

Swap Line Arbitrage^{*}

Pēteris Klok[†]

June 4, 2025

Abstract

While Federal Reserve swap lines have become a reliable policy tool for easing surges in covered interest rate deviations during times of U.S. dollar funding stress, their transmission to the FX market remains only partially understood, largely due to lack of globally representative data on trading activity. Using novel global settlement data, I conduct the first comprehensive study of agent positioning in OTC FX swaps around swap line take-ups and provide two main results. First, swap lines lower U.S. dollar borrowing cost not only through a reduction in non-U.S. bank *demand*, as commonly thought, but also through an increase in *supply* (arbitrage lending). Second, I find that U.S. banks play a central role in this process. A simple conceptual framework linking limits to arbitrage capital with U.S. bank balance sheet constraints shows that any scaling back of swap lines—such as through an abrupt policy shift in the U.S.—would have unintended negative consequences for U.S. banks’ ability to provide dollar liquidity in the FX market.

Keywords: Central bank swap lines, Covered interest parity, Global funding markets, Intermediary constraints.

JEL classification: F31, G12, G15.

^{*} I am especially thankful to Angelo Ranaldo (principal adviser) as well as Andrea Barbon, Can Gao, Cara Stromeyer, Carlos Cañon, Claudio Borio, Eddie Gerba, Edouard Mattille, Gerardo Ferrara, Marco Gortan, Martin Brown, Ming Zeng, Pasquale Della Corte, Patrick McGuire, Petros Katsoulis, Ricardo Correa, Ricardo Reis, Robert Czech, Vladyslav Sushko and Wenxin Du for useful comments and discussions, and audiences at the BIS–CEPR–Gerzensee–SFI Conference on Financial Intermediation (poster session, 2025), IFABS-Oxford (2025), the GPEF PhD Day at the University of St.Gallen (2024), the Young Swiss Economists Meeting (poster session, 2025), the Annual Meeting of the Swiss Society for Financial Market Research (poster session, 2025) and the Fourth PhD Workshop in Money and Finance organized by the Sveriges Riksbank and the Center for Monetary Policy and Financial Stability at Stockholm University (2025). This paper is further scheduled to be presented at the IBEFA-WEAI Summer Meeting (2025), the Third Durham Conference for Finance Job Market Papers (2025), and SFI Research Days (2025). I further thank Vladimir Visipkov at the Continuous Linked Settlement Group (CLS) for help in constructing the dataset. This work did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. All remaining errors are my own.

[†] Send correspondence to Peteris Klok, University of St. Gallen, Switzerland. E-mail: peteris.klok@unisg.ch.

1. Introduction

Access to uninterrupted U.S. dollar funding in times of stress is crucial to prevent financial stability episodes given the outsize role that the reserve currency serves in global trade and finance. In terms of policy response, Federal Reserve swap lines have become the main tool to ease the cost of U.S. dollar borrowing in synthetic funding markets. The size of swap lines is large and growing, with the combined network of U.S. dollar liquidity lines reaching up to 20% of the world's GDP. However, policymakers still have surprisingly little empirical evidence as regards to the nature of the pass-through mechanism of an active swap line (an agreement between two central banks) to the private markets (contracts involving commercial banks and non-bank customers), largely due to a lack of globally representative and granular data on the over-the counter (OTC) FX swap market.

This paper fills the gap by leveraging a bespoke high-frequency dataset from Continuous Linked Settlement (CLS), which offers unparalleled global coverage of settled FX swap transactions and thereby enables the most comprehensive analysis of quantities and prices in the literature to date. Two main results emerge. First, by analyzing agent positioning in the synthetic U.S. dollar funding market across geographical jurisdictions, currencies and tenors over the past decade, I present evidence that Federal Reserve swap lines help ease offshore U.S. dollar borrowing cost not only through a reduction in non-U.S. bank *demand* for the dollar in FX swaps (substitution channel), which is the commonly known pass-through mechanism, but also through an increase in non-U.S. bank dollar *supply* (arbitrage channel). To identify the role of swap lines, I examine COVID 2020 as well as quarter-end reporting periods, which serve as important historical market stress episodes. The intuition is that a swap line arbitrage trade is unlikely to be attractive during normal times due to a penalty rate imposed by the central bank, but may become profitable in periods of market stress. I find that in segments of the market where the price of the U.S. dollar exceeded the threshold for swap line arbitrage during these episodes, up to 25% of the Federal Reserve's swap line take-up was intermediated back into the FX market. Whereas prior literature has predominantly focused on the effects of foreign bank demand for the U.S. dollar, this work explores the supply side. By uncovering the role of foreign banks as willing arbitrageurs in the FX swap market, I paint a more complete picture of the various swap line pass-through mechanisms

at play, thereby adding to our understanding of this critical policy tool.

Second, I leverage the granularity of the settlement data and *follow the dollar*, tracing who ultimately receives swap line liquidity beyond the initial recipient banks. In doing so, I add a novel layer of analysis that has not yet been explored in the scarce but growing empirical literature on swap lines (Ferrara, Mueller, Viswanath-Natraj, and Wang, 2022). While my analysis shows that non-banks are the ultimate end-borrowers, as expected, it also reveals that swap line recipient banks appear to channel it to them partly through the hands of U.S. dealer banks. In particular, affected non-U.S. banks sell the dollars in the interbank market to U.S. banks, who play a central role in the global FX swap market matching end-customers, who consume dollar liquidity, with arbitrageurs, who provide it. This result is counter-intuitive, as the existing literature typically views non-U.S. banks either as borrowers of U.S. dollars for their own funding and hedging needs or as intermediaries borrowing in the inter-dealer market on behalf of clients. In either case, the presumed direction of dollar liquidity flows always 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, which supports the central intuition of this paper that non-US banks act as willing arbitrageurs in the FX swap market. I support this intuition with a simple model of trading to show why balance-sheet constrained U.S. banks may become willing borrowers of U.S. dollar in the FX swap market even if it involves paying the cross-currency basis.

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-US bank access to U.S. dollar liquidity matter for macroeconomic outcomes (CGF, 2020) as well as price efficiency in the FX market (Ivashina, Scharfstein, and Stein, 2015, Cenedese, Della Corte, and Wang, 2021). This study provides new evidence of how such frictions hinder the ability of foreign banks to arbitrage deviations from the law of one price, that is, deviations from covered interest rate parity (CIP). On the other hand, I contribute to the literature on how central bank swap lines affect pricing in the FX market (Bahaj and Reis, 2021, Goldberg and Ravazzolo, 2021, Ferrara et al., 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 virtually ignored 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). U.S. banks play a critical role in supporting

an efficient functioning of the FX market, bringing together parties that wish to trade and share risks. In this paper, I argue that the ability of U.S. banks to provide U.S. dollar liquidity to non-banks 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-US bank access to the U.S. dollar is impaired.

The paper proceeds in four main steps. 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. 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. 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 only a locational view, and would thereby classify J.P. Morgan's London branch as a UK entity, making it harder to identify the role of U.S. banks in global market making.¹ Finally, to differentiate dollar demand and supply effects, I classify each trade into dollar borrowing or lending. That is, trades that result in dollar cash inflows at the near leg of the contract are flagged as dollar purchases; in contract, those that result in dollar cash outflows are classified as sales. Separating 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.

Second, I employ the newly constructed data set to provide novel empirical evidence for a swap line arbitrage lending channel by foreign banks in times of stress. To do so, I examine two important historical stress episodes, namely, COVID 2020 and quarter-end reporting periods. While a swap line arbitrage trade is unlikely to be attractive during normal times due to a penalty rate imposed by the central bank, it may become profitable in periods of stress if two conditions are simultaneously met: U.S. dollar borrowing costs must test the level at which swap line arbitrage

¹I 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 (ROW).

becomes profitable, and the arbitrageur must have access to central bank dollar operations. In this respect, COVID 2020 is a particularly important case-study as it marked the highest Federal Reserve swap-line take-up since the Great Financial Crisis. The episode nevertheless provides a challenge for an empirical study in terms of identification strategy. I overcome such identification challenges in two important ways. On the one hand, I exploit a unique quasi-natural experiment using treatment at the currency level. Specifically, I use the observation that while the U.S. dollar borrowing rate had returned to well within the bounds at which swap line arbitrage is no longer profitable for most dollar pairs immediately following the peak of the COVID crisis, it continued to test the no-arbitrage ceiling in the dollar-yen pair for several weeks after the peak of the crisis. This likely occurred both because of persistently high non-bank demand for U.S. dollar in Asia ([Aldasoro, Cabanilla, Disyatat, Ehlers, McGuire, and Goetz von, 2020](#)) as well as due to operational challenges in exploiting the swap line arbitrage trade due to time zone differences between Tokyo and the other major FX trading hubs ([Bahaj and Reis, 2021](#)).

On the other hand, I consider treatment at the banking group level. While access to local central bank dollar operations is locational in principle, which means that any foreign bank with an account at the Bank of Japan is eligible for swap lines, prior work has documented that it was the domestic Japanese banks who accounted for as much as 90% of the Bank of Japan's swap line take-up ([Akitaka, Nojima, Horikawa, Semba, and Shinozaki, 2020](#)). Even if these banks drew on swap lines motivated by precautionary hoarding reasons as suggested by [Aoki, Antoku, Shunsuke, Tomoyuki, and Shinichiro \(2021\)](#), they are nevertheless likely to have sought for ways to park this dollar funding at profit, including by lending it out short-term in the FX swap market. Using this episode in a difference-in-difference-in-difference (DDD) setting, I indeed find evidence for excess dollar lending and estimate that at least one quarter of the Bank of Japan's swap line take-up was ultimately transmitted to the private FX market through the hands of the affected banks.

As a robustness check, I also study quarter-end reporting episodes. Following the identification strategy of [Bahaj and Reis \(2021\)](#), whereby I compare days when swap lines are active with those when they are not, I find similar support for elevated dollar supply in the FX market by affected non-U.S. banks, albeit at lower levels than during the COVID episode.

Third, I turn to examining who receives such foreign bank U.S. dollar supply. Before turning to empirical evidence, I develop a simple conceptual framework to explain why it is conceivable

that U.S. banks might be among the list of willing borrowers of swap line funding — that is, why U.S. banks may be willing to pay a premium to obtain U.S. dollars in the FX swap market. 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 the importance of U.S. bank balance sheet constraints. 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 customer positions do not net out and the nature of an FX swap contract implies a cash outflow at the near leg of the trade. Crucially, my settlement data reveal that non-bank demand in FX swaps globally is indeed heavily imbalanced and tilted towards consuming U.S. dollar liquidity, a finding in line with prior research ([Bräuer and Hau, 2022](#)). In such a case, a U.S. bank faces a decision of how to fund its open position, and it has two options of how to do so. One method is to fund the position by borrowing U.S. dollars *outside* of the FX swap market, say via repo in U.S. money markets or via draining 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](#)) and more so than borrowing via FX swaps ([Kloks, Mattille, and Ranaldo, 2024](#)). Similarly, keeping excess reserves for the FX swap dollar intermediation business is costly from a balance sheet perspective. Moreover, draining down reserves has a natural limit due to the minimum reserve requirement ([Correa, Du, and Liao, 2020](#)). The alternative method for a U.S. banks, currently overlooked in the literature, is to attract funding *within* the FX swap market from other market participants, including from foreign banks. Because non-bank demand consumes dollar liquidity in total, a U.S. bank can do so by offering to *pay* a non-zero cross-currency basis to willing arbitrageurs, thereby attracting U.S. dollar liquidity and thus achieving a smaller net open position. 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. In such a setting, U.S. banks may become willing to pay a cost in the form of a cross-currency basis to avoid the balance sheet impact of funding outside of the FX market. It is in this scenario when a constrained U.S. bank benefits from an uninterrupted availability of arbitrage capital 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 by borrowing within the FX swap market. In fact, settlement data on U.S. bank global positions reveal quite a stunning picture: 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 monthly *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 those of non-U.S. banks. Over the last decade, non-banks have increasingly become large U.S. dollar *borrowers*, thereby having an increasingly negative net position with U.S. banks. Simultaneously, U.S. banks have run an increasingly positive net position with foreign (non-U.S.) banks, as seen in Panel (b), implying that non-U.S. banks *lend* U.S. dollar at the near leg of an FX swap contract. The correlation (over monthly changes) is extremely strong at -0.52% .² Moreover, U.S. banks' net total position is merely 4% of their gross total. Compiled with the fact that more than two-thirds of dollar volumes run through the hands of U.S. banks, I argue that U.S. banks effectively act as the global market makers in FX swaps and can thus be negatively affected by the (in)ability of foreign banks to act as willing counterparties in times of stress, which Federal Reserve swap lines help to alleviate.

