Synthetic Dollar Funding

Umang Khetan*

July 2024

Abstract

US dollar funding is crucial to the functioning of the global economy. However, the sources of and frictions in the international supply of the dollar are not well understood. In this paper, I show that foreign exchange (FX) swaps emerge as alternative ("synthetic") dollar funding instruments when its wholesale supply is constrained. Global banks increase dollar borrowing via FX swaps in response to reduced flows from US money market funds, which leads to substantial deviations from covered interest parity (CIP). I construct granular instruments using money market funds' investments in bank-issued debt and find that CIP deviations worsen when large foreign banks face negative shocks to wholesale dollar funding. This shift in aggregate demand is absorbed by non-bank users of FX derivatives in the form of higher hedging costs: I estimate the elasticity of non-bank investors' hedging demand to CIP deviations and find only a partial adjustment in quantities traded. My results indicate that frictions in the global market for the US dollar provide a demand-based explanation for the violation of no-arbitrage pricing conditions.

Keywords: FX swaps, US dollar, currency hedging, covered interest rate parity, financial frictions.

JEL classification: F31, G11, G12, G15, G20

*University of Iowa. Contact information: www.umangkhetan.com, umang-khetan@uiowa.edu
I am grateful to David Bates, Tong Yao, Ishita Sen, Fotis Grigoris, and Petra Sinagl for regular guidance and feedback. This paper benefited from helpful comments by Iñaki Aldasoro, Fousseni Chabi-Yo, Ioana Neamțu, Jonathan Parker, Ashish Tiwari, and seminar participants at the University of Iowa. I thank Mark Socha and Femi Opeodu at the Continuous Linked Settlement Group (CLS) for providing me with the data and for answering my numerous questions. The findings and conclusions in this paper do not necessarily reflect the views of CLS. All errors and omissions are my own.

1. Introduction

The US dollar plays a dominant role in the international financial system, with over three-fourths of cross-border trade and two-thirds of foreign currency debt denominated in the dollar.[1] A growing literature shows that frictions in the international supply of the US dollar affect real economy through credit contraction (Ivashina, Scharfstein, and Stein, 2015, Barajas, Deghi, Raddatz, Seneviratne, Xie, and Xu, 2020), and asset markets through pricing anomalies (Avdjiev, Du, Koch, and Shin, 2019, Du and Schreger, 2022), with episodes of severe dollar shortage requiring emergency support from the Federal Reserve (Bahaj and Reis, 2022). Strikingly, a majority of US dollar lending is conducted by *non-US* banks that do not have access to natural funding sources such as a deposit franchise. As a result of their extensive involvement in US dollar intermediation, funding constraints faced by large global banks can significantly impact international financial stability.

As intermediaries' dollar constraints gain more attention, the rapid expansion of off-balance sheet instruments that create "hidden leverage" for borrowers has also come into focus. Foreign exchange (FX) swaps are among the largest of these off-balance sheet instruments; Borio, McCauley, and McGuire (2022) report over $80 trillion in outstanding FX swaps and forwards as of 2022, mostly concentrated in the short tenor segment. By any measure, this is an enormous market that is believed to facilitate "synthetic" dollar funding by temporarily converting foreign currency into US dollars. Yet, important questions on this source of dollar supply remain unanswered: (i) What are the underlying drivers behind banks' use of FX swaps? (ii) How does it affect asset prices? (iii) What is the spillover impact on other investors that are active in international capital markets? Answering these questions is crucial to assess both the linkages between various funding markets, and the international implications of domestic money market regulations.

This paper investigates the specific drivers behind global financial intermediaries' demand for synthetic dollar funding, and its broader impact on financial markets. Using a comprehensive database on sector-level daily FX swap transactions, I show that globally active dealer banks raise dollars synthetically in response to reduced wholesale supply from US money market funds. This substitution of demand increases swap prices, i.e., widens covered interest parity (CIP) deviations, across tenors from one week to three months. To address the endogeneity from simultaneous determination of quantities and prices, I construct granular instruments using security-level holdings of US money market funds in foreign banks' debt, and confirm that CIP deviations widen when

[1]Further, 85% of foreign exchange (FX) trades involve the use of dollar (Somogyi, 2022), 60% of FX reserves are dollar denominated (Bertaut, von Beschwitz, and Curcuru, 2021), 40% of international payments are made in the dollar (Davies and Kent, 2020), and foreign investors derive convenience yield from holding US dollar assets (Jiang, Krishnamurthy, and Lustig, 2021). Gopinath and Stein (2021) provide a theoretical framework for dollar dominance in global finance.

large foreign banks experience negative wholesale funding shocks. Finally, I use the instrumented swap price to estimate the demand elasticity of non-bank investors to CIP deviations, and find that foreign investors absorb these price shocks in the form of increased hedging costs, potentially amounting to billions of dollars annually.

Frictions in the global market for US dollar funding explain the economic channels underlying these patterns. On the demand side, non-US banks hold large amounts of dollar-denominated assets but do not have matching levels of dollar liabilities because they lack US depositor base (Ivashina, Scharfstein, and Stein, 2015, Abbassi and Bräuning, 2021). As a result, they are heavily reliant on wholesale investors such as US money market funds (MMFs), who in turn are subject to tight regulatory and liquidity constraints (Rime, Schrimpf, and Syrstad, 2022). I find that global banks, who can access money markets across currency areas, increase their borrowing of dollars through FX swaps in response to a reduced supply from US MMFs despite a higher cost of borrowing synthetically, pointing towards a substitution pattern. Moreover, this channel represents an increased demand pressure in the swap market which, combined with an upward-sloping supply curve, increases prices, i.e. makes the cross-currency basis more negative.[2] Figure 1 correlates Euro-area banks' wholesale funding constraints with the EURUSD cross-currency basis, and shows that when a larger fraction of non-US banks is constrained from accessing additional wholesale funding, the cross-currency basis turns more negative.

On the supply side, I find that cash-rich US real-money investors do not fully arbitrage these price deviations away. Using the US life insurance sector as representative of cash-rich institutional investors, I find only a small increase in their FX derivative and foreign bond holdings on account of wider CIP deviations. To gain further insights into the mechanism behind the price effect, I estimate the FX hedging demand elasticities of non-bank investors such as investment managers ("funds"), non-bank financial institutions, and corporations. I find that only funds react to wider CIP deviations but with an elasticity parameter that suggests imperfect adjustment in quantities. Therefore, the impact of these frictions is an increased cost of hedging FX exposure borne by investors with USD asset holdings.

I provide empirical support for these channels using one of the most comprehensive transactions data available in FX derivatives. Synthetic dollar funding is facilitated by foreign exchange swaps, that are among the most heavily traded financial derivatives in the world (Bank for International Settlements, 2022). Despite its large size and a significant role in the international financial architecture, limited research exists on this market. This is primarily due to its over-the-counter nature that makes granular transaction-level data difficult to obtain. My analysis leverages daily aggre-

[2] This result is consistent with Du and Schreger (2022) who suggest that cross-currency bases represent a compensation for suppliers of synthetic dollar funding in the FX swap market.

gated dealer-to-client transactions from CLSMarketData that are compiled by the CLS Group, which operates the largest multi-currency cash settlement system in the world. The data provide me with signed order flows in the FX swap market across seven tenors, and nine major currency pairs that together represent over 90% of the trading volume in FX swaps. I estimate that these data cover about a quarter of global dealer-to-client swap transaction volume.

Several features of this dataset make it particularly suitable for studying the synthetic dollar funding market. First, unlike the aggregated triennial survey statistics reported by the Bank for International Settlements (BIS), CLS data provide *signed* order flow volumes at a daily frequency, which allows me to quantify high-frequency dollar borrowings and connect them to indicators of dollar funding shortage. Second, I observe trades contracted between core dealers and all other sectors put together, as well as between banks and price-takers such as funds, non-banking financial institutions, and corporations, which enables me to estimate the spillover impact of synthetic funding on several non-bank sectors through their demand elasticities. Third, the time-series runs from January 2013 through December 2023 for a total of 11 years, which captures the entire business cycle and variations caused by important events such as the 2016 money market fund reform and the 2022 interest rate hiking cycle. I complement the CLS flow data with bank-specific MMF holdings sourced from the SEC filings, and detailed derivative holdings of US life insurance companies to estimate the supply-side reaction. To my knowledge, this is one of the most comprehensive databases covering the flow of FX swap transactions utilized in academic research to date.

Synthetic dollar funding is concentrated in the overnight to one-week tenors of the swap curve, and is primarily undertaken against the Euro (EUR), the Japanese yen (JPY), and the Swiss franc (CHF). Further, global dealer banks are the largest dollar borrowers in this market, while non-dealer banks act as suppliers. I analyze the evolution of global banks' synthetic dollar borrowing against changes in MMF holdings of bank securities, both for a panel of currencies and for EURUSD individually, and find a strong negative association between the two. This characterization is consistent with a pecking order of USD funding sources, going from cheaper wholesale funding (if available) to costly synthetic funding as an alternative.

My results are robust to using alternate indicators of order flow, such as count of trades, as well as different regressors, such as the value-weighted maturity of MMF holdings. Furthermore, I rule out two alternate explanations. First, I find that a decline in MMF holdings affects synthetic dollar funding only for the banking sector, which suggests that intermediation for other sectors is not the reason for this substitution. Second, I show that the order flow in FX forwards (that entail a single set of cash flows) does not react to changes in MMF holdings, and that the shift in funding demand is specific to FX swaps (that entail two sets of cash flows), which indicates that the hedging of currency risk cannot explain my findings.

Dollar demand via FX swaps leads to deviations from a no-arbitrage pricing rule. I find that an increase in net dollar borrowing by global banks leads to larger deviations from covered interest parity (CIP), turning the cross-currency basis more negative. These deviations are visible across the term structure, from maturities of 1 week to 3 months where the vast majority of currency derivatives are traded. My findings are robust to the inclusion of a large number of controls that have been shown in the literature to affect CIP deviations. An implication of this finding is that demand for dollars interacts with constrained supply and limits to arbitrage to explain why CIP deviations persist. However, a valid concern with the reduced-form results is the simultaneous determination of quantities and prices in the equilibrium, as well as omitted variable bias from macro-economic variables. To address endogeneity concerns, I employ a granular instrumental variables (GIV) strategy that exploits variation in MMF holdings in bank-specific securities.

My identification strategy is based on Gabaix and Koijen (2024), who argue that in economies dominated by a few but large agents, idiosyncratic shocks to these agents can lead to nontrivial aggregate shocks. Borrowers of dollars from US MMFs represent a concentrated set of large global banks in each currency area (Aldasoro, Ehlers, and Eren, 2022). These banks collectively borrow hundreds of billions of dollars each month from US MMFs. On one hand, the aggregate MMF borrowing by the banking sector may co-move with CIP deviations for reasons other than MMF supply frictions. On the other hand, when some of these large banks face differential flow of funds compared to the sector as a whole, that could affect their FX swaps activity and thereby the cross-currency basis. In my granular data set of MMF holdings in bank securities, I find that a subset of large banks occasionally face funding constraints due to (i) concentration limits that restrict MMFs from lending more than 5% of their assets to single issuers, (ii) bank-specific credit rating changes, and (iii) large inflows or outflows experienced by individual funds that specialize in lending to certain banks. Therefore, idiosyncratic shocks to wholesale funding faced by large banks can serve as valid instruments for synthetic dollar funding against each currency.

I implement the GIV strategy by extracting idiosyncratic shocks as the difference between size-weighted and equally-weighted changes in MMF flows to non-US banks, and aggregating them within each currency area. First, I show the relevance of the instrument to FX swap quantities traded by global dealer banks, and confirm that instrumented FX swap quantities impact cross-currency bases. Then, I use the instrument directly for cross-currency basis as an endogeneous variable, in order to estimate demand elasticities of other users of FX derivatives. In the first stage, I find that cross-currency bases strongly react to instrumented flows from MMFs to non-US banks, both in a panel of currencies and for EURUSD individually. A higher value of the instrument (an increase in the value-weighted funding from MMFs) positively associates with cross-currency basis, implying that when relatively bigger banks receive a larger share of MMF flows, the CIP deviations for that currency become narrower. This association is statistically and economically strong even after allowing for a negative correlation induced by a potential increase in demand for dollar credit.

Then, I proceed to estimate the impact of instrumented price shocks on non-bank users of FX derivatives: investment funds, non-financial corporations, and non-bank financial intermediaries. Each investor in this market can respond in one of two ways: absorb the price change in the form of hedging cost while keeping quantities unchanged (price inelastic), or adjust the quantity traded to maintain the same overall hedging cost (price elastic). I find that, while all non-bank sectors are generally price inelastic, funds show the highest elasticity of FX hedging demand to instrumented CIP deviations in a direction that suggests downward-sloping demand curve. For a 1% reduction in cross-currency basis (i.e., synthetic dollars are more expensive), funds reduce forward sale of the dollar by 0.54% in the panel of all currencies and by 0.18% against the Euro. Further, funds reduce buy-sell USD swaps by 0.43% in the panel and by 0.27% against the Euro. However, these elasticity estimates are all below 1, which suggests relatively inelastic demand and absorption of higher costs by foreign investors. Likewise, non-bank financial institutions and corporations exhibit minimal response of hedging demand to price changes. A back-of-the-envelope calculation suggests that, for an estimated $2 trillion in outstanding FX hedges (Du and Huber, 2023), foreign investors pay an additional $3.6 billion in FX hedging costs per annum due to negative cross-currency bases.

How do potential suppliers of dollars react? I find that the large effect of synthetic dollar funding on equilibrium prices is possible due to the limited adjustment in the marginal supply of dollars from other, cash-rich US investors. Existing literature documents that traditional arbitrageurs such as dealer banks face limits to arbitrage, particularly after the financial crisis. At the other extreme, the Federal Reserve supplies dollars internationally via swap lines only during market-wide disruptions, such as the COVID-19 pandemic. I complement the analysis by studying US-based global institutional investors who could, in theory, benefit from wider CIP deviations. I study the FX derivative and foreign bond portfolios of US life insurance companies that hold over $200 billion in foreign bonds and a large amount of FX derivatives to hedge the currency risk. I find that while they increase their holding of FX forwards and swaps when the cross-currency basis turns more negative, the elasticity is well under 1 and therefore the volume of marginal dollars supplied is not large enough to fully offset the impact of demand shifts from global banks.

Taken together, my results show that the use of FX swaps for international dollar funding represents more than just demand substitution from one market (US money market) to another (currency market). It is a significant driver of asset prices in the largest derivatives market and provides a demand-side explanation for the existence of cross-currency basis highlighted in the recent literature. In addition to supply-side and regulatory constraints (Du, Tepper, and Verdelhan, 2018), my findings suggest that frictions in the international supply of the US dollar provide a demand channel that leads to violations of covered interest parity. This has real spillover effects on non-bank investors' portfolios through higher hedging costs borne by foreign investors. For US institutional investors, this implies a small adjustment in the composition of asset portfolios and potentially large foregone profits due to their price inelasticity.

My work also informs regulatory discussions on the fragility of short-term funding markets and the prudential policies to safeguard the system. The post-financial crisis reforms in US money markets increased frictions in the international supply of the dollar. As I show in this paper, part of this demand for dollars shifted to the FX swap market, an off-balance sheet form of borrowing that is more difficult to track and can add to financial fragility (Barajas et al., 2020). The increased importance of FX swaps has also increased the reliance on the US Federal Reserve's dollar swap lines during stress episodes, such as the COVID-19 pandemic (Bahaj and Reis, 2020). However, the globally dispersed regulatory supervision of FX markets and off balance-sheet nature of swap borrowing implies that central banks set swap lines "in fog" (Borio et al., 2022). To this end, my paper presents an early step in understanding the linkage and spillovers between US money markets and global FX markets, which could help to assess how domestic liquidity policies affect globally inter-connected markets.

Related literature. This paper contributes to the literature which argues that intermediary constraints matter for asset prices (Haddad and Muir, 2021, Du, Hebert, and Huber, 2022). Recent studies highlight that intermediaries face capital constraints, and their balance sheet space is scarce (Siriwardane, 2019, Fleckenstein and Longstaff, 2020). My unique contribution is to analyze the growth of off-balance sheet derivative instruments that enable global banks to reduce dollar funding constraints. In this sense, my paper also speaks to the literature on banks' capital management under market frictions: Hilander (2014) reports that major Swedish banks raise short-term funding in foreign currency; Iida, Kimura, and Sudo (2018) document increasing dependence of non-US banks on FX swaps; Anderson, Du, and Schlusche (2021) show that banks use unsecured borrowing to conduct arbitrage; Siriwardane, Sunderam, and Wallen (2022) document segmentation in banks' internal funding sources; and Aldasoro, Ehlers, and Eren (2022) highlight price dispersion in banks' wholesale funding. My paper adds to this literature by jointly assessing two major funding sources – wholesale unsecured markets and foreign exchange swaps – which offers a new perspective on the pecking order of different funding instruments available to financial intermediaries.

My paper also adds to the literature on the determinants of covered interest parity (CIP) deviations. Several studies document that supply-side frictions, driven either by post-financial crisis regulations (Du, Tepper, and Verdelhan, 2018) or funding costs faced by investors (Rime, Schrimpf, and Syrstad, 2022), create limits to arbitrage, thereby allowing CIP deviations to persist.

However, the role of *demand* as a factor has been understudied. Notable exceptions include Baba, Packer, and Nagano (2008) who correlate the demand for dollar funding and cross-currency basis during the financial crisis, Liao and Zhang (2020) who study FX hedging by non-US investors, and Syrstad and Viswanath-Natraj (2022) who document heterogeneity in the impact of order flow on FX swap prices. However, these sources of demand abstract away from the role of US dollar funding shortage faced by global banks on an ongoing basis. Focusing on the largest set of institutions that regularly bear on-balance sheet dollar funding gap, my paper provides a direct link between their swap market activity and CIP deviations, and traces the source of this activity to frictions in the international supply of US dollar.

Closer to my setting, Abbassi and Bräuning (2021) document the use of FX forwards by German banks to close their dollar funding gap at quarter-ends, and Becker, Schmeling, and Schrimpf (2023) use granular instruments to document that cross-border lending affects CIP deviations. My analysis highlights the role of frictions that lead banks to substitute (cheaper) wholesale funding with (costlier) synthetic funding, which has large asset pricing consequences. Further, I extend the analysis to the broader financial system by studying the demand elasticities of non-bank players to highlight that limited adjustment in hedging quantities enables these frictions to have large impact on CIP deviations.

I also build on the growing literature on risk management using derivatives. Recent studies include Khetan, Li, Neamtu, and Sen (2023) in interest rate swaps, and Bahaj, Czech, Ding, and Reis (2023) in inflation swaps. Within the FX context, Liao (2020) jointly considers CIP and corporate bond spreads, Wallen (2020) studies markups paid by funds on their FX hedges, Bräuer and Hau (2022) study the hedging behavior of institutional investors, and Du and Huber (2023) estimate the dollar holdings and hedge ratios of non-US investors. Using *cross-sector* swap transactions data, my paper is the first to estimate the FX hedging demand elasticity of multiple non-bank sectors, and quantifies the spillover impact of frictions in the international supply of the dollar on the hedging costs faced by investors. Moreover, using the US insurance sector as an example, I show that the asset portfolio of cash-rich institutional investors responds to CIP deviations, but in a magnitude smaller than would be necessary to offset these pricing anomalies.

This paper proceeds as follows. Section 2 provides the institutional background, and Section 3 discusses the data. Section 4 provides reduced-form evidence for FX swap demand and impact on CIP deviations, while Section 5 details the granular identification strategy with spillover impact on non-bank sectors. Section 6 concludes.

2. Institutional background

With over $13 trillion in US dollar assets, non-US global banks play a pivotal role in supplying dollars to various segments of the world economy. These banks are headquartered outside of the US and do not have direct access to retail dollar deposits; Ivashina, Scharfstein, and Stein (2015) and Abbassi and Bräuning (2021) argue that a large portion of non-US banks' dollar assets is not matched by equivalent liabilities, creating a dollar funding gap on their balance sheets.[3] However, these banks have easier access to local currency funding, e.g., in Euro, especially when their home country central banks keep liquidity conditions loose. To meet the balance sheet mismatch between dollar-denominated assets and liabilities, non-US banks rely heavily on wholesale funding sources such as the US money market funds (MMFs).

MMFs invest in short-term liquid fixed income assets issued by governments, banks, non-bank financial institutions, and non-financial entities. Aldasoro, Ehlers, and Eren (2022) and Aldasoro and Doerr (2023) show that MMFs are crucial suppliers of short-term dollars to banks around the world; US MMFs held over $6 trillion in assets as of 2023, half of which was invested in instruments issued by banks such as commercial paper and certificate of deposit. While their investments in banks are crucial to meet dollar funding shortages, US MMFs are subject to tight regulatory controls on liquidity risk. Rime et al. (2022) report that MMFs have strict regulatory concentration limits (e.g., they cannot invest more than 5% of total assets in any A-1/P-1-rated issuer) that constrain MMFs to provide additional funding even to credit-worthy borrowers. Given that MMFs are important but constrained suppliers of dollars to global banks, I hypothesize that global banks resort to FX swaps in response to reduced MMF investment in their debt securities.

An FX swap allows the borrower to exchange its local currency funds for the US dollar at a near date (typically the trade date or spot date), with the transaction reversing at a later date. Figure A1 depicts the balance sheet implications of dollar borrowing under direct route in panel (a) and synthetic route in panel (b). Note that, while the FX swap transaction itself is off-balance sheet, the collateral provided, i.e. the other currency, does expand the size of the balance sheet. The net effect is, therefore, approximately the same as direct dollar borrowing except that the "dollar" debt is not reported on the books. However, borrowing through swaps can be optimal in certain situations because other funding sources entail provision of scarce collateral for secured or counterparty credit risk for unsecured borrowing.[4] The investors most likely to benefit from

[3] Iida et al. (2018) report that non-US banks have a larger market share in international USD lending than US banks; Barajas et al. (2020) show that dollar funding shocks lead to financial stress in non-US banks' home economies; and Sun (2023) documents the prevalence of dollar funding crises across countries.

[4] For example, repo transactions require pledging of US treasuries as collateral that can be scarce in times of stress (Dieler, Mancini, and Schürhoff, 2021).

synthetic funding instruments are those with access to multiple money markets, i.e. global banks.

The foreign exchange derivatives market facilitates synthetic dollar borrowing. Figure A2 shows that FX derivatives are among the most heavily traded financial instruments in the world, and a vast majority of trades are of short-tenor (less than 1 year). In terms of sector composition, this market is dominated by banks and institutional investors. Bank for International Settlements (2022) reports that outside of inter-dealer trades, 42% of the traded volume is with non-dealer banks, 23% with institutional clients, 10% with investment funds, and 10% with non-financial entities. While banks trade swaps to raise funding in foreign currencies, other institutional investors mainly trade forwards to hedge currency risk on foreign assets and liabilities.[5]

The FX derivatives market is also characterized by persistent deviations from covered interest parity, the breakdown of a fundamental no-arbitrage pricing rule that pins down theoretical swap prices. The price of an FX swap should neutralize the cost differential between direct and synthetic dollar borrowing, i.e., the "cross-currency basis" should be zero. Violations of this rule, known as covered interest parity deviations, entail an arbitrage opportunity. Figure A3 shows that the cross-currency basis deviates from zero across multiple currencies, and turns sharply negative during periods of economic contraction. In my setting, synthetic dollar funding represents a rightward shift in the demand curve for FX swaps. Together with upward sloping supply curves documented in recent literature (Du et al., 2018), we should expect the synthetic price to increase, i.e. cross-currency basis to turn more negative, in response to increased dollar borrowing through swaps.

The primary hypothesis in this paper links frictions in the supply of dollars from US money market funds to negative cross-currency basis. Figure A4 illustrates a strong negative correlation between the on-balance sheet dollar funding gap of non-US banks, and the average cross-currency basis across currency pairs. Locational banking statistics from the BIS show that the aggregate funding gap of non-US banks amounts to $1.2 trillion. Figure A4 shows that this funding gap has ranged between 15-20% of outstanding claims in recent years, and that an increase in the gap associates with more negative cross-currency basis, suggesting that non-US banks need to bridge the gap using FX swaps.[6] Reduced dollar supply from MMFs plays a major role in increasing banks' dollar funding gap: for example, we observe an uptick in the funding gap during the 2011 Euro debt crisis when MMFs reduced lending to Euro-area banks (Ivashina et al., 2015), and again during the transition phase of 2016 reform when banks lost over $800 billion in MMF funding (Anderson et al., 2021). In the sections that follow, I test these channels empirically and study their broader impact on other users of FX derivatives.

[5] A forward entails a single cash-flow exchange at the far leg only, as opposed to a swap that entails two sets of cash-flow exchange similar to a term loan.

[6] It is unlikely that banks run large open foreign exchange mismatches on their balance sheets because of regulatory pressure to limit the risk arising from net open FX positions (Barajas et al., 2020).

3. Data

I analyze over-the-counter (OTC) foreign exchange swap and forward transactions, aggregated at a sector level, that cover trades between (a) global dealer banks and rest of the market, and (b) banks of all kinds and three end-user sectors: funds, corporations, and non-bank financial institutions. The agents in my sample are geographically dispersed and their trades are executed over electronic as well as trader-enabled execution platforms. The sample period runs from January 2013 through December 2023 at a daily frequency, and separately includes the volume and count of buy and sell trades. The dataset is further split into 9 currency pairs that altogether represent 90% of the global FX swap trading volume, and 7 tenor buckets ranging from overnight to over one year. I source the data from CLSMarketData, a platform owned by the CLS Group which operates the world's largest multi-currency cash settlement system. As part of its central role in the settlement of OTC FX transactions, the CLS Group collects and aggregates these data for use by researchers.[7]

CLS data provide one of the largest and most representative coverage of this market. Using the April 2022 Bank for International Settlements (BIS) triennial survey as a benchmark, I estimate that my data cover between a quarter to a third of the global OTC swaps turnover between dealers and various types of clients, see Table A1. The large coverage of this market is enabled by the fact that over half of FX trades are settled through risk-mitigation channels, of which CLS has a 72% share (Glowka and Nilsson, 2022). Furthermore, Table A1 shows that CLS data are representative of the broader market in terms of the share of individual currencies and different maturities over which swaps are traded. Appendix A provides further details on how CLS collects and constructs this data set, and the exact methodology of comparing it to the BIS survey. I augment the CLS transactions data with granular holdings of US money market funds, and cross-currency basis constructed using FX spot, forward, and interest rates.

3.1. Swaps and Forwards

I source daily records of signed order flow across 9 currency pairs that collectively represent 90% of the traded volume in this market (Bank for International Settlements, 2022).[8] The daily data include key economic details such as the sectors trading the instrument, buy and sell volumes and counts of trade, maturity buckets, and the currencies involved, separately for swaps and forwards.

[7]Other studies that use CLS data include Hasbrouck and Levich (2021), Ranaldo and Somogyi (2021), Khetan and Sinagl (2023) for FX spot, and Cespa, Gargano, Riddiough, and Sarno (2022), Ranaldo (2022), Bräuer and Hau (2022), Kloks, Mattille, and Ranaldo (2023), Kloks, McGuire, Ranaldo, and Sushko (2023) for FX derivatives.

[8]These currencies are the Euro (EUR), British pound (GBP), Japanese yen (JPY), Swiss franc (CHF), Australian dollar (AUD), New Zealand dollar (NZD), Norwegian krone (NOK), Swedish krona (SEK), and Canadian dollar (CAD), all facing the US dollar (USD).

Both the swaps and forwards data are structured similarly except that swaps are split by 7 tenor buckets, while forwards are split by 6 buckets (forwards exclude the overnight tenor). Further, swaps entail two sets of cash-flows, with the near leg settling on the trade date or the spot date, while forwards entail a single set of cash-flows only at the far date. These two products comprise the bulk of FX derivatives volume and jointly provide me with a comprehensive picture of the funding and hedging activity in this market.

I calculate the daily net dollars borrowed at the near leg of a swap trade as the signed difference between buy and sell volumes from the perspective of the market-maker, within each currency pair and tenor bucket. To do this, I express all units in terms of USD borrowed at the near leg of a swap by the market-making banks in each of the two data cuts. Specifically, for the dataset on trades between sell-side and buy-side institutions, I express units in terms of USD borrowed by sell-side institutions, that are primarily large global dealer banks. For the dataset between banks and end-user sectors, I express units in terms of USD borrowed by banks from other end-users. I also approximate the trading between market-making dealers ("global banks") and non-dealer banks as the residual from buy-side trades less fund, corporate, and non-bank financial institution trades. Appendix A provides further details on variable construction. Table 1 provides descriptive statistics of net dollar borrowing from the perspective of global banks.

Global banks borrow an average of over $43 billion on a given day from all other investors put together. Table 1 shows that this borrowing is almost entirely supplied by non-dealer banks. Looking at other end-user sectors, funds behave similar to global banks in that they borrow on average $14 billion per day, while corporate entities and non-bank financial institutions (NBFIs) borrow about half a billion dollars daily from banks. These facts are consistent with global banks having access to multiple money markets, and non-dealer banks' willingness to supply excess dollars in return for cross-currency basis as the compensation.

A vast majority of borrowing takes place in extremely short tenor of the currency term structure. Panel B of Table 1 shows that overnight ("0 days") tenor accounts for $35.6 billion or 82% of the total daily borrowing, followed by 1-3 days tenor at $9.3 billion and 4-7 days tenor at $4.1 billion. A preference for short tenor swaps is likely because they carry little to no counterparty credit risk, with negligible impact on the risk-based capital requirements from regulatory perspective. The activity in long-tenor swaps likely supports asset purchase, given that banks supply dollars in those tenors to the rest of the end-user sectors. Finally, panel C shows that most of the dollar borrowing is against Euro (EURUSD pair) at $25.8 billion per day, with the Japanese yen (USDJPY pair) being a distant second at $12.2 billion, followed by the Swiss franc (USDCHF pair) and other currencies in low single digits.

Dollar funding activity through FX swaps is concentrated between global banks and non-dealer banks, for tenors up to one week, and mostly against the Euro. These facts collectively suggest that FX swap market is segmented along multiple dimensions. In contrast, Table A2 shows that FX forwards are largely traded by end-users such as funds (net USD sellers) and corporations (net USD buyers), and with volumes more uniformly distributed up to the 3-month tenor.

I complement the sector-level CLS swaps and forwards data with more granular entity-level holdings for the US insurance sector. US insurers are real-money institutional investors who can act as suppliers of dollars, and take the other side of the trade to benefit from CIP deviations. I collect data on the universe of foreign bonds and FX derivatives held by US life insurance companies reported in Schedule D (bonds) and Schedule DB (derivatives) regulatory filings, and compiled by the National Association of Insurance Commissioners (NAIC). The data are reported for individual legal entities at a quarterly frequency. Appendix A details the data cleaning procedure, including the identification of foreign bonds and direction of net exposure for derivative holdings.

3.2. Money Market Fund Holdings

US money market funds report their holdings at a monthly frequency. I source these data from the N-MFP filings data set made available by the Securities and Exchange Commission (SEC), which covers both secured (repo) and unsecured (commercial paper, certificate of deposit, asset-backed commercial paper) instruments.[9] I focus on three reports to construct monthly bilateral flows between each MMF and the borrower's legal entity identifier (LEI): security-level holdings file, submission details file, and fund adviser file. I follow Chernenko and Sunderam (2014) and Cipriani and La Spada (2021) in the merging and cleaning of these data sets. Then, I match the borrower LEIs to their parent firms, their countries of domicile, and the "home" currencies. For example, all LEIs belonging to Deutsche Bank roll into the currency Euro, with the idea that it is easiest for the bank to access its local currency money market for conducting synthetic dollar borrowing. Using these data, I construct the monthly time-series of the total MMF investment in each bank LEI, mapped to the country and currency of its parent's domicile. Appendix A provides additional details on the data processing steps.

Panel A of Table 2 provides descriptive statistics on both the level and change in monthly holdings of US money market funds. The average monthly holdings of non-government securities during my sample period was \$2.7 trillion, with a monthly average increase of \$10.2 billion (chiefly in the high-interest rate regime starting 2022). Euro-area banks were the largest foreign beneficiaries

[9] Aggregate data can be downloaded from the Federal Reserve Board's website, while granular data are available from the SEC's data catalog. These data cover the universe of US MMF investments, but exclude foreign-domiciled offshore MMFs that supply dollars in the "Eurodollar" markets. Aldasoro et al. (2021) report that under 15% of total MMF dollar funding of foreign banks was from offshore funds between 2013-20.

of MMF investment, at an average of $391.7 billion per month. The weighted average maturity of MMF investments is 75 days or 2.5 months, reflecting the short-term nature of these investments. These findings are consistent with Aldasoro and Doerr (2023) who show that the largest non-government borrowers from money market funds are banks.

3.3. Prices and Market Variables

The relevant measure of price in the context of FX swaps is deviations from the no-arbitrage swap premium, known as covered interest parity (CIP), and expressed as cross-currency basis. It represents the cost differential between borrowing dollars directly in the wholesale funding markets, and borrowing dollars synthetically through the FX swap market. I follow Du et al. (2018) to construct the cross-currency basis for each currency pair across tenors ranging from one week to six months. I source daily FX spot and forward prices, and the overnight indexed swap (OIS) yields from Bloomberg. Then, I calculate the annualized difference between USD OIS yield (direct borrowing) and the corresponding synthetic borrowing yield (foreign currency OIS yield plus the swap premium) as the daily cross-currency basis, where a negative basis indicates that it is costlier to borrow dollars using the swap market.

Panel B of Table 2 shows that the average monthly CIP deviation in EURUSD is negative across the term structure. On average between 2013 and 2023, the cross-currency basis was negative 19 bps for 1-week tenor, and negative 25 bps for 6-month tenor. The EURUSD spot rate declined about 18 bps per month, indicating USD appreciation during the sample period. However, the change in overnight swap points was negligible. This indicates one of the reasons why swaps may be a preferred instrument for dollar borrowing over outright spot or forwards: they carry minimal price risk. I also source control variables such as the intermediary leverage ratio (squared) provided by He, Kelly, and Manela (2017) and denote it "ILRS"; the difference between the European Central Bank and the Federal Reserve Bank's balance sheet size as a percentage of GDP (this is a monthly variable with GDP linearly interpolated) and denote it "CBBS/GDP"; and the US 1-month OIS yield as a state variable for interest rates.

4. Demand for Synthetic Dollar Funding

Figure 2 plots the time-series of monthly net USD borrowing by global banks (i.e., sell-side institutions in the CLS data) against EUR. Strikingly, global banks are net dollar borrowers in almost every month from January 2013 through December 2023, with the magnitude occasionally exceeding \$1 trillion.[10] A notable exception is April 2020, when global banks became net suppliers of dollars after various central banks activated emergency swap lines with the Federal Reserve in the aftermath of the disruption caused by the COVID-19 pandemic. Moreover, panel (a) of Figure 3 shows that this demand is almost entirely supplied by non-dealer banks. In contrast, funds supplied less than \$100 billion each month until end-2019, and borrowed about \$200 billion each month thereafter. Non-financial corporations are consistently net borrowers, and non-bank financial institutions do not display large volumes except in the months following the onset of the pandemic.

Synthetic dollar funding is costlier than direct borrowing due to negative cross-currency basis, which raises the question of why global banks choose to borrow through this route. In this section, I present reduced-form evidence to support the substitution hypothesis: global banks demand dollars via FX swaps in response to reduced wholesale supply from US money market funds. Further, I test the asset pricing implications of this demand shift on CIP deviations. If synthetic dollar funding substitutes for quantitatively constrained wholesale funding, then we should expect the cross-currency basis to turn more negative in response to a demand shift.

4.1. Constrained Wholesale Funding

Using the monthly time-series of net dollars borrowed by global banks, I test whether synthetic dollar funding via FX swaps increases in response to reduced investment by US money market funds (MMFs). I start with the impact of changes in aggregate MMF holdings in non-government securities on EURUSD overnight swaps, which represents the largest segment of the FX swaps market (Table 1). Specifically, I estimate the model:

$$\text{Net \$ Borrowing}_t = \beta \Delta \text{MMF Holdings}_{t-1} + \text{Controls}_t + \varepsilon_t. \tag{1}$$

The dependent variable, Net \$ Borrowing$_t$, is the average daily flow of net dollars borrowed by global banks against EUR in the overnight tenor in month t. I use both the net volume in dollars and the net count of trades as two alternative dependent variables. The regressor of interest, ΔMMF Holdings$_{t-1}$, is the change in the total non-government holdings of MMFs. I lag the regressor by one period to attenuate simultaneity bias. I also control for other factors that are known to affect swap markets: (i) sector-level intermediary leverage ratio squared (ILRS) to account for dealers' aggregate capital constraints, (ii) the difference between the balance sheet size of European Central Bank and Federal Reserve Bank scaled by GDP (CBBS/GDP), (iii) US

[10] Figure A5 shows a similar pattern for USDJPY and USDCHF currency pairs. Further, banks headquartered outside of the US have about 70% share in the USD borrowed through EURUSD overnight swaps.

1-month interest rates, (iv) EURUSD spot price, and (iii) EURUSD overnight swap price. All regressors are expressed as month-on-month changes. Table 3 reports the estimation results where standard errors are adjusted for heteroskedasticity and auto-correlation (Newey and West, 1986).

A decline in US MMF holdings significantly increases global banks' dollar borrowing through FX swaps. Column (1) of Table 3 reports a negative and statistically significant coefficient on the lagged change in MMF holdings. Column (2) adds controls and continues to report a strongly negative association between dollars borrowed by global banks via swaps and changes in MMF (non-government) holdings. In dollar terms, a one-standard-deviation decline in MMF holdings in month $t-1$ associates with a \$9.6 billion additional synthetic dollar funding per day in month t (556.27 $\times$ 17.2 / 1,000), which is likely an under-estimate because my sample covers the universe of MMF holdings but only a quarter of FX swap trading volume. Columns (3) and (4) repeat the estimation using count of trades as the dependent variable, and report consistent results.[11]

An alternate measure of global banks' reliance on MMFs and substitution to FX swaps is the weighted maturity of MMF portfolio. A longer maturity of their holdings indicates longer-term supply of dollars, while a decline in the maturity suggests greater need to resort to the swap market. I repeat the estimation of Equation 1 using the monthly changes in volume-weighted *average tenor* of MMF portfolio as the regressor and report the results in Table A3. Similar to Table 3, all coefficients of interest are negative and statistically significant. The alternate measure supports the interpretation of substitution between supply of dollars from MMFs and FX swap markets.

I rule out other potential explanations for the negative association between MMF holdings and synthetic dollar funding. First, I analyze the marginal suppliers of FX swap dollars to confirm that trading outside of the banking sector is not impacted by MMF supply shocks. As Figure 3 shows, non-dealer banks are the main suppliers of swap dollars to global banks. I re-estimate Equation 1 separately for trades between global and non-dealer banks, and for trades between banks and three end-users: funds, corporations, and non-bank financial institutions. Table A4 shows that only non-dealer banks increase their supply of swap dollars to global banks in economically large magnitude when money market fund holdings decline. While funds and NBFIs do not change their swap trading, corporations slightly reduce their borrowing of dollars through swaps when MMF holdings decline, but the economic magnitude is trivial (under \$0.1 billion for a one-standard-deviation change in MMF holdings). Overall, I conclude that only non-dealer banks with likely access to

[11] I also consider Federal Home Loan Banks (FHLBs) as other suppliers of short-term funding in the US whose holdings may impact borrowing through swaps. Ashcraft, Bech, and Frame (2008) and Gissler and Narajabad (2017) document that FHLBs have played an increasingly important role in short-term funding markets and are sometimes considered to be "lenders of second-to-last resort". However, I do not find that changes in quarterly FHLB holdings affect FX swap demand. This is potentially because FHLB investments are directed towards US banks and insurance firms, who are less likely to rely on FX swaps as alternative dollar funding source compared to foreign banks.

local USD deposits increase their supply to global banks when wholesale funding is constrained, supporting the substitution channel.

Second, I address a potential concern that swap transactions are correlated with FX hedging needs of intermediaries. Swaps are used as inputs into other hedging products, such as forwards, and therefore any correlation between hedging needs and MMF investments could bias the interpretation that global banks use swaps for dollar funding in response to decline in MMF holdings. I rule out this alternate explanation by showing that FX *forward* order flow is not affected by changes in money market funds' holdings. I estimate the below model using signed FX forward volume as the dependent variable.

$$\text{Net \$ Bought Forward}_t = \alpha + \beta\Delta\text{MMF Holdings}_{t-1} + \text{Controls}_t + \varepsilon_t. \tag{2}$$

The dependent variable in this equation is the quantity of dollars bought forward by global banks from non-dealer banks against Euro in month t, with rest of the specification analogous to Equation 1. Table A5 collects the estimation results using both the net volume of dollars bought forward and the count of trades as alternate dependent variables. I find no impact of changes in MMF holdings on the quantity or count of trades in the forward market. The hedging demand, therefore, does not appear to be correlated with MMF holdings, and any change in swap trades is likely because of funding demand only.

I broaden the scope of this analysis to include other currency areas where large global banks are located. In addition to EUR, I use granular holdings of MMFs in debt securities of banks headquartered in Japan (JPY), Switzerland (CHF) and the UK (GBP). I construct a currency-month panel of MMF investments and FX swap borrowing that allows me to control for currency-specific time-invariant and common time trends. I estimate the below model with currency and time fixed effects:

$$\text{Net \$ Borrowing}_{C,t} = \beta\Delta\text{MMF Holdings}_{C,t-1} + \text{Controls}_{C,t} + \alpha_C + \alpha_t + \varepsilon_{C,t}. \tag{3}$$

Table 4 shows estimation results for the panel. Consistent with the patterns observed for EURUSD, in the panel of currencies I find that a decline in MMF holdings in month $t-1$ associates with greater synthetic dollar funding demand by global banks. These results hold across the four columns of Table 4 that account for various combinations of controls and fixed effects.

In Appendix B, I present corroborative evidence for these results using a quasi-natural experiment. The reduced-form results in this section can be potentially biased due to omitted variables that simultaneously affect swap markets and money market fund holdings. I sharpen the identification of the link between the wholesale and synthetic funding markets by using plausibly exogenous changes in MMF holdings around the time of a major regulatory reform that took effect in 2016. I find that global banks' swap borrowing significantly increased in the quarters following the transition phase of the reform, while other sectors as well as the forwards market were unaffected.

4.2. Asset Pricing Implications

Persistent deviations from the covered interest parity (CIP) have received increased attention in recent years. In this section, I show that synthetic dollar demand contributes to this asset pricing anomaly. I follow Du et al. (2018) and calculate the daily currency-specific cross-currency basis as:

$$x_{t,t+n} = y^{\$}_{t,t+n} - (y_{t,t+n} - \rho_{t,t+n}). \tag{4}$$

The left-hand term, $x_{t,t+n}$, is a measure of cross-currency basis at time t and for tenor $t+n$. On the right-hand side, $y^{\$}_{t,t+n}$ represents the rate of borrowing directly in US money markets, while $y_{t,t+n}$ represents the cost of foreign currency (e.g., EUR) borrowing, and $\rho_{t,t+n}$ is the FX swap premium for converting the foreign currency into USD on the spot date and swapping it back into the foreign currency at the far date, thereby eliminating FX spot risk. I use the overnight indexed swap (OIS) rate as a measure of local currency borrowing cost (Augustin et al., 2024). I calculate the cross-currency basis over four different tenors (n) that together cover the vast majority of trading in the FX derivatives market: 1 week, 1 month, 3 months, and 6 months, as well as the first principal component of the basis at these tenors. Finally, FX swap premium is the percentage premium over the prevailing spot rate at time t. All the rates are annualized.

Table 2 shows that the average CIP deviations, $x_{t,t+n}$, are negative across the term structure. A negative cross-currency basis indicates that it is costlier to borrow dollars synthetically using FX swaps compared to direct borrowing in the US money market. Under perfectly integrated markets, borrowing dollars through either option would cost the same, because borrowers can choose the cheaper of the two options and optimize borrowing costs. Further, even if price distortions arise, they could be easily arbitraged away. Therefore, under frictionless markets, cross-currency basis should be zero. However, recent work has shown the existence of limits to arbitrage. In the below analysis, I test the demand-side channel: because global banks are compelled to use FX swaps as alternative funding instruments, CIP deviations worsen. I estimate the model:

$$\Delta x_{C,t,t+n} = \beta \text{Net \$ Borrowing}_{C,t} + \text{Controls}_{C,t} + \alpha_C + \alpha_t + \varepsilon_{C,t}, \tag{5}$$

where the dependent variable is the change in cross-currency basis in currency C in month t for tenor n. I regress the basis on the average daily net synthetic dollar borrowing by global banks in currency C and month t, with the amounts aggregated across all tenor buckets. I also include controls for both supply-side factors and other confounding variables: intermediary leverage ratio (squared), difference between European Central Bank and Federal Reserve Bank's balance sheet size as a ratio of GDP, the level of CIP deviations in the previous period, FX spot and swap rates, and US 1-month interest rates. I include currency and month fixed effects, and estimate Equation 5 in turn for maturities of 1-week, 1-month, 3-months, and 6-months, as well as for their first principal component. I also estimate this equation separately for EURUSD, given the large share of EURUSD swaps. Table 5 reports the estimation result for all specifications.

Synthetic dollar borrowing through FX swaps turns cross-currency basis significantly more negative. Table 5 reports negative and statistically significant coefficients on the net \$ borrowing variable across tenors up to 3 months. The strongest impact is visible in the 1-week tenor, where the bulk of FX swaps are traded (Figure 2). These results hold true for EURUSD swaps as well: Table 5 reports negative and statistically significant coefficients attached to the net \$ borrowing variable specifically in EURUSD for all tenors. The economic magnitude of price impact is also large: for a \$100 billion increase in average daily synthetic dollar funding in a month in my sample, the change in 1-week EURUSD cross-currency basis is about 1.1 basis points (0.011×100), which is 4.4% of the full sample average of negative 25 basis points.

I repeat the estimation of Equation 5 at a weekly frequency and find consistent results in Table A6. These results collectively suggest that the substitution of global banks' dollar funding from wholesale to off-balance sheet FX derivatives market comes at the cost of larger asset pricing anomalies. Therefore, constraints faced by wholesale suppliers such as money market funds can translate into price distortion in the international financial markets.

5. Identification and spillover impact

The previous section presented supportive reduced-form evidence that global banks borrow US dollars synthetically (i.e., via foreign exchange swaps) due to reduced investments from US money market funds (MMFs), which in turn leads to deviations from covered interest parity. In this section, I sharpen the identification of these channels using granular data on MMF investments in specific bank-issued short-term debt to instrument for CIP deviations. Further, I estimate the demand elasticity of non-bank investors to instrumented CIP deviations, and estimate the real portfolio implications of frictions in the international supply of the US dollar.

5.1. Granular Instrumental Variables (GIV)

A GIV extracts idiosyncratic shocks to a few but large players in the market, whose actions can significantly impact the economy. It confers three advantages in my setting: (i) addresses endogeneity from factors that co-move with MMF investments and swap markets by netting out "common shocks", such as macro-economic factors; (ii) directly endogenizes the price (cross-currency basis) to allow for the estimation of demand elasticities of other sectors; and (iii) rules out the impact of *US-banks'* actions (e.g., reduction in arbitrage capital documented in Anderson et al. (2021)) that could confound the link between MMF investments and global banks' synthetic dollar borrowing.

Identification strategy. Gabaix and Koijen (2024) argue that in economies dominated by a few but large agents, idiosyncratic shocks to these agents can lead to nontrivial aggregate shocks. In my context, borrowers from US MMFs are large global banks, headquartered in currency areas such as the Euro (EUR), Japanese yen (JPY), and Swiss franc (CHF). On one hand, aggregate MMF borrowing by the banking sector may co-move with CIP deviations for reasons other than MMF supply frictions. On the other hand, when some of these large banks face differential flow of funds compared to the sector as a whole, that could affect their FX swaps activity and thereby the cross-currency basis. The difference between common and idiosyncratic fund flows serves as a valid instrument for the endogeneous price variable, whose sources can be micro-founded as below.[12]

1. Concentration limits: SEC regulations prohibit MMFs from lending more than 5% of their assets to a single issuer (Hanson et al., 2015). Banks closer to this limit may attract a smaller fraction of additional flows compared to those further away from the binding constraint.
2. Credit rating changes: MMFs invest only in highly rated securities, which exposes banks to funding shocks on account of idiosyncratic credit rating changes.
3. MMF-specific inflows/outflows: some MMFs may face larger inflows or outflows from their investors, differentially impacting the banks they specialize in lending to.

Construction of the instrument. Let there be N banks based out of a currency-area C that source US dollar funding from money market funds. The month-on-month change in MMF funding to bank i is given by:

$$\Delta y_{i,t} = \underbrace{\phi^d p_t}_{\text{elasticity and price}} + \underbrace{\lambda \eta_t}_{\text{common shock}} + \underbrace{u_{i,t}}_{\text{idiosyncratic shock}} \tag{6}$$

[12]This is similar to a Bartik-style shift-share instrument but allows for aggregating shocks to the entire sector, which is useful to estimate the impact on macro-variables such as asset prices.

Further, let each bank's share in MMF funding in currency-area C and month t be $S_{i,t}$. Note that $S_{i,t}$ can be time-varying. Then, the size-weighted change in MMF funding :=

$$\Delta y_{S,t} = \sum_i S_{i,t}\Delta y_{i,t} = \phi^d p_t + \lambda\eta_t + u_{S,t}, \tag{7}$$

and the equal-weighted change in MMF funding :=

$$\Delta y_{E,t} = \frac{1}{N}\sum_i \Delta y_{i,t} = \phi^d p_t + \lambda\eta_t + u_{E,t}. \tag{8}$$

Finally, the granular instrumental variable, z_t, is the difference between the size-weighted and equally-weighted sums of idiosyncratic shocks in each currency area C:

$$z_t = \Delta y_{S,t} - \Delta y_{E,t} = u_{S,t} - u_{E,t}. \tag{9}$$

I construct z_t using data on monthly bilateral flows from MMFs to individual banks' legal entities, sourced from the SEC N-MFP filings. I assign the currency area C to each bank based on the country of its parent's domicile. Further, I make three simplifying assumptions that net out the price elasticity and common shock components in Equation 6. First, all banks within a currency area C have equal price elasticity (ϕ^d), which means that their demand for MMF funding is equally sensitive to price changes. Second, the loading on common shocks (λ), is also equal for all banks within the currency area. Third, idiosyncratic shocks ($u_{i,t}$) are homoskedastic.

GIV diagnostics. A valid GIV requires that the economy is constituted by large players, i.e. has a high concentration, and that idiosyncratic shocks are large enough to matter, i.e. are relevant to the endogeneous variable. I find support for both conditions.

First, panel (a) of Figure 4 shows a high level of concentration (excess Herfindahl > 0.2) across all the three currencies against which global banks borrow dollars synthetically. For the Euro (EUR) and Swiss franc (CHF) in particular, the concentration increased after 2015 because some banks lost access to MMF funding as a result of the 2016 MMF regulatory reform (Appendix B provides additional background). Following Gabaix and Koijen (2024), I define excess Herfindahl in each currency area C as $h = \sqrt{\frac{1}{N} + \sum_i^N S_i^2}$, where N=number of borrowing banks, and S_i is the share of bank i in total dollar funding from MMFs, analogous to Equation 7.

Second, using EURUSD as an example, panel (b) of Figure 4 shows that idiosyncratic shocks can be economically significant: there are large and frequent deviations in the size-weighted changes in MMF holdings from equal-weighted changes.[13] Most of these shocks can be traced to one of three sources mentioned earlier. For example, (i) In November 2017, large funds had 5% of their assets invested into BNP Paribas, which led to a sharp decline in its subsequent additional funding; (ii) In 2018, Deutsche Bank's credit downgrade by Moody's and S&P contracted its MMF funding compared to an overall increase for Euro-area banks; (iii) Large inflows experienced by Charles Schwab in March 2014 and Federated Investments in August 2016 disproportionately benefited some banks. In contrast, common shocks that affect all banks, such as the European debt crisis in 2011 and the COVID-19 pandemic, do not reflect as major outliers in the time-series.

Relevance and exclusion. I test the relevance of the instrument to price changes (cross-currency basis) in the month when idiosyncratic shocks are realized. I specify a factor structure for cross-currency basis that accounts for the same set of variables as in Equation 5, and add z_t to represent demand-shifts from global banks due to constrained wholesale dollar funding. I estimate the below first-stage model for a panel of three currency pairs that collectively account for over 90% of synthetic dollar funding (EUR, JPY, CHF), and separately for EURUSD that accounts for 63% of the total volume:

$$\Delta \text{Cross-currency basis}_{C,t} = \beta z_{C,t} + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t}. \tag{10}$$

The panel specification uses currency fixed-effects and clustered standard errors, while the EURUSD version is a time-series regression with Newey-West standard errors. Controls include first differences in: US 1-month OIS yield, intermediary-leverage ratio squared from He et al. (2017), spot rate, overnight swap rate, and the relative size of central bank balance sheets as a proportion of GDP (Rime et al., 2022). Table 6 reports the estimation results for both the panel specification and the EURUSD version, for cross-currency bases calculated using the first principal component of 1-week, 1-month, 3-month, and 6-month tenors, as well as for the 1-week and 1-month tenors separately.

Cross-currency bases strongly correlate with the granular instrument constructed using flows from MMFs to non-US banks. In all the columns of Table 6, there is a positive and statistically significant relation between the currency-specific GIV and CIP deviations. A positive coefficient implies that when relatively bigger banks receive a larger share of MMF flows, the cross-currency basis for that currency becomes *less* negative. These results hold both for the panel and for EURUSD, with and without controls, and across all the tenors.[14]

[13] For comparison, the average monthly MMF investment in Euro-area banks is $392 billion, see Table 2.

[14] Alternatively, one can endogenize FX swap quantities instead of CIP deviations to estimate the impact of wholesale funding shocks on prices. Table A7 shows the first-stage results for the net dollar borrowing in

In terms of the exclusion criteria, the GIV by construction nets out shocks that affect all banks in a currency area. The residual reflects the over- or under-investment from MMFs into specific banks. However, one alternative explanation for differential MMF flows could be that the banks demanding dollars have differential underlying demand shocks (from end-borrowers), not supply shocks from MMFs. If it is the case that some banks borrow less from MMFs due to weaker loan growth, then it should bias against finding an impact on the swap market and CIP deviations. That is, if underlying USD loan demand is the reason for differential MMF investment, then it should induce a *negative* correlation between the instrument and cross-currency bases. Therefore, the strong positive coefficient in Table 6 reflects the impact of substitution across funding markets, potentially attenuated by changes in underlying demand for dollar credit.

5.2. Spillover to Non-banks Investors' Hedging Demand

In addition to banks, investors such as funds, corporations, and non-bank financial institutions (NBFIs) are major users of FX derivatives. Figure 3 shows that funds trade large quantities of FX swaps, both as borrowers and suppliers of dollars across the term structure, while corporations predominantly borrow dollars using swaps. Figure 5 shows that funds sell dollars forward, implying that they are net holders of US assets. On the other hand, corporations and NBFIs are buyers of dollars in the forward market. In this section, I investigate the impact of global banks' synthetic dollar funding on the FX hedging activity of non-bank investors.

I use the instrumented cross-currency bases to estimate non-bank sectors' elasticity of FX hedging demand to CIP deviations. This analysis helps to understand both the spillover effects of dollar supply frictions on FX risk management (whether quantities adjust or the cost changes), and the reaction of investors that could act as marginal suppliers of dollars. If non-bank users of FX derivatives adjust their hedging quantities in response to changes in cross-currency bases, then the frictions in dollar funding markets affect the *variance* in investors' international asset portfolios. On the other hand, if the demand is inelastic, then investors pay a higher hedging cost and realize lower *returns* on such assets. I estimate the below model to test which effect dominates:

$$\text{Hedging Demand}^{S}_{C,t} = \beta \widehat{\text{Cross-currency}}\ \text{basis}_{C,t} + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t}. \tag{11}$$

EURUSD swaps as the instrumented variable, and second-stage results on EURUSD cross-currency basis. The first-stage continues to support the relevance of the granular instrument for FX swap quantities: a greater flow of MMF-based wholesale funding to large Euro-area banks associates with reduced synthetic dollar borrowing. The second-stage reports a negative coefficient between the instrumented net dollar borrowing through swaps and the cross-currency basis, consistent with the reduced form results in Table 5. However, directly using the price as an endogeneous variable allows me to estimate demand elasticities of other sectors, rather than elasticity of price to FX swap borrowing.

I measure hedging demand using two separate products: the net sale of USD in the forward market, and the net buy-sell USD trades in the swap market. Both the flow variables are calculated for each sector S in currency C and month t. Analogous to the first stage, I use both a panel version with currency fixed-effects, and a time-series version for EURUSD specifically, with the same set of controls. The non-bank sectors I estimate the model for are: funds, non-bank financial institutions (NBFIs), and non-financial corporations. Table 7 reports the estimation results for parameter β.

Funds react to changes in cross-currency basis in a direction that suggests downward-sloping demand curve. For a 1% reduction in cross-currency basis (i.e., synthetic dollars are more expensive), funds reduce forward sale of the dollar by 0.54% in the panel of all currencies and by 0.18% against the Euro. Further, funds reduce buy-sell USD swaps by 0.43% in the panel and by 0.27% against the Euro. While statistically significant, the elasticity estimates are all below 1, which suggests relatively inelastic demand, consistent with recent literature on inelastic institutional investors (Gabaix and Koijen, 2021, Davis, Kargar, and Li, 2023). In contrast, NBFIs do not show a statistically significant reaction, while corporations react in the opposite direction (with near-zero elasticity: 0.08% for the panel of forwards and 0.03% for EURUSD forwards).[15] These estimates are comparable when considering cross-currency basis over a 1-week tenor in Table A8.

A more negative cross-currency basis makes it *costlier* to sell USD forward or conduct a buy-sell USD swap, because the investor pays the synthetic cost of holding dollars for the time period.[16] This means that foreign investors who hedge the FX risk on their USD-denominated investments face higher hedging costs as a result of increased synthetic dollar borrowing by global banks. Contrarily, US-based investors with non-USD denominated assets face lower FX hedging costs, because they supply USD in the near-term and buy it back on a later date (i.e., buy USD forward or conduct a sell-buy USD swap). In my sample, funds, on net, sell USD forwards and conduct buy-sell USD swaps. This suggests that the sample represents a net of foreign investors who invest in USD-denominated assets. This is also true in the broader population; the US runs a negative net external assets position with more foreign investments into the US than the other way round.

A back-of-the-envelope calculation suggests that the economic magnitude of the cost absorbed by inelastic investors is large. Du and Huber (2023) report that non-US insurance, pension funds, and mutual funds held about \$8 trillion of US assets in 2020, of which an estimated \$2 trillion were currency hedged. Assuming a 50% cost pass-through of more negative CIP deviations, and

[15] Calculation of elasticities is as follows. The coefficient attached to funds' forward trades is -9.989 (\$ billion), and the average USD forward sale is \$6.63 billion over the sample period. Further, a 1% change in cross-currency basis is 0.36 bps. The elasticity is therefore equal to: $(-9.989/6.63) \times 0.0036 = 0.54\%$. This estimate is comparable to Kubitza, Sigaux, and Vandeweyer (2024) who study the impact of changes in cross-currency basis on foreign investors' FX derivative and USD bond holdings.

[16] An FX forward sale of USD can be written as:= Spot (Sell) + Swap (Buy-Sell).

given the average cross-currency basis of negative 36 basis points, these investors pay an estimated additional \$3.6 billion in FX hedging costs per annum (\$2 trillion $\times$ 0.0036/2).

5.3. Marginal Suppliers of Dollars

The large impact of synthetic dollar funding on asset prices raises an important question: how do cash-rich US investors react? My findings so far suggest that most non-bank sectors are price inelastic. Therefore, their hedging demand (usually to sell USD forward or buy-sell USD swap) does not fully offset the increased demand from banks, which implies large adjustment in price to accommodate the additional funding demand. However, these price effects could still be muted if, within the subset of non-bank sectors, US-based institutional investors were to supply dollars and arbitrage these deviations away. Existing literature suggests that the traditional arbitrageurs such as dealer banks are regulatorily and capital constrained after the financial crisis (Du et al., 2018). At the other end of the spectrum, suppliers of last-resort such as the Federal Reserve intervene only during episodes of severe market disruptions (Bahaj and Reis, 2022). In this section, I present novel evidence on the reaction of real-money institutional investors who face distinct incentives and constraints compared to other sectors: US life insurance companies.

US life insurers are among the largest holders of foreign fixed income securities. Figure 6 shows that, for the sector as a whole, foreign bond holdings have quadrupled between the years 2000 and 2020, accompanied by a large increase in the stock of FX derivatives. Further, Figure A6 plots large fluctuation in insurers' hedge ratios of foreign currency assets, which suggests that these investors frequently adjust their FX hedges. US insurers represent a large and growing segment of FX derivative users who can potentially benefit from CIP deviations because they buy USD in the forward market and conduct sell-buy USD swaps to hedge their net foreign asset portfolio.

I test the impact of wider cross-currency basis on the FX hedging activity of US life insurance companies using granular, entity-level transactions data at a quarterly frequency sourced from the National Association of Insurance Commissioners (NAIC). These data allow me to compute the net exposure from swaps and forwards for each investor in a given currency pair and at the end of a quarter. I focus on EURUSD hedges, that comprise a majority of their FX derivatives portfolio, held between 2013 and 2023. Appendix A details the steps in data processing and identification of trade direction (i.e., sell or buy USD).

For each investor i, I sum the *net* exposure, where a positive value represents buy USD forward or sell-buy USD swap to hedge currency exposure on EUR assets, and estimate the below model:

$$\Delta \text{Net Exposure}_{i,t} = \beta \Delta \widehat{\text{Cross-currency}} \text{ basis}_t + \gamma \text{Demand factors}_{i,t} + \alpha_i + \varepsilon_{i,t} \tag{12}$$

where Net $\text{Exposure}_{i,t}$ is the net EURUSD derivative holding of investor i in quarter t. I scale the change in net exposure for comparability across firms.[17] The regressor of interest is the quarterly change in EURUSD cross-currency basis, instrumented using the idiosyncratic shocks of money market fund flows to Euro-area banks. I control for the demand factors which include 5-year US-EU interest rate differential and 3-month EURUSD FX implied volatility. Finally, α_i controls for investor (firm) fixed effects. Table 8 reports the estimation results.

US insurers react to changes in cross-currency basis in a direction consistent with a downward sloping demand curve. However, their price elasticity is well below 1. Table 8 shows that a 1% reduction in EURUSD cross-currency basis (0.01 × -25 bps) leads to a 0.25% increase in net EURUSD FX hedges (-1.0182 × -0.0025) for an average insurer. As cross-currency basis becomes more negative due to increased synthetic dollar funding pressure, insurers increase their holdings of buy USD forwards and sell-buy USD swaps. Both the direction and the overall elasticity are comparable to those of funds, documented earlier. However, despite a statistically significant price elasticity, the marginal supply of dollars in the FX derivative market falls short of the additional demand from global banks because of insurers' relatively smaller holdings and inelastic demand.

I also investigate whether insurers adjust their foreign bond portfolios in response to CIP deviations, and continue to find evidence of inelastic demand. I estimate Equation 12 using the (scaled) changes in each insurer's annual holdings of EUR-denominated bonds as the dependent variable. However, since the time frequency is lower, the instrument loses power and I present suggestive evidence using ordinary least squares estimation in Table A9. I find that for a 1% more negative EURUSD cross-currency basis, insurers increase their holding of EUR bonds by only 0.07% (-0.304 × -0.0025). Overall, insurers do not act as significant suppliers of dollars to offset the price impact caused by synthetic dollar demand of global banks.

The reaction of large real-money investors to CIP deviations is in the direction consistent with the exploitation of arbitrage. Thus, at a micro-level, wider cross-currency bases affect these investors' global asset portfolios. However, their price inelasticity and smaller size as a sector do not provide a large enough offset to the incremental demand shocks from global banks. Constraints underlying the limited price elasticity of real money investors to arbitrage opportunities in FX derivative markets remains an open question for further research.

[17] For each firm i, I calculate $\Delta\text{Net Exposure}_t = \frac{\text{Net Exposure}_t - \text{Net Exposure}_{t-1}}{(|\text{Net Exposure}_t| + |\text{Net Exposure}_{t-1}|)/2}$. This scaled variable is similar to the Davis and Haltiwanger (1992) growth rate measure which enables comparison across entities and is bounded between +2 and -2.

6. Conclusion

The US dollar underpins the global monetary system. Therefore, a steady supply of the dollar for both current account and capital account transactions is critical to the functioning of the world economy. This paper shows that frictions in the international supply of the US dollar create demand for synthetic funding through FX swaps. Global banks resort to synthetic dollar funding in response to constrained supply from wholesale markets, which represents a rightward shift in swap demand and exacerbates deviations from the covered interest rate parity (CIP). Using a granular instrumental variables identification strategy, I show that wholesale funding shocks experienced by large foreign banks widen the cross-currency basis, with spillover impact on non-bank participants in the FX derivative markets. I estimate the demand elasticity of investors that use FX derivatives to hedge currency risk and find that they absorb these price shocks mainly through changes in the cost of hedging. I also show that US-based institutional investors only slