Swap Line Dollar Supply*

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Abstract

The mechanism through which Federal Reserve swap lines alleviate the cost of hedging for the real economy remains insufficiently understood, largely due to the absence of globally representative data on OTC FX derivatives. Using a new data source on worldwide settlement records, I document three novel findings. First, I provide causal evidence that swap line availability reduces the net order flow that U.S. banks absorb as intermediaries in the global FX swap market. Second, this translates into lower transaction costs for the real economy: a one–standard-deviation decline in net U.S. dollar demand reduces the effective spread by 0.7 bps on average. Third, decomposing net order flow into U.S. dollar purchases and sales reveals that swap lines ease offshore funding costs not only by reducing non-U.S. banks' *demand* for dollars (substitution channel), as commonly thought, but also by raising their *supply* (lending channel).

Keywords: Federal Reserve swap lines, U.S. dollar funding markets, intermediary constraints, covered interest parity.

JEL classification: F31, G12, G15.

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1. Introduction

Interruptions in access to U.S. dollar funding can undermine global financial stability, given the dollar's dominant role in international trade and finance. Federal Reserve swap lines have become the key policy response in times of stress and represent its largest liquidity facility ever. Yet little empirical evidence exists on how active swap line affects U.S. dollar demand and supply in financial markets. Progress has been limited by the absence of granular, globally representative data on the over-the-counter (OTC) foreign exchange (FX) swap market, the largest source of dollar liquidity with daily turnover above US$3.8 trillion (Bank for International Settlements, 2022). This paper fills the gap by introducing a novel dataset of global trade settlement records, providing unparalleled coverage and enabling the most comprehensive analysis to date of how swap lines shape global FX swap quantities and prices.

Three main results emerge. First, although often viewed as an offshore dollar market traded largely outside the U.S., the global FX swap market is dominated by U.S. banks, which intermediate about two thirds of global volumes. Global settlement data reveal that U.S. banks are the largest suppliers of dollar liquidity to the real economy worldwide, with net positions exceeding half a trillion dollars over the past decade on average. At the same time, their net lending averages only 3% of gross volumes, underscoring their role as intermediaries rather than pure U.S. dollar liquidity suppliers and motivating an analysis of how order flow imbalances shape their pricing.

Second, I provide causal evidence that swap lines reduce the net order flow U.S. banks accommodate, which in turn translates to lower transaction costs charged to the real economy. To analyze U.S. bank price setting, I compute volume-weighted forward points, $F - S$, by trade direction, which proxy the average daily effective spreads charged by U.S. banks. I then use the *availability* of Federal Reserve swap lines as an instrument for net dollar order flow. Because swap line auctions are held only on predetermined days set for operational reasons, availability is plausibly exogenous to short-term pricing shocks, more so than actual swap line usage. In the first stage, swap line availability is associated with reduced dollar buying pressure from U.S. bank customers; in the second stage, smaller order flow imbalances lead to lower effective spreads. The finding is economically meaningful: a $10 billion decline in net U.S. dollar demand reduces effective spreads by 1.1 basis points. A simple model of trading rationalizes these findings, showing that U.S. banks require compensation for absorbing imbalanced order flow, especially in periods of stress when balance-sheet constraints are more binding.

Third, I decompose U.S. bank net order flow into dollar purchases and sales. I find that Federal Reserve swap lines help ease offshore U.S. dollar borrowing costs not only through a reduction in non-U.S. bank *demand* for the dollar in FX swaps (substitution channel), as commonly thought, but also through an increase in their dollar *supply* (lending channel). To identify this mechanism, I study the COVID-19 crisis as a historical market stress episode. The evidence shows that non-U.S. banks increase their dollar supply in FX swaps when swap line usage rises; for instance, about 22% of the Bank of Japan's swap line borrowing during COVID-19 can be attributed to the supply channel I identify. At first glance, the mechanism appears counter-intuitive, as the prior literature typically views non-U.S. banks as borrowers of U.S. dollars either for their own needs or for the needs of their clients. In either case, the presumed direction of U.S. dollar liquidity points away from U.S. banks and toward foreign banks. In contrast, my results show that U.S. dollar liquidity flows in the opposite direction as well. Whereas prior literature has predominantly focused on demand effects for the U.S. dollar in the FX market in response to swap lines, this work explores the supply side.

A better understanding of how a U.S. dollar liquidity line between two central banks passes through into private markets is important for several reasons. On the one hand, prior research has highlighted that frictions in non-U.S. bank access to U.S. dollar liquidity matter for macroeconomic outcomes (Committee on the Global Financial System, 2020) as well as price efficiency in the FX market (Ivashina, Scharfstein, and Stein, 2015, Cenedese, Della Corte, and Wang, 2021). On the other hand, central bank swap lines can affect the cost of hedging for the real economy (Bahaj and Reis, 2021, Goldberg and Ravazzolo, 2021, Ferrara, Mueller, Viswanath-Natraj, and Wang, 2022). In contrast to prior work, this study is the first to establish a link between Federal Reserve swap lines and U.S. banks, an angle overlooked in the current literature despite the fact that it is U.S. banks who dominate the FX market globally according to survey data (Euromoney, 2020). I argue that the ability of U.S. banks to provide U.S. dollar liquidity to non-bank customers may suffer in periods when constraints to their risk-bearing capacity coincide with there being less counterparties willing to share such risks, such as when non-U.S. bank access to the U.S. dollar is impaired. Moreover, I show the limited role of central banks in alleviating U.S. dollar funding pressures directly. In fact, public dollar liquidity via central banks requires the involvement of commercial banks for greater effectiveness.

The paper proceeds as follows. First, I obtain a bespoke dataset on quantities and prices in settled FX swap contracts globally across U.S. and non-U.S. actors. The novel dataset was first described in Kloks, McGuire, Ranaldo, and Sushko (2023b), but I am the first to apply it to study the effects of Federal Reserve swap lines. To carry out such an analysis, 4,170 banking entities are manually classified per *nationality* of the overarching banking group.[1] The data allows me to observe both the volumes and prices and is available at a daily frequency and across all the major U.S. dollar currency pairs and FX swap maturities offering a highly representative picture of FX swap market activity globally. To differentiate dollar demand and supply effects, I classify each trade into U.S. dollar borrowing or lending.[2] The data show that the global FX swap market is heavily dominated by the U.S. dollar, which features in 95% of all transactions. Moreover, despite being an offshore U.S. dollar market, over two-thirds of FX swap U.S. dollar volumes are intermediated by U.S. banks. Both of these empirical observations underscore the importance of studying Federal Reserve U.S. dollar-denominated swap lines.

Second, I present novel empirical evidence that swap line take-up is associated with higher U.S. dollar supply in FX swaps by non-U.S. banks, that is, I uncover the swap line *lending channel.* I argue that this mechanism may be driven by two underlying motivations: liquidity hoarding or arbitrage. On the one hand, non-U.S. banks who hoard swap line liquidity for precautionary reasons accumulate U.S. dollar cash at the end of the trading day. Since U.S. dollars cannot be deposited at a non-U.S. central bank, liquidity hoarding implies allocating these funds somewhere, and the FX swap market is attractive due to the premium on U.S. dollar lending. On the other hand, non-U.S. banks may borrow from swap lines to exploit pure arbitrage opportunities. In such a case, lending U.S. dollars in the FX swap market yields a profit once the premium on U.S. dollar lending in the FX swap market exceeds the cost of borrowing from swap lines. To

[1]Importantly, in my classification an FX swap traded by J.P. Morgan in London identifies the party as a U.S. global systemically important bank (G-SIB). This data is particularly novel given that other sources, such as BIS statistics, provide a locational view and would thereby classify J.P. Morgan's London branch as a UK entity, making it harder to isolate U.S. banks. I can sort market participants into six regions of the world: the U.S., the Eurozone, the UK, Switzerland, Japan, and a residual group combining all other nationalities.

[2]That is, trades that result in dollar cash inflows at the near leg of the contract are flagged as U.S. dollar purchases; in contrast, those that result in U.S. dollar cash outflows are classified as sales. Separating U.S. dollar purchases and dollar sales allows to perform analyses distinct from merely looking at the net total position, which would reflect demand and supply effects jointly, or the gross position, which would gauge only total trading activity.

distinguish between the two motivations described above, I introduce a testable hypothesis centered on the intensive margin of FX swap supply. Both motives can lead to increased FX swap supply following swap line take-up, but only arbitrage implies a discrete change in the supply response once the basis exceeds the arbitrage threshold. I test this prediction using the historically significant stress episode of COVID-19, which featured elevated CIP deviations and active swap line usage. I calculate the no-arbitrage threshold for each currency pair and tenor following the CIP ceiling as proposed by Bahaj and Reis (2021). I further augment my identification with a difference-in-difference strategy along treatment across tenors, currencies and banking groups.[3] Overall, results confirm an increase in FX swap U.S. dollar supply in response to swap line take-up, particularly by domestic banks. My results are economically strongest during the COVID-19 episode and in the dollar-yen currency pair. In particular, at least one quarter of the Bank of Japan's swap line take-up was intermediated into private FX swap markets. However, I find no significant change in FX swap supply volumes when the basis exceeds the arbitrage threshold and swap lines are available, suggesting that the observed increase in supply is better explained by precautionary hoarding than by active arbitrage by the affected non-U.S. banks.

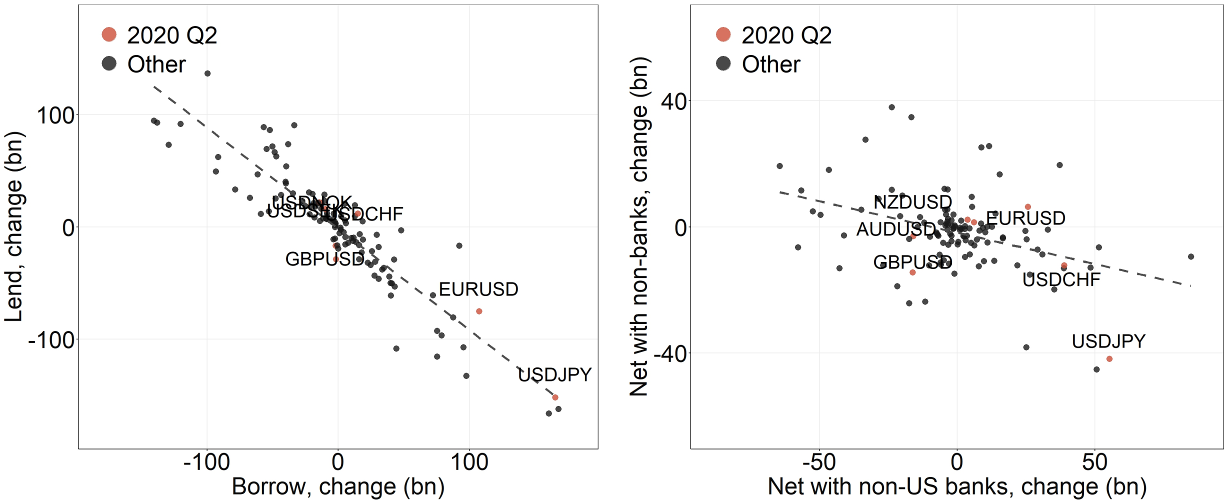
Third, I examine who receives such foreign bank U.S. dollar supply. I develop a simple conceptual framework to explain why it is conceivable that U.S. banks may prefer to fund their U.S. dollar lending *within* the FX swap market, even if it involves paying a premium in the form of a cross-currency basis. This is counter-intuitive, as these banks have other natural sources of dollar liquidity, such as access to U.S. repo markets or reserves, that are cheaper than borrowing via FX swaps, which command a premium. To understand why, consider dealer balance sheet costs. U.S. banks observe client demand across a continuum of customers in the FX swap market. In case such demand is not balanced, U.S. banks face the need to fund the imbalanced FX swap position somewhere, as the nature of an FX swap contract implies a cash outflow at the near leg of the trade. Crucially, global non-bank demand in FX swaps is large and heavily skewed, consuming about USD 1 trillion in net dollar volumes outstanding, consistent with Bräuer and Hau (2022). In such a case, a U.S. bank faces a decision of where to borrow U.S. dollar cash. One option is to fund the position by borrowing U.S. dollars *outside* of the FX swap market, say via repo or via drain-

[3]For example, at the maturity level, swap lines are offered only at short-term tenors (up to 84 days), whereas the FX swap market remains liquid up to one year. As a result, arbitrage lending is only feasible at the short-end of the curve but not in longer tenors, since it would require rolling over swap line funding at a cost that is unknown ex ante as it depends on the prevailing OIS reference rate.

ing down reserves. While cheaper in terms of the effective interest rate, repo borrowing entails hidden shadow costs that significantly expand the balance sheet of a bank and thereby hurt the Basel III leverage ratio (Du, Tepper, and Verdelhan, 2018), more so than borrowing via FX swaps (Kloks, Mattille, and Ranaldo, 2024). Similarly, keeping excess reserves for the FX swap U.S. dollar intermediation business is costly and cannot be drawn down at scale (Correa, Du, and Liao, 2020). The alternative is to attract funding *within* the FX swap market from other market participants, including from foreign banks. In contrast to a repo, an FX swap is an off-balance sheet instrument. In periods of market stress when balance sheet constraints bind, the FX forward desk of a U.S. bank may face increasing internal risk limits on its open net FX swap exposure and may become more willing to avoid the balance sheet impact. It is in this scenario when a constrained U.S. bank benefits from an uninterrupted availability of U.S. dollar supply in the FX market, including from foreign banks, because it provides it the flexibility to fund its U.S. dollar intermediation business off-balance sheet in times of stress. Fig. (1) presents the main motivating evidence in support of the idea that U.S. banks fund part of their imbalanced customer position within the FX swap market. In fact, settlement data on U.S. bank global positions reveal a striking pattern: U.S. banks operate a close-to matched-book of trading even in the absence of stress episodes, as visible in Panel (a). A simple correlation between the quarterly *change* in U.S. bank borrowing and lending positions in their total FX swap gross books across all currencies and tenors combined shows that buy and sell positions typically closely match each other. Moreover, when one turns to U.S. bank *net* positions, data reveal that U.S. banks achieve a close-to-zero net position by offsetting non-bank customer flows against flows of non-U.S. banks. The correlation is extremely strong at -0.52.[4] U.S. banks' net position is merely 3% of their gross total.

Fourth, I provide causal evidence that net U.S. dollar order flow faced by U.S. banks in the FX swap market affects the transaction costs they charge. To address the simultaneity of prices and quantities, I use the *availability* of Federal Reserve swap lines as an instrument for net order flow. Swap lines are offered only on predetermined days of the week under a schedule set in advance for operational reasons (e.g., the ECB's dollar auctions are held on Wednesdays). This institutional feature generates plausibly exogenous variation in customer order flow pressures: when swap lines are available, non-U.S. banks can substitute away from market-based dollar borrowing or

[4]The correlation between daily changes with foreign banks vs. daily changes with non-banks amounts to -0.29.



(a) US bank U.S. dollar **gross** position

(b) US bank U.S. dollar **net** position, per c-party

Fig. 1: US bank matched-book U.S. dollar intermediation in the global FX swap market. Panel (a): Quarterly change in U.S. bank U.S. dollar borrowing vs. lending gross positions outstanding. Each dot refers to the quarterly change across all tenors and U.S. dollar currency pairs. Panel (b): Quarterly U.S. bank net U.S. dollar position with foreign (non-U.S.) banks vs. with non-bank customers. Bars refer to net across all parties, tenors and currencies and are quarterly averages. For both figures data is from 2017 until 2022.

supply swap line liquidity there, reducing the imbalances U.S. dealers must absorb. As my main dependent variable in the instrumental variable (IV) regression, I use CLS settlement data to compute forward points separately for buy and sell transactions and construct a daily measure of the volume-weighted average effective spread charged by U.S. banks. These spreads exhibit sizable asymmetries: in 3M EURUSD FX swaps, the median daily spread is roughly 72% of the Bloomberg quoted bid–ask spread, rising to about 432% at the 90th percentile. The instrumental variable estimates indicate that a a one–standard-deviation decline in net U.S. dollar demand reduces the effective spread by 0.7 bps on average. Moreover, consistent with the conceptual framework, I show that this pass-through is amplified when dealers' balance sheets are more constrained. These findings are robust to controlling for reserve balances, as proxied by the repo–IOR spread (Copeland, Duffie, and Yang, 2025), and to alternative measures of dealer constraints following He, Kelly, and Manela (2017). Overall, these results underscore the role of non-U.S. bank dollar supply, which swap lines support, in alleviating pricing pressures during periods of stress.

Related literature. I contribute to the sparse but growing empirical work on central bank swap lines (Rose and Spiegel, 2012, Allen, Galati, Moessner, and Nelson, 2017, Goldberg and Ravazzolo, 2021, Choi, Goldberg, Lerman, and Ravazzolo, 2022, Bahaj and Reis, 2021, Ferrara et al., 2022, Kekre and Lenel, 2023). Much of the prior research has focused exclusively on prices, showing that both the availability of swap lines (Bahaj and Reis, 2021) and related policy announcements (Kekre and Lenel, 2023) help lower the premium on U.S. dollar borrowing in the FX swap market. However, the underlying pass-through mechanism remains insufficiently explored, as its analysis requires data on transaction volumes. To date, the most compelling data source for addressing this gap is trade repository data collected by central banks (Ferrara et al., 2022). Trade repository data, as granular as it is, is inherently local[5], which underscores the need for more globally representative data. For this reason, a growing body of research relies on global settlement data from CLS, which covers a much broader range of FX trading venues. Existing studies using CLS data have predominantly focused on the FX *spot* segment (Hasbrouck and Levich, 2021, Ranaldo and Somogyi, 2021, Cespa, Gargano, Riddiough, and Sarno, 2022), leaving the corresponding literature on the FX *swap* segment much less developed, albeit growing Kloks et al. (2024, 2023b), Bräuer and Hau (2022). I am the first to apply CLS settlement data to analyze trading activity in FX swaps around swap line take-ups across jurisdictions, currencies, and time.

By highlighting that non-U.S. banks not only demand but also supply the dollar in the FX market during periods of stress, I contribute to the literature on how non-U.S. banks shape global U.S. dollar funding markets (Aldasoro, Ehlers, and Eren, 2022, Borio, Iqbal, McCauley, McGuire, and Sushko, 2018). A substantial body of research argues that non-U.S. banks generate higher demand in FX markets during stress periods (Ivashina et al., 2015, Rime, Schrimpf, and Syrstad, 2022). Abbassi and Bräuning (2021) identify regulatory reporting requirements as an additional driver of demand. Khetan (2024) shows that regulatory constraints on the non-bank side can also generate demand effects, as concentration limits restrict non-U.S. banks' access to U.S. money markets. In contrast to these studies, I am the first to provide empirical evidence that non-U.S. banks increase U.S. dollar supply in FX swaps in response to Federal Reserve swap lines.

My work also contributes to the broader literature documenting that the breakdown of no-arbitrage conditions can be attributed to intermediary constraints in the post-GFC environment (Duffie, 2016, Du et al., 2018). Cenedese et al. (2021) show causally that Basel III Leverage Ratio worsens CIP deviations. Kloks et al. (2024) reveal that the primary regulatory constraint arises

[5]EMIR data requires at least one counterparty to be a domestic entity.

from the balance sheet treatment of U.S. repo transactions, rather than FX swaps themselves. I identify U.S. banks as the market makers in synthetic funding market and demonstrate that when U.S. bank balance sheet constraints bind, off-balance sheet funding instruments become more attractive. This interpretation is consistent with Syrstad and Viswanath-Natraj (2022), who highlight the role of market makers' order flow in the price-setting of FX forward and swap contracts, and connects to recent work on liquidity provision in one-sided markets (Kruttli, Macchiavelli, Monin, and Zhou, 2024, Comerton-Forde, Ford, Foucault, and Jurkatis, 2025). My framework can also be interpreted through the lens of Gabaix and Maggiori (2015). In that setup, financial intermediaries have limited risk-bearing capacity, which generates deviations from no-arbitrage conditions. In my context, arbitrageurs in the FX swap market can be seen as heterogeneous financiers with different levels of effective risk-bearing capacity. Finally, my work builds on the findings of Correa et al. (2020) and Copeland et al. (2025), who argue that U.S. banks face increased net U.S. dollar buying pressure during periods of market stress but may become constrained in their ability to supply such dollar liquidity.

2. Data on the Global FX Swap Market

This paper examines synthetic U.S. dollar funding flows in response to central bank swap line usage. To do so, I use a bespoke dataset on prices and volumes in the global FX swap market from Continuous Linked Settlement (CLS), the world's largest settlement platform. While the data was first introduced by Kloks et al. (2023b), this is the first study to apply it to analyze Federal Reserve swap lines. This section provides a detailed description of the dataset.

2.1. FX swap volumes and prices: US vs. non-US agents

The FX swap market, with a global daily turnover of approximately US$3.8 trillion (Bank for International Settlements, 2022), ranks as the largest financial market worldwide. Yet, its over-the-counter and highly fragmented nature makes it challenging to obtain data that accurately captures global activity. Transactions are executed bilaterally across various platforms or directly between counterparties, meaning data from any single venue may fail to reflect the full picture. To address this, I use data from CLS, the largest currency cash settlement system globally. CLS captures trading activity across a wide range of trades, thereby providing a uniquely comprehensive view of the FX swap market. The data is available from from January 3rd, 2012 to June 30th, 2022 and at a daily frequency. On average, settlement data accumulate to a total of US$ 12.7 trillion of open FX swap contracts outstanding across 17 U.S. dollar currency pairs and 8 tenors, which captures at least 30% to 50% of the FX market in comparison to BIS estimates (see Appendix A).

I order two bespoke data adjustments for the purposes of this paper. First, I break down the data on outstanding FX swap positions per *market participant nationality* to isolate U.S. banks from non-U.S. banks. Note that the *nationality* view, which I pursue in the subsequent analysis, is different from the *residence view*.[6] While both perspectives offer complementary perspectives, it is the nationality view that recognises the importance of global financial intermediaries whose balance sheets go beyond national borders (McGuire, Goetz von, and Zhu, 2024). Agents are sorted into six region of the world: the US, the Eurozone, the UK, Switzerland, Japan, and all others combined.[7] Table (1) reports the summary statistics of the data set in comparison to data from the BIS. For robustness check, I obtained a sample of the data set based on the residence principle. As seen, both CLS and BIS coverage match closely based on the residence principle, highlighting the role of London as the global FX trading hub. While CLS FX spot data has been studied before by Hasbrouck and Levich (2019), Ranaldo and Somogyi (2021), and Cespa, Gargano, Riddiough, and Sarno (2022), I am the first to study it in the context of U.S. dollar swap lines.[8]

Second, I obtain a similar breakdown for prices. Swap points $(F - S)$ are the traded price and are therefore the natural target for what consistutes a price of an FX swap. To this end, I therefore request CLS to manually match, for each contract i, its respective FX rates at the near (S) and far (F) legs respectively. I then request CLS to aggregate all the contracts and compute the daily volume-weighted average price for a currency k, tenor j, party l and counterparty m. Figure (2) depicts how FX swap points inferred from settlement data, which are based on trade data, compare to those available on Bloomberg, which are generally based on quote data. It reports the volume-weighted average swap points $(F - S)$ for 1-week euro-dollar FX swaps executed by U.S. banks on

[6] To give an example, JP Morgan London branch would be classified as a U.S. firm under the nationality view, as its headquarters are in New York, whereas it would be a UK firm from a residence perspective, as the traders sit in London

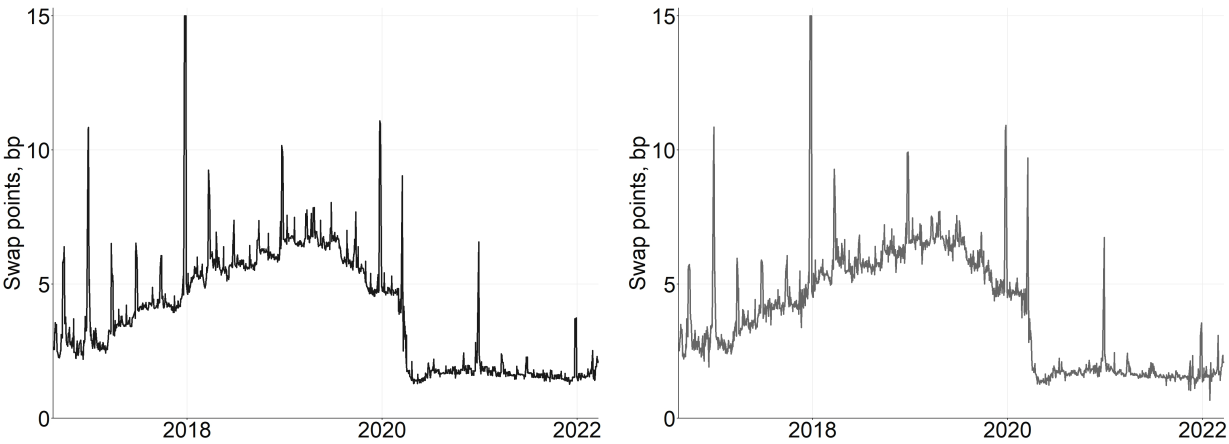
[7] The choice is guided by, among other aspects, the standing swap lines that the Federal Reserve has established globally.

[8] Kloks et al. (2023b) study FX swap liquidity using flow data. Bräuer and Hau (2022) use CLS FX swap data on fund order flow for seven currencies against the U.S. dollar.

	Residence		Nationality
	BIS	CLS	CLS
UK	54	54	16
U.S.	19	19	47
Japan	7	2	5
Eurozone	13	14	23
Switzerland	5	4	7
Other	3	6	2
Total (%)	100	100	100

Table 1: CLS and BIS coverage comparison. CLS data is based on a sample from 2016 and is benchmarked against the BIS Triennial Central Bank Survey of foreign exchange and OTC derivatives in 2016.

a given trading day, compared with Bloomberg midquotes. While CLS rates are naturally noisier, they track Bloomberg prices closely, lending confidence to their use in the subsequent analysis



(a) Quoted swap points (Bloomberg)

(b) US bank traded swap points (CLS)

Fig. 2: EURUSD 1W swap points based on *quoted* swap points (Bloomberg, lhs) vs. volume-weighted daily average *traded* swap points charged by U.S. banks (CLS, rhs). Note that the values of both series are capped at 15 basis points for better visualisation purposes. Data is daily from January 2017 until March 2022.

2.2. Federal Reserve data on liquidity swap operations

There are more than 100 cross-border liquidity lines between central banks, connecting countries that together account for roughly 80% of world GDP (Bahaj, Fuchs, and Reis, 2024). In this paper, I focus specifically on Federal Reserve swap lines, since these involve the U.S. dollar in particular. First established in December 2007, they have become the primary tool for addressing U.S. dollar funding squeezes, with usage peaking at $586 bn in late 2008. Made permanent in

2013, they have since been available on a standing basis to the BoE, BoJ, ECB, SNB, and BoC, but were rarely tapped during subsequent years of ample dollar liquidity. In March 2020, drawdowns surged again, reaching about $540 bn—just below the 2008 peak (see Appendix C). This paper restricts attention to the post-2008 period, as my FX swap market settlement data begin in 2012. I obtain daily data on swap line draw downs from the Federal Reserve Bank of New York.[9] The data includes the following variables: amount, interest rate, trade date, settlement date, maturity, currency, counterparty central bank. For the ease of following the subsequent discussion, I also briefly summarize the nature of the swap line contract. A Federal Reserve swap line is essentially a swap of two currencies between the Fed and a recipient-country central bank for a certain maturity and a fixed cost. In such a contract, the Fed loans out U.S. dollars and receives the foreign currency as collateral. The recipient-country central bank taps the swap line when its domestic banks apply for the U.S. dollar lending facility via an auction. Swap line funds are then transferred to a commercial bank at the next business day after the auction date (T+1 settlement), with the recipient-country central bank acting as an intermediary and receiving recipient-country cash as collateral. It thus bears no foreign exchange risk but does bear the credit risk that the domestic bank will default. Note that swap lines come at a cost for the domestic commercial bank. The cost stems from primarily two sources. First, the interest rate of borrowing the U.S. dollar comes at a penalty rate (currently at 25bp) above the overnight index swap (OIS) rate. However, since no actual borrowing happens at this reference rate, swap line funding may become attractive when the actual borrowing rates exceed the OIS rate. Second, the commercial bank also incurs a haircut on the collateral it provides to the recipient-country central bank. Ultimately, the Federal Reserve, through its bilateral swap line network, achieves its role as an international lender of last resort for U.S. dollar liquidity.

2.3. Additional market data

Ever since 2008, borrowing U.S. dollar via FX swaps is more expensive than doing so directly via U.S. money markets for many of the largest currency pairs incl. EURUSD, USDCHF, USDJPY and GBPUSD. This spread is referred to as the premium on USD borrowing in the FX swap market

[9]Data is accessible online at: https://www.newyorkfed.org/markets/desk-operations/central-bank-liquidity-swap-operations.

and is measured by the cross-currency basis, which I define formally in Section 4. I compute the basis from two main data sources. First, I infer FX swap points from settlement data at a currency-tenor-party-counterparty level, which are available at daily frequency. This includes data on daily volume-weighted average swap points ($F - S$) as well as spot rate (S). Second, for a measure of risk-free interest rates rates, I obtain daily data on historical Libor and OIS rates from Bloomberg.

3. Conceptual Framework

This section develops a conceptual framework for price formation in the FX swap market and generates four testable hypotheses for the empirical analysis that follows. It characterizes U.S. banks as market-making liquidity providers and their trading counterparties as price takers. First, I explain why U.S. banks may fund via FX swaps under balance sheet constraints, even if it involves paying the cross-currency basis. Second, I explain how Federal Reserve swap line take-up can lead to higher U.S. dollar supply in the FX swap market by non-U.S. banks.

3.1. U.S. banks as constrained intermediaries

Consider U.S. bank FX swap intermediation in a stylized model of trading in the spirit of Syrstad and Viswanath-Natraj (2022). U.S. banks play a critical role in supporting the efficient functioning of the FX market by providing U.S. dollar liquidity to customers worldwide. However, this results in an open risk position, which is costly from a balance sheet perspective. The primary contribution of the set-up outlined below is to formalize why a decline in U.S. bank balance sheet capacity is associated with increased reliance on inventory funding within the FX market.

Customers. The FX swap market includes two types of price-taking customers with opposite hedging motives. USD-demanding customers who hedge USD-denominated assets seek to buy USD via FX swaps and thus exert demand of amount $x_t^{D,-}$. In contrast, foreign-currency-demanding customers seek to obtain foreign currency (e.g., JPY) and supply USD of amount $x_t^{D,+}$. Let $x_t^D = x_t^{D,-} - x_t^{D,+}$ define global aggregate (signed) demand for U.S. dollar liquidity at the near leg of all FX swap contracts:

$$x_t^D = \int_0^1 \tilde{f}(b, \theta, \chi_t)\, db \tag{1}$$

where $b \in [0,1]$ indexes the continuum of customer types and $\tilde{f}(b,\theta,\chi_t)$ represents their individual net demand for U.S. dollars. Customers with $b \in [0,\alpha]$ are USD-demanding and their demand decreases in the basis, i.e., $\partial\tilde{f}/\partial\chi_t < 0$. Customers with $b \in (\alpha,1]$ are USD-supplying (foreign-currency demanding) and their supply of USD increases in the basis, $\partial\tilde{f}/\partial\chi_t > 0$. In both cases, customer demand increases with the inverse of counterparty quality θ.[10] Importantly, x_t^D refers to aggregate *signed* volume observed by dealers. If such demand is balanced, there is an equal amount of customer orders that consume and provide U.S. dollars, and $x_t^D = 0$. If demand is imbalanced and tilted towards net U.S. dollar purchases, then $x_t^D < 0$.

Arbitrageurs. The FX market contains arbitrageurs who stand ready to capture any risk-free profit opportunities. Let their utility function take the following exponential form:

$$U_t = -e^{-\rho W_t} \tag{2}$$

where ρ denotes the coefficient of absolute risk aversion. The arbitrageur can decide to supply q amount of dollars in the FX swap market. He earns the cross-currency basis χ by doing so but must fund this position by borrowing U.S. dollars at a cost c. Taking such a position involves at least two other costs. First, his counterparty may default with some probability θ. Because an FX swap is effectively collateralized by the foreign currency, the arbitrageur is able to sell the collateral in case of default. His return in case of default is stochastic and based on the actual observed spot exchange rate in the next period s_{t+1}, where $s_{t+1} \sim N(f_t, \sigma^2)$. Second, the arbitrageur takes an open position in the FX market by supplying U.S. dollars and acquires leverage $\frac{q}{W}$ that incurs a cost ψ increasing with position size (Cenedese et al., 2021). Finally, assuming the initial wealth can be invested at the risk-free interest rate r^f, the arbitrageur's next-period wealth is:

$$W_{t+1} = \underbrace{W_t \cdot (1+r^f)}_{\text{Return on initial wealth}} + \underbrace{q_t \cdot \chi_t}_{\text{Basis return}} + \underbrace{\theta \cdot q_t \cdot (s_{t+1} - f_t)}_{\text{Return if default}} - \underbrace{q_t \cdot c_t}_{\text{Funding cost}} - \underbrace{W_t \cdot \psi_t\left(\frac{q_t}{W_t}\right)}_{\text{Cost of leverage}} \tag{3}$$

The arbitrageur supplies liquidity in the market to maximize expected utility with respect to q. Using mean-variance preferences, the arbitrageur solves:

$$\max_{q_t} \rho \cdot \left(W_t(1+r^f) + q_t(\chi_t - c_t) - \tfrac{1}{2}\rho\theta^2\sigma^2 q_t^2 - W_t \cdot \psi_t\left(\tfrac{q_t}{W_t}\right) \right) \tag{4}$$

[10] This reflects the notion that counterparties with lower quality are more prevalent in the FX swap market since they are less able to find alternative cheaper funding sources elsewhere.

The first-order condition yields:

$$q_t^* = \frac{\chi_t - c_t - \psi_t(\frac{q_t}{W_t})}{\rho \cdot \theta^2 \cdot \sigma^2} \tag{5}$$

U.S. banks. U.S. banks provide liquidity to end-customers globally. The total net amount of U.S. dollars provided by N U.S. banks, after they internally aggregate and offset customer flows across their networks, does not net to zero if customer demand is imbalanced:

$$\sum_{j=1}^{N} D_{t,1}^{j} = x_t^D \tag{6}$$

Let q_t denote the volume of U.S. dollars supplied by external arbitrageurs. Then, the residual position that U.S. banks must fund on their own balance sheets is given by $\Delta_t = x_t^D - q_t$. Maintaining a negative open position in FX swaps is costly for U.S. banks because it involves a regulatory cost associated with sourcing cash to meet the USD cash outflow. This is because in contrast to an FX forward, an FX swap involves the exchange of gross notionals at the near leg of the trade (Kloks et al., 2024). While U.S. banks have plenty of access to USD cash such as via the U.S. repo market or via reserves, sourcing it is costly from the perspective of Basel III leverage ratio and/or internal risk limits. This is because borrowing repo expands the balance sheet and worsens the Basel III leverage ratio (Ranaldo, Schaffner, and Vasios, 2021). These costs can be modeled as a convex function that captures increasing marginal costs of absorbing larger positions:

$$\Psi(\Delta_t) = \frac{\kappa}{2} \cdot \Delta_t^2 \tag{7}$$

Here, $\kappa > 0$ captures the sensitivity of balance sheet costs to the size of the residual position. A higher κ implies tighter balance sheet constraints, making internal funding more expensive. U.S. banks choose the level of arbitrage capital q_t to minimize total funding costs, which include (i) the basis paid to attract arbitrage capital and (ii) the cost of carrying the remaining position:

$$\min_{q_t} \left\{ \chi_t \cdot q_t + \frac{\kappa}{2}(x_t^D - q_t)^2 \right\} \tag{8}$$

The first term is linear in q_t and refers to the cost of offloading exposure to arbitrageurs; the second term penalizes reliance on balance sheet space. Solving the first-order condition gives:

$$\chi_t - \kappa(x_t^D - q_t) = 0 \tag{9}$$

Rearranging yields the optimal amount of arbitrage capital that U.S. banks source in FX swaps:

$$q_t^* = x_t^D - \frac{\chi_t}{\kappa} \tag{10}$$

This implies that tighter balance sheet constraints (higher κ) raise the marginal cost of on-balance sheet funding. As a result, U.S. banks are more likely to offload positions to arbitrageurs and seek a matched-book position in FX swaps. At the limit, when $\kappa \to \infty$, U.S. banks offload the entire customer net demand with arbitrageurs. Note that if non-bank hedging demand is imbalanced globally, with counterparties predominantly borrowing U.S. dollars at the near leg of the FX swap trade, U.S. banks can return to a matched-book of trading only by attracting U.S. dollar supply from foreign banks.

Proposition 1 (U.S. bank matched-book intermediation). *U.S. bank net positions with non-U.S. banks is negatively predicted by the net USD demand from non-banks x_t^D.*

Proposition 2 (U.S. bank price setting). *When U.S. bank balance sheet constraints tighten ($\kappa \uparrow$), U.S. banks offer worse prices for USD purchases relative to USD sales in response to an increase in U.S. dollar demand, leading to wider transaction costs.*

These propositions jointly imply that U.S. bank pricing and inventory behavior are systematically shaped by both end-user demand and dealer constraints, and that pricing asymmetries can emerge endogenously from intermediation frictions.

3.2. Non-U.S. banks and swap lines

This subsection outlines why borrowing U.S. dollars from Federal Reserve swap lines may lead non-U.S. banks to increase their U.S. dollar supply in the FX swap market. Two competing mechanisms are identified: precautionary liquidity hoarding and arbitrage. A testable hypothesis is introduced to distinguish between these behaviors, supporting the empirical analysis in the subsequent section.

First, non-U.S. banks may increase their U.S. dollar supply in the FX swap market even when acting purely as customers. This can occur if a bank borrows from swap lines for the purpose of precautionary liquidity hoarding. To understand why, consider the operational aspects of liquidity management from a bank's perspective. Under precautionary hoarding, a non-U.S. bank borrows U.S. dollars from the Federal Reserve but does not immediately on-sell the full amount to its clients. This may occur, for example, if the bank seeks to hold a liquidity buffer to manage rollover risk or funding uncertainty. Alternatively, the bank may face potential client drawdowns on pre-committed credit lines, where the maximum exposure is known in advance, but the realized amount is uncertain ex ante. Since U.S. dollars cannot be deposited at the home central bank, the bank must allocate this buffer elsewhere.[11] If the cross-currency basis reflects a premium for lending U.S. dollars, the bank can temporarily park its excess cash in the FX swap market and receive domestic currency in return. This mechanism is consistent with the previous subsection, where customers supply U.S. dollars in exchange for foreign (i.e., domestic) currency. In this case, non-U.S. banks incur a loss due to the swap line penalty rate but attempt to mitigate this cost by parking liquidity in the FX swap market, where dollar lending earns a premium.

Alternatively, non-U.S. banks may borrow from swap lines to exploit arbitrage opportunities. In this case, lending dollars in the FX swap market yields a profit. Arbitrageurs need not have access to central bank facilities, but they can still supply arbitrage capital in the FX swap market ($q_t > 0$) as long as the return implied by the cross-currency basis χ_t exceeds their effective cost of funds, as expressed in:

$$\chi_t - c_t - \psi_t\left(\frac{q_t}{W_t}\right) > 0 \tag{11}$$

To understand the arbitrage mechanics, consider the relevant funding cost c_t. To arbitrage the basis in a U.S. dollar currency pair $k/\$$, an arbitrageur borrows U.S. dollars at rate $i_t^{\$}$ in the U.S. money market, supplies those dollars in the FX swap market by borrowing the foreign currency k spot (at rate s_t), agrees to deliver it forward, and deposits the non-dollar currency k at the foreign central bank's deposit facility, earning interest i_t^{v*}. Because this deposit typically earns a floating overnight rate, the arbitrageur uses an OIS contract to fix the return, generating a spread $i_t^* - i_t^{p*}$ between the fixed and floating legs. Thus, the effective cost c_t includes both the dollar funding cost $i_t^{\$}$ and the OIS hedge cost, as discussed in Bahaj and Reis (2021). Substituting these components into the arbitrage condition yields:

$$\chi_t - i_t^{\$} + i_t - i_t^{v*} + i_t^{p*} - \psi_t(\tfrac{q_t}{W_t}) > 0 \tag{12}$$

[11]Non-U.S. banks often use overnight and short-term FX swaps (with maturities below one week) to source domestic currency funding and offset open foreign exchange exposures accumulated throughout the day.

