	04/01/2020	04/02/2020	06/25/2020	84	16468.00	0.32
European Central Bank	04/02/2020	04/03/2020	04/09/2020	6	925.00	0.32
European Central Bank	04/03/2020	04/06/2020	04/14/2020	8	165.00	0.32
European Central Bank	04/06/2020	04/07/2020	04/14/2020	7	2270.00	0.31
European Central Bank	04/07/2020	04/08/2020	04/15/2020	7	943.00	0.30
European Central Bank	04/08/2020	04/09/2020	04/16/2020	7	5922.30	0.30
European Central Bank	04/08/2020	04/09/2020	07/02/2020	84	11230.70	0.33
European Central Bank	04/09/2020	04/14/2020	04/21/2020	7	463.00	0.31
European Central Bank	04/14/2020	04/15/2020	04/22/2020	7	485.00	0.31
European Central Bank	04/15/2020	04/16/2020	07/09/2020	84	2260.20	0.33
European Central Bank	04/15/2020	04/16/2020	04/23/2020	7	4805.50	0.30
European Central Bank	04/16/2020	04/17/2020	04/24/2020	7	440.00	0.30
European Central Bank	04/17/2020	04/20/2020	04/27/2020	7	205.00	0.30
European Central Bank	04/20/2020	04/21/2020	04/28/2020	7	1740.00	0.30
European Central Bank	04/22/2020	04/23/2020	07/16/2020	84	2003.00	0.32
European Central Bank	04/22/2020	04/23/2020	04/30/2020	7	3814.00	0.29
European Central Bank	04/23/2020	04/24/2020	05/04/2020	10	920.00	0.30
European Central Bank	04/24/2020	04/27/2020	05/04/2020	7	200.00	0.31
European Central Bank	04/27/2020	04/28/2020	05/05/2020	7	1868.00	0.32
European Central Bank	04/29/2020	04/30/2020	07/23/2020	84	1610.00	0.32
European Central Bank	04/29/2020	04/30/2020	05/07/2020	7	3005.30	0.32
European Central Bank	04/30/2020	05/04/2020	05/11/2020	7	500.00	0.29
European Central Bank	05/04/2020	05/05/2020	05/12/2020	7	1721.30	0.30
European Central Bank	05/05/2020	05/06/2020	05/13/2020	7	200.00	0.29
European Central Bank	05/06/2020	05/07/2020	07/30/2020	84	1795.00	0.29
European Central Bank	05/06/2020	05/07/2020	05/14/2020	7	2291.50	0.30
European Central Bank	05/07/2020	05/11/2020	05/18/2020	7	5.00	0.30
European Central Bank	05/11/2020	05/12/2020	05/19/2020	7	76.30	0.30
European Central Bank	05/13/2020	05/14/2020	05/22/2020	8	791.60	0.31
European Central Bank	05/13/2020	05/14/2020	08/06/2020	84	3245.00	0.30
European Central Bank	05/15/2020	05/18/2020	05/26/2020	8	10.00	0.30
European Central Bank	05/18/2020	05/19/2020	05/26/2020	7	94.30	0.30
European Central Bank	05/20/2020	05/22/2020	05/28/2020	6	442.00	0.31
European Central Bank	05/20/2020	05/22/2020	08/13/2020	83	600.00	0.31
European Central Bank	05/22/2020	05/26/2020	06/02/2020	7	184.00	0.30
European Central Bank	05/27/2020	05/28/2020	06/04/2020	7	50.50	0.30
European Central Bank	05/27/2020	05/28/2020	08/20/2020	84	1510.00	0.30
European Central Bank	05/29/2020	06/02/2020	06/09/2020	7	5.00	0.30

Table A3: Summary of Swap Line Allotments to the Bank of Japan

Counterparty	Trade Date	Settlement Date	Maturity Date	Term (Days)	Amount (USD mil)	Interest Rate (%)
Bank of Japan	03/17/2020	03/19/2020	03/26/2020	7	2053.00	0.41
Bank of Japan	03/17/2020	03/19/2020	06/11/2020	84	30272.00	0.37
Bank of Japan	03/23/2020	03/25/2020	04/01/2020	7	34850.00	0.38
Bank of Japan	03/24/2020	03/26/2020	04/02/2020	7	15465.00	0.36
Bank of Japan	03/24/2020	03/26/2020	06/18/2020	84	73805.00	0.35
Bank of Japan	03/25/2020	03/27/2020	04/03/2020	7	4950.00	0.34
Bank of Japan	03/26/2020	03/30/2020	04/06/2020	7	2265.00	0.32
Bank of Japan	03/27/2020	03/31/2020	04/07/2020	7	13100.00	0.34
Bank of Japan	03/30/2020	04/01/2020	04/08/2020	7	24100.00	0.32
Bank of Japan	03/31/2020	04/02/2020	04/09/2020	7	9285.00	0.32
Bank of Japan	03/31/2020	04/02/2020	06/25/2020	84	29724.00	0.32
Bank of Japan	04/01/2020	04/03/2020	04/10/2020	7	950.00	0.32
Bank of Japan	04/02/2020	04/06/2020	04/13/2020	7	1135.00	0.32
Bank of Japan	04/03/2020	04/07/2020	04/14/2020	7	5750.00	0.32
Bank of Japan	04/06/2020	04/08/2020	04/15/2020	7	12880.00	0.31
Bank of Japan	04/07/2020	04/09/2020	04/16/2020	7	9360.00	0.30
Bank of Japan	04/07/2020	04/09/2020	07/02/2020	84	29442.00	0.33
Bank of Japan	04/08/2020	04/10/2020	04/17/2020	7	1080.00	0.30
Bank of Japan	04/09/2020	04/13/2020	04/20/2020	7	998.00	0.31
Bank of Japan	04/10/2020	04/14/2020	04/21/2020	7	600.00	0.30
Bank of Japan	04/13/2020	04/15/2020	04/22/2020	7	931.00	0.30
Bank of Japan	04/14/2020	04/16/2020	04/23/2020	7	2210.00	0.31
Bank of Japan	04/14/2020	04/16/2020	07/09/2020	84	26958.00	0.33
Bank of Japan	04/15/2020	04/17/2020	04/24/2020	7	1260.00	0.30
Bank of Japan	04/16/2020	04/20/2020	04/27/2020	7	664.00	0.30
Bank of Japan	04/17/2020	04/21/2020	04/28/2020	7	640.00	0.30
Bank of Japan	04/20/2020	04/22/2020	04/30/2020	8	1020.00	0.30
Bank of Japan	04/21/2020	04/23/2020	04/30/2020	7	1290.00	0.30
Bank of Japan	04/21/2020	04/23/2020	07/16/2020	84	19903.00	0.32
Bank of Japan	04/22/2020	04/24/2020	05/07/2020	13	971.00	0.31
Bank of Japan	04/23/2020	04/27/2020	05/07/2020	10	722.00	0.30
Bank of Japan	04/24/2020	04/28/2020	05/07/2020	9	310.00	0.31
Bank of Japan	04/27/2020	04/30/2020	05/07/2020	7	541.00	0.32
Bank of Japan	04/28/2020	04/30/2020	07/16/2020	77	1016.00	0.33
Bank of Japan	04/28/2020	04/30/2020	05/14/2020	14	6670.00	0.32
Bank of Japan	04/30/2020	05/07/2020	05/14/2020	7	2042.00	0.29
Bank of Japan	05/07/2020	05/11/2020	05/18/2020	7	400.00	0.30
Bank of Japan	05/08/2020	05/12/2020	05/19/2020	7	200.00	0.30
Bank of Japan	05/11/2020	05/13/2020	05/20/2020	7	86.00	0.30
Bank of Japan	05/12/2020	05/14/2020	08/06/2020	84	2890.00	0.30
Bank of Japan	05/12/2020	05/14/2020	05/21/2020	7	9489.00	0.31
Bank of Japan	05/18/2020	05/20/2020	05/27/2020	7	118.00	0.30
Bank of Japan	05/19/2020	05/21/2020	08/13/2020	84	2373.00	0.31
Bank of Japan	05/19/2020	05/21/2020	05/28/2020	7	9292.00	0.31
Bank of Japan	05/22/2020	05/27/2020	06/03/2020	7	164.00	0.30
Bank of Japan	05/26/2020	05/28/2020	06/04/2020	7	5250.00	0.30
Bank of Japan	05/27/2020	05/29/2020	08/20/2020	83	1501.00	0.30

Appendix B: Ceiling test

We test the hypothesis through a probit specification in equation (9), where $x_{i,j,t}$ represents the CIP deviation for currency i and maturity j, and $Post_t$ is is a dummy variable that takes a value of 1 from March 19, 2020, which is the first auction (settlement) day after the new swap policy announcement. Using the OIS rate as a benchmark, and we test for ceiling violations for the EUR/USD, GBP/USD and JPY/USD at the swap line maturities of 1 week, 1 month and 3 month. The outcome is a dummy variable that takes a value of 1 when the CIP deviation violates a ceiling threshold, where we measure the penalty rate $\delta = 25bp$. For interbank rates we use a LIBOR reference rate for each duration, and for the rate of renumeration on excess reserves we use the bank rate for the BOE, the deposit facility rate for the ECB and the policy rate for the BOJ.

$$\mathbb{1}[|x_{i,j,t}| > 25bp + i^i_{interbank} - i^i_{reserve}|] = \beta Post_t + \epsilon_{i,j,t} \tag{9}$$

The results are presented in Table A4. The probability of ceiling violations reduce following the change in the penalty rate across currency pairs and maturities. The decline in ceiling violations is most pronounced for the EUR and JPY 1W and 1M maturities. Our findings suggest that mispricing in the FX market declines with the provision of swap lines, and is most effective at reducing the ceiling on 1 week CIP deviations. However, we find limited evidence that swap lines caused a decline in the ceiling for 3M JPY/USD CIP deviations, and could suggest limits to arbitrage at longer maturities and increased hedging demand by non-financial counterparties at the 3 month maturity in the JPY/USD FX markets.

Table A4: CIP Deviations: Ceiling Test

	I	II	III	IV	V	VI	VII	VIII	IX
	EUR 1W	GBP 1W	JPY 1W	EUR 1M	GBP 1M	JPY 1M	EUR 3M	GBP 3M	JPY 3M
post	-1.19***	-0.41	-1.38***	-1.65***	-0.44*	-2.06***	-1.05***	-1.44***	
	(0.25)	(0.28)	(0.23)	(0.23)	(0.26)	(0.23)	(0.25)	(0.42)	
Constant	1.35***	1.47***	1.15***	0.99***	1.35***	0.73***	1.35***	2.10***	0.92***
	(0.24)	(0.25)	(0.22)	(0.20)	(0.24)	(0.19)	(0.24)	(0.40)	(0.20)
Observations	241	241	241	241	241	241	241	241	56

Note: Table estimates a probit model for the effects of swap lines on CIP deviations for maturities of 1 Week, 1 Month and 3 Month. Outcome variable is a dummy variable which takes a value of 1 when the CIP deviation exceeds (in absolute value) the ceiling, which is the sum of the swap line penalty (25 basis points) and the difference between the interbank and reserve rates. $post$ is a dummy variable which takes a value of 1 when swap line auctions were first settled on March 19 2020. The coefficient on $post$ is omitted for JPY 3M as there are no observations in the post period that are below the ceiling. Sample period is from January 1 2020 to November 20 2020. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Appendix C: Price Effects

C.1 DiD specification

While we have shown the Federal Reserve policy of lowering the penalty rate by 25 basis points leads to a statistically significant reduction in the ceiling on 1 week CIP deviations, we also want to test if CIP deviations changed relative to a control group that did not activate the swap lines.

We test a DiD specification in equation (10), where we compare currencies that activated the swap line (EUR, GBP, JPY) to a control group of currencies that did not activate the swap line (AUD and NZD). The outcome variable of the framework is $\Delta x_{\$,i,t}$, which is the first difference in the CIP deviation in basis points. $SwapLine_i$ is a dummy variable for whether the currency i sovereign central bank has a swap arrangement with the Federal Reserve. We control for currency and maturity differences in CIP deviations with fixed effects α_i and α_c, respectively. Following Cerutti et al. (2019), we use controls of the first differences in the VIX and the difference in overnight indexed swap (OIS) interest rates between the foreign currency and USD. In addition, we use the change in the broad USD index based on Avdjiev et al. (2019), which is connected to CIP deviations through bank leverage according to Bruno and Shin (2015). Changes in the bid-ask spread are indicators of illiquidity and volatility in foreign exchange markets. The final determinant of CIP deviations that we use is the intermediary capital ratio factor utilized in He et al. (2017). This follows empirical work which documents that the leverage ratio determines asset prices through affecting the marginal value of wealth for the U.S. investor. All variables except the Post dummy and the intermediary capital ratio factor utilized are in first-differences.

$$\Delta x_{i,t} = \alpha_i + \alpha_c + \beta \times Post_t \times SwapLine_i + controls_{i,t} + \epsilon_{i,t} \tag{10}$$

Table A5 reports the results. With controls, the DiD coefficient estimates a statistically significant net reduction in synthetic funding costs of 12.98 basis points relative to the control group. In an alternative specification in columns (III) and (IV), we test the interaction of allotments with the post date. $Allotment_{i,t}$ measures the change in outstanding swap lines for currency i in billions USD. A 1 Billion USD increase in swap line allotments reduces the spread between synthetic and direct USD funding costs by 0.48 basis points. This is economically significant: aggregate swap line allotments reached a peak of approximately 142 Billion USD for EUR/USD, 196 USD Billion for JPY/USD and 38 Billion USD for GBP/USD. Using our coefficient estimate of 0.486 or the effect of allotments on

the change in CIP deviations, our results would attribute a narrowing of CIP deviations by approximately 70 basis points for the EUR/USD, 100 basis points for the JPY/USD pair and 20 basis points for the GBP/USD pair.

One empirical concern is the non-random selection of control group currencies. In this case, control group currencies like AUD and NZD have lower synthetic USD borrowing costs, and therefore choose not to access the swap line for USD funding. Instead, we can compare CIP deviations involving the euro, pound, and yen to currencies that had an increase in CIP deviations vis-a-vis the USD during the pandemic but did not have access to the swap line. We find our results are robust to using an alternative control group, the DKK and SEK. Table A6 reports the results. For the interaction term of $Allotment_{i,t} \times Post_t$, the DiD coefficient estimates are quantitatively similar to using AUD and NZD as the control group.

Another concern is our selection of the treatment date of March 19 2020, which could be problematic due to a number of confounding events during the pandemic. In Table A7, we run placebo tests using alternative treatment dates, February 1, 2020 and May 1, 2020, and find insignificant treatment effects using these dates. Finally, we test long-term maturities of 1 year, 5 year and 10 year. Consistent with swap lines providing USD at 1 week to 3 month, we find a significantly smaller magnitude of treatment effects on longer-term maturities.

Table A5: Panel Differences-in-Differences Specification: CIP Deviations (OIS)

	I	II	III	IV
	$\Delta x_{i,j,t}$	$\Delta x_{i,j,t}$	$\Delta x_{i,j,t}$	$\Delta x_{i,j,t}$
Swapline$_i$ × Post$_t$	13.675**	12.982**		
	(3.821)	(3.514)		
Allotment$_{i,t}$ × Post$_t$			0.486***	0.475***
			(0.120)	(0.089)
Post$_t$	-0.895	-5.484**	7.760*	2.702
	(1.286)	(1.599)	(3.537)	(2.167)
$\Delta\ (i - i_{us})$		-0.715***		-0.725***
		(0.170)		(0.175)
Δ log(board dollar)		-4.583*		-4.449**
		(1.981)		(1.658)
Δ log(VIX)		-0.279**		-0.277**
		(0.083)		(0.083)
Δ fwd bid-ask		0.558		0.266
		(2.287)		(2.138)
HKM		-107.912**		-109.979**
		(30.834)		(30.514)
constant	-4.444**	-0.206	-4.444*	-0.219
	(1.218)	(0.797)	(1.767)	(0.689)
R^2	0.03	0.09	0.03	0.08
N	756	756	756	756
Treatment	EUR, GBP, JPY and CAD			
Control	AUD and NZD			

Note: Table estimates a panel DiD specification. Outcome variable is the change in CIP deviation $\Delta x_{i,j,t}$. Treatment currencies include central banks that engaged in a swap line. Control currencies include central banks that did not engage in a swap with the Federal Reserve. Controls include daily first differences in the broad dollar index (expressed in percentage), the VIX index (expressed in percentage), the difference in overnight indexed swap (OIS) interest rates between the foreign currency and USD (expressed in basis points), as well as the level of the intermediary capital risk factor of He et al. (2017), which measures shocks to the equity capital ratio. Additional controls include currency and maturity fixed effects. Standard errors clustered at the currency level are reported in parentheses. Estimation period is a 1 month pre and post the swap line settlement date of March 19, 2020.

Table A6: Panel Differences-in-Differences Specification: CIP Deviations (OIS): Alternative control group with DKK and SEK currencies

	I	II	III	IV
	$\Delta x_{i,j,t}$	$\Delta x_{i,j,t}$	$\Delta x_{i,j,t}$	$\Delta x_{i,j,t}$
Swapline$_i$ × Post$_t$	3.032	3.519		
	(4.009)	(3.230)		
Allotment$_{i,t}$ × Post$_t$			0.453**	0.443***
			(0.116)	(0.083)
Post$_t$	9.748***	1.902	11.337***	3.939**
	(1.770)	(1.791)	(2.312)	(1.330)
$\Delta\ (i - i_{us})$		-0.862***		-0.856***
		(0.124)		(0.121)
Δ log(board dollar)		-6.280**		-6.106**
		(1.903)		(1.588)
Δ log(VIX)		-0.407***		-0.409***
		(0.066)		(0.066)
Δ fwd bid-ask		0.066		0.076
		(0.133)		(0.138)
HKM		-143.883***		-144.554***
		(27.068)		(26.156)
constant	-6.312***	0.161	-6.312***	0.058
	(1.235)	(0.433)	(1.166)	(0.602)
R^2	0.03	0.10	0.04	0.10
N	756	756	756	756
Treatment	EUR, GBP, JPY and CAD			
Control	SEK and DKK			

Note: Table estimates a panel DiD specification. Outcome variable is the change in CIP deviation $\Delta x_{i,j,t}$. Treatment currencies include central banks that engaged in a swap line. Controls include daily first differences in the broad dollar index (expressed in percentage), the VIX index (expressed in percentage), the difference in overnight indexed swap (OIS) interest rates between the foreign currency and USD (expressed in basis points) and bid-ask spreads, as well as the level of the intermediary capital risk factor of He et al. (2017), which measures shocks to the equity capital ratio. Additional controls include currency and maturity fixed effects. Standard errors clustered at the currency level are reported in parentheses. Estimation period is a 1 month pre and post the swap line settlement date of March 19, 2020.

Table A7: Panel Differences-in-Differences Specification: CIP Deviations (OIS): Placebo tests using alternative treatment dates and maturity

	I	II	III
	Date Placebo (Feb 1, 2020)	Date Placebo (May 1, 2020)	Maturity Placebo (IBOR)
$\text{Swapline}_i \times \text{Post}_t$	0.368	-2.717***	1.140***
	(1.063)	(0.611)	(0.229)
Post_t	-1.570	0.277	-0.571*
	(1.133)	(0.164)	(0.242)
$\Delta\ (i - i_{us})$	-0.533**	-0.179	-0.012
	(0.147)	(0.492)	(0.028)
Δ log(board dollar)	0.795	1.262	-0.427
	(1.351)	(1.390)	(0.239)
Δ log(VIX)	0.071*	-0.056	-0.023
	(0.028)	(0.060)	(0.012)
Δ fwd bid-ask	-3.416**	-1.644*	0.103
	(1.125)	(0.769)	(0.141)
HKM	74.499***	-12.385	-7.993*
	(15.941)	(8.579)	(3.438)
constant	0.969***	1.594***	-0.080
	(0.208)	(0.145)	(0.168)
R^2	0.08	0.08	0.04
N	720	756	756
Treatment	EUR, GBP, JPY and CAD		
Control	AUD and NZD		

Note: Table estimates a panel DiD specification. Outcome variable is the change in CIP deviation $\Delta x_{i,j,t}$. Treatment currencies include central banks that engaged in a swap line. Control currencies include central banks that did not engage in a swap with the Federal Reserve. In column (I), placebo date of February 1st, 2020 is used with a 1 month pre and post window. In column (II), a placebo date of May 1st, 2020 is used with a 1 month pre and post window. In column (III), the sample a 1 month pre and post the swap line settlement date of March 19, 2020, and it tests long-term LIBOR-based CIP deviations (1Y, 5Y and 10Y) replacing the 1W, 1M and 3M CIP deviations in the baseline specification. Controls include the daily first differences in the broad dollar index, VIX index, interest-rates of the foreign currency (OIS) and bid-ask spreads, as well as the level of the intermediary capital risk factor of He et al. (2017), which measures shocks to the equity capital ratio. Additional controls include currency and maturity fixed effects. Standard errors clustered at the currency level are reported in parentheses.

C.2 Synthetic control method

In this section we use a synthetic control approach to estimate the causal effects of the swap line on CIP deviations. We follow the artificial counterfactual (ArCo) approach proposed by Carvalho et al. (2018). We define two potential outcomes: $Y^N_{i,t}$ refers to the CIP deviation that would be observed for currency i at time t if currency i is not exposed to the intervention, and $Y^I_{i,t}$ refers to the outcome that would be observed if currency i is exposed to the intervention.

$$Y^I_{i,t} = \begin{cases} Y^{I*}_{i,t}, & 1 \leq t \leq T_0 - 1 \\ Y^{I*}_{i,t} + \delta_t, & T_0 \leq t \leq T \end{cases} \tag{11}$$

where $Y^{I*}_{i,t}$ is an unobserved counterfactual variable. We measure the variable in pre-intervention period with OLS matching as

$$Y^I_{i,t} = Y^{I*}_{i,t} = w_0 + \sum_i w_i Y^N_{i,t} + \epsilon_t, \quad 1 \leq t \leq T_0 - 1 \tag{12}$$

After OLS matching the pre-period, we can then construct the post-intervention difference between the actual variable and counterfactual variable at time t is $\tau_{i,t} = Y^I_{i,t} - Y^{I*}_{i,t}$.

Using a control group of currencies that did not activate the swap line, we match the controls in the pre-period to construct a counterfactual series of CIP deviations. The treatment group is GBP, EUR, JPY and the control group is AUD, NZD. The pre-matching period is 42 trading days before the intervention day. In Figure A2, we plot the actual and counterfactual values for the EUR/USD, GBP/USD and JPY/USD CIP deviations, using March 19 2020 as the date of the intervention in the analysis.[7]

We then proceed to test the hypothesis that the difference between the actual and counterfactual values are statistically significant over different horizons. Defining the actual and counterfactual variable at each time as τ_t, we can test the joint significance of the average τ_t over a defined period following the swap lines at T_0. Defining the average τ_t from T_0 to T as Δ_T, we construct a test statistic with the null hypothesis that $\Delta_T = 0$.[8]

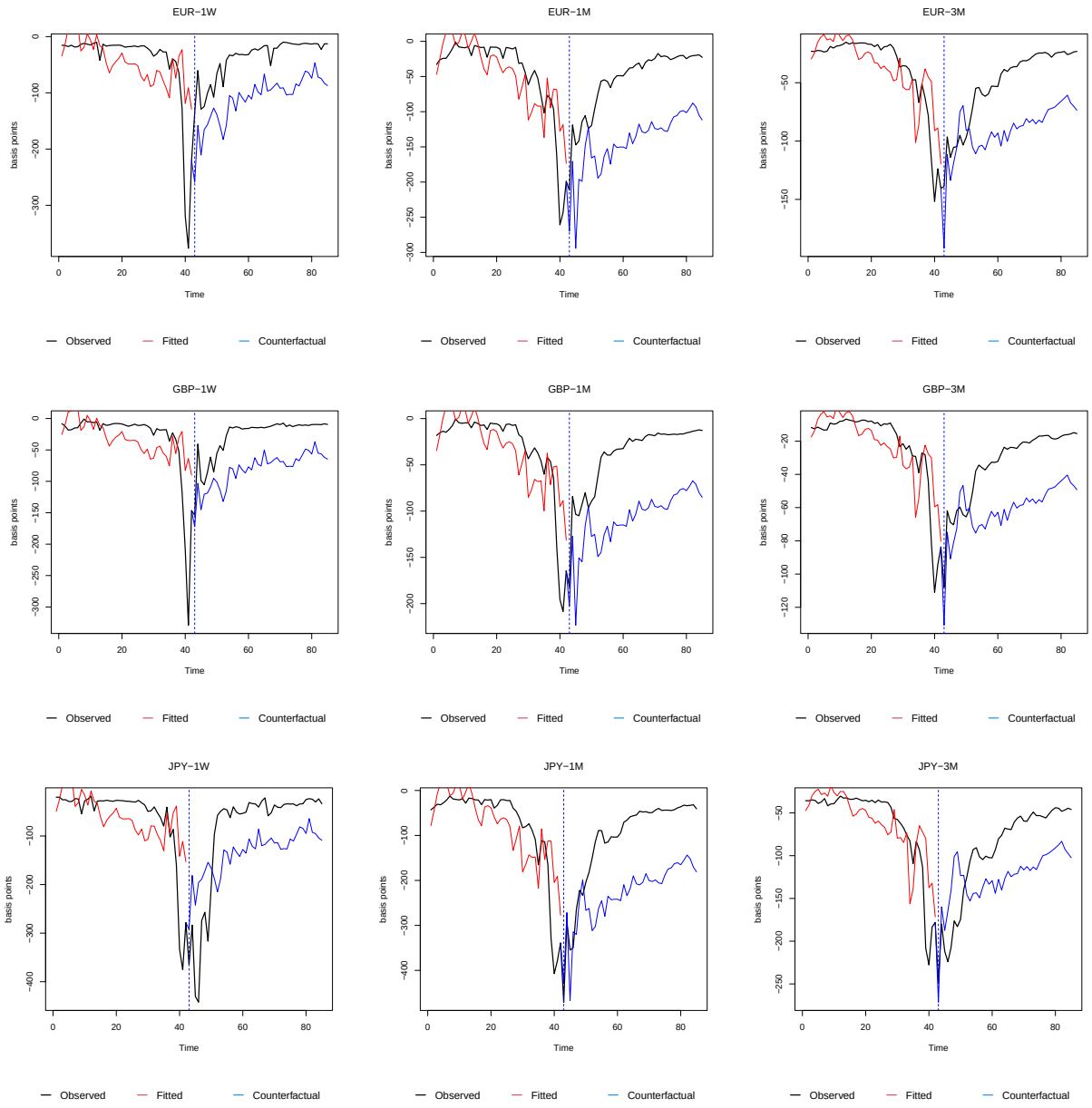
[7]Specifically, we use March 19 2020 as T_0 in our analysis, which is the date at which we construct a counterfactual for our treatment.

[8]The test is based on Newey and West (1987) covariance matrix with prewhitening. The lag is calculated based on rule of thumb $lag = .75 * (T - T_0 + 1)^{1/3}$

$$H_0 : \Delta_T = \frac{1}{T - T_0 + 1} \sum_{t=T_0}^{T} \tau_t = 0, \quad T_0 \leq t \leq T \tag{13}$$

Table A8 presents the results of Δ_T and its statistical significance for different horizons. Consistent with our hypothesis, we observe a significant difference between the observed values and the counterfactual following the swap line for all currencies and maturities. In particular, the magnitude of CIP deviations with the swap line is lower than implied by the counterfactual. The results for the 1 week maturity are strongest for the EUR/USD with a narrowing of deviations within 4 days, however the JPY/USD deviation narrows over a longer horizon of 2-3 weeks. Across all pairs, we find the largest effects for the 1 month maturities, with a peak difference between observed and counterfactual estimates of 90 basis points for the EUR/USD, 70 basis points for the GBP/USD and 120 basis points for the JPY/USD pairs. In contrast, the results for the 3 month maturity find significant differences only for the EUR/USD and GBP/USD pairs, with a peak effect of 40 basis points and 30 basis points respectively. In summary, the results of the synthetic control method support our panel DiD specification with estimates of the net impact on CIP deviations in the same order of magnitude, with the largest effects associated with the JPY/USD, followed by the EUR/USD and GBP/USD pairs respectively.

Figure A2: CIP Deviations: Counterfactual vs Actual Using Synthetic Controls



Note: Figure presents CIP deviations (benchmark OIS rate) for EUR/USD, GBP/USD and JPY/USD maturities of 1 week, 1 month and 3 month. Counterfactual CIP deviations are constructed using a synthetic control method, based on a control group of currencies that did not activate the swap line (AUD/USD and NZD/USD). Data for OIS rates, forward and spot rates are taken from Bloomberg. Dotted line indicates Federal Reserve settlement date of March 19 2020.

Table A8: Synthetic Control; Estimates of Difference between Actual and Counterfactual

	4	7	14	21	28	35	43
EUR-1W	86.07**	67.94	79.97**	78.31***	75.36***	76.34***	72.62***
GBP-1W	35.58*	33.24	52.15**	55.24	55.06	55.81	53.64
JPY-1W	-152.18**	-134.49**	-23.28	11.81	27.00	37.31	41.95
EUR-1M	77.86***	62.61**	79.74***	86.75***	88.8***	90.41***	88.09***
GBP-1M	57.24***	46.51**	60.99***	68.14***	69.9***	70.79***	69.05***
JPY-1M	3.26	7.63	74.20	96.85**	110.31***	117.96***	119.28***
EUR-3M	25.4**	6.93	19.72	29.15	35.07*	38.8**	39.63***
GBP-3M	17.13**	7.54	15.24	21.98	25.42**	27.48***	27.68***
JPY-3M	-20.08	-44.3***	-11.28	5.78	18.81	26.11	29.93

Note: Table estimates the δ_t over different horizons, where δ_t measures the average difference between the counterfactual and actual values at time t. The average difference between the actual and counterfactual is estimated for different horizons ranging from 4 to 43 days following the swap line date of March 19 2020. CIP deviations (benchmark OIS rate) for EUR/USD, GBP/USD and JPY/USD maturities of 1 week, 1 month and 3 month. Counterfactual CIP deviations are constructed using a synthetic control method, based on a control group of currencies that did not activate the swap line (AUD/USD and NZD/USD). Data for OIS rates, forward and spot rates are taken from Bloomberg. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Appendix D: Volatility Effects

An aggregate measure of price-quote dispersion is to test the effects of swap lines on realized volatility. We use the HAR model introduced in Corsi (2009). The specification is in equation (14). The outcome variable RV_t is the daily realized volatility of forward rates based on intra-day data. The realized volatility is calculated as the square root of the sum of square log returns based on 5 minute intervals. Controls include lags of realized volatility, where $RV_{t-1:t-6}$ is realized volatility in the last week, and $RV_{t-1,:t-26}$ is realized volatility over the last month. Swap line$_{set,t}$ is the dummy variable and take 1 on the day of settlement. Following Ferrara et al. (2021), we control for the Covid pandemic with variables Covid$_{t-1}$ and Covid$_{US,t-1}$ that measure the change in hospitalizations with Covid-19 symptoms for the corresponding country and U.S., respectively. The estimation period is from March 1, 2020 to September 30, 2020, and we exclude days with no trading in our sample.[9]

$$RV_t = \alpha + \beta_d RV_{t-1} + \beta_w RV_{t-1:t-6} + \beta RV_{t-1,:t-26} + \delta_1 \text{Swap line}_{set,t} + \delta_2 \text{Swap line}_{set,t-1} + \delta_3 \text{Swap line}_{set,t-2} + \gamma_1 \text{Covid}_{t-1} + \gamma_2 \text{Covid}_{US,t-1} + \epsilon_t \quad (14)$$

Table A9 presents the results. Columns (I) to (III) are results using 1 week EUR/USD, GBP/USD and JPY/USD. The next two sets of columns are for 1 month and 3 month maturities respectively. We find that across all currencies and maturities, there is a significant negative effect on volatility two days after the settlement. The effects are strongest for the EUR/USD with a 2.9 percent decline in volatility, and weakest for the JPY/USD with a 1.6 percent decline in volatility on the second day following settlement. Interestingly, we find positive effects on the day of settlement. One possibility for the delayed effect is that swap line auctions are endogenous to periods of increased volatility in the FX market. For example, central bank auctions are often timed following an increase in volatility and increased USD funding costs in interbank markets.

[9]The U.S. FX market closes on Friday at 5pm EST and opens on Sunday 5pm EST. Therefore we exclude Saturdays in our analysis.

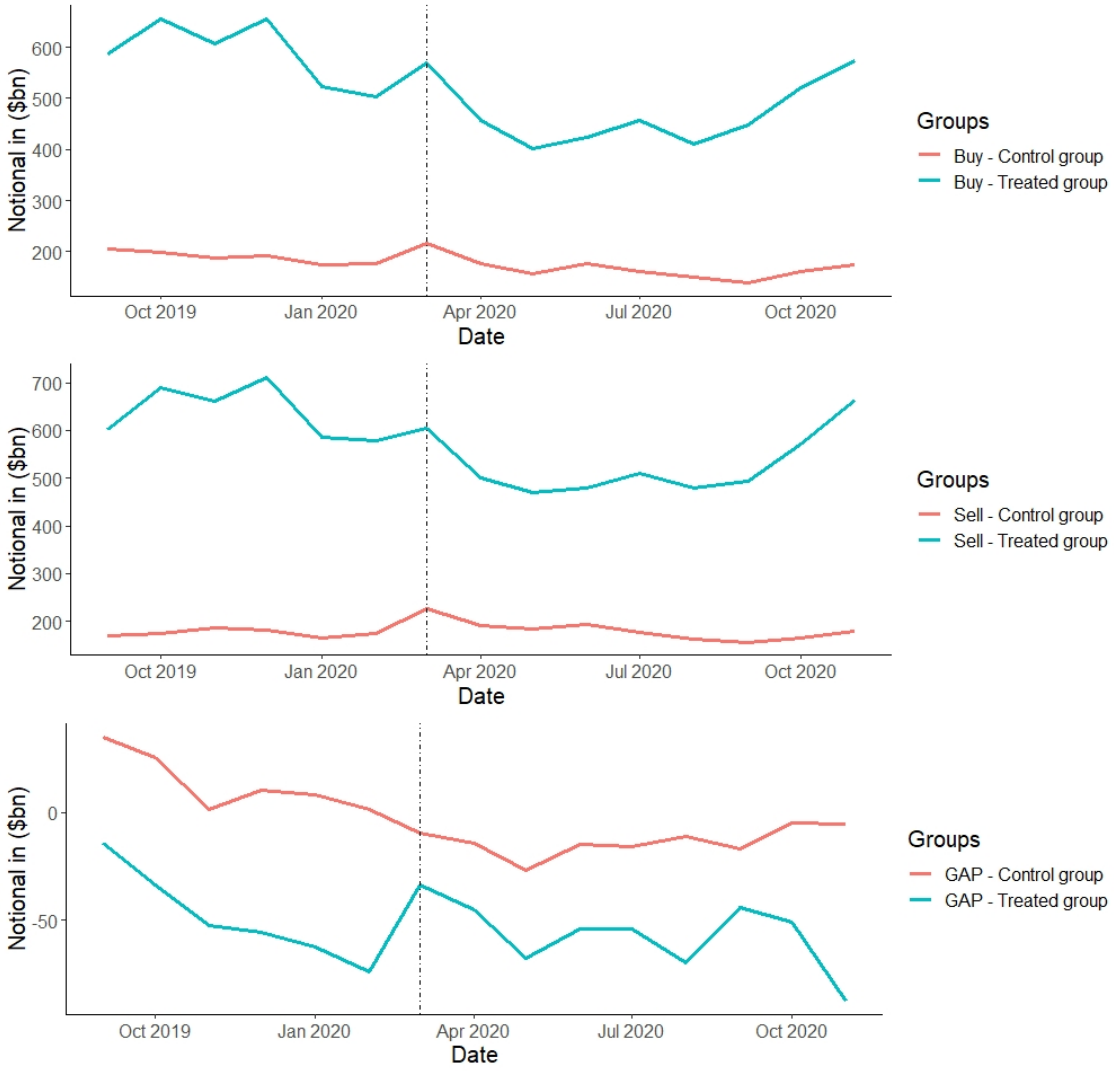
Table A9: HAR Model Results: Forward Volatility 1W, 1M and 3M

	I	II	III	IV	V	VI	VII	VIII	IX
	EUR 1W	GBP 1W	JPY 1W	EUR 1M	GBP 1M	JPY 1M	EUR 3M	GBP 3M	JPY 3M
Const	0.776	1.240	1.133***	0.766	1.233	1.130***	0.877	1.236	1.137***
	(1.168)	(1.255)	(0.373)	(1.173)	(1.25)	(0.372)	(1.144)	(1.248)	(0.377)
RV_{t-1}	-0.024	0.170*	0.307**	-0.023	0.171*	0.310***	-0.011	0.172*	0.300**
	(0.068)	(0.096)	(0.12)	(0.067)	(0.096)	(0.119)	(0.067)	(0.096)	(0.122)
$RV_{t-1:t-6}$	1.196***	0.914***	0.684***	1.196***	0.914***	0.680***	1.171***	0.913***	0.694***
	(0.165)	(0.146)	(0.155)	(0.165)	(0.146)	(0.155)	(0.164)	(0.147)	(0.158)
$RV_{t-1:t-26}$	-0.256*	-0.201*	-0.117	-0.255*	-0.201*	-0.115	-0.255*	-0.201*	-0.121
	(0.143)	(0.112)	(0.098)	(0.143)	(0.112)	(0.098)	(0.143)	(0.112)	(0.099)
Swap $line_{set,t}$	2.212***	1.722**	0.970***	2.213***	1.731**	0.961***	2.167***	1.721**	0.968***
	(0.399)	(0.874)	(0.346)	(0.398)	(0.872)	(0.345)	(0.397)	(0.87)	(0.348)
Swap $line_{set,t-1}$	0.327	0.575	-0.150	0.322	0.561	-0.148	0.324	0.553	-0.134
	(0.384)	(0.882)	(0.358)	(0.384)	(0.88)	(0.358)	(0.38)	(0.877)	(0.36)
Swap $line_{set,t-2}$	-2.878***	-2.704***	-1.645***	-2.880***	-2.707***	-1.650***	-2.853***	-2.694***	-1.641***
	(0.358)	(0.988)	(0.366)	(0.358)	(0.986)	(0.367)	(0.355)	(0.984)	(0.37)
$Covid_{t-1}$	-1.337**	-1.772***	-0.083	-1.340**	-1.772***	-0.079	-1.245*	-1.772***	-0.083
	(0.654)	(0.464)	(0.429)	(0.658)	(0.463)	(0.429)	(0.668)	(0.465)	(0.427)
$Covid_{US,t-1}$	0.200	0.058	-0.076	0.200	0.058	-0.077	0.181	0.059	-0.075
	(0.164)	(0.244)	(0.093)	(0.164)	(0.244)	(0.093)	(0.16)	(0.244)	(0.093)
N	184	184	184	184	184	184	184	184	184
R^2	0.67	0.64	0.74	0.67	0.64	0.74	0.67	0.64	0.74

Note: Table estimates a HAR model specification to test the effects of swap lines on forward rate volatility for maturities of 1 Week, 1 Month and 3 Month. Outcome variable is forward rate volatility calculated using intra-day data taken from Thomson Reuters tick history. Explanatory variables include lagged realized volatility. $Swapline_{set,t}$ is a dummy variable for Federal Reserve settlement dates of auctions with the Bank of England, Bank of Japan and the European Central Bank. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Appendix E: Other counterparties

Figure A3: Dealer outstanding FX exposures with commercial banks



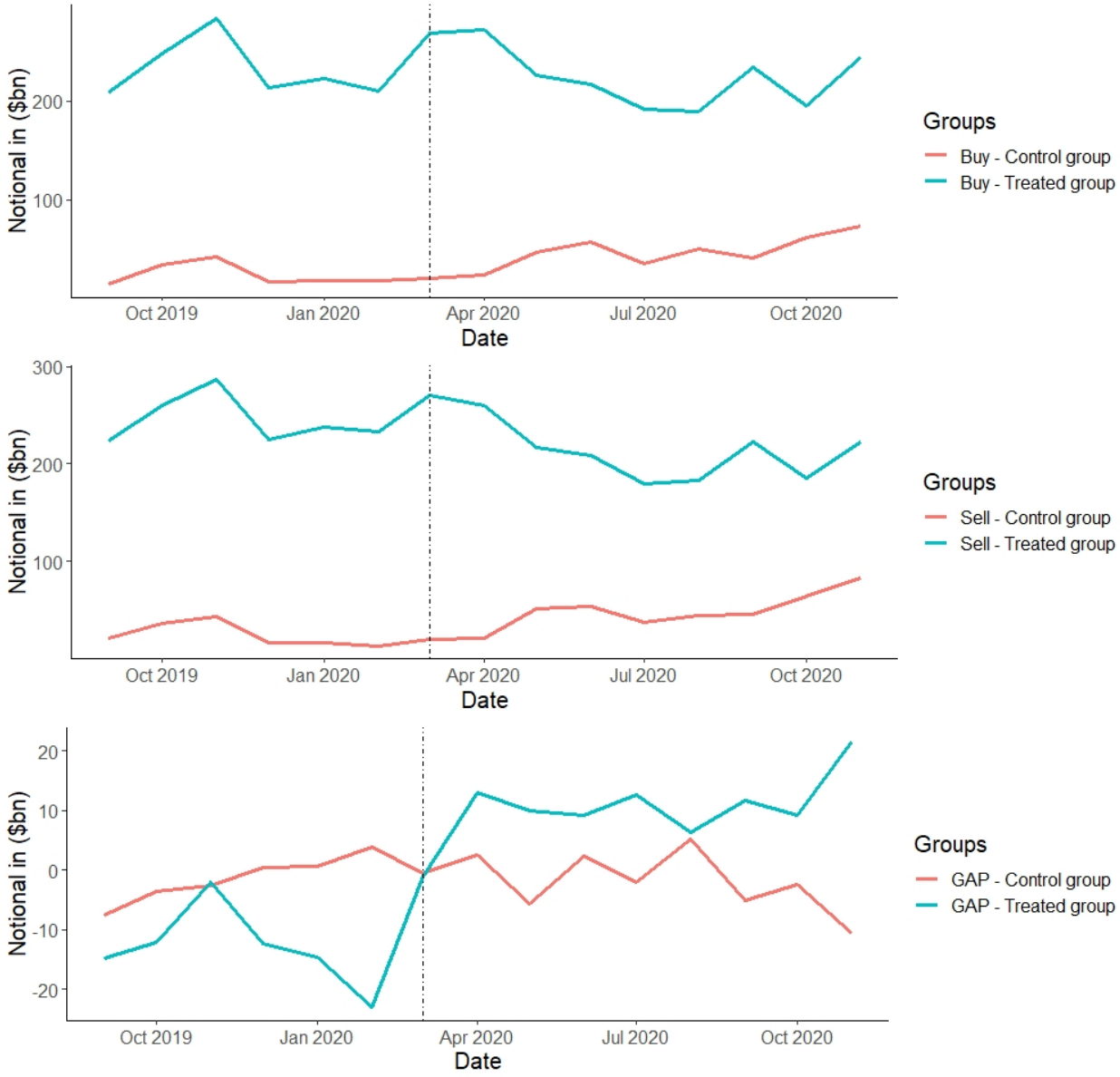
Note: Figure presents aggregate Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty commercial banks. Dealers that have drawn on BOE swap lines are classified as "treated", and the set of dealers that did not draw on BOE swap lines are "control".outstanding FX exposures at maturities less than or equal to 95 days are aggregated across the two groups and are the outstanding notional positions at end of month. Sample period is from September 2019 to November 2020. Dotted line indicates March 2020 which is when Covid swap lines were activated.

Table A10: Dealer FX Exposures for maturities ≤ 95 days: commercial bank

	I	II	III	IV	V	VI
	Buy	Buy	Sell	Sell	Net	Net
D_{treat}	924.73**	1618.10***	1036.76***	1819.45***	-198.48**	-201.35
	(369.77)	(538.75)	(385.71)	(563.10)	(95.89)	(169.54)
$D_{swap\ line} \times D_{treat}$	-300.06*	-266.54*	-260.82*	-337.69**	83.78	71.15
	(152.54)	(137.72)	(141.20)	(153.35)	(66.23)	(64.03)
$\frac{RWA}{Assets}$		3703.49***		3172.22***		531.27
		(1295.98)		(1159.11)		(547.13)
$distance_{CET1\ Ratio}$		48.43		5.97		42.46**
		(58.93)		(64.23)		(20.93)
$distance_{Leverage\ Ratio}$		-296.42		-313.10		16.68
		(236.75)		(235.66)		(59.89)
constant	598.04***	-1027.21	569.04***	-389.89	10.87	-637.32*
	(180.50)	(739.98)	(188.24)	(699.40)	(47.12)	(356.92)
R2	0.31	0.31	0.25	0.29	0.25	0.25
N	9933	9933	10437	9933	9933	9933

Note: Table estimates a difference-in-difference specification to test the effects of swap lines on FX exposures for maturities less or equal to 95 days. Outcome variables include Buy, Sell and Net FX (Gap) exposures for dealers with respect to (non-dealer) commercial bank counterparties. D_{treat} is a dummy variable for dealers that activated the BoE dollar repo. $D_{swapline}$ is a dummy variable for the months of March, April and May 2020 in which the BoE repo lines were drawn. Controls include the distance from the leverage ratio and CET1 requirements, and the ratio of risk-weighted assets to total assets. Sample is monthly from September 2019 to November 2020, and aggregates GBP/USD, EUR/USD and JPY/USD FX swaps for maturities less than 3 months. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Figure A4: Dealer outstanding FX exposures with hedge funds



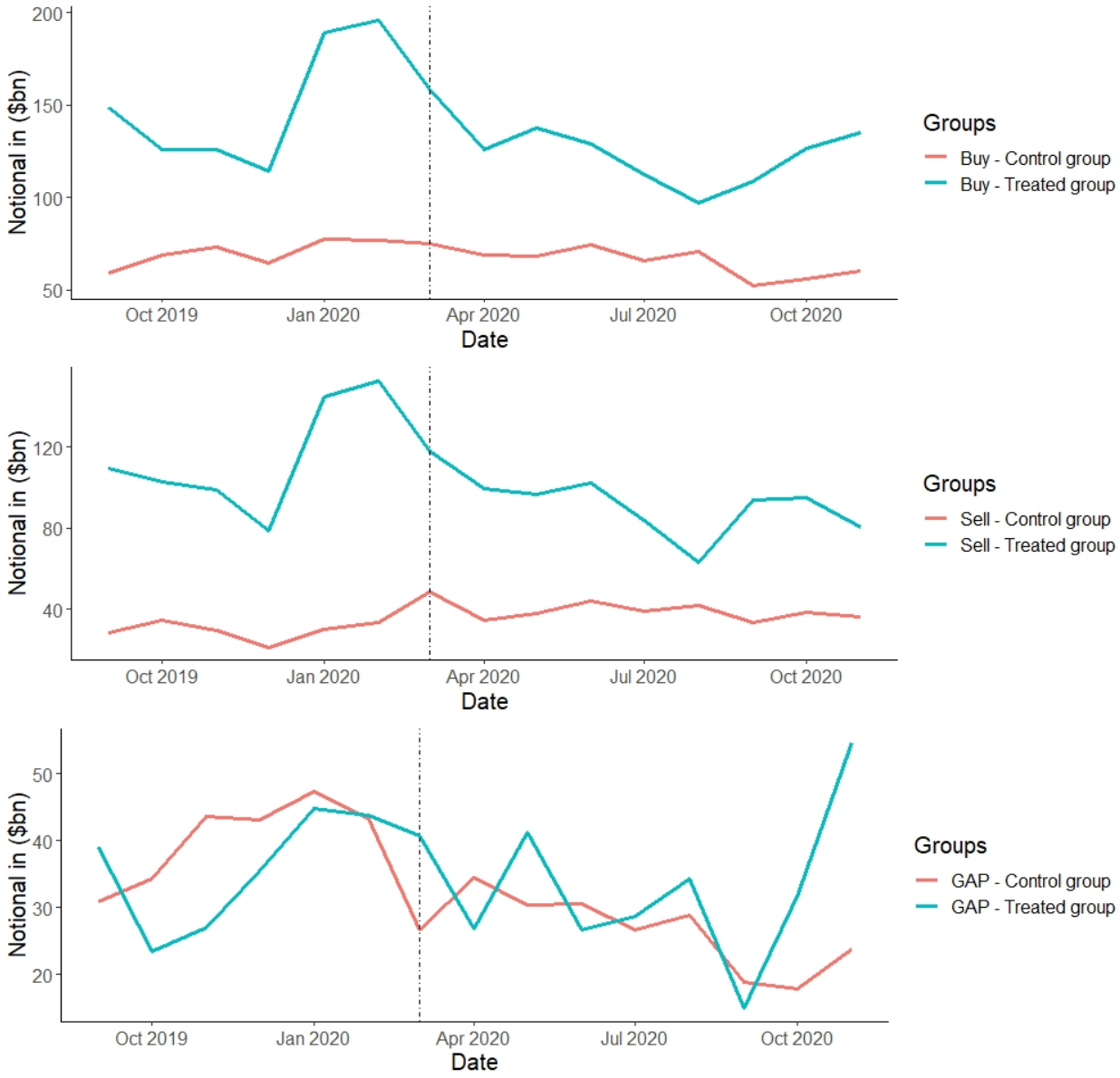
Note: Figure presents aggregate Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty hedge funds. Dealers that have drawn on BOE swap lines are classified as "treated", and the set of dealers that did not draw on BOE swap lines are "control".outstanding FX exposures at a maturities less than or equal to 95 days are aggregated across the two groups and are the outstanding notional positions at end of month. Sample period is from September 2019 to November 2020. Dotted line indicates March 2020 which is when Covid swap lines were activated.

Table A11: Dealer FX Exposures for maturities ≤ 95 days: counterparty hedge fund

	I	II	III	IV	V	VI
	Buy	Buy	Sell	Sell	Net	Net
D_{treat}	1194.02*	1428.98	1156.78*	1475.60	37.24	-46.62
	(702.12)	(951.03)	(694.70)	(939.83)	(70.77)	(84.83)
$D_{swap\ line} \times D_{treat}$	-623.53	-795.64	-521.59	-643.83	-101.94	-151.81*
	(555.73)	(586.66)	(586.27)	(603.49)	(73.89)	(85.70)
$\frac{RWA}{Assets}$		-3267.07		-2888.36		-378.71
		(2949.02)		(2561.16)		(592.16)
$distance_{CET1\ Ratio}$		-159.09		-191.38		32.29
		(197.40)		(195.93)		(21.54)
$distance_{Leverage\ Ratio}$		-781.32		-646.67		-134.65
		(672.56)		(562.49)		(143.85)
constant	887.11**	5024.77*	864.19**	4860.34**	22.92	164.43
	(400.59)	(2564.78)	(392.75)	(2234.56)	(39.51)	(513.14)
R2	0.46	0.47	0.46	0.47	0.47	0.47
N	2131	2131	2131	2131	2131	2131

Note: Table estimates a difference-in-difference specification to test the effects of swap lines on FX exposures for maturities less or equal to 95 days. Outcome variables include Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty hedge fund. D_{treat} is a dummy variable for dealers that activated the BoE dollar repo. $D_{swapline}$ is a dummy variable for the months of March, April and May 2020 in which the BoE repo lines were drawn. Controls include the distance from the leverage ratio and CET1 requirements, and the ratio of risk-weighted assets to total assets. Sample is monthly from September 2019 to November 2020, and aggregates GBP/USD, EUR/USD and JPY/USD FX swaps for maturities less than 3 months. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Figure A5: Dealer outstanding FX exposures with asset managers



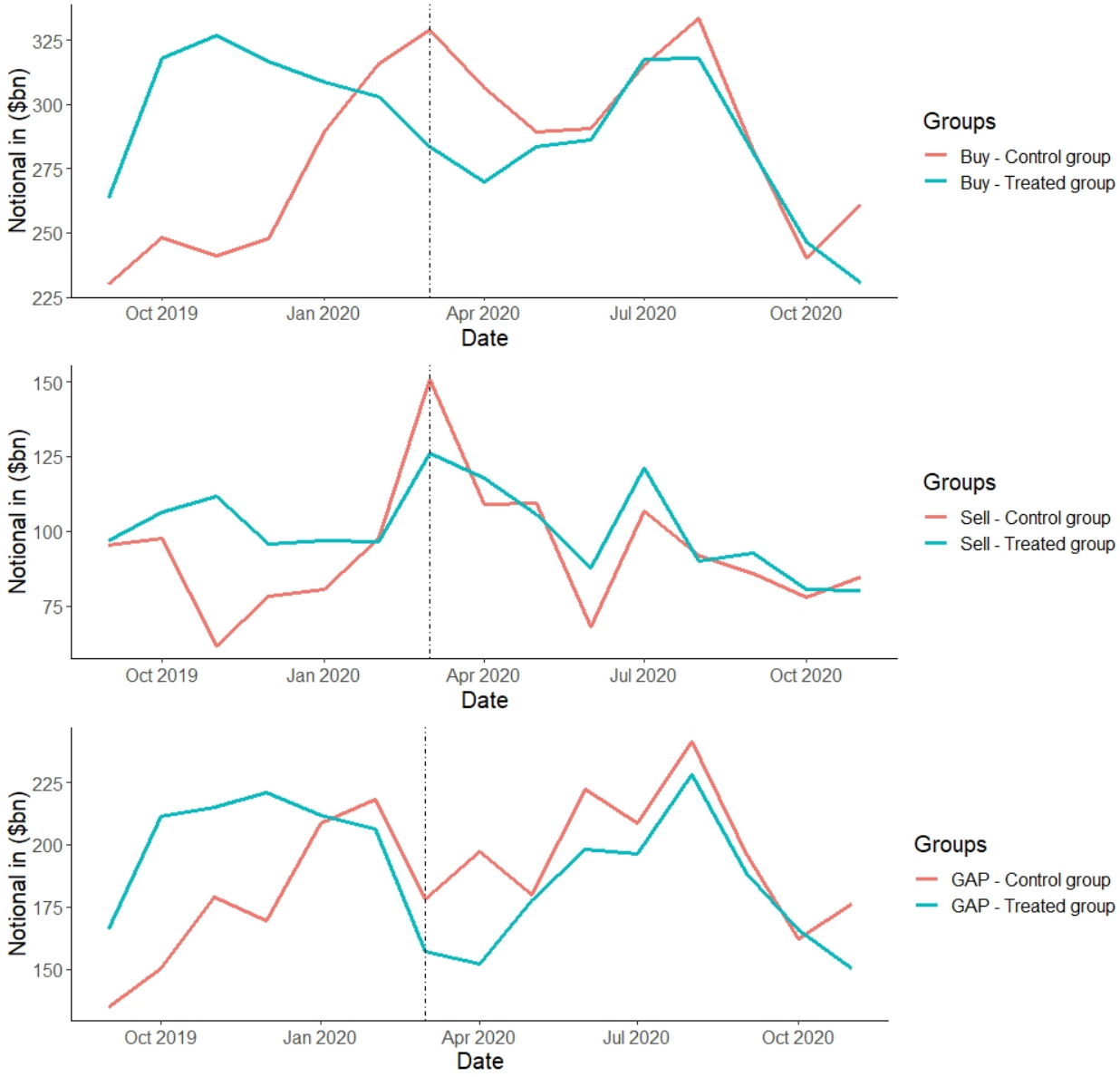
Note: Figure presents aggregate Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty asset managers. Dealers that have drawn on BOE swap lines are classified as "treated", and the set of dealers that did not draw on BOE swap lines are "control".outstanding FX exposures at a maturities less than or equal to 95 days are aggregated across the two groups and are the outstanding notional positions at end of month. Sample period is from September 2019 to November 2020. Dotted line indicates March 2020 which is when Covid swap lines were activated.

Table A12: Dealer FX Exposures for maturities ≤ 95 days: counterparty asset manager

	I	II	III	IV	V	VI
	Buy	Buy	Sell	Sell	Net	Net
D_{treat}	33.03***	91.69***	18.87**	60.58***	14.16**	31.11**
	(11.80)	(29.22)	(7.58)	(19.16)	(6.82)	(14.20)
$D_{swap\ line} \times D_{treat}$	-1.92	4.88	-5.16	-0.83	3.24	5.71
	(9.51)	(9.73)	(6.77)	(6.88)	(7.74)	(7.93)
$\frac{RWA}{Assets}$		309.86***		252.51***		57.35
		(108.78)		(90.76)		(35.23)
$distance_{Leverage\ Ratio}$		5.22		5.55**		-0.33
		(3.75)		(2.59)		(2.83)
$distance_{Leverage\ Ratio}$		-28.66**		-18.28**		-10.38
		(12.47)		(8.38)		(7.78)
constant	81.51***	-62.92	55.54***	-80.78	25.98***	17.85
	(6.21)	(54.06)	(3.75)	(53.46)	(3.72)	(25.86)
R2	0.45	0.45	0.49	0.49	0.41	0.41
N	27411	27411	27411	27411	27411	27411

Note: Table estimates a difference-in-difference specification to test the effects of swap lines on FX exposures for maturities less or equal to 3 months. Outcome variables include Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty asset managers. D_{treat} is a dummy variable for dealers that activated the BoE dollar repo. $D_{swapline}$ is a dummy variable for the months of March, April and May 2020 in which the BoE repo lines were drawn. Controls include the distance from the leverage ratio and CET1 requirements, and the ratio of risk-weighted assets to total assets. Sample is monthly from September 2019 to November 2020, and aggregates GBP/USD, EUR/USD and JPY/USD FX swaps for maturities less than 3 months. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Figure A6: Dealer outstanding FX exposures with Pension funds and LDI



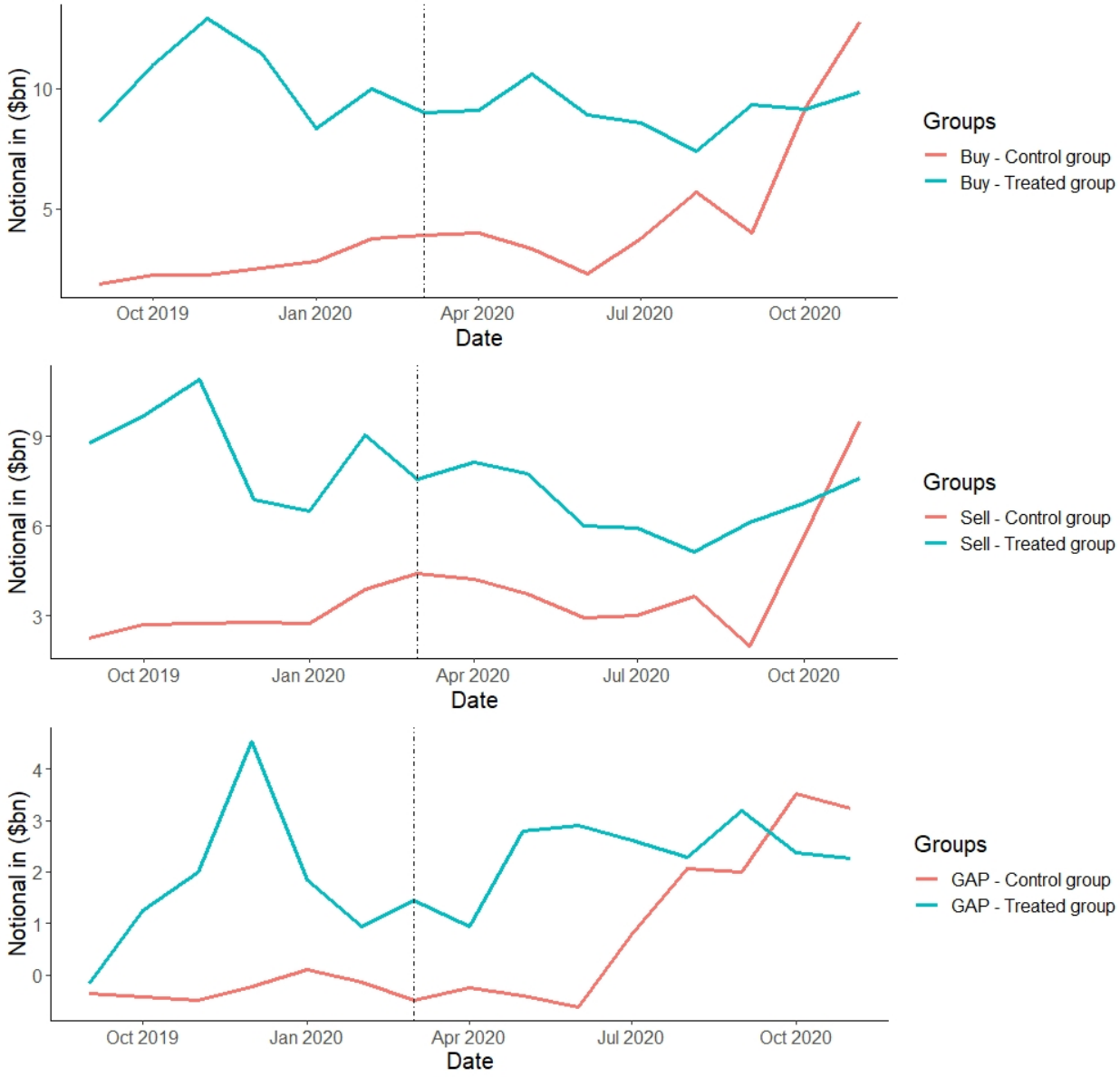
Note: Figure presents aggregate Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty ICPF and LDI. Dealers that have drawn on BOE swap lines are classified as "treated", and the set of dealers that did not draw on BOE swap lines are "control".outstanding FX exposures at a maturities less than or equal to 95 days are aggregated across the two groups and are the outstanding notional positions at end of month. Sample period is from September 2019 to November 2020. Dotted line indicates March 2020 which is when Covid swap lines were activated.

Table A13: Dealer FX Exposures for maturities ≤ 95 days: ICPF and LDI counterparties

	I	II	III	IV	V	VI
	Buy	Buy	Sell	Sell	Net	Net
D_{treat}	38.57	161.67***	13.13	52.40***	25.44	109.26**
	(32.86)	(58.12)	(11.04)	(17.24)	(26.72)	(50.22)
$D_{swap\ line} \times D_{treat}$	-61.79*	-39.87	-16.58	-15.15	-45.21	-24.72
	(33.27)	(30.01)	(23.98)	(20.91)	(31.74)	(28.67)
$\frac{RWA}{Assets}$		953.74***		381.53***		572.21***
		(243.50)		(117.14)		(142.28)
$distance_{CET1\ Ratio}$		27.62		9.01		18.61*
		(16.80)		(7.89)		(10.85)
$distance_{Leverage\ Ratio}$		-49.90***		2.42		-52.32***
		(17.36)		(16.05)		(15.32)
constant	279.23***	-309.07	94.13***	-159.47	185.09***	-149.60
	(14.35)	(216.19)	(4.59)	(107.96)	(11.26)	(119.82)
R2	0.57	0.57	0.39	0.39	0.54	0.54
N	28946	28940	28946	28940	28946	28940

Note: Table estimates a difference-in-difference specification to test the effects of swap lines on FX exposures for maturities less or equal to 3 months. Outcome variables include Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty ICPF and LDI. D_{treat} is a dummy variable for dealers that activated the BoE dollar repo. $D_{swapline}$ is a dummy variable for the months of March, April and May 2020 in which the BoE repo lines were drawn. Controls include the distance from the leverage ratio and CET1 requirements, and the ratio of risk-weighted assets to total assets. Sample is monthly from September 2019 to November 2020, and aggregates GBP/USD, EUR/USD and JPY/USD FX swaps for maturities less than 3 months. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Figure A7: Dealer outstanding FX exposures with other financials



Note: Figure presents aggregate Buy, Sell and Net FX (Gap) exposures for dealers with respect to other financials. Dealers that have drawn on BOE swap lines are classified as "treated", and the set of dealers that did not draw on BOE swap lines are "control".outstanding FX exposures at a maturities less than or equal to 95 days are aggregated across the two groups and are the outstanding notional positions at end of month. Sample period is from September 2019 to November 2020. Dotted line indicates March 2020 which is when Covid swap lines were activated.

Table A14: Dealer FX Exposures for maturities ≤ 95 days: other financial counterparties

	I	II	III	IV	V	VI
	Buy	Buy	Sell	Sell	Net	Net
D_{treat}	-7.76	87.94	26.89	121.14	-34.64	18.36
	(64.08)	(138.55)	(48.96)	(84.63)	(36.82)	(66.03)
$D_{swap\ line} \times D_{treat}$	106.05	122.31*	61.72	76.37	44.33**	58.58***
	(77.82)	(67.97)	(84.23)	(79.19)	(16.63)	(18.56)
$\frac{RWA}{Assets}$		430.92		459.51		19.54
		(421.76)		(315.03)		(154.89)
$distance_{CET1\ Ratio}$		-0.31				-26.56**
		(29.42)				(12.17)
$distance_{Leverage\ Ratio}$		-48.81***		-38.89***		-1.48
		(14.07)		(13.25)		(10.24)
constant	212.82***	107.19	151.44***	14.43	61.38***	283.88**
	(36.37)	(230.11)	(25.65)	(135.66)	(21.07)	(120.21)
R2	0.65	0.66	0.55	0.57	0.76	0.77
N	895	895	895	895	895	895

Note: Table estimates a difference-in-difference specification to test the effects of swap lines on FX exposures for maturities less or equal to 3 months. Outcome variables include Buy, Sell and Net FX (Gap) exposures for dealers with respect to counterparty other financial. D_{treat} is a dummy variable for dealers that activated the BoE dollar repo. $D_{swapline}$ is a dummy variable for the months of March, April and May 2020 in which the BoE repo lines were drawn. Controls include the distance from the leverage ratio and CET1 requirements, and the ratio of risk-weighted assets to total assets. Sample is monthly from September 2019 to November 2020, and aggregates GBP/USD, EUR/USD and JPY/USD FX swaps for maturities less than 3 months. White heteroscedasticity-robust standard errors are reported in parentheses. Standard errors are clustered at the dealer-counterparty level. *** denotes significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.