Fourth, I show empirically that U.S. banks indeed have benefited from swap line arbitrage lending by foreign banks in times of stress. The above-mentioned conceptual framework presents testable hypotheses with respect to both quantities and prices charged by U.S. banks. My bespoke granular settlement data on U.S. banks' activity in FX swaps *per counterparty group* enables me to test these hypotheses directly using market data. For quantities, I show that parts of the excess supply by foreign banks was consumed by U.S. banks, and that such foreign bank flows negatively predict U.S. bank net position with non-U.S. banks. This holds true across various frequencies (daily, weekly, and monthly) as well as across currency pairs, even when I control for market-wide trading conditions. For prices, I estimate a linear probability model for the like-

²The correlation between daily changes with foreign banks vs. daily changes with non-banks amounts to -0.29% .

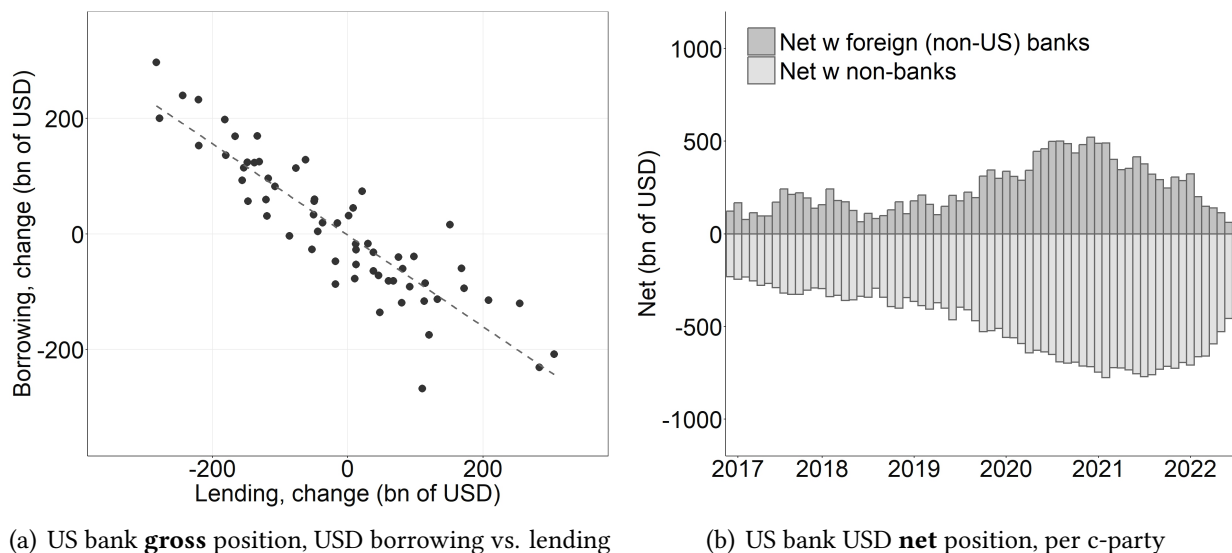


Fig. 1: US bank matched-book USD intermediation in the global FX swap market. Panel (a): Monthly change in U.S. bank USD borrowing vs. lending gross positions outstanding. Each dot refers to the monthly change across all tenors and U.S. dollar currency pairs. Panel (b): Monthly U.S. bank net USD position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

likelihood of CIP ceiling violations. This allows me to test whether swap line arbitrageurs offered prices closer to the no-arbitrage CIP ceiling compared to a control group during the 2020 COVID episode. Through a difference-in-differences analysis, I show causal evidence that the COVID period was characterized by a higher probability of CIP violations, as expected, but the likelihood of ceiling violations was lower when U.S. banks *borrowed* U.S. dollars from Japanese banks, which I previously identify as swap line arbitrageurs in the dollar-yen currency pair, compared to a control group of non-U.S. banks who had no access to swap lines. As an important counterfactual exercise, the result does not hold true for contracts where U.S. banks *sold* U.S. dollars at the near leg of an FX swap, which supports my mechanism since it was U.S. dollar lending– but not borrowing– that was attractive to a swap line arbitrageur.

Understanding the link between swap lines and the private FX swap market is important as it reveals the limited role of central banks in alleviating U.S. dollar funding pressures directly. In fact, I show that public dollar liquidity (central banks) requires the involvement of private banks (private dollar liquidity) for better effectiveness. The Federal Reserve delegates to other central banks the responsibility of providing dollars, given their expertise and positioning within their own jurisdictions. However, my results indicate that private banks within these jurisdictions are

better positioned to distribute U.S. dollars where they are most needed (through a lending channel) and where it is most advantageous (CIP basis). Private liquidity is thus crucial to achieve the Fed’s aim of easing private U.S. dollar borrowing conditions.

Related literature. I contribute to the sparse but growing empirical work on central bank swap lines (Rose and Spiegel, 2012, Goldberg and Ravazzolo, 2021, Choi and Ravazzolo, 2021). 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, while the effects on prices are well documented, the underlying pass-through mechanism remains insufficiently explored, as its analysis requires data on transaction volumes, which are not readily available for this OTC market. To date, the most compelling data source for addressing this gap is trade repository data collected by central banks. Ferrara et al. (2022) employ EMIR data and find evidence of substitution effects— namely, a reduction in U.S. dollar demand by banks who draw on Bank of England swap lines. Nevertheless, central bank trade repository data, as granular as it is, is inherently local, as it requires at least one counterparty to be a domestic (e.g., UK-based) entity, which underscores the need for more globally representative data to paint a more complete picture of the swap-line pass-through mechanisms. For this reason, a growing body of research relies on global FX 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, 2021), leaving the corresponding literature on the FX *swap* segment much less developed. Bräuer and Hau (2022) use settlement data to demonstrate that non-bank demand for FX derivatives helps explain the cross-section of currency returns. Kloks et al. (2023b) show that disaggregating settlement data by the geography of banking groups enables the separation of U.S. and non-U.S. banks, allowing researchers to link banks’ FX derivative positions to their balance sheet currency mismatches. Kloks et al. (2024) use this data to examine non-U.S. banks’ demand for U.S. dollars around regulatory reporting dates. I am the first to employ the CLS settlement data by geography to analyze the U.S. dollar *supply* of non-U.S. banks 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 FX 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, 2019](#), [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 e.g. [Ivashina et al. \(2015\)](#) and [Rime, Schrimpf, and Syrstad \(2022\)](#) emphasize credit quality as a key driver, showing that non-U.S. banks turn to FX swaps when confronted with creditworthiness shocks, such as during the Eurozone sovereign crisis. [Abbassi and Bräuning \(2020\)](#) and [Du, Strasser, and Verdelhan \(2025\)](#) identify regulatory reporting requirements as an additional driver of demand, demonstrating that FX hedge demand increases among banks subject to Basel III Leverage Ratio disclosure. [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 stand ready to exploit arbitrage opportunities created by a widening CIP basis and the availability of central bank 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 from the balance sheet treatment of U.S. repo transactions, rather than FX swaps themselves. I identify U.S. banks as the ultimate market makers in the FX swap market and demonstrate that when U.S. bank balance sheet constraints bind, U.S. banks may seek the opposite flow from non-U.S. arbitrageurs in off-balance sheet instruments such as FX swaps. 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 ("financiers") 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. Those with access to central bank swap lines face lower marginal

costs of dollar funding, which effectively increases their capacity to absorb FX risk. Swap line access can thus be modeled as a reduction in the financier’s risk aversion or constraint parameter, enabling them to respond more elastically to deviations from covered interest parity. Finally, my work builds on the findings of [Correa et al. \(2020\)](#) and [Copeland, Duffie, and Yang \(2025\)](#), 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 sheds light on the short-term U.S. dollar funding flows in response to swap line drawings. To do so, I use a bespoke data set on prices and volumes in the global FX swap market from Continuous Linked Settlement (CLS), the largest settlement firm in the world. This section describes the data in detail.

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

With its sheer size of around US\$ 3.8 trillion of global daily turnover ([Bank for International Settlements, 2022](#)), the FX swap market is the largest market in the world. However, obtaining representative data for this markets is notoriously difficult given the fragmented, over-the-counter nature of this segment. Trading occurs bilaterally and is dispersed throughout many exchanges, and relying on data from a single source may not be representative of the global landscape. My solution is to use data from CLS, the world’s largest multi-currency cash settlement system. CLS records the settlement of trades and thus allows U.S. to observe trades regardless of where or on what platform (if any) they were executed. As many if not all transactions require settlement,³ it is global settlement data that can yield a representative picture for U.S. dollar borrowing dynamics in the global FX swap market.

The data, which runs from from January 3rd, 2012 to June 30th, 2022 and is available at a daily frequency, show that, on an average day, market participants have a total of US\$ 12.7 trillion

³ There are some exceptions: for instance, CLS does not perform settlement for overnight swaps, the Chinese renminbi, or the Russian ruble. Moreover, a bank will not use CLS settlement when a customer has a deposit account with it (e.g., a retail investor using the banks’ wealth management services). Furthermore, institutions (e.g., hedge funds) with a prime brokerage arrangement with a dealer-bank are not settled through CLS.

worth of open FX swap contracts *outstanding*⁴ across 17 U.S. dollar currency pairs and 8 tenors⁵ (see summary statistics in Table 1). This captures at least 30% of the FX market according to BIS Triennial Survey estimates (Bank for International Settlements, 2019). Further comparison (see Appendix A) shows that CLS and BIS data display very similar figures when considering relative breakdowns by maturity and currencies, confirming that the data is highly representative of the global FX market. For further analysis of the FX swap market liquidity conditions using CLS data, see Klok, Mattille, and Ranaldo (2023a).

	Volume (in tn \$)	Trades (’000)	Volume (%)	Trades (%)
EURUSD	4.75	77,940	37.4	30.9
USDJPY	2.54	31,963	20.0	12.7
GBPUSD	1.66	30,401	13.1	12.0
USDCHF	0.54	10,346	4.2	4.1
Other dollar	3.20	101,893	25.2	40.3
Maturity <= 7 days	0.87	7,413	6.9	2.9
Maturity > 7 days	11.82	245,129	93.1	97.1
Bank to Bank	10.15	155,951	80.0	61.8
Bank to Non-Bank	2.54	96,591	20.0	38.2
Involves a G-SIB Bank	11.83	230,444	93.2	91.2
w/o a G-SIB Bank	0.86	22,098	6.8	8.8
Total	12.69	252,543	100	100

Table 1: FX swap outstanding open positions: 2012-2022 daily averages.

Importantly, I order three bespoke adjustments to CLS data for the purposes of this paper. First, I break down the data on open FX swap positions per *market participant nationality*. The rationale for doing so is to isolate U.S. banks from all other banks as well as to recognize that some bank nationality groups are affected by swap lines whereas others are not. Note that the *nationality* view, which I pursue in the subsequent analysis, is fundamentally different from the *residence* view. 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. While both perspectives offer comple-

⁴The data set allows U.S. to consider the *outstanding* amount of swaps active between certain counterparties. An FX swap is included on date t if its near-leg settlement date $\leq t$ and its far-leg settlement date is $> t$. The data set defines a trading as rolling over at 5 p.m. New York time, in line with FX convention.

⁵I assign swaps to a total of 8 tenor buckets designed to represent tom-next, spot-next, 1-week, 2-week, 1-month, 2-month, 3-month, and longer maturities.

mentary perspectives, it is the nationality view that recognises the importance of global financial intermediaries whose balance sheets go beyond national borders ([Bank for International Settlements, 2024](#)). As a result, I proceed to manually classify 4,170 banking entities per nationality based on the location of their headquarters. In case of ambiguity, I consulted the banks’ investor reports. I am able to perform the classification because CLS is aware of the identity of the entities conducting the trades. I choose to sort banks into six regions of the world: the US, the Eurozone, the UK, Switzerland, Japan, and all others combined. The choice is guided by, among other aspects, the standing swap lines that the Federal Reserve has established globally.

	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 2: 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.

Table (2) reports the summary statistics of the nationality data set across the six regions for all the banks in the sample and in comparison to data from the BIS. For robustness check, I obtained a sample of the data set based on the residence principle, which is the principle that guides the BIS Triennial Central Bank Survey of foreign exchange and OTC derivatives. As can be seen, both CLS and BIS coverage match closely based on the residence principle, both highlighting the role of London as the global hub for FX trading. In contrast, the nationality data set reveals significant and crucial differences as to who is actually trading in the market. While CLS FX spot data has been studied before by [Hasbrouck and Levich \(2019\)](#), [Ranaldo and Somogyi \(2021\)](#), and [Cespa, Gargano, Riddiough, and Sarno \(2021\)](#), I am, to the best of the knowledge, the first to study it in the context of U.S. dollar swap lines.⁶

Second, I manually classify banks according to whether they are a global systemically important bank (G-SIB) or not. This allows me to isolate global U.S. banks from smaller U.S. commercial

⁶ [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.

banks and thus analyse the role of large dealers who dominate the FX market (Somogyi, 2021). Appendix B lists the G-SIB banks in the data.⁷ As seen in Table (1), the FX swap market is indeed concentrated in the hands of a small set of global G-SIB dealer-banks, with more than 90% of positions globally involving a global dealer on at least one side of the trade.

Third, I request and obtain a similar breakdown for prices. Swap points ($F - S$) are the traded price and are therefore the natural target for what constitutes 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 . To the best of my knowledge, I am the first to study CLS FX swap prices using their settlement data.

Figure (2) depicts an example of prices charged by U.S. banks, sourced from the bespoke CLS data set and based on actual trades, in comparison to those sourced in Bloomberg, which are generally based on quote data. It shows the volume-weighted average swap points ($F - S$) for 1W EURUSD FX swaps traded on a given trading day by U.S. banks across all counterparties in comparison to the midquotes available on Bloomberg. As visible in the figure, CLS rates, albeit naturally more noisy, are generally well behaved and highly correlated with Bloomberg prices, providing confidence for their use in the subsequent analysis.

2.2. Federal Reserve data on liquidity swap operations

Federal Reserve swap lines have become the main policy tool to deal with U.S. dollar funding squeezes. They were first established in December 2007 and were subsequently heavily used in end of 2008, with the maximum drawdown amount peaking at $586bn$. In 2013, swap lines became a permanent policy tool and on a standing basis have been available to the Bank of England (BoE), the Bank of Japan (BoJ), the European Central Bank (ECB), the Swiss National Bank (SNB) and the Bank of China (BoC) ever since. However, swap lines were rarely tapped in the following years, reflecting a period of calmness around U.S. dollar scarcity. That changed in March 2020, which began the period of second-highest drawdowns in swap line history, reaching a maximum

⁷I classified banks as G-SIBs if they were designated as such at least 7 times during the years 2012-2021 according to the List of Global Systemically Important Banks (G-SIBs) published annually by the Financial Stability Board (FSB) in consultation with Basel Committee on Banking Supervision (BCBS) and national authorities. A welcome consequence of the classification system is that only Chinese banks are included in the ROW G-SIB bucket.

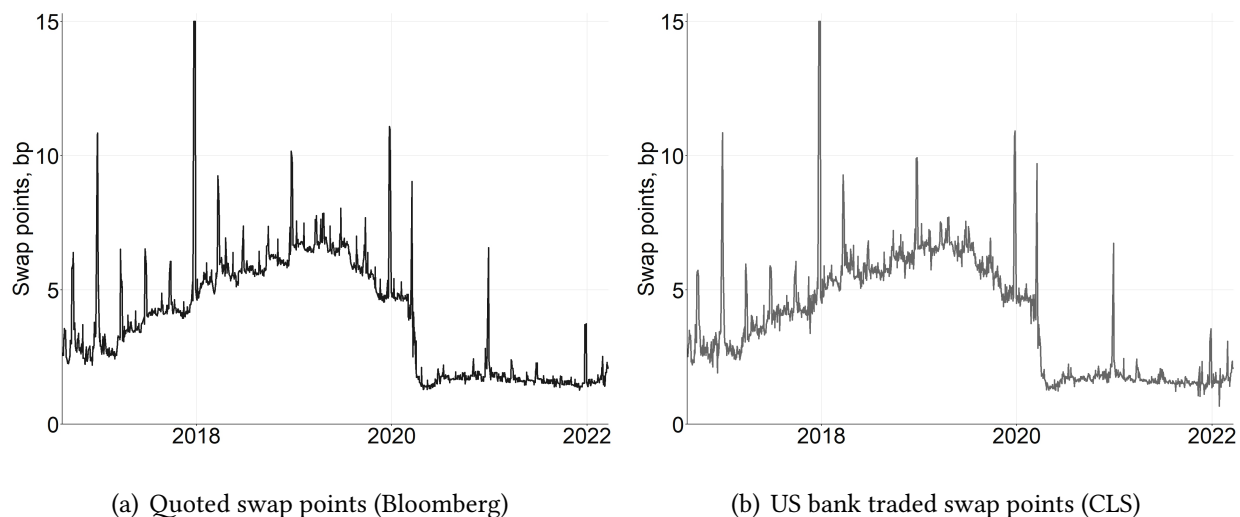


Fig. 2: EURUSD 1W swap points based on *quoted* swap points (Bloomberg, lhs) vs. volume-weighted daily average *traded* swap points charged by U.S. banks (CLS, rhs). Note that the values of both series are capped at 15 basis points for better visualisation purposes. Data is daily from January 2017 until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

peak of roughly $540bn$ or only slightly less than during the end of 2008 (see Appendix G, which plots the volumes of Federal Reserve swap lines over time and across the major central banks). The broad usage and effectiveness of swap lines lead to an expansion of bilateral swap lines to a worldwide network that covers more than a hundred bilateral agreements as of today. In this paper, I focus on Federal Reserve swap lines, since these refer to the liquidity provision of U.S. dollar, and restrict myself to the post-2008 period since the FX swap market data begins in 2012. I obtain daily data on swap line draw downs from the Federal Reserve Bank of New York.⁸ 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

⁸Data is accessible online at: <https://www.newyorkfed.org/markets/desk-operations/central-bank-liquidity-swap-operations>.

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 and the basis

An FX swap allows market participants to borrow the U.S. dollar using a foreign currency as collateral without being exposed to exchange rate risk. This is because an FX swap contract entails an initial cash flow at the near leg of the contract while simultaneously fixing the exchange rate at the far leg of the contract. It is often referred to as 'synthetic' U.S. dollar borrowing in contrast to 'direct' borrowing in U.S. money markets. The covered interest parity (CIP) principle states that the interest rate charged to borrow U.S. dollar synthetically should be the same as the cost of borrowing U.S. dollar directly:

$$F_{t,t+1} = S_t \cdot \left(\frac{1 + i_{t,t+1}^k}{1 + i_{t,t+1}^\$} \right) \quad (1)$$

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 $i_{t,t+1}^k$ 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. In log terms, it is therefore expressed as:

$$\chi_t^{k/\$} = \underbrace{i_t^\$}_{\text{Cash Market Dollar Rate}} - \underbrace{i_t^k - \rho_t^{k/\$}}_{\text{FX Swap Market Dollar Rate}} \quad (2)$$

where ρ is the forward premium e.g. the difference between the forward (F) and the spot (S) rates respectively:

$$\rho_t^{k/\$} = \log(F_t^{k/\$}) - \log(S_t^{k/\$}) \quad (3)$$

Ever since 2008, borrowing USD synthetically is more expensive than doing so directly in U.S. money markets for many of the largest currency pairs incl. EURUSD, USDCHF, USDJPY and GBPUSD. The cross-currency basis can thus be viewed as a premium on USD borrowing in the FX swap market.

I am able to compute CIP deviations from two main FX data sources. First, I rely on CLS rates 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, I obtain daily FX swap points and FX spot rate from Bloomberg. In both cases, I obtain the forward rate by adding swap points to the spot rate. For Bloomberg, values refer to midquotes when a traded price is not available whereas for CLS values are always traded prices. For a measure of risk-free interest rates, I obtain daily data on historical Libor rates. I also obtain data on the overnight index swap (OIS) rates as they are necessary to compute the cost of swap line borrowing, which is calculated according to the OIS closing rate of the previous days.

3. Conceptual Framework

This section develops a conceptual framework for price formation in the FX swap market and generates three testable hypotheses for the empirical analysis that follows. It characterizes U.S. banks as dollar 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 show how Fed swap lines reduce funding frictions of arbitrageurs, thereby making arbitrage capital more elastic and enabling foreign banks to respond to arbitrage opportunities presented by constrained U.S. intermediaries.

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, 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 arbitrage capital in the FX market.

Customers. Customers, particularly non-banks, use the FX swap market to finance their foreign investment portfolios on a currency-hedged basis. Let x_t^D define global aggregate (signed) demand for U.S. dollar liquidity at the near leg of all FX swap contracts:

$$x_t^D = \int_0^1 f(\theta, \chi) db \quad (4)$$

where $f(\theta, \chi)$ is individual demand that decreases with basis χ and increases with the inverse of counterparty quality θ . The latter 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. Importantly, x_t^D refers to *signed* volume. In case such demand is balanced, there is an equal amount of customer orders that consume and provide U.S. dollars, and $x_t^D = 0$. In case such demand is not balanced and tilted towards net U.S. dollar purchases, $x_t^D < 0$.

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

$$U_t = -e^{-\rho W_t} \quad (5)$$

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 has to fund this position by borrowing U.S. dollars at a cost c . Taking such a position involves at least two other costs, however. On the one hand, 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 I assume that $s_{t+1} \sim N(f_t, \sigma^2)$. On the other hand, the arbitrageur takes an open position in the FX market by supplying U.S. dollars and acquires leverage $\frac{q}{W}$ that has some cost ψ that increases with position size (Cenedese et al., 2021). Finally, considering that the initial wealth can be invested at the risk-free interest rate r^f , arbitrageur's wealth in the next period can be written as:

$$W_{t+1} = \underbrace{W_t \cdot (1 + r^f)}_{\text{Return on initial wealth}} + \underbrace{q_t \cdot \chi_t}_{\text{Basis return}} + \underbrace{\theta \cdot q_t \cdot (s_{t+1} - f_t)}_{\text{Return if default}} - \underbrace{q_t \cdot c_t}_{\text{Funding cost}} - \underbrace{W_t \cdot \psi_t \left(\frac{q_t}{W_t} \right)}_{\text{Cost of leverage}} \quad (6)$$

The arbitrageur supplies liquidity in the market so as to maximize his expected utility with respect to the supply of U.S. dollars q . Using mean-variance preferences, the arbitrageur solves:

$$\max_{q_t} \rho \cdot \left(W_t(1 + r^f) + q_t(\chi_t - c_t) - \frac{1}{2}\rho\theta^2\sigma^2 q_t^2 - W_t \cdot \psi_t\left(\frac{q_t}{W_t}\right) \right) \quad (7)$$

First-order condition yields:

$$q_t^* = \frac{\chi_t - c_t - \psi_t\left(\frac{q_t}{W_t}\right)}{\rho \cdot \theta^2 \cdot \sigma^2} \quad (8)$$

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 since customer demand is imbalanced:

$$\sum_{j=1}^N D_{t,1}^j = x_t^D \quad (9)$$

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. These costs can be modeled as a convex function that captures increasing marginal costs of absorbing larger positions:

$$\Psi(\Delta_t) = \frac{\kappa}{2} \cdot \Delta_t^2 \quad (10)$$

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:

$$\min_{q_t} \left\{ \chi_t \cdot q_t + \frac{\kappa}{2} (x_t^D - q_t)^2 \right\} \quad (11)$$

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:

$$\chi_t - \kappa(x_t^D - q_t) = 0 \quad (12)$$

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

$$q_t^* = x_t^D - \frac{\chi_t}{\kappa} \quad (13)$$

This implies that tighter balance sheet constraints (higher κ) raise the marginal cost of internal 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 $\kappa \rightarrow \infty$, U.S. banks offload the entire position with arbitrageurs.

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 effective spreads.*

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 as arbitrageurs with access to swap lines

An arbitrageur does not generally have access to central bank funding facilities. This does not necessarily prevent him from supplying arbitrage capital in the FX swap market ($q > 0$) as long as the basis return from doing so χ exceeds his costs *ex ante*, as noticeable in eq. (8):

$$\chi_t - c_t - \psi_t \left(\frac{q_t}{W_t} \right) > 0 \quad (14)$$

Let us now examine more carefully the mechanics of an arbitrage trade and the respective trade funding cost c . To arbitrage the basis in any U.S. dollar currency pair $k/\$$, the arbitrageur borrows U.S. dollar in the U.S. money market that it must pay back with interest rate $i_t^\$$ at the end of the fixed term. The arbitrageur then supplies the dollar in the FX market and, by definition, simultaneously borrows the non-dollar currency k at the near leg at a spot rate s_t , signs a forward

contract to exchange back k for $\$$ at the far leg, and deposits the non-dollar currency k at the foreign central bank's deposit facility (either directly or via a correspondent bank), earning an interest on reserves i_t^{v*} . As reserves are typically overnight, while the FX swap contract entails a fixed term, the arbitrageur buys an OIS contract that allows him to fix the interest on reserves to a fixed rate rather than a floating rate. The OIS trade results in a return of $i_t^* - i^{p*}$ where i_t^* is the fixed part of the OIS rate and i^{p*} is the reference rate. In summary, the cost of funding an arbitrage trade c involves not only the cost of borrowing the dollar in U.S. money market $i^\$$ but also the costs, which is in line with the intuition provided in [Bahaj and Reis \(2021\)](#). Eq. (14) can thus be re-written as:

$$\chi_t - i_t^\$ + i_t - i_t^{v*} + i^{p*} - \psi_t\left(\frac{q_t}{W_t}\right) > 0 \quad (15)$$

In other words, an arbitrageur will step in the FX swap market if the basis χ is larger than the difference between his marginal U.S. dollar borrowing cost $i_t^\$$ and the reference U.S. dollar interest rate (say, the Libor rate), minus the difference between non-U.S. central bank's policy and deposit rates, minus his cost of leverage.

Add now the possibility for some arbitrageurs to access Federal Reserve swap line via access to their local central bank U.S. dollar operations. An arbitrageur with access can borrow U.S. dollar at the rate that is the lower value of the swap line rate i^{SL} and the private U.S. money market rate i_M , i.e. $i_t^\$ = \min(i_t^M, i_t^{SL})$, where the cost of borrowing via swap lines is the OIS interest rate plus a penalty term i.e. $i_t^{SL} = i_t^{OIS} + \omega$, and $\omega = 25$ bp. By analogy, $c_t = \min(c_t^M, c_t^{SL})$. Because funding via swap lines comes at a penalty term, such borrowing is only attractive when the borrowing cost soars in the private markets such as during March 2020. We can now express the quantity q of dollar liquidity supply by an arbitrageur as a function of the cross-currency basis, marginal funding costs, and access to the central bank swap line:

$$q_t := \begin{cases} \frac{\chi_t - c_t - \psi_t(\frac{q_t}{W_t})}{\rho\theta^2\sigma^2}, & \text{if } \chi_t \geq c_t^M + \psi_t(\frac{q_t}{W_t}) \\ \mathbb{1}_{D_{access}} \cdot \frac{\chi_t - c_t - \psi_t(\frac{q_t}{W_t})}{\rho\theta^2\sigma^2}, & \text{if } c_t^{SL} + \psi_t(\frac{q_t}{W_t}) \leq \chi_t < c_t^M + \psi_t(\frac{q_t}{W_t}) \\ 0, & \text{if } \chi_t < c_t^{SL} + \psi_t(\frac{q_t}{W_t}) \end{cases} \quad (16)$$

where D_{access} is a swap line access dummy variable that equals 1 for arbitrageurs with access to recipient-country swap line, and zero for all other arbitrageurs.

To give an example, consider an arbitrageur who observes some non-zero basis χ_t . He is only able to enter into the CIP arbitrage trade if his U.S. dollar borrowing cost is smaller than some threshold level i.e. $i_t^M < i_0^M$. If borrowing costs in the private market soar above that level, he would provide $q_t = 0$ if swap line funding is not available and $q_t > 0$ if it is accessible under the condition that $i_t^{SL} < i_0^M$, i.e. that swap lines cap arbitrageur's dollar borrowing cost. Note that it is only foreign banks (and not non-banks) that are directly able to access the U.S. dollar operations of its local central bank.

Proposition 3 (Swap line access and market share).

Foreign banks with access to central bank swap lines increase their share in U.S. dollar lending relative to non-access banks when $\chi_t > c_t^{SL}$ and $\chi_t > c_t$.

This result implies that, as swap lines reduce effective funding costs for eligible arbitrageurs, these institutions gain a competitive advantage in supplying dollar liquidity when private markets are stressed.

Proposition 4 (Swap line availability and arbitrage activity).

Foreign banks with access to central bank swap lines increase their quantity of U.S. dollar lending when $\chi_t > c_t^{SL}$ and $\chi_t > c_t$ on days when swap line operations are active relative to days when they are not.

This proposition introduces a temporal variation: the presence of active swap line operations increases arbitrage participation conditional on swap line access. The mechanism hinges on the actual availability and usability of swap lines, which reduce the effective marginal cost of funding and hence relax arbitrage constraints.

4. U.S. Banks as Constrained Intermediaries in FX Swaps

Section 3 presents a conceptual framework in which U.S. banks act as global dealers in FX swaps, supplying U.S. dollars to price-taking counterparties. According to Propositions 1 and 2, U.S. banks balance non-bank customer flows with external arbitrage capital to minimize costly inventory absorption. The model yields two key implications: (i) U.S. banks offset non-bank customer demand by borrowing from non-U.S. banks, and (ii) they adjust prices asymmetrically

depending on the direction of imbalance and the tightness of their balance sheet constraints. 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:

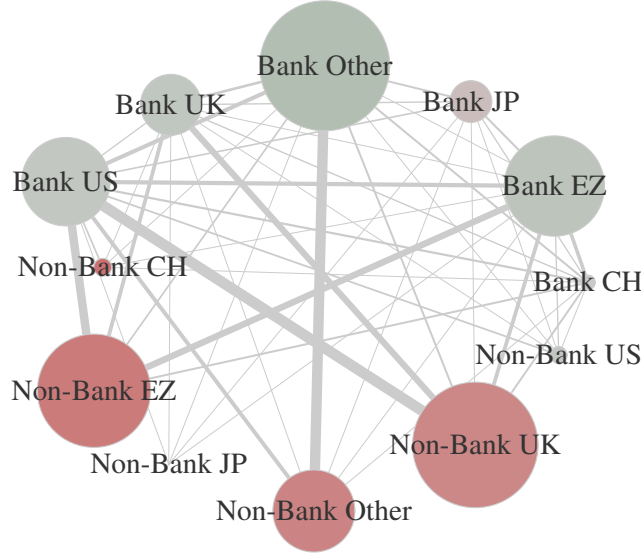
$$Net_{t,i,j,k} = \sum_{l=1}^L \mathbb{1}[T_t = B] - \mathbb{1}[T_t = S], \quad (17)$$

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 :

$$Net_{t,i} = \sum_{j=1}^J \sum_{k=1}^K Net_{t,i,j,k}. \quad (18)$$

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 (H) 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 4% 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 generally well predicted by the non-bank customer demand that they observe. This is because



(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.

U.S. banks aim to run a matched-book and thus attract arbitrage flow to offset non-bank demand.

I test this relationship with the following ordinary-least squares panel regression:

$$\Delta Net_{NonUS\ Banks,i,t} = \beta \cdot \Delta Net_{NonBanks,i,t} + \gamma \cdot X_{i,t} + \alpha_i + \gamma_t + \epsilon_t. \quad (19)$$

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 $X_{i,t}$ 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). Time-fixed effects include week-of-day or month-of-year dummies as well as a holiday dummy. 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 they lend more to customers.

Regression results (Table 3) 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

Dep: $\Delta \text{Net}_{\text{NonUS Banks}}$							
	Panel of G7 currencies			Per Currency			
	Daily (1)	Weekly (2)	Monthly (3)	EUR (4)	GBP (5)	CHF (6)	JPY (7)
$\Delta \text{Net}_{\text{NonBanks}}$	-0.12*** (0.01)	-0.32*** (0.03)	-0.31*** (0.05)	-0.33*** (0.04)	-0.23*** (0.05)	-0.26*** (0.07)	-0.31*** (0.07)
Constant				0.32** (0.14)	0.02 (0.09)	0.16*** (0.05)	0.41*** (0.12)
Constant	No	No	No	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Currency FE	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 3: 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. 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.

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 pricing asymmetries emerge when U.S. banks face tighter balance sheet constraints. Specifically, U.S. banks should charge higher prices when selling USD (i.e., when accommodating customer purchases) than when buying USD, particularly under dealer stress. To analyze US bank pricing in the FX swap market I express the forward points implied from settlement volumes in the CLS data separately for Buy and Sell transactions. A USD sale is defined as an FX swap transaction in which the U.S. bank delivers USD on the near leg i.e. it has a cash outflow. US bank Sell minus Buy transaction price spread is then defined as the difference between:

$$x_{t,i} = \rho_{t,i} \cdot \mathbb{1}[T_t = S] - \rho_{t,i} \cdot \mathbb{1}[T_t = B], \quad (20)$$

where ρ is the implied forward premium e.g. the difference between the forward (F) and the spot (S) rates respectively. Table 4 reports summary statistics on observed spreads. For EURUSD at 3-month tenor, the median spread is 0.23 basis points, with a 90th percentile of 1.52 bps or roughly 430% of the prevailing bid-ask spread. These patterns are consistent across major currency pairs and maturities.

		US bank Sell-minus-Buy transaction price 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 4: 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.

I then estimate the sensitivity of this spread to net volume across different quantiles of dealer constraint, as proxied by the [He, Kelly, and Manela \(2017\)](#) balance sheet utilization index. Table N1 presents quantile regressions of the price spread on net volume. Results show that the spread-volume slope increases monotonically across 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 supports the prediction that price asymmetries widen when U.S. banks are balance sheet constrained.

Appendix (N) replicates the main regression using gross trading volumes instead of net volumes. This exercise tests my argument that it is primarily the net (rather than gross) positions

	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)	0.01* (0.01)	0.02** (0.01)	0.03*** (0.01)	0.03*** (0.01)
Bid-ask spread	0.05* (0.05)	0.05 (0.06)	0.19*** (0.05)	0.28*** (0.04)	0.19*** (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	0.27	0.27	0.26	0.27
<i>Note:</i>			*p<0.1; **p<0.05; ***p<0.01		

Table 5: Quantile 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 Net (sell minus 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.

that U.S. banks care about when managing balance sheet risk. The results reveal that gross and net volumes indeed have distinct—and in fact, opposite—effects on the spread, 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 in a deeper, more liquid market with more counterparties on both sides of the trade.

Lastly, I examine the spreads charged by U.S. banks vis-a-vis reserve balances. As discussed in Section 3, an efficient way for U.S. banks to at least partly fund their open FX swap U.S. dollar position is to drain down reserves. This is efficient because U.S. banks then do not need to borrow dollars in the repo market, which is costly from a balance sheet perspective. This tool is, however, only partly available as the level of excess reserves during the past decade has likely been much lower than the size of the U.S. bank total FX swap open position. For example, [Correa et al. \(2020\)](#) estimates that U.S. banks draw down reserves in periods of market stress only to an amount of USD

20 billion; in comparison, total U.S. bank funding needs in FX swaps stemming from non-bank demand are much larger and closer to USD 1,000 billion. Nevertheless, when reserves are ample, U.S. banks are likely to have less of a problem in meeting such funding needs than otherwise. Appendix (P) 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. For robustness, the repo rate is proxied using both the General Collateral Financing Rate (GCF) and the Secured Overnight Financing Rate (SOFR).

Taken together, these findings validate the core mechanisms in Section 3: U.S. banks adjust their net positions with foreign banks in response to customer demand (Proposition 1), and pricing becomes more asymmetric as balance sheet constraints bind (Proposition 2).

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

Propositions 3 and 4 hypothesize that violations of the CIP ceiling should result in swap line arbitrage. This section tests the proposition empirically. To do so, I rely on a carefully designed identification strategy. After describing the identification strategy in detail, the section then turns to presenting the main empirical results, which quantify the degree of swap line arbitrage in the global FX swap market around (1) 2020 COVID crisis and (2) quarter-end reporting episodes.

5.1. Identification strategy

A key challenge in studying the link between central bank swap lines and the private FX swap market is that a swap line arbitrage trade is only available when the CIP ceiling is violated but such violations are rare in practice. They are rare because it would offer an opportunity to

arbitrageurs to make a sure profit by borrowing from the central bank and lending in the FX swap market and thus compete the price of U.S. dollar down back to the level implied by the ceiling. After all, in an efficient market no arbitrage opportunities should exist even when central bank swap lines are available. The researcher studying the FX swap market is therefore faced with a problem insofar as that what he wishes to observe – a high enough CIP violation that it induces swap line arbitrage flows – is never observed if the ceiling is not violated, and thus cannot be measured empirically. I address these challenges by crafting an identification strategy based on two pillars: first, swap line arbitrage flows should be zero (non-zero) if the CIP ceiling does not bind (binds or is violated); second, the operational details of swap lines (maturity requirements, settlement cycles) imply that swap line arbitrage was directly possible in some segments of the FX swap market but only indirectly in others.

Identification at the currency level. As shown in [Bahaj and Reis \(2021\)](#) and discussed in Section 3, swap line arbitrage becomes feasible only when the cross-currency basis exceeds the no-arbitrage ceiling. Ignoring the shadow costs ψ for simplicity, the swap line arbitrage is thus possible only if the following inequality holds, where χ_t denotes the CIP basis, i_t the swap-line dollar borrowing rate, i_t is the domestic borrowing rate, i_t^{v*} is the foreign central bank’s deposit facility rate, and i^{p*} is the reference rate of the OIS contract:

$$\chi_t - i_t^{\$} + i_t - i_t^{v*} + i^{p*} > 0 \quad (21)$$

During the COVID crisis, the basis for most currency pairs quickly returned within swap-line arbitrage bounds after the mid-March 2020 peak, as expected with the activation of central bank swap lines. However, I exploit a quasi-natural experiment at the currency level identified by [Bahaj and Reis \(2021\)](#): while the swap line ceiling held for most pairs, it remained persistently tested in Asian currencies—especially USDJPY. This divergence stemmed from sustained non-bank demand for dollars in Asia ([Aldasoro et al., 2020](#)), time zone misalignments with major FX hubs ([Bahaj and Reis, 2021](#)), and the fact that swap line arbitrage was profitable at lower CIP deviations in USDJPY due to the level of Bank of Japan policy rates. Figure (4) illustrates this by plotting the 1W CIP basis for USDJPY and EURUSD from March 1 to June 30, 2020, against the symmetric no-arbitrage ceiling bounds $[(i_t - i^{S_t}) + (i^{v*}_t - i^{p*}_t); (i^{S_t} - i_t) + (i^{p*}_t - i^{v*}_t)]$. A similar analysis for other major pairs appears in Appendix (I).

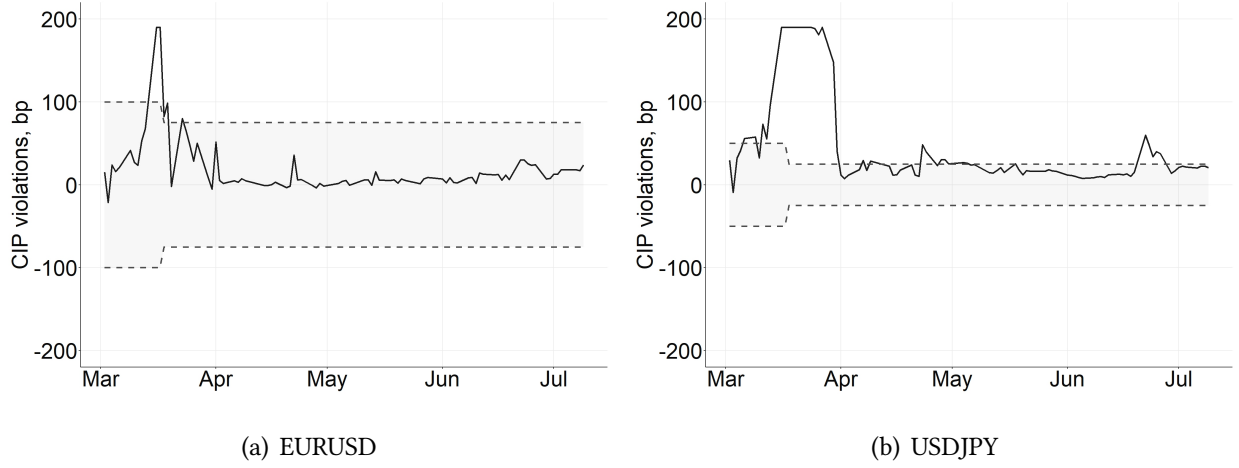


Fig. 4: 1W CIP basis (Bloomberg) vs. no-arbitrage-implied CIP ceiling bounds (author’s calculations). Dashed red lines refer to the upper and lower bound of the swap line-implied ceiling; shaded ribbon thus refers to the area of CIP violations χ_t that do not violate the price ceiling: $(i_t - i_t^S)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

A binding ceiling is consistent with a setting in which a swap line arbitrageur has driven prices to the point of no-profit. By contrast, when prices remain well within the ceiling, arbitrage is unlikely to have occurred. USDJPY is central to my identification strategy, as it is the only swap line-eligible currency where the CIP ceiling consistently bound—or was exceeded—after March 18, making it the most likely segment of the market to reveal swap line arbitrage, if any.

Identification at the banking group level. Access to local central bank dollar operations is locational in principle, which means that any financial institution with an account at the respective central bank is eligible to participate in its swap line auctions. Unfortunately, I do not have access to data on which individual banks drew on swap lines at each respective central bank, as this information is held by the central banks and is not publicly available to academic researchers. As a result, identification at the banking group level is not directly feasible in this study. However, prior work by the Bank of Japan indicates that during the COVID episode, up to 90% of its swap line take-up came from domestic Japanese banks (Akitaka et al., 2020). Conveniently, these banks are observable in my dataset, grouped under Japanese nationality. Because the size of Bank of Japan swap line take-up was large both in absolute terms and in comparison to Japanese banks’ regular FX swap positions, I conjecture that it is U.S. dollar net lending by Japanese banks where I should see the clearest evidence of any excess lending. Note that even if these banks drew on swap lines motivated by precautionary hoarding reasons as suggested by Aoki et al. (2021), they

are nevertheless likely to have sought for ways to park this dollar funding at profit, including by lending it out short-term in the FX swap market.

A second source of bank-level variation I can exploit is the fact that some banks never accessed swap lines in the first place such as Australian and Canadian banks. I know that such banks did not access the FED's swap lines because their local central banks never requested to access them in the first place.

Identification at the tenor level. I augment our identification strategy by considering the operational details of the use of U.S. dollar swap lines. In particular, the Federal Reserve offers U.S. dollar swap lines in only two terms: 7 and 84 days, which correspond to 1W and 3M tenor points. In contrast, the FX swap market is liquid in maturities all the way up to 365 days (1 year tenor point). I conjecture that a swap line arbitrageur is therefore able to easily arbitrage mispricing in tenors up to the 3M tenor point but not thereafter. The reason is that arbitraging mispricing say in the 6M or 1Y tenor would imply rolling-over swap line funding at a cost that is not known ex-ante, as it depends on the OIS rate of the preceding day.

Identification over time. During the COVID-19 episode, the Federal Reserve offered swap lines at a daily frequency, which complicates identification over time as the counterfactual i.e. days without swap line access is unobserved. This stands in sharp contrast to swap line operations during quarter-end reporting periods, when swap lines can be generally drawn only once per week (on every Wednesday). Quarter-ends are well-known stress points in dollar funding markets, marked by elevated demand for short-term USD liquidity and spikes in the cross-currency basis (Kloks et al., 2024). The weekly frequency of swap line operations during these periods allows for a clean identification strategy, serving as a robustness check to COVID-era findings. Following Bahaj and Reis (2021), I compare days with and without swap line access during quarter-ends to isolate the effect of central bank dollar provision. The identification hinges not on quarter-end timing itself, but on the conditional availability of swap line liquidity, assuming similar financial conditions across treated and untreated days absent intervention.

5.2. COVID episode

5.2.1. Non-U.S. bank net lending position

Before providing causal evidence for swap line arbitrage, I first provide prima facie evidence for it. To do so, I take a naive approach and ask if any abnormal increase in net U.S. dollar *lending* is observable during the active period of U.S. dollar swap line take-up - namely, from March 23 to June 30, 2020 - by any non-U.S. bank nationality group in the currency where CIP ceiling violations were persistently violated? Such evidence would be consistent with a higher market share by a swap line arbitrageur as hypothesized in Proposition 1 of section 3. I therefore run the following ordinary-least squares panel regression:

$$Net_{t,i} = \beta_1 \cdot SwapLines + \beta_2 \cdot USDJPY + \beta_3 \cdot SwapLines \cdot USDJPY + \alpha_i + \gamma_t + \epsilon_t. \quad (22)$$

where $Net_{t,i}$ refers to the net (buy minus sell) dollar borrowing for currency pair i , $SwapLines$ is a dummy that equals 1 from March 23 until June 30, 2020 and 0 otherwise, $USDJPY$ is a dummy that equals 1 for the dollar-yen currency pair and 0 for other pairs, and α_i and γ_t are counterparty- and time-fixed effects respectively. I run a regression for all non-U.S. bank nationality groups individually (columns (1) to (5)) as well as their total (6). I expect a negative and significant result on β_3 , our coefficient of interest, if arbitrageurs accessed the BoJ swap line and lent out the dollars at the spot leg of the FX swap contract in USDJPY, where the ceiling was persistently violated. In contrast, I do not expect a significant result on β_1 since for the rest of the currency pairs the cross-currency basis was well within the ceiling bounds, offering no arbitrage opportunities.

Results are shown in Table (6) and are in line with our expectations. In particular, I find no evidence for excess U.S. dollar lending during the swap line period above and beyond what one would expect to see in any other time period in our sample. This is expected, since the cross-currency bases behaved well within the bounds of the ceiling for most currency pairs post-March 18, 2020 when the augmented swap line framework became operational. At the same time, and perhaps more importantly, I find clear empirical evidence that points to more U.S. dollar lending in the FX swap market by Japanese banks - banks who took up swap lines with BoJ - and more so than all the other non-U.S. banks such as Eurozone banks, who also exhibit some levels of excess lending.

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 (0.66)	−1.32 (1.14)	−0.14 (0.38)	−0.62* (0.33)	1.18 (0.83)	−0.04 (0.33)
SwapLines:USDJPY	−15.08*** (0.09)	−1.86* (1.03)	3.40*** (0.21)	1.92*** (0.57)	0.21 (0.60)	−2.28 (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 6: 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.

I confirm the significant result of an increase in U.S. dollar lending in dollar-yen pair by Japanese banks by running the following regression:

$$Net_{t,i} = \alpha + \sum_{n=2}^{35} \beta_n \cdot D_n + \epsilon_t. \quad (23)$$

where D_n equals 1 for the n^{th} week of the year of 2020 and 0 otherwise. In comparison to the result in Table (6), I am able to quantify the total increase in lending across all counterparties. I report the β_n estimates in Figure (4). The figure indicates that Japanese banks increased their provision of U.S. dollar liquidity exactly at the peak of the March 2020 but did so more after the lowering of the swap line penalty rate on March 18. At its peak, Japanese bank excess lending exceeded 70bn USD. This compares with the peak of the BoJ swap line allotments which stood at 225bn of USD. A simple back-of-the-envelope calculation estimates that as much as 25% - 30% of the BoJ swap line take-up ended up in the private FX swap market in the form of arbitrage lending.

5.2.2. Difference-in-differences

I further test the evidence through a difference-in-differences strategy whereby I combine the special role of the dollar-yen with insights from the operational details of the swap lines.

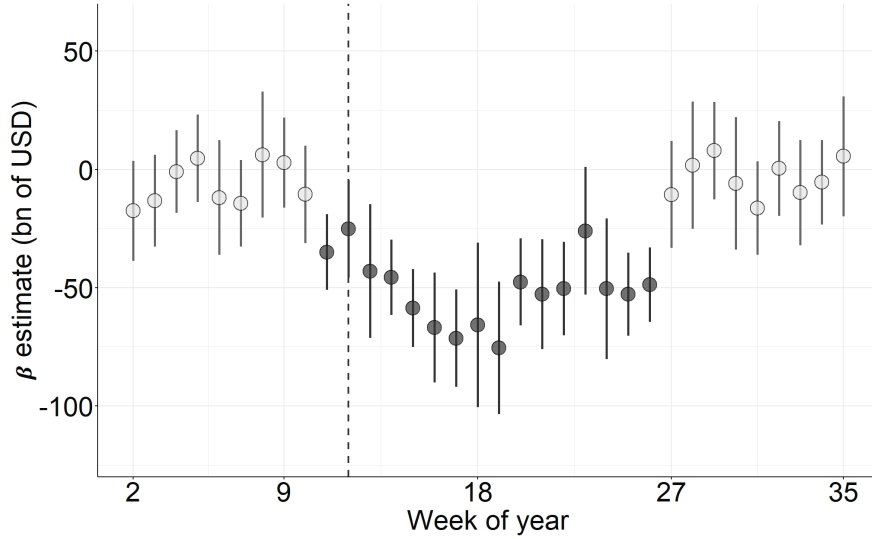


Fig. 5: Excess U.S. dollar lending by JP banks in 2020. The figure displays the coefficient on the net change in net U.S. dollar borrowing in a given week of the year, β_n , from the following ordinary least squares (OLS) regression: $Net_t = \alpha + \sum_{n=2}^{35} \beta_n \cdot D_n + \epsilon_t$ where D_n equals 1 for the n^{th} week of the year of 2020 and 0 otherwise. Net_t refers to the net (buy minus sell) dollar borrowing for USDJPY and is measured in bn of USD. Dark (light) coloring indicates a statistically significant (insignificant) β_n coefficient at the 1% significance level. The dots refer to the point estimates of the β_n ; line bars add and subtract three times its standard deviation. Dashed line is Week 12 and refers to the start of the augmented swap line allotment on March 18. Data is daily for a sample from 2019 to 2022.

First, I design a difference-in-differences regression that tests whether the above-reported result for Japanese banks (1) is driven by an increase in U.S. dollar sales rather than a drop in purchases, (2) is more pronounced for the affected FX swap maturities (at and below the 3-month tenor point) in comparison to the unaffected maturities (above 3-months and up to the 1 year tenor point) and (3) is evident in dollar-yen but not in the yen currency pairs that do not involve the dollar, namely, CHFJPY, EURJPY and AUDJPY. The latter allows U.S. to identify the change in positions as a dollar-driven phenomenon rather than a need for yen liquidity. I thus estimate the regression model (3) for the buy and sell volume and for the two tenor groups separately. Columns (7) to (10) of Table (7) report our results. For conciseness, only the difference-in-difference estimator is reported in the paper and the full regression table is delegated to the Appendix. Our results give clear evidence that the change in net position of Japanese banks is driven by an increase in sales ($\beta_{DD} = 0.57$) in the currency pair that involved the dollar (USDJPY). In contrast, dollar purchases in maturities at or below the 3M remain unaffected. Column (9) further indicates that such an increase in sales is not visible in long-term tenors whose maturity exceeded that of the swap line, and where swap line arbitrage trade was thus not available.

Second, I augment the approach with difference-in-difference-in-differences (DDD) set-up. I run the following regression, which, in the case of (U.S. dollar) sell volume, looks as follows:

$$Sell_{t,i} = \beta_1 \cdot SwapLines + \beta_2 \cdot USDJPY + \beta_3 \cdot isJPBank + \beta_{DDD} \cdot SwapLines \cdot USDJPY \cdot isJPBank + \theta \cdot X_{i,t} + \gamma_t + \epsilon_t. \quad (24)$$

where β_{DDD} measures whether JP banks do more U.S. dollar sales than the control group in USDJPY during the active swap line take-up period from March 18 until June 30, 2020. I repeat the regression for sell, buy and net volume. I further consider two control groups for the Japanese banks: banks whose local central bank did not tap the FED swap line ('Non-Access Banks') i.e. Australian and Canadian banks, as well as a group of non-U.S. banks who accessed swap lines but are not Japanese banks ('Non-JP Access Banks'). Results are reported in columns (1) to (6) of Table (7) and confirm our main result: Japanese banks increased their sales volume more than the control group of banks during this period for the dollar-yen currency pair in such a way that had a meaningful impact on their *net* U.S. dollar liquidity position, as seen in columns (3) and (6).

5.2.3. U.S. dollar lending and ceiling violations

As a final step, I ask whether the excess U.S. dollar lending by Japanese banks stopped when the dollar-yen cross-currency basis dropped to levels that are *inside* the ceiling bounds. Evident to the naked eye in Figure (4), the dollar-yen basis was at or above the ceiling until mid-May after which it stabilized inside the bound until the second part of June, when it tested the bound again due to the approaching quarter-end period during which the price of FX swaps typically trade higher. Thus, the period between mid-May and mid-June offers a few weeks of a window to test our hypothesis. If the Japanese trading behavior is driven by swap line arbitrage considerations, I would expect a lower degree of dollar lending during the period when ceiling bounds were not violated. Results are reported in Appendix (K) and confirm our intuition.

	Difference-in-difference estimates									
	<i>Affected vs. Unaffected Banks</i>						<i>Dollar vs. Non-Dollar Pairs</i>			
	vs. Non-Access Banks			vs. Non-JP Access Banks			Up to 3M		Above 3M	
	(1) Buy, log	(2) Sell, log	(3) Net, tn	(4) Buy, log	(5) Sell, log	(6) Net, tn	(7) Sell, log	(8) Buy, log	(9) Sell, log	(10) Buy, log
β_{DDD}	-0.11*** (0.05)	0.28*** (0.04)	-0.005*** (0.001)	-0.19*** (0.04)	0.22*** (0.02)	-0.01*** (0.001)				
β_{DD}							0.57*** (0.11)	-0.06 (0.14)	0.18 (0.17)	-0.34*** (0.13)
Constant	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Currencies	17	17	17	17	17	17	4	4	4	4
Tenors	7	7	7	7	7	7	7	7	1	1
Obs.	26,012	26,012	26,012	26,046	26,046	26,046	4,397	4,256	4,072	3,758
Adj. R^2	0.87	0.89	0.47	0.91	0.93	0.43	0.77	0.59	0.61	0.69

Table 7: 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.

6. Conclusion

Although the size of the Federal Reserve swap line network represents a stunning 20% of the world's GDP, policymakers still have very little empirical evidence as to how such central bank funding transmits to offshore U.S. dollar borrowing rates. My research sheds new light on this mechanism. First, I document that settlement data offers an alternative source of data to map agent positioning in the FX swap market, complementing existing studies that use more granular but less globally representative data such as central bank trade repository data. Second, I uncovered novel evidence that foreign banks use swap line funding not only to reduce dollar demand in FX swaps (substitution channel), but also to increase dollar supply. I interpret the second as arbitrage lending, which is consistent with the idea that non-US banks play a dual role in global synthetic dollar funding markets, acting at times to both demand and supply dollar liquidity, not just the former, as is commonly assumed. Third, I studied who receives such foreign bank dollar supply during market stress episodes such as during COVID 2020 and concluded that it has primarily been absorbed by the interbank market, including by U.S. banks. This is counter-intuitive, since one would expect the direction of the flow of U.S. dollar liquidity to always point away from U.S. banks and towards foreign banks whereas I reveal it flows in the other direction, too. I rationalize this finding with a simple conceptual framework arguing that U.S. banks need to fund an imbalanced customer demand and may choose to do so off-balance sheet via FX swaps when their balance sheets are constrained.

The findings of this study have important policy implications. When U.S. dealers are constrained, repo markets and, by analogy, even standard Federal Reserve facilities may be unviable sources of funding an imbalanced customer demand in FX swaps because it expands the balance sheet. Swap lines are effective because the Federal Reserve can indirectly rely on foreign banks as vehicles for transmitting U.S. dollar liquidity off-balance sheet to the private markets. In such a case, public dollar liquidity (central banks) requires the involvement of private banks (private dollar liquidity) for better effectiveness.

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Appendix A

The BIS Triennial Survey ([Bank for International Settlements, 2019](#)) represents the most recognized documentation of the FX market; the following tables show that our FX swap data is highly representative. Table (A1) compares our daily turnover figures for those months which the BIS surveys (i.e. April of each survey year). Table (A2) compares the maturity breakdown of swaps in CLS versus swaps in the Triennial survey. Tables (A3) and (A4) do the same with currencies and counterparties, respectively. Note that while the numbers in Table (A1) denote that CLS covers only about a third of volumes in the BIS survey, both [Hasbrouck and Levich \(2019\)](#) and [Cespa et al. \(2021\)](#) demonstrate that CLS coverage in spot is underestimated compared to the BIS survey, since a large fraction of the volume reported by the BIS is related to interbank trading across desks and double-counts prime-brokered “give-up trades.”

Table A1: Daily Turnover (B), CLS and BIS Triennial Survey

	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 comparison with BIS Triennial Survey

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

Table A3: Currency breakdown comparison with 2016 BIS Triennial Survey

	CLS Share	BIS Share	BIS Share adj.
USD	95.8%	90.8%	96.6%
EUR	34.7%	33.9%	36.1%
JPY	22.0%	19.3%	20.5%
GBP	13.2%	12.8%	13.6%
CHF	7.8%	6.3%	6.7%
AUD	7.2%	5.8%	6.2%
CAD	3.5%	4.3%	4.6%
Other	≈15.8%	≈ 26.8%	≈ 15.6%

Note: “BIS share adj.” is an approximation of what BIS currency shares would be if the BIS only considered CLS currencies.

Table A4: Counterparty breakdown comparison with BIS Triennial Survey

	Counterparty	CLS Share	BIS Share
April '13	Dealers	57.9%	48.6%
	Other financial	41.9%	44.7%
	Non-financial	0.2%	6.7%
April '16	Dealers	51.3%	50.7%
	Other financial	48.6%	43.1%
	Non-financial	0.1%	6.2%
April '19	Dealers	50.3%	46.8%
	Other financial	49.6%	48.0%
	Non-financial	0.1%	5.2%

Note: This counterparty breakdown leverages a separate CLS dataset which classifies parties into sell-side and buy-side banks (based on their network and frequency of trading) as well as non-bank financial institutions, funds, and corporates. We label sell-side banks as dealers, corporates as non-financial firms, and all other parties as “Other financial” to match the BIS survey nomenclature.

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

		TN	SN	1W	2W–1M	1M	1M–3M	3M	3M+	Σ
G-SIBs	US	519	120	195	328	1435	1,233	1,883	3,567	9,280
	EZ	246	54	97	163	619	487	794	1,827	4,287
	UK	217	41	73	132	580	469	742	1,376	3,630
	CH	120	23	42	83	348	309	448	685	2,058
	JP	52	8	14	28	110	91	179	423	905
	Other	47	11	16	40	209	147	244	439	1,151
	Σ	1,200	256	437	774	3,301	2,736	4,289	8,317	21,310
Small banks	US	4	1	1	6	55	17	23	47	154
	EZ	90	16	33	46	127	130	268	506	1,217
	UK	41	8	21	51	127	145	205	456	1,053
	CH	30	4	10	17	47	40	57	104	308
	JP	47	8	10	21	75	59	109	253	583
	Other	248	39	77	119	455	450	827	1,418	3,632
	Σ	461	76	152	259	885	841	1,489	2,785	6,947
Non-Banks	US	3	1	6	27	410	241	195	385	1,268
	EZ	11	3	6	10	149	63	216	87	546
	UK	5	2	4	11	179	135	179	182	698
	CH	0	1	7	6	28	14	15	50	120
	JP	0	0	0	0	3	1	1	6	11
	Other	4	2	5	10	61	74	123	218	498
	Σ	24	9	28	64	829	529	730	929	3,141

Table C1: FX swap open (outstanding) **total** volumes (dollar purchases **plus** sales), 2012-22 daily average, in bn of USD.

Appendix D

		TN	SN	1W	2W–1M	1M	1M–3M	3M	3M+	Σ
G-SIBs	US	0.10	0.02	0.02	0.02	-0.08	-0.06	-0.16	-0.16	-0.30
	EZ	-0.01	0.00	0.00	-0.01	-0.07	-0.03	-0.12	0.02	-0.22
	UK	-0.02	-0.01	0.00	0.00	-0.01	-0.01	-0.02	-0.06	-0.13
	CH	0.01	0.00	0.00	0.01	0.02	0.01	0.00	-0.03	0.02
	JP	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.04
	Other	-0.01	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.04
	Σ	0.07	0.01	0.02	0.02	-0.13	-0.09	-0.30	-0.23	-0.64
Small banks	US	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.01	0.05
	EZ	-0.03	0.00	-0.01	-0.01	-0.02	-0.01	-0.01	-0.02	-0.11
	UK	-0.01	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.01	-0.06
	CH	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01
	JP	-0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.04
	Other	-0.02	0.00	-0.01	-0.01	-0.06	-0.03	-0.07	-0.09	-0.29
	Σ	0.46	0.08	0.15	0.27	0.89	0.84	1.49	2.79	-0.37
Non-Banks	US	0.00	0.00	0.00	0.00	-0.03	0.01	0.00	-0.04	-0.06
	EZ	-0.01	0.00	0.00	0.00	0.07	0.04	0.17	0.06	0.33
	UK	0.00	0.00	0.00	0.00	0.10	0.05	0.12	0.12	0.39
	CH	0.00	0.00	0.01	0.00	0.02	0.01	0.01	0.03	0.08
	JP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other	0.00	0.00	0.00	0.00	0.2	0.04	0.07	0.14	0.27
	Σ	-0.01	0.00	0.01	0.00	0.18	0.15	0.37	0.31	1.01

Table D1: FX swap open (outstanding) **net** volume (dollar purchases **minus** sales), 2012-22 daily average, in tn of USD. A positive number indicates US dollar net borrowing in the FX swap market at the near leg.

Appendix E

		EUR	JPY	GBP	CHF	AUD/NZD/CAD	SEK/NOK/DKK	Other dollar	Σ
G-SIBs	US	3,039	2,056	1,316	434	741	396	1,296	9,280
	EZ	1,782	817	485	193	265	136	609	4,287
	UK	1,158	701	606	174	241	119	631	3,630
	CH	639	356	239	315	177	91	240	2,058
	JP	172	533	44	9	31	5	111	905
	Other	258	221	244	48	84	27	269	1,151
	Σ	7,048	4,685	2,935	1,173	1,539	775	3,155	21,310
Small banks	US	36	24	40	5	30	4	14	154
	EZ	773	90	82	82	28	20	141	1,217
	UK	380	147	257	58	74	40	98	1,053
	CH	79	18	18	171	6	4	12	308
	JP	125	285	42	12	29	4	85	583
	Other	872	410	318	72	542	557	861	3,632
	Σ	2,265	974	758	400	710	629	1,210	6,947
Non-Banks	US	433	319	192	30	101	29	164	1,268
	EZ	448	18	41	10	10	4	15	546
	UK	251	56	275	35	36	9	36	698
	CH	38	3	2	72	2	0	4	120
	JP	0	11	0	0	0	0	0	11
	Other	98	33	21	7	99	132	108	498
	Σ	1,267	440	532	153	248	175	326	3,141

Table E1: FX swap open (outstanding) **total** volume (buy **plus** sell), 2012-22 daily average, in bn of USD.

Appendix F

		EUR	JPY	GBP	CHF	AUD/NZD/CAD	SEK/NOK/DKK	Other dollar	Σ
G-SIBs	US	-0.18	0.06	-0.04	-0.02	-0.04	-0.01	-0.06	-0.30
	EZ	0.07	-0.13	-0.03	-0.04	-0.03	-0.01	-0.01	-0.22
	UK	-0.02	-0.04	-0.02	-0.03	-0.02	0.00	0.00	-0.13
	CH	-0.01	-0.02	-0.01	0.05	0.01	0.00	-0.01	0.02
	JP	-0.06	0.14	-0.01	0.00	-0.01	0.00	-0.02	0.04
	Other	-0.02	-0.04	-0.02	0.00	-0.01	-0.01	0.04	-0.04
	Σ	-0.22	-0.03	-0.13	-0.04	-0.10	-0.03	-0.08	-0.64
Small banks	US	-0.01	0.01	0.02	0.00	0.02	0.00	0.00	0.05
	EZ	-0.04	-0.02	-0.01	-0.03	0.00	0.00	0.00	-0.11
	UK	0.00	-0.01	-0.02	-0.01	-0.01	0.00	-0.01	-0.06
	CH	0.02	-0.01	0.00	0.00	0.00	0.00	0.00	0.01
	JP	-0.02	0.09	-0.01	0.00	0.00	0.00	0.00	0.04
	Other	-0.07	-0.11	-0.06	-0.01	0.01	-0.07	0.01	-0.29
	Σ	-0.12	-0.05	-0.08	-0.05	0.02	-0.07	0.00	-0.37
Non-Banks	US	-0.15	0.07	-0.01	0.01	0.01	-0.01	0.03	-0.06
	EZ	0.31	0.00	0.02	0.01	0.00	0.00	0.00	0.33
	UK	0.13	0.02	0.21	0.02	0.01	0.00	0.00	0.39
	CH	0.01	0.00	0.00	0.06	0.00	0.00	0.00	0.08
	JP	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	Other	0.03	0.00	0.00	0.00	0.07	0.11	0.06	0.27
	Σ	0.33	0.10	0.22	0.10	0.09	0.10	0.09	1.01

Table F1: FX swap open (outstanding) **net** volume (purchases **minus** sales), 2012-22 daily average, in tn of USD. A positive number indicates US dollar net borrowing in the FX swap market at the near leg.

Appendix G

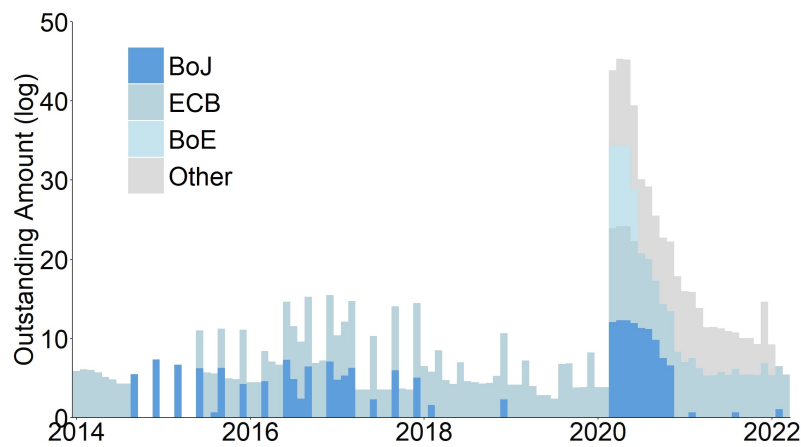


Fig. G1: Federal Reserve U.S. dollar liquidity swap amounts outstanding, in logs. Each bar represents monthly average values and is measured in USD. Data created by the author using data from the New York Fed.

Appendix H

		Net open position (in tn of USD)					Net	Net, %
		EUR	JPY	GBP	CHF	Other		
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 H1: 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 I

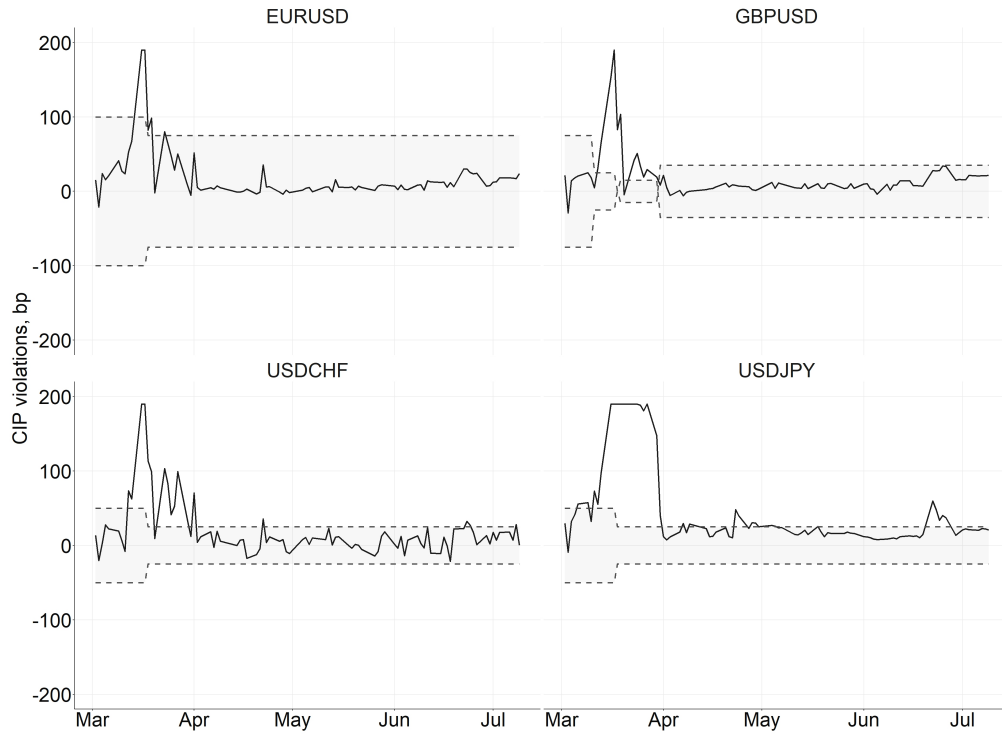


Fig. I1: 1W CIP basis (Bloomberg) vs. no-arbitrage-implied CIP ceiling bounds (author's calculations). Dashed red lines refer to the upper and lower bound of the swap line-implied ceiling; shaded ribbon thus refers to the area of CIP violations χ_t that do not violate the price ceiling: $(i_t - i_t^S) + (i_t^{v*} - i_t^{p*}) \leq \chi_t \leq (i_t^S - i_t) + (i_t^{p*} - i_t^{v*})$. Data is daily from March 1 until June 30, 2020.

Appendix J

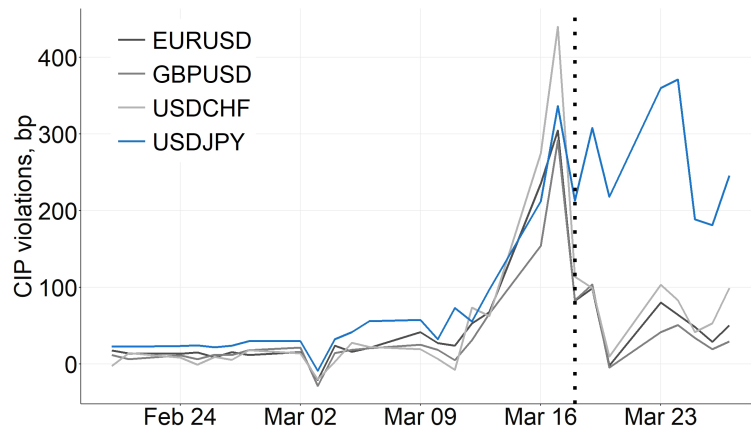


Fig. J1: CIP violations around March 2020 across the largest currency pairs for the 1W tenor. Interest rates are LIBOR. FX rates are from Refinitiv. CIP deviations refer to annualized values. Dashed line is refers to the start of the augmented swap line allotment on March 18. AUDUSD and USDCAD are excluded as these currencies were not affected by U.S. dollar swap lines. Data is daily.

Appendix K

	Dep: Dollar sales, 1W		
	JP	Non-JP	All
Pre-Implementation	0.03 (0.97)	1.68*** (0.58)	1.37** (0.59)
Implementation	3.03*** (1.03)	1.22 (1.05)	0.78 (0.91)
$D_1: \rho - c > 0$	6.73*** (1.05)	0.27 (0.28)	1.44*** (0.35)
$D_2: \rho - c < \approx 0$	-0.45 (0.53)	-1.67*** (0.26)	-1.50*** (0.23)
$D_3: \rho - c > 0$	1.85*** (0.70)	0.69 (0.46)	0.70** (0.42)
Constant	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Obs	174	696	870
Adjusted R ²	0.41	0.50	0.44
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01		

Appendix L

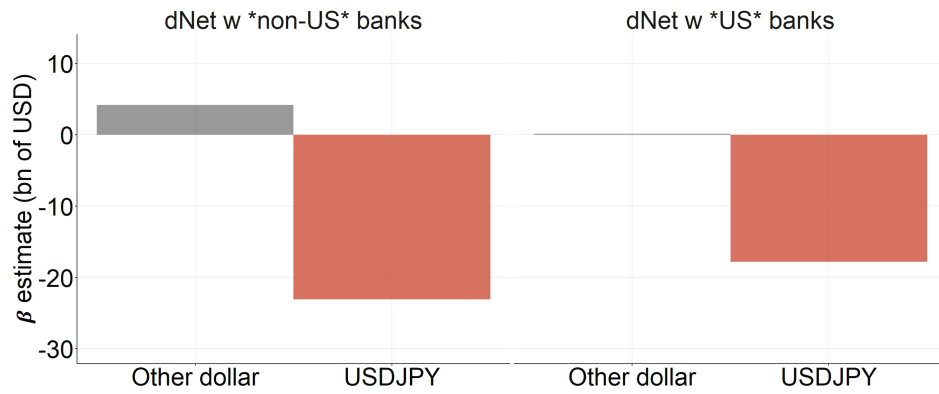


Fig. L1: Excess U.S. dollar lending by JP banks in 2020 per counterparty group. The figure displays the coefficient on the net change in net US dollar lending, β , from the following ordinary least squares (OLS) regression: $Net_{i,t} = \alpha + \beta \cdot SwapLines + \epsilon_{i,t}$ where $SwapLines$ equals 1 for March 18 to June 30 of 2020 and 0 otherwise. $Net_{i,t}$ refers to the net (buy minus sell) dollar borrowing for currency i and is measured in bn of USD. Red (green) coloring indicates a statistically significant increase in net lending (borrowing) whereas gray shading indicates no significant change at the 1% significance level. Data is daily for a sample from 2019 to 2022.

Appendix M

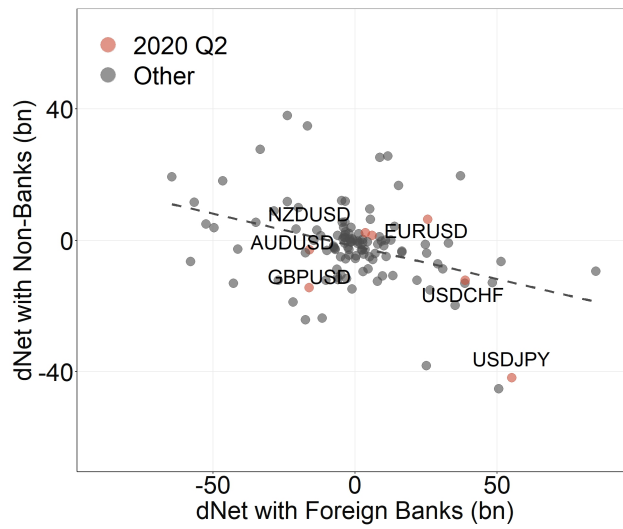


Fig. M1: US dealer net position in the interbank market vs. with non-bank customers. Each dot represents the quarterly change in US bank *net* position in a currency-counterparty group. Counterparties refer to foreign (non-US banks) vs. non-bank customers and are grouped together. Currencies refer to the G7 currencies. Data is 2018 to 2022.

Appendix N

In the figure below, I report the regression 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.

	US bank Sell-minus-Buy transaction price spread				
	<i>HKM</i> ^{Q1}	<i>HKM</i> ^{Q2}	<i>HKM</i> ^{Q3}	<i>HKM</i> ^{Q4}	<i>HKM</i> ^{Q5}
	(1)	(2)	(3)	(4)	(5)
Gross volume	−0.03*** (0.004)	−0.04*** (0.004)	−0.04*** (0.004)	−0.03*** (0.005)	−0.04*** (0.005)
Bid-ask spread	0.04 (0.05)	0.05 (0.06)	0.20*** (0.05)	0.28*** (0.04)	0.19*** (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 N1: Quantile 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 O

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 slope 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 5% and the 95% confidence level. Results show that the spread-volume slope increases across constraint quintiles.

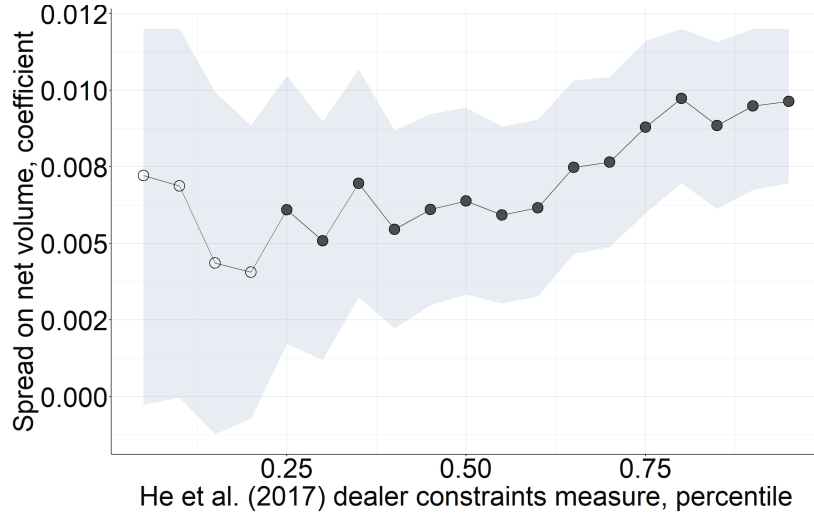


Fig. O1: Estimated slope coefficient of the U.S. bank sell-minus-buy transaction price spread on U.S. bank sell-minus-buy trading volume, by dealer constraint percentiles. The dealer constraints measure is based on [He et al. \(2017\)](#), who provide a daily time series for primary dealers that includes all major U.S. banks. The slope 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 5% and the 95% confidence level.

Appendix P

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:	
	≤ 0	> 0	≤ 0	> 0
Sell-minus-Buy volume	0.01*** (0.004)	0.02*** (0.004)	0.01*** (0.004)	0.02*** (0.01)
Bid-ask spread	0.28*** (0.03)	0.38*** (0.06)	0.45*** (0.05)	0.36*** (0.08)
VXY	0.81*** (0.23)	0.36* (0.25)	0.42** (0.20)	0.98*** (0.35)
Quarter.Cross	0.19*** (0.04)	0.15*** (0.05)	0.11** (0.05)	0.16** (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 P1: 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.