In other words, an arbitrageur enters the FX swap market if the cross-currency basis exceeds the marginal dollar funding cost net of return on non-dollar assets and leverage costs.

Now consider arbitrageurs with access to Federal Reserve swap lines via their local central banks. Such institutions can borrow at the lower of the swap line rate c_t^{SL} and the private market funding rate c_t^M, i.e., $c_t = \min(c_t^M, c_t^{SL})$. The swap line cost is typically set at the OIS rate plus a penalty spread, i.e., $c_t^{SL} = i_t^{OIS} + \omega$, where $\omega = 25$ basis points.[12] Because swap lines are only attractive when private funding costs are elevated, they serve as a ceiling on the marginal funding cost during stress episodes. The arbitrageur's U.S. dollar supply q_t is thus a function of the basis χ_t, the marginal cost of funding c_t, and swap line access:

$$q_t := \begin{cases} \frac{\chi_t - c_t - \psi_t(\frac{q_t}{W_t})}{\rho\theta^2\sigma^2}, & \text{if } \chi_t \geqslant c_t^M + \psi_t(\frac{q_t}{W_t}) \\ \mathbb{1}_{D_{access}} \cdot \frac{\chi_t - c_t - \psi_t(\frac{q_t}{W_t})}{\rho\theta^2\sigma^2}, & \text{if } c_t^{SL} + \psi_t(\frac{q_t}{W_t}) \leqslant \chi_t < c_t^M + \psi_t(\frac{q_t}{W_t}) \\ 0, & \text{if } \chi_t < c_t^{SL} + \psi_t(\frac{q_t}{W_t}) \end{cases} \tag{13}$$

where D_{access} is a swap line access dummy variable:

$$\mathbb{1}_{D_{access}} := \begin{cases} 1 & \text{for arbitrageurs with access to recipient-country swap line,} \\ 0 & \text{for all other arbitrageurs.} \end{cases}$$

Evidently, access to swap lines enables arbitrageurs to supply a greater quantity of arbitrage capital relative to those without access, conditional on the cross-currency basis being sufficiently favorable. For example, consider an arbitrageur observing a positive basis χ_t. He will only engage in arbitrage if his borrowing cost c_t is below a threshold c_0. If market conditions raise c_t^M above c_0, arbitrage activity ceases unless swap line access allows the arbitrageur to borrow at $c_t^{SL} < c_0$, thereby capping his marginal cost.

Only banks (not non-bank financial institutions) are eligible to access U.S. dollar auctions through their local central bank.[13] In addition, under the standard operational framework, swap line auctions typically occur once per week (e.g. on Wednesdays), introducing temporal variation in access and participation. This gives rise to the following two propositions.

Proposition 3 (Swap line availability and FX swap supply).

[12]Note that prior to March 23, 2020, the swap line penalty rate was set at 50 basis points.

[13]More specifically, swap line facilities are available only to institutions that maintain a depository account at their home central bank.

Non-U.S. banks with access to central bank swap lines exhibit behavior consistent with either an arbitrage motive or a precautionary hoarding motive if they increase their U.S. dollar lending on days when swap line operations are active, relative to days when they are inactive.

As established above, an increase in FX swap U.S. dollar supply alone does not distinguish between arbitrage and precautionary motives, as both imply a positive response to the basis. The key identification lies in the intensive margin: arbitrage predicts a discrete change in the slope of supply at the arbitrage ceiling. Specifically, if banks engage in swap line arbitrage, then FX swap supply should exhibit a kink when the basis exceeds the effective arbitrage threshold:

$$\left.\frac{\partial q_t}{\partial \chi_t}\right|_{\chi_t > c_t^{SL}+\psi_t} \gg \left.\frac{\partial q_t}{\partial \chi_t}\right|_{c_t^{SL} < \chi_t \leq c_t^{SL}+\psi_t}.$$

Proposition 4 (Swap line arbitrage and FX swap supply).

Non-U.S. banks with access to central bank swap lines exhibit behavior consistent with arbitrage motives if their market share in U.S. dollar lending increases when the cross-currency basis χ_t exceeds both the swap line cost c_t^{SL} and the private market funding cost c_t^M.

4. U.S. Bank Price Setting and Balance Sheet Constraints

Section 3 presented a conceptual framework in which U.S. banks act as global dealers in FX swaps, supplying U.S. dollars to price-taking counterparties. The model yields two key implications: (i) U.S. banks offset imbalanced non-bank demand with U.S. dollar supply by non-U.S. banks, in line with matched-book intermediation, and (ii) U.S. banks offer worse prices in response to higher net U.S. dollar demand particularly when balance sheet constraints bind. This section tests these hypotheses empirically using granular settlement-level data.

4.1. Quantities

Fig. (3) visualizes the global market for U.S. dollar borrowing and lending in FX swaps through a network of outstanding positions using CLS settlement data by agent nationality. I calculate the *net* FX swap position, i.e. I allow participants to offset buy and sell volumes of FX swap contracts at the day-currency level. Thus, for each agent group i, currency j and tenor k, the daily *net* open position across all settled outstanding FX swap contracts l as follows:

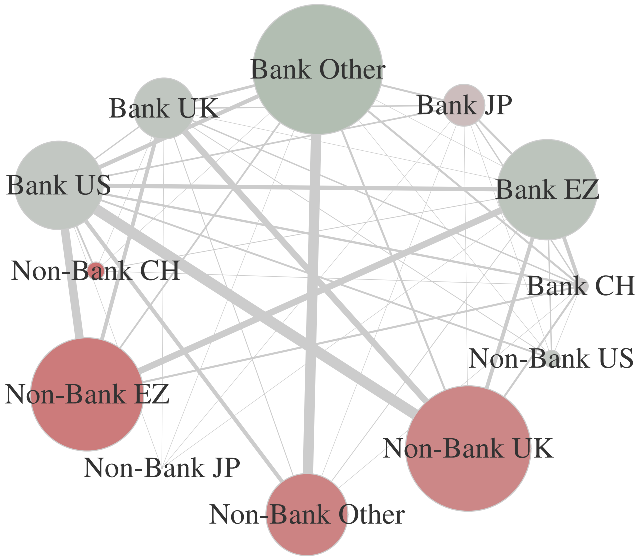
$$Net_{t,i,j,k} = \sum_{l=1}^{L} \mathbb{1}[\mathrm{T_t} = \mathrm{B}] \; - \; \mathbb{1}[\mathrm{T_t} = \mathrm{S}], \tag{14}$$

where B and S refer to trade direction and indicate whether a given trade resulted in a dollar cash inflow or outflow at the near leg of an FX swap contract (thus, indicating U.S. dollar purchases or sales respectively). The sum of net positions across all U.S. dollar currency pairs and tenors yields, for each banking group i, its net U.S. dollar borrowing at any given day t as $Net_{t,i} = \sum_{j=1}^{J} \sum_{k=1}^{K} Net_{t,i,j,k}$. Fig. (3) colors net U.S. dollar lenders (borrowers) in green (red); the color is assigned for the agents' total overall net position across all currencies, counterparties and tenors. For example, if JP Morgan and UBS agree a three-month, 100 million EURUSD FX swap on January 1st 2018 whereby UBS receives U.S. dollar cash flow two days after the trade date, JP Morgan is a net lender (green) and UBS is a net borrower (red). Appendix (D) breaks down banks' total net position observed in Fig. (3) per currency pairs. As expected, non-banks are the largest net dollar borrowers, driven by their need to hedge the currency risk of their USD investments, whereas U.S. banks are net U.S. dollar liquidity lenders. Moreover, consistent with the intuition of Section 3, U.S. banks maintain relatively flat net positions across counterparties and tenors. Despite intermediating the largest gross volumes, their net position averages just 3% over the sample, underscoring their role as matched-book dealers.

According to Proposition 1 of Section 3, U.S. bank net position with foreign banks should be well predicted by the non-bank customer demand that they observe. This is because U.S. banks aim to run a matched-book of trading and thus offset non-bank imbalanced demand. I test this relationship with the following ordinary-least squares panel regression:

$$\Delta Net_{NonUS\ Banks,i,t} = \beta \cdot \Delta Net_{NonBanks,i,t} + \gamma \cdot \mathrm{X}_{i,t} + \alpha_i + \gamma_t + \epsilon_t. \tag{15}$$

where Net_t refers to the net (buy minus sell) U.S. dollar borrowing volume for currency pair i, α_i and γ_t are counterparty- and time-fixed effects respectively, and $\mathrm{X}_{i,t}$ is a vector of control variables. A positive (negative) net position refers to net borrowing (lending) at the near leg of an FX swap contract. The control variables include proxies market-wide conditions such as volatility (VXY), liquidity (BAS) as well as week-of-day, month-of-year and holiday dummy variables. Above all, I expect a negative and statistically significant result on β, our coefficient of interest, if U.S. banks aim to run a matched-book and therefore borrow more from non-U.S. banks when



(a) Net (sell minus buy) FX swap outstanding position

Fig. 3: Global network of FX swap open *net* positions across all tenors and for 17 U.S. dollar currency pairs combined. The net position refers to buy minus sell volume, with red (green) color referring to a party being a net USD borrower (lender) at the near leg and gray color indicating a neutral net overall position. Circle size represents each party's (scaled) overall net position. Data refer to daily average values from 2012 until 2022.

they lend more to customers.

	Dep: Δ Net$_{NonUS\ Banks}$						
	Panel of G7 currencies			*Per Currency*			
	Daily (1)	Weekly (2)	Monthly (3)	EUR (4)	GBP (5)	CHF (6)	JPY (7)
Δ Net$_{NonBanks}$	-0.12^{***}	-0.32^{***}	-0.31^{***}	-0.33^{***}	-0.23^{***}	-0.26^{***}	-0.31^{***}
	(0.01)	(0.03)	(0.05)	(0.04)	(0.05)	(0.07)	(0.07)
Constant				0.32^{**}	0.02	0.16^{***}	0.41^{***}
				(0.14)	(0.09)	(0.05)	(0.12)
Constant	No	No	No	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	No	No	No	No
Observations	11,127	2,784	540	557	557	557	556
Adjusted R^2	0.03	0.09	0.11	0.12	0.07	0.04	0.07

Table 2: Determinants of U.S. bank net position with foreign (non-U.S.) banks. Columns (1) to (3) report the results of a panel regression across G7 currency pairs whereas columns (4) to (7) conduct the same regression on the four largest currencies individually (EURUSD, GBPUSD, USDCHF, USDJPY). All variables are considered in changes. Currency fixed effects are included. Standard errors are clustered by time for the panel regressions and report Newey-West standard errors for the remaining regressions. The superscripts $***$, $**$ and $*$ indicate significance at 1%, 5% and 10% significance level respectively.

Regression results (Table 2) confirm this hypothesis. Across all frequencies and major currencies, β is significantly negative. For instance, in monthly changes (column 3), $\beta = -0.31$ with a standard error of 0.05, indicating that a one-unit increase in non-bank net demand is associated with a 31% offset via borrowing from non-U.S. banks. The coefficient remains below one, in line with U.S. banks occasionally absorbing part of the imbalance via internal funding, as predicted by the model.

4.2. Prices

I now test Proposition 2, which predicts that imbalanced U.S. dollar borrowing pressure has a larger impact on prices when U.S. banks face tighter balance sheet constraints. I first use swap lines as an instrumental variable to provide causal evidence that U.S. banks' price setting responds to net order flow. I then examine whether this effect intensifies during periods of balance sheet stress, as measured by the intermediary constraints index of He et al. (2017).

Measuring transaction costs charged by U.S banks. To analyze US bank price setting, I analyze forward points, $F - S$, which is the traded price of an FX swap (Kloks, Mattille, and Ranaldo, 2023a). Using settlement volumes, I calculate the volume-weighted average forward points charged by U.S. banks at the currency–tenor–counterparty–day–trade direction level. Table 3 presents summary statistics for the spread between the daily vwa-forward points for sell vs. buy trades over the 2012–2022 period. For EURUSD at the 3-month tenor, the median daily volume-weighted average spread earned by U.S. banks is 72% of the Bloomberg quoted bid-ask spread. The 10th percentile of observed spreads is equivalent to 12% of the prevailing indicative spread, while the 90th percentile reaches 430% of the quoted spread. Overall, the spreads inferred from settlement data appear lower than the effective spreads observed in dealer–client markets; for instance, Hau, Hoffmann, Langfield, and Timmer (2021) report average realized spreads at around 6 basis points for EURUSD trades with non-financial clients. The difference is expected, as the settlement data include the interdealer market, which dominates trading volume and is characterized by markedly lower effective transaction costs than those faced by non-bank customers.

I then express the forward points in terms of deviations from the covered interest parity (CIP) principle to account for contemporaneous changes in interest rates. The CIP principle states that

		US banks' sell-buy swap point spread							
		In basis points				As % of bid-ask spread			
		1W	1M	3M	1Y	1W	1M	3M	1Y
EURUSD	Median	0.08	0.21	0.23	0.84	67	102	72	46
	10pct	0.01	0.02	0.04	0.19	8	11	12	11
	90pct	0.64	1.49	1.52	3.51	492	730	432	182
USDJPY	Median	0.09	0.24	0.35	0.75	44	66	71	40
	10pct	0.01	0.03	0.05	0.14	6	8	10	8
	90pct	0.72	1.88	2.49	3.41	327	480	512	198
GBPUSD	Median	0.07	0.17	0.23	0.93	44	62	57	37
	10pct	0.01	0.02	0.04	0.20	5	8	9	8
	90pct	0.52	1.21	1.30	3.47	323	406	297	135
USDCHF	Median	0.10	0.22	0.32	1.16	45	67	50	35
	10pct	0.01	0.02	0.04	0.25	4	6	8	8
	90pct	0.81	1.50	1.86	3.97	388	455	241	112

Table 3: Difference between U.S. bank dollar Sell and Buy FX swap transaction prices (i.e. swap points), expressed in basis points (lhs) and as a percentage of the corresponding bid-ask spread (rhs). Values represent volume-weighted daily average prices when a U.S. bank sells USD versus when it buys USD from a specific counterparty. A dollar sale is defined as an FX swap transaction in which the U.S. bank delivers USD on the near leg. The sample covers the period from 2012 to 2022.

the interest rate charged to borrow U.S. dollar via FX swaps should be the same as the cost of borrowing U.S. dollar directly in U.S. money markets:

$$F_{t,t+1} = S_t \cdot \left(\frac{1 + i^k_{t,t+1}}{1 + i^\$_{t,t+1}} \right) \tag{16}$$

where S_t represents the spot rate at time t, $F_{t,t+1}$ is the forward rate agreed at time t for a transaction occurring at time $t+1$, and $i^k_{t,t+1}$ and $i^\$_{t,t+1}$ represent the interest earned in the foreign and U.S. dollar currencies respectively. Then, any deviation between the cash market and FX swap market dollar rate for a given maturity and is defined as the cross-currency basis, which in log terms is expressed as:

$$\chi^{k/\$}_t = \underbrace{i^\$_t}_{\text{Cash Market Dollar Rate}} - \underbrace{i^k_t - \rho^{k/\$}_t}_{\text{FX Swap Market Dollar Rate}} \tag{17}$$

where $\rho^{k/\$}_t = log(F^{k/\$}_t) - log(S^{k/\$}_t)$ is the forward premium e.g. the difference between the forward (F) and the spot (S) rates respectively. For trading day t, tenor i, counterparty j and currency k, the daily volume-weighted Sell-Buy spread (expressed in terms of the CIP deviation and measured in basis points) across individual contracts w is then defined as:

$$x^{k/\$}_{t,i,j,k} = \sum_{w=1}^{W} \chi^{k/\$}_{t,i,j,w} \cdot V_{t,i,j,w} \cdot \mathbb{1}[T_t = S] - \sum_{w=1}^{W} \chi^{k/\$}_{t,i,j,w} \cdot V_{t,i,j,w} \cdot \mathbb{1}[T_t = B]. \tag{18}$$

Note that the objective is not to examine price discrimination at the individual trade level; instead, I aggregate transaction spreads to the daily–tenor–currency–counterparty level, which smooths out idiosyncratic deal-specific noise and captures the average effective spread earned by U.S. banks. This level of aggregation allows me to focus on systematic variation in pricing and to assess the overall rents U.S. banks extract from their customer relationships, rather than contract-specific deviations.

Instrumental Variable. Next, I use the *availability* of Federal Reserve swap lines as an instrument for the net U.S. dollar order flow faced by U.S. banks in the FX swap market, thereby providing causal evidence that realized transaction costs respond to shifts in net order flow. Because order flow and transaction costs are jointly determined in equilibrium, an instrument is required to isolate exogenous variation in order flow and recover the causal effect of net order flow on the transaction costs charged by U.S. banks. As discussed in Section 1, U.S. dollar funding via swap lines is an imperfect substitute for funding via FX swaps, since the cash flows of both transactions closely resemble each other. Swap line availability is not directly influenced by transaction costs in the FX market, but can reduce the funding and hedging pressure that non-U.S. agents exert on U.S. dealers in FX swaps e.g. via substitution effects as documented in Ferrara et al. (2022). This implies that the net U.S. dollar demand that U.S. banks accommodate in the FX derivative market can be affected by the availability and use of the Federal Reserve liquidity facility. I capture such discrete U.S. dollar demand shocks with a dummy variable $z_{t,k}$ equal to one if, on a given trading day, swap lines were *available* for tapping, regardless of actual usage. Under standard arrangements, swap lines are only available on specific days of the week; for most of my sample, dollar auctions occurred once a week.[14] The auction schedule is set in advance by central banks for operational reasons and is not adjusted in response to short-term FX market developments, making it plausibly exogenous to same-day pricing shocks. While actual allotments (in bn of USD) could also be instrumented, it may respond directly to the same market stresses that influence transaction costs, creating endogeneity concerns. Availability, by contrast, provides predetermined variation that can still affect customer order flow. The first-stage regression

[14] For example, the ECB's U.S. dollar liquidity auctions took place on Wednesdays.

is therefore specified as:

$$Net_{t,i,j,k} = \beta_1 \cdot z_{t,k} + \beta_2 \cdot BAS_{t,i,k} + \beta_3 \cdot VXY_t + \alpha_i + \gamma_j + \tau_k + \varepsilon_{t,i,j,k}. \tag{19}$$

satisfies the exclusion restriction ($E(z_{t,k}\,\varepsilon^s_{t,i,j,k}) = 0$) with respect to supply shocks ϵ^s in the price-setting equation. In other words, since swap lines are primarily designed to ease *offshore* U.S. dollar borrowing costs, I expect their availability to affect U.S. banks' transaction prices only through its effect on their customer order flow and not directly. Based on this instrument for the net order flow faced by U.S. banks, I estimate the following equation using a 2SLS method:

$$x_{t,i,j,k} = \beta_1 \cdot \widehat{Net}_{t,i,j,k} + \beta_2 \cdot BAS_{t,i,k} + \beta_3 \cdot VXY_t + \alpha_i + \gamma_j + \tau_k + \varepsilon_{t,i,j,k}. \tag{20}$$

where the terms α_i, γ_j, and τ_k are tenor-, counterparty-, and currency-fixed effects, respectively. To measure U.S. banks' order flow imbalances, I calculate, for tenor i, counterparty j and currency k, their daily total *net* FX swap trading volume as defined in eq. (14). To control for market-wide conditions, I also add the quoted bid–ask spread $BAS_{t,i,k}$ (as sourced from Bloomberg and available at the currency–tenor–day level) and the FX volatility index VXY_t as additional explanatory variables. Under the exclusion restriction $E(z_{t,k}\,\varepsilon^s_{t,i,j,k}) = 0$ and instrument relevance, the 2SLS estimator identifies β_1 as the causal pass-through from order flow to transaction spreads.

Table (4), Panels A and B, present the first and second stage results, respectively. Columns (1) and (2) report the OLS coefficients for completeness. The coefficient estimates for the main instrument in Panel A, Columns (3) and (4), are negative and significant. This suggests that days when Federal Reserve swap lines are available are generally associated with lower U.S. dollar buying pressure (as measured by net order flow) in the FX swap market by U.S. bank customers. For both versions of the IV, the Kleibergen–Paap Wald F-statistics are 13.5 and 13.8, indicating moderately strong instruments.[15] In other words, greater imbalances in customer demand for U.S. dollars are associated with higher transaction costs charged by U.S. banks. The point estimate in Column (4) is 1.21. The economic magnitude of the effect is non-negligible: a one–standard-deviation increase in net order flow raises the forward-premium effective spread by about 0.12 bps at the 1W tenor, 0.51 bps at 1M, and 1.53 bps at 3M, corresponding to an average of roughly

[15] The Kleibergen–Paap rk Wald F-statistic is a heteroskedasticity-robust first-stage statistic used to assess instrument relevance. Values above the conventional threshold of 10 are typically considered evidence against weak instruments. In small samples, or when the statistic is close to this threshold, finite-sample bias and size distortions can still be a concern, so my results suggest the instrument is moderately strong but not exceptionally so.

0.7 bps across these maturities.[16]

Panel A: First Stage				
Dep. variable:	Net order flow, $Net_{t,i,j,k}$ (bn of USD)			
	OLS1	OLS2	IV1	IV2
	(1)	(2)	(3)	(4)
$z_{t,k}$			-0.0861***	-0.0872***
			(0.0104)	(0.0022)
$BAS_{t,i,k}$				-0.0567*
				(0.0276)
VXY_t				0.1566
				(0.0925)
Panel B: Second Stage				
Dep. variable:	Effective spreads, $x_{i,j,k}$ (basis points, log)			
	OLS1	OLS2	IV1	IV2
	(1)	(2)	(3)	(4)
$Net_{t,i,j,k}$	0.0067	0.0077		
	(0.0061)	(0.0058)		
$\widehat{Net}_{t,i,j,k}$			0.8758*	1.2093***
			(0.3989)	(0.3305)
$BAS_{t,i,k}$		0.3809***		0.4504***
		(0.0495)		(0.0490)
VXY_t		0.4407**		0.2895*
		(0.1433)		(0.1384)
Observations	45686	45686	45686	45686
KP F-statistic			13.5	13.8

Table 4: 2SLS regressions of daily U.S. bank effective spreads, $x_{t,i,j,k}$, on the instrumented net U.S. dollar buying pressue faced by U.S. banks, $Net_{t,i,j,k}$. All variables except the net U.S. dollar buying pressure (as measured by net order flow) are considered in logs. Currency, counterparty and tenor fixed effects are included. Standard errors are clustered by time and counterparty. The superscripts $***$, $**$ and $*$ indicate significance at 1%, 5% and 10% significance level respectively.

U.S. bank balance sheet constraints. Having established a causal link between net order flow and transaction costs, I now present supporting correlational evidence that U.S. banks demand higher compensation to accommodate more imbalanced order flow when dealer constraints are more binding, consistent with Proposition 2. To measure dealer health, I use the daily balance sheet capacity index proposed by He, Kelly, and Manela (2017), calculated for *primary dealers*, who largely overlap with the largest U.S. banks active in FX markets, as identified in the Euromoney

[16] To convert annualized CIP to tenor-specific forward-premium terms, I use $b_\tau \approx i - i^* - \text{fp}_\tau$, so $\Delta\text{fp}_\tau \approx \Delta b_\tau \cdot (\tau/360)$ (ACT/360).

(2020) FX survey. Specifically, I estimate the following ordinary least squares regression separately across five quantiles of the He, Kelly, and Manela (2017) dealer capacity distribution:

$$x_{t,i,j,k} = \beta_0 + \beta_1 \cdot Net_{t,i,j,k} + \beta_2 \cdot BAS_{t,i,k} + \theta \cdot \mathrm{X}_{t,i} + \alpha_i + \gamma_j + \tau_k + \epsilon_t. \quad (21)$$

where $x_{t,i,j,k}$ denotes the Sell-Buy spread (i.e. proxy for effective spread), and $Net_{t,i,j,k}$ captures net dollar buying pressure (as measured by net order flow) faced by U.S. banks, measured as the difference between sell and buy volume (in billions of USD). $BAS_{t,i,k}$ is the indicative bid-ask spread quoted on Bloomberg. The vector $\mathrm{X}_{t,i}$ includes controls such as the VIX and TED spreads. α_i, γ_j and τ_k denote tenor-, counterparty- and currency-fixed effects, respectively. Appendix (K) presents the results. It reveals that the spread-volume slope increases monotonically across constraint quintiles. In the most constrained quintile (Q5), a unit increase in net order flow raises the sell-minus-buy spread by 3 basis points (significant at the 1% level), compared to only 1 basis point in the least constrained quintile (Q1). This pattern supports the prediction that dealers seek compensation for shadow balance sheet costs when constraints become more binding. The finding aligns with the emerging literature on liquidity conditions in OTC FX derivatives. For instance, Syrstad and Viswanath-Natraj (2022) uses one-week swap data from Refinitiv to show that order flow has greater price impact at quarter-end, when balance sheet constraints tighten. My analysis extends this work by focusing specifically on U.S. bank pricing and documenting the relationship over a broader time series and across maturities.

4.3. Additional results

4.3.1. IOR-repo spreads and the role of reserve balances

As noted in Section 3, U.S. banks can also fund open FX swap dollar positions by drawing down reserves, avoiding costly repo borrowing. In practice, however, this option is limited: excess reserves have been far smaller than banks' FX swap positions. For instance, Correa et al. (2020) estimate that banks drew only about USD 20 billion during stress episodes, compared with FX swap funding needs of roughly USD 1 trillion from non-bank demand. Still, when reserves are ample, meeting such needs becomes less problematic. Appendix (H) reports the results of ordinary least squares panel regressions of the spread between sell and buy FX swap transaction prices charged by U.S. banks on net (sell minus buy) U.S. bank trading volume. The analysis is split based on whether the spread between overnight repo rates and the interest rate on reserves (IOR) is negative (columns (1) and (3)) or positive (columns (2) and (4)). A positive repo–IOR spread indicates a reduced ability of U.S. banks to unwind reserve balances, consistent with the interpretations of Correa et al. (2020) and Copeland et al. (2025). The coefficient on net volume is larger on days when reserves are less ample (0.02) than when they are more abundant (0.01), suggesting that U.S. banks are indeed less willing to maintain an imbalanced sell position in FX swaps under tighter reserve conditions.[17]

4.3.2. Gross vs. net volume

Appendix (F) replicates the main regression using gross trading volumes instead of net volumes. This exercise tests the argument that it is primarily the net positions that matter for U.S. bank balance sheet costs. Results reveal that gross and net volumes indeed have distinct effects on transaction costs charged, as anticipated. Specifically, the spread that U.S. banks earn from FX swap transactions tends to *decline* with higher gross trading volumes. This is consistent with the idea that greater trading activity enables banks to offer tighter spreads, as they can profit from volume-based revenues and manage inventory more efficiently (Schultz, 2001, Harris and Piwowar, 2006, Green, Hollifield, and Schürhoff, 2007).

5. Non-U.S. Bank Dollar Supply and Swap Lines

Propositions 3 and 4 predict that swap line take-up increases dollar supply in the FX swap market when banks borrow to hoard liquidity or, if the CIP ceiling is binding, to arbitrage. This section tests these propositions empirically using COVID-19 as a case study, a period with the largest swap line drawdowns in the past decade.

[17]For robustness, the repo rate is proxied using both the General Collateral Financing Rate (GCF) or the Secured Overnight Financing Rate (SOFR).

5.1. COVID-19 episode

5.1.1. Identification strategy

Identification at the banking group level. The ideal identification strategy would link the bespoke settlement data with bank-level data on U.S. dollar auctions conducted at each foreign central bank. This is not feasible because the identities of individual banks that tap U.S. dollar swap lines are not publicly disclosed.[18] Nonetheless, the COVID-19 episode allows to use the Bank of Japan as a case study, thereby circumventing the lack of recipient-level data. This is possible for two main reasons. First, the Bank of Japan publicly disclosed that swap line drawings during this period were predominantly extended to domestic banks, which I can identify in my settlement data. Japanese banks are significant U.S. dollar borrowers, and the COVID-19 crisis triggered an especially acute dollar liquidity shortage for them, prompting substantial use of the Bank of Japan's swap lines. Because more than 90% of Bank of Japan total swap-line take-up during this period can be attributed to domestic banks (Akitaka, Nojima, Horikawa, Semba, and Shinozaki, 2020), I can proxy the swap line take-up of this group of banks, who are identifiable in my settlement data, using aggregate Bank of Japan dollar auction results, which are publicly available.[19] Second, Bank of Japan swap line drawings were economically substantial during COVID-19. The outstanding amounts averaged USD 200bn from March to June 2020 and thus corresponded to over 50% of total Federal Reserve swap line usage among all central banks with permanent liquidity arrangements during this period. Similarly, the size of the Bank of Japan swap line drawings is large in comparison to domestic Japanese banks total FX swap position in settlement data (approximately USD 800bn in the dollar-yen currency pair on an average trading day). In contrast, Bank of Japan swap line drawings at quarter-end average less than USD 2 billion, making it more difficult to detect any effect in those episodes. The combination of these factors justify studying Bank of Japan swap line allotments during COVID-19 as a unique setting to empirically test the hypothesis as to whether higher Bank of Japan swap line take-up is associated with higher U.S. dollar supply in the FX swap market by domestic banks, even if the absence of similar data on

[18] Participation in local central bank operations is generally determined on a locational basis; that is, any institution maintaining a settlement account with the respective central bank is eligible to participate.

[19] The Federal Reserve Bank of New York publishes only aggregate swap line usage at the day-currency-tenor level.

other global central banks precludes a global estimate of the elasticity of FX swap dollar supply in response to swap line drawings across all jurisdictions.

Identification at the currency and tenor Level. I augment my identification strategy by incorporating the operational details of U.S. dollar swap line usage, which suggest variation in treatment across currencies and tenors. On the one hand, foreign central bank dollar auctions exchange U.S. dollars for collateral in the domestic currency. Consistent with the mechanism outlined in Section 3, banks that tap the swap line auction at their local central bank (e.g. Bank of Japan) deploy these dollars in FX swap contracts in the domestic currency pair (e.g. dollar-yen) if they attempt to match it with the currency where the bank holds deposits. On the other hand, the Federal Reserve offers swap line operations only at short term maturities up to the 3-month tenor point[20] whereas the FX swap market remains liquid at longer maturities, extending up to 12 months. I therefore conjecture that swap line activity affects trading behavior primarily at tenors up to 3M, but not beyond. Arbitraging mispricing in longer tenors, such as 6M or 1Y, would require rolling over short-term swap line funding at a cost that is uncertain ex ante, as it depends on the prevailing OIS rate at each rollover date. Moreover, hoarding liquidity in long-dated maturities is both operationally impractical and inconsistent with market convention.

5.1.2. Difference-in-differences

Building on the identification strategy outlined above, I examine whether Bank of Japan swap line take-up is associated with an increase in U.S. dollar supply in the FX swap market by domestic banks. To test this, I implement two complementary difference-in-differences (DiD) specifications, each exploiting a different source of variation in exposure to the swap line intervention.

Dollar vs. non-dollar pairs. The first specification compares domestic bank activity in USDJPY swaps to their activity in yen-denominated currency pairs that do not involve the U.S. dollar, namely CHFJPY, EURJPY, and AUDJPY. On days when the Bank of Japan conducted dollar auctions, swap line access should directly affect trading in USDJPY, but not in the other yen pairs. The dependent variable, $Volume_{t,i}$, is measured in two ways: (i) in absolute terms (billions of USD) and (ii) as a market share, defined as the percentage of total USD sales in the global FX swap

[20] Specifically, the Fed's swap lines are limited to two maturities—7 and 84 days—which map to the 1W and 3M tenors in the FX swap market.

market on a given day. The market-share specification serves to control for aggregate supply shocks affecting all participants, as discussed in Section 3.

I also separately estimate the effect on U.S. dollar *sales* (i.e., USD delivered on the near leg) and on U.S. dollar *purchases* (USD received on the near leg). A larger treatment effect for dollar sales than for purchases would indicate that the intervention specifically affected the supply of dollars rather than simply increasing overall trading activity. I thus run the following ordinary least squares baseline regression:

$$Volume_{t,i} = \beta_0 + \beta_1 \cdot SwapLines + \beta_2 \cdot IsUSD + \\ + \beta_{DD} \cdot SwapLines \cdot IsUSD + \theta \cdot \mathrm{X}_{i,t} + \epsilon_t. \quad (22)$$

where $Volume$ refers to either U.S. dollar buy or sell transactions and is measured as a market share in the baseline regression (robustness: in billions of USD), $SwapLines$ is a dummy equal to one from March 23 to June 30, 2020, $IsUSD$ is a dummy that equals 1 for USDJPY and 0 for other yen currency pairs (CHF-, EUR-, and AUDJPY), X refers to control variables such as the VIX and TED spreads, and β_{DD} is the difference-in-difference coefficient of interest.[21] Results are reported in columns (1) to (4) of Table 5. The estimates show that domestic banks increase sales of the non-yen currency more in dollar pairs than in non-dollar pairs. The difference in economic magnitude corresponds to an increase in market share of approximately 2 percentage points.

Affected vs. unaffected tenors. The second specification exploits variation across swap maturities. The Federal Reserve swap lines were made available only for short-dated tenors (up to and including 3 months). I therefore compare activity in *affected* maturities (at or below 3M) to *unaffected* maturities (above 3M up to 1Y) within the same currency pair. The difference-in-difference regression specification is:

$$Volume_{t,i} = \beta_0 + \beta_1 \cdot SwapLines + \beta_2 \cdot IsAffected + \\ + \beta_{DD} \cdot SwapLines \cdot IsAffected + \theta \cdot \mathrm{X}_{i,t} + \epsilon_t. \quad (23)$$

where $IsAffected$ is a dummy that equals 1 for FX swap maturities of at or under 3M and 0 otherwise, β_{DD} is the difference-in-difference coefficient of interest, and other variables are defined as above. Columns (5) to (8) of Table 5 present the results for treatment at the maturity level. Results reveal that, during the period when Bank of Japan swap lines were drawn, domestic

[21] In the baseline specification, I consider affected tenors only, as these were affected by swap lines.

Japanese banks reduced their FX swap borrowing, as expected and as consistent with substitution effects (columns (6) and (8)). Importantly, however, this was accompanied by an increase in domestic bank U.S. dollar sales, as measured both in absolute terms (column (5)) and as a share of the market (column (7)). The economic magnitude of the increase in dollar liquidity provision by domestic banks during this period is non-negligible: dollar sales by increased by approximately USD 70 billion per day on average, while their market share rose by roughly 1 percentage point. Appendix (J) confirms that the surge in U.S. dollar sales occurred for tenors where swap lines were available whereas long-term tenors where largely unaffected.

Finally, I visualize the increase in U.S. dollar net lending in by domestic banks by running the following regression: $Net_{t,i} = \alpha + \sum_{n=2}^{35} \beta_n \cdot D_n + \epsilon_t$, where D_n equals 1 for the n^{th} week of the year of 2020 and 0 otherwise. I report the β_n estimates in the Internet Appendix (not displayed here). It indicates that domestic banks increased their provision of U.S. dollar liquidity when Bank of Japan swap lines were tapped. At its peak, excess lending by these banks exceeded 70bn USD. This compares with the peak of the BoJ swap line allotments of 225bn of USD. Thus, a simple back-of-the-envelope calculation allows to gauge that as much as 25% - 30% of the Bank of Japan swap line take-up was intermediated into the FX swap market.

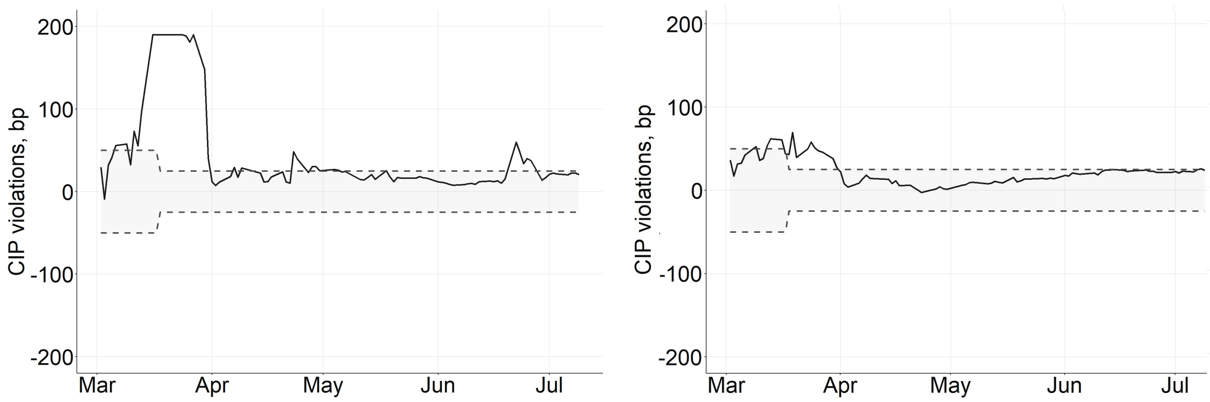
	Difference-in-difference estimates							
	Dollar vs. Non-Dollar Pairs				*Affected vs. Unaffected Tenors*			
	Volume, log		Market share, %		Volume, log		Market share, %	
	(1) Sell, log	(2) Buy, log	(3) Sell, %	(4) Buy, %	(5) Sell, log	(6) Buy, log	(7) Sell, %	(8) Buy, %
SwapLines	-0.19	-0.07	-0.01^{***}	0.003^{**}	-0.19^{***}	0.03^{***}	-0.01^{***}	0.01^{***}
	(0.12)	(0.17)	(0.002)	(0.001)	(0.01)	(0.01)	(0.001)	(0.0004)
isUSD	5.31^{***}	5.36^{***}	0.01^{***}	0.03^{***}				
	(0.03)	(0.04)	(0.0005)	(0.001)				
IsAffected					0.08^{***}	0.20^{***}	-0.01^{***}	-0.01^{***}
					(0.01)	(0.003)	(0.0002)	(0.0002)
β_{DD}	0.57^{***}	-0.06	0.02^{***}	-0.01^{***}	0.44^{***}	-0.05^{***}	0.01^{***}	-0.02^{***}
	(0.11)	(0.14)	(0.001)	(0.001)	(0.01)	(0.01)	(0.001)	(0.001)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Currencies	4	4	4	4	4	4	4	4
Tenors	7	7	7	7	8	8	8	8
Obs.	4,397	4,256	4,397	4,256	2,208	2,208	2,208	2,208
Adj. R^2	0.77	0.59	0.07	0.30	0.37	0.66	0.56	0.65

Table 5: Difference in difference regression estimates. Columns (1) to (6) report the results of a difference-in-difference-in-differences (DDD) estimation whereby β_{DDD} is the coefficient of interest $SwapLines : isUSDJPY : isJP$ and shows whether more affected banks borrow or lend more during the swap line period in a currency pair where the price ceiling is violated (USDJPY). Columns (7) to (10) report the results of a difference-in-difference (DD) estimation whereby β_{DD} is the coefficient of interest $SwapLines : isUSD$ and shows whether borrowing or lending occurred more in dollar than non-dollar pairs that involve the yen, effectively comparing EURJPY, CHFJPY, GBPJPY and USDJPY vis-a-vis each other. Data is daily. Standard errors are clustered by time. The superscripts $***$, $**$ and $*$ indicate significance at 1%, 5% and 10% significance level respectively.

5.1.3. What drives swap line dollar supply?

As discussed in Section 3, an increase in U.S. dollar supply in FX swaps by non-U.S. banks does not, by itself, distinguish between arbitrage and precautionary motives, as both imply a positive response to the basis. The key difference lies on the intensive margin: arbitrage implies a discrete change in the slope of supply when the basis exceeds the arbitrage ceiling. If banks engage in swap line arbitrage, FX swap supply should exhibit a kink at this threshold, consistent with Proposition 4. I now tests that prediction empirically. Following Bahaj and Reis (2021), I define the arbitrage threshold as the point where the cross-currency basis exceeds the no-arbitrage ceiling. Ignoring shadow costs ψ for simplicity, swap line arbitrage is feasible when the following inequality holds, where χ_t is the (inverse of the) CIP basis, $i_t^\$$ the swap line dollar rate, i_t the domestic funding rate, i_t^{v*} the foreign central bank's deposit rate, and i_t^{p*} the foreign OIS reference rate:

$$|\chi_t - i_t^\$ + i_t - i_t^{v*} + i^{p*}| > 0 \tag{24}$$



(a) 1W USDJPY CIP deviations

(b) 1Y USDJPY CIP deviations

Fig. 4: 1Y vs. 1W USDJPY CIP basis (Bloomberg) vs. no-arbitrage-implied CIP ceiling bounds (author's calculations). Dashed red lines refer to the upper and lower bound of the swap line-implied ceiling; shaded ribbon thus refers to the area of CIP violations χ_t that do not violate the price ceiling: $(i_t - i_t^S) + (i_t^{v*} - i_t^{p*}) \leqslant \chi_t \leqslant (i_t^S - i_t) + (i_t^{p*} - i_t^{v*})$. Data is daily from March 1 until June 30, 2020.

Figure 4 plots the inverse[22] of the 1W and 1Y USDJPY basis (solid line) against the no-arbitrage bounds (dotted lines) from March to June 2020. These bounds are symmetric and given by $[(i_t - i^\$t) + (i^{v*}t - i^{p*}t); (i^\$t - i_t) + (i^{p*}t - i^{v*}t)]$. As swap lines are only available at short tenors, only the

[22] By market convention, the CIP basis equation would reflect a negative basis; here, for simplicity, the inverse of the basis is plotted, with a higher value referring to U.S. dollar becoming more expensive

1W maturity is relevant for arbitrage. For both tenors, the basis typically remains within bounds but occasionally tests them.[23] Episodes where the basis nears or hits the ceiling likely reflect persistent non-bank demand for dollars in Asia (Aldasoro, Cabanilla, Disyatat, Ehlers, McGuire, and Goetz von, 2020), time zone misalignments with major FX hubs (Bahaj and Reis, 2021), Japan's low policy rates, or unobserved shadow costs. Similar charts for other currency pairs appear in Appendix E. A binding ceiling suggests that arbitrage has eliminated profit opportunities; conversely, if prices remain within bounds, arbitrage is unlikely.

I then test whether domestic banks' dollar supply exhibits a kink on days when the no-arbitrage ceiling binds. USDJPY is central to this test, as it is the only swap line-eligible currency where the ceiling was consistently tested—or exceeded—after March 18. If arbitrage were driving supply, this segment should reveal it. Results are reported in Appendix L. Overall, I find no significant kink in supply when the threshold is crossed (i.e. no evidence of an increase in supply when *SwapLines**IsViolated == 1*), which suggests that the observed increase in dollar provision is more consistent with precautionary motives than ex-ante arbitrage.

5.2. Additional results

5.2.1. Dollar supply across jurisdictions during COVID-19

The previous section documented an increase in net U.S. dollar supply by Japanese banks that borrowed from the Bank of Japan during the COVID-19 crisis. I now examine whether a similar abnormal change in dollar lending is observable in other jurisdictions during the same period. To this end, I estimate the following ordinary least squares panel regression: $Net_{t,i} = \beta_1 \cdot SwapLines + \beta_2 \cdot USDJPY + \beta_3 \cdot SwapLines \cdot USDJPY + \alpha_i + \gamma_t + \epsilon_t$, where $Net_{t,i}$ denotes net (buy minus sell) dollar borrowing for currency pair i by bank group t, *SwapLines* is a dummy equal to 1 from March 23 to June 30, 2020 and 0 otherwise, and $USDJPY$ is a dummy equal to 1 for the dollar-yen currency pair and 0 for other pairs. Fixed effects α_i and γ_t control for counterparty and time variation, respectively. I estimate this regression separately for each non-U.S. bank nationality group (columns (1) to (5)) and for the full sample (column (6)). Table I presents the results. I find a negative and statistically significant coefficient on β_3 for domestic Japanese banks,

[23] The market price may breach the ceiling if arbitrageurs face additional shadow costs ψ, omitted here for simplicity.

consistent with elevated net dollar lending in USDJPY during the swap line period. In contrast, β_1 is not significant for other currency pairs or other bank groups, in line with the theoretical expectations outlined in Section 3.

6. Conclusion

Although the Federal Reserve's swap lines represent its largest liquidity facility, policymakers still lack a full understanding of how they affect offshore U.S. dollar borrowing costs. This paper provides three new insights into this mechanism. First, I show that trade settlement records offer a novel lens to study agent positioning in the FX swap market, complementing existing studies that rely on more granular but less globally representative data. I reveal that, despite often being portrayed as an offshore market largely outside the U.S., global FX swap trading is dominated by U.S. banks, which act as market makers in dollar liquidity. Second, I provide causal evidence that swap lines reduce the net order flow absorbed by U.S. banks, which in turn lowers effective spreads for the real economy. Third, I find that swap lines ease offshore borrowing costs by shaping both non-U.S. banks' dollar demand and supply, rather than demand alone. These findings carry important policy implications. When U.S. dealers face balance sheet constraints, meeting imbalanced FX swap demand through repo markets or even standard Federal Reserve facilities can be costly, since both expand the balance sheet. Swap lines are effective in part because the Federal Reserve can indirectly rely on non-U.S. banks to transmit dollar liquidity off balance sheet into private markets. In this way, public dollar liquidity provided by central banks requires the intermediation of private banks to be most effective.

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Appendix A

The following tables demonstrate that our FX swap dataset closely mirrors the patterns observed in the BIS Triennial Survey (Bank for International Settlements, 2022). Table ?? contrasts our daily turnover data with BIS figures for the survey month of April in each respective year, while Table ?? compares the maturity distribution of swaps in our dataset with that reported in the BIS survey.

Table A1: Volume, CLS vs. BIS

	CLS	BIS	CLS as % of BIS
April '13	740.8	2'240	33.1%
April '16	805.6	2'378	33.9%
April '19	986.9	3'198	30.9%

Table A2: Maturity breakdown vis-à-vis BIS Triennial Survey

	Maturity	CLS Share	BIS Share
	<= 7 days	69.3%	70.2%
April '13	> 7 days, <= 1 year	30%	25.9%
	> 1 year	0.7%	3.9%
	<= 7 days	64.2%	68.7%
April '16	> 7 days, <= 1 year	35.2%	30%
	> 1 year	0.6%	1.3%
	<= 7 days	61.0%	64.4%
April '19	> 7 days, <= 6 months	36.8%	33.1%
	> 6 months	2.2%	2.5%

Appendix B

Region	**G-SIB**
United States	Bank of America
	Bank of New York Mellon
	Citigroup
	Goldman Sachs
	JP Morgan Chase
	Morgan Stanley
	State Street
	Wells Fargo
Eurozone	BNP Paribas
	BPCE Groupe
	Crédit Agricole
	Deutsche Bank
	ING Bank
	Santander
	Société Générale
	UniCredit
United Kingdom	Barclays
	HSBC
	Standard Chartered
Japan	Mitsubishi UFJ FG
	Mizuho FG
	Sumitomo Mitsui FG
Switzerland	Credit Suisse Groupe
	UBS
ROW (China)	Agricultural Bank of China
	Bank of China
	China Construction Bank
	Industrial and Commercial Bank of China

Table B1: List of G-SIBs in our dataset, by region. Banks were classified as G-SIBs if they were designated such at least 7 times during the years 2012-2021 according to the List of Global Systemically Important Banks published annually by the Financial Stability Board.

Appendix C

The figure below plots the Federal Reserve swap line amounts over time and across the corresponding recipient central bank.

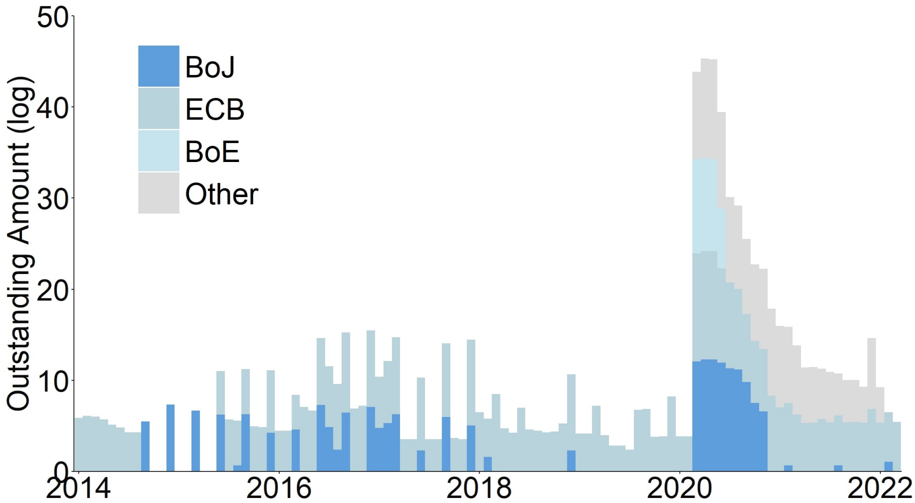

Fig. C1: Federal Reserve U.S. dollar liquidity swap line amounts oustanding, in logs. Each bar represents monthly average values and is measured in USD. Data created by the author using data from the New York Fed.

Appendix D

The table below plots the net open outstanding FX swap positions per largest U.S. dollar currency pairs.

		Net open position (in tn of USD)						
		EUR	JPY	GBP	CHF	Other	Net	Net, %
Banks	US	-0.18	0.07	-0.02	-0.02	-0.08	-0.25	4.0 %
	EZ	0.03	-0.15	-0.04	-0.08	-0.09	-0.33	11.8 %
	UK	-0.02	-0.05	-0.04	-0.03	-0.05	-0.19	7.2 %
	CH	0.01	-0.03	-0.01	0.06	-0.00	0.03	7.0 %
	JP	-0.08	0.23	-0.02	-0.00	-0.03	0.09	29.8 %
	Other	-0.09	-0.15	-0.08	-0.01	-0.02	-0.36	12.4 %
	Total	-0.33	-0.09	-0.21	-0.09	-0.28	-1.01	5.3 %

Table D1: FX swap open (outstanding) *net* volume (buy minus sell), 2012-22 daily average, in tn of USD. A positive (negative) number indicates US dollar net borrowing (net lending) in the FX swap market at the near leg. Percentages refer to the average net position relative to total gross position, averaged across time and all USD currency pairs.

Appendix E

The figure below plots the 1W CIP basis in comparison to the no-arbitrage-implied CIP ceiling bounds for the largest U.S. dollar currency pairs.

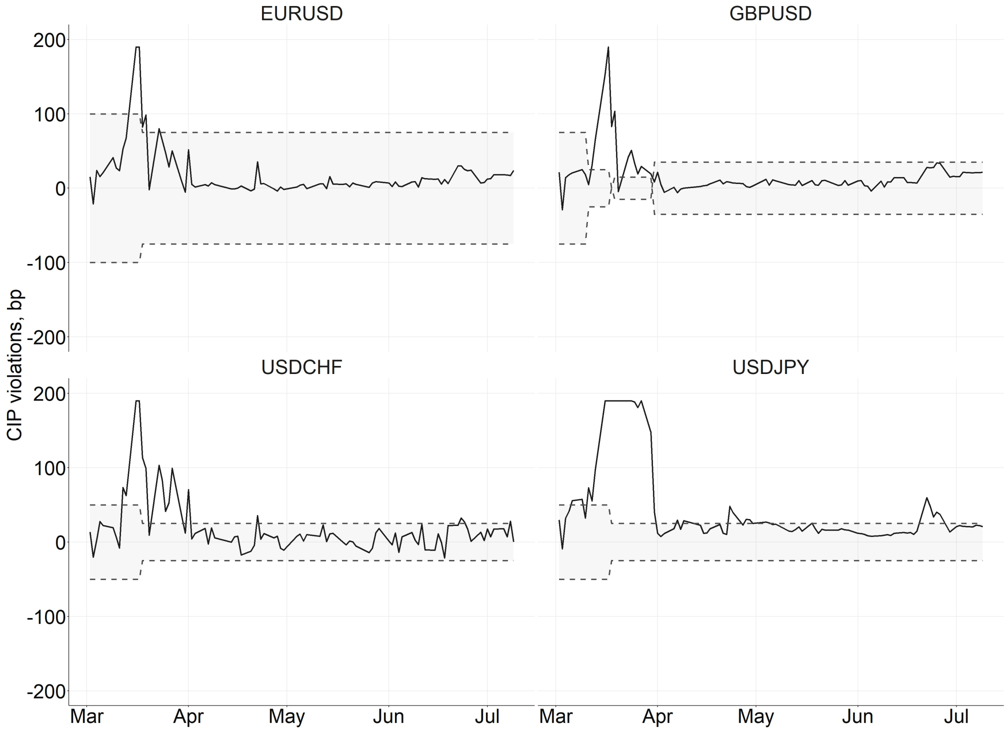

Fig. E1: 1W CIP basis (Bloomberg) vs. no-arbitrage-implied CIP ceiling bounds (author's calculations). Dashed red lines refer to the upper and lower bound of the swap line-implied ceiling; shaded ribbon thus refers to the area of CIP violations χ_t that do not violate the price ceiling: $(i_t - i_t^S) + (i_t^{v*} - i_t^{p*}) \leqslant \chi_t \leqslant (i_t^S - i_t) + (i_t^{p*} - i_t^{v*})$. Data is daily from March 1 until June 30, 2020.

Appendix F

In the table below, I present regression results across quintiles of the HKM distribution following He et al. (2017), ranging from the first quintile (below the 20th percentile) to the fifth quintile (above the 80th percentile). The dependent variable is the spread between U.S. dollar sell and buy FX swap transaction prices charged by U.S. banks, regressed on gross trading volume.

	US bank Sell-minus-Buy transaction price spread				
	HKM^{Q1}	HKM^{Q2}	HKM^{Q3}	HKM^{Q4}	HKM^{Q5}
	(1)	(2)	(3)	(4)	(5)
Gross volume	-0.03^{***}	-0.04^{***}	-0.04^{***}	-0.03^{***}	-0.04^{***}
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
Bid-ask spread	0.04	0.05	0.20^{***}	0.28^{***}	0.19^{***}
	(0.05)	(0.06)	(0.05)	(0.04)	(0.04)
Curr-Tenors	4-4	4-4	4-4	4-4	4-4
Constant	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	26,629	26,585	26,751	26,611	26,654
Adjusted R^2	0.25	0.28	0.28	0.26	0.27
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$		

Table F1: Panel regressions based on dealer capacity utilization as measured by He, Kelly, and Manela (2017), who overlap with the largest market-makers identified in the Euromoney (2020) FX survey. The regressions report results across quintiles of the HKM distribution, from the first quintile (below the 20th percentile) to the fifth quintile (above the 80th percentile), using the spread between Sell and Buy FX swap transaction prices charged by U.S. banks as the dependent variable on Gross (sell plus buy) volume. Controls include the bid-ask spread, VXY, and TED spreads. Time-fixed effects comprise quarter-cross indicators, as well as year and month fixed effects. Standard errors are clustered at the date level. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix G

In the figure below, I plot the estimated slope coefficient of the U.S. bank sell-minus-buy transaction price spread on U.S. bank sell-minus-buy trading volume, by dealer constraint percentiles. The dealer constraints measure is based on He et al. (2017), who provide a daily time series for primary dealers that includes all major U.S. banks. The sloe coefficient is estimated from a univariate regression of the following form: $Spread_{t,i,k} = \beta \cdot Net_{t,i,k} + \alpha_i + \gamma_t + \tau_k + \epsilon_t$. The ordinary least squares (OLS) coefficient is represented by a circle, which is filled if statistically significant at the 90% level and empty otherwise. The blue shaded area refers to the coefficient value at the the 5% and the 95% confidence level. Results show that the spread-volume slope increases across constraint quintiles.

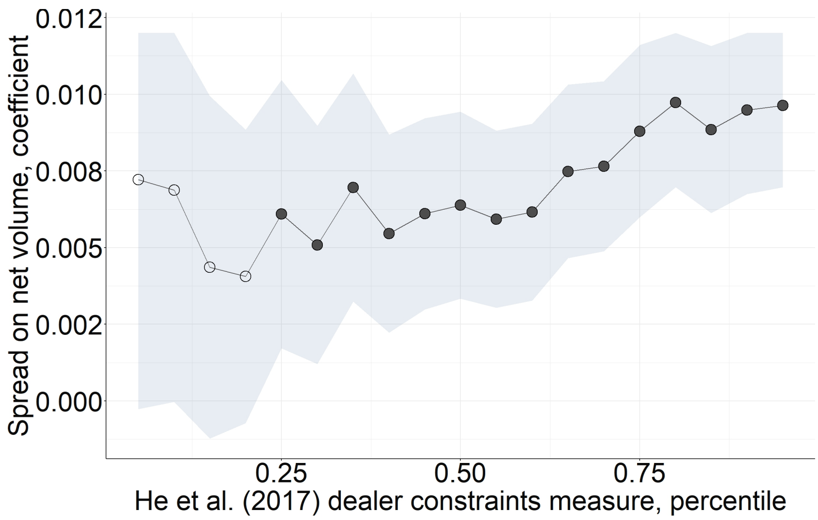

Fig. G1: Estimated slope coefficient of the U.S. bank sell-minus-buy transaction price spread on U.S. bank sell-minus-buy trading volume, by dealer constraint percentiles. The dealer constraints measure is based on He et al. (2017), who provide a daily time series for primary dealers that includes all major U.S. banks. The sloe coefficient is estimated from a univariate regression of the following form: $Spread_{t,i,k} = \beta \cdot Net_{t,i,k} + \alpha_i + \gamma_t + \tau_k + \epsilon_t$. The ordinary least squares (OLS) coefficient is represented by a circle, which is filled if statistically significant at the 90% level and empty otherwise. The blue shaded area refers to the coefficient value at the the 5% and the 95% confidence level.

Appendix H

The table below reports the results of ordinary least squares panel regressions of the spread between sell and buy FX swap transaction prices charged by U.S. banks on net (sell minus buy) U.S. bank trading volume. The analysis is split based on whether the spread between overnight repo rates and the interest rate on reserves (IOR) is negative (columns (1) and (3)) or positive (columns (2) and (4)), as motivated by the work of Correa et al. (2020) and Copeland et al. (2025). The coefficient on net volume is larger on days when reserves are less ample (0.02) than when they are more abundant (0.01), suggesting that U.S. banks are less willing to maintain an imbalanced sell position in FX swaps under tighter reserve conditions.

	US bank Sell-minus-Buy spread			
	GCF-IOER spread:		SOFR-IOER spread:	
	$\leqslant 0$	> 0	$\leqslant 0$	> 0
Sell-minus-Buy volume	0.01***	0.02***	0.01***	0.02***
	(0.004)	(0.004)	(0.004)	(0.01)
Bid-ask spread	0.28***	0.38***	0.45***	0.36***
	(0.03)	(0.06)	(0.05)	(0.08)
VXY	0.81***	0.36*	0.42**	0.98***
	(0.23)	(0.25)	(0.20)	(0.35)
Quarter.Cross	0.19***	0.15***	0.11**	0.16**
	(0.04)	(0.05)	(0.05)	(0.07)
Curr-Tenors	4-4	4-4	4-4	4-4
Controls	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Observations	59,879	49,744	44,483	18,238
Adjusted R^2	0.27	0.25	0.28	0.25
Note:	*p<0.1; **p<0.05; ***p<0.01			

Table H1: Ordinary Least Squares panel regressions of the spread between Sell and Buy FX swap transaction prices charged by U.S. banks on Net (sell minus buy) volume. The analysis is split by whether the spread between overnight repo rates and the interest rate paid on reserves (IOR) is negative (columns (1) and (3)) or positive (columns (2) and (4)). A positive repo-IOR spread signals reduced ability of U.S. banks to unwind reserve balances. Controls include the bid-ask spread, VXY, and TED spreads. Time-fixed effects comprise quarter-cross indicators, as well as year and month fixed effects. Standard errors are clustered at the date level. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix I

The table below reports the results of ordinary least squares panel regressions of net dollar sales during the swap line period across jurisdictions.

	Dep: Net dollar sales in the interbank market, bn of USD					
	JP banks	EZ banks	UK banks	CH banks	Other banks	Total
	(1)	(2)	(3)	(4)	(5)	(6)
SwapLines	0.69	−1.32	−0.14	−0.62*	1.18	−0.04
	(0.66)	(1.14)	(0.38)	(0.33)	(0.83)	(0.33)
USDJPY	38.36***	−33.85***	−6.39***	−1.99	−33.46***	−7.47
	(0.94)	(6.43)	(3.21)	(1.25)	(2.63)	(11.32)
SwapLines:USDJPY	−15.08***	−1.86*	3.40***	1.92***	0.21	−2.28
	(0.09)	(1.03)	(0.21)	(0.57)	(0.60)	(2.99)
Constant	No	No	No	No	No	No
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Entity FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustered s.e.	Yes	Yes	Yes	Yes	Yes	Yes
Obs (in ’000)	112.1	112.1	112.1	112.1	112.1	563.3
Adjusted R^2	0.48	0.07	0.04	0.03	0.22	0.02
Note:				*p<0.1; **p<0.05; ***p<0.01		

Table I1: Panel regressions of net dollar sales during the swap line period. For simplicity, only the coefficients that involve *SwapLines* are reported. Panel regressions report the within R^2. The superscripts $***$, $**$ and $*$ indicate significance at the 1%, 5%, and 10% significance levels respectively.

Appendix J

The table below reports the results of the following ordinary least squares panel regression:

$$Sell_{t,i} = \beta_0 + \beta_1 \cdot SwapLines + \beta_2 \cdot IsJPY + \\ + \beta_{DD} \cdot SwapLines \cdot IsJPY + \theta \cdot \mathrm{X}_{i,t} + \epsilon_t. \quad (J.1)$$

where *Sell* (robustness: *Buy*) refers to U.S. dollar sales at the near leg of the FX swap contract and is measured in log of billions of USD, *SwapLines* is a dummy equal to one from March 23 to June 30, 2020, *IsUSDJPY* is a dummy that equals 1 for USDJPY and 0 for EUR-, CHF- and GBP-JPY, X refers to control variables such as the VIX and TED spreads, and β_{DD} is the difference-in-difference coefficient of interest.

	Dollar vs. Non-Dollar Pairs			
	Up to 3M		Above 3M	
	(7) Sell, log	(8) Buy, log	(9) Sell, log	(10) Buy, log
β_{DD}	0.57***	−0.06	0.18	−0.34***
	(0.11)	(0.14)	(0.17)	(0.13)
Constant	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Currencies	4	4	4	4
Tenors	7	7	1	1
Obs.	4,397	4,256	4,072	3,758
Adj. R^2	0.77	0.59	0.61	0.69

Table J1: Difference-in-difference regression estimates. Columns (7) to (10) report results for a DD specification in which β_{DD} captures whether borrowing or lending behavior differs between dollar and non-dollar pairs involving the yen. This includes EURJPY, CHFJPY, GBPJPY, and USDJPY. Data are daily; standard errors are clustered by time. Superscripts $***$, $**$, and $*$ denote significance at the 1%, 5%, and 10% levels, respectively.

Appendix K

The table below reveals that the spread-volume slope increases monotonically across dealer constraint quintiles. In the most constrained quintile (Q5), a unit increase in net USD demand raises the sell-minus-buy spread by 3 basis points (significant at the 1% level), compared to only 1 basis point in the least constrained quintile (Q1). This pattern supports the prediction that dealers seek compensation for shadow balance sheet costs when constraints become more binding.

	US bank Sell-minus-Buy transaction price spread				
	HKM^{Q1}	HKM^{Q2}	HKM^{Q3}	HKM^{Q4}	HKM^{Q5}
	(1)	(2)	(3)	(4)	(5)
Sell-minus-Buy volume	0.01**	0.01*	0.02**	0.03***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Bid-ask spread	0.05*	0.05*	0.19***	0.28***	0.19***
	(0.05)	(0.06)	(0.05)	(0.04)	(0.04)
Curr-Tenors	4-4	4-4	4-4	4-4	4-4
Constant	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	26,629	26,585	26,751	26,611	26,654
Adjusted R^2	0.25	0.27	0.27	0.26	0.27
Note:			*p<0.1; **p<0.05; ***p<0.01		

Table K1: Subsample regressions of the spread between Sell and Buy FX swap transaction prices charged by U.S. banks on net (sell-minus-buy) volume, splitting the sample by dealer constraint quantiles based on the capacity utilization measure of He, Kelly, and Manela (2017), which largely overlaps with the largest market makers identified in the Euromoney (2020) FX survey. Currency, tenor and counterparty fixed effects are included. Controls include the daily bid-ask spread, VXY, and TED spreads as well as quarter-cross indicators and year and month dummies. Standard errors are clustered at the date level. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Appendix L

I test whether domestic banks' dollar supply in USDJPY exhibits a kink on days when the no-arbitrage ceiling is violated in the weeks following COVID-19 in 2020. If arbitrage were driving supply, this segment should reveal it. Overall, I find no significant kink in supply when the threshold is crossed (i.e. no evidence of an increase in supply when *SwapLines*IsViolated == 1*), which suggests that the observed increase in dollar provision is more consistent with precautionary motives than ex-ante arbitrage.

	Difference-in-difference estimates					
	1W tenor				*1Y tenor*	
	Volume, log		Market share, %		Market share, %	
	(1) Sell (log)	(2) Buy (log)	(3) Sell (%)	(4) Buy (%)	(5) Sell (%)	(6) Buy (%)
SwapLines	0.50***	−0.57***	0.03***	−0.01***	0.003	0.004
	(0.07)	(0.08)	(0.003)	(0.001)	(0.002)	(0.003)
IsViolated	0.002	−0.0000	−0.001	0.0003	−0.004***	−0.005**
	(0.03)	(0.04)	(0.001)	(0.001)	(0.001)	(0.002)
SwapLines:IsViolated	−0.16	0.14	−0.01*	0.002	0.0002	0.0003
	(0.10)	(0.14)	(0.01)	(0.002)	(0.004)	(0.01)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,665	1,665	1,665	1,665	879	879
Adjusted R^2	0.23	0.15	0.20	0.14	0.03	0.02
Note:						*p<0.1; **p<0.05; ***p<0.01

Table L1: Ordinary least squares regressions of domestic banks' trading volume in dollar-yen FX swaps on an indicator for CIP ceiling violations in the spirit of Bahaj and Reis (2021). The analysis is split by buy and sell volumes. Controls include the bid-ask spread, VXY, and TED spreads. Time-fixed effects comprise quarter-cross indicators, as well as year and month fixed effects. Newey-West standard errors are reported. Superscripts ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Sample is 2018 to 2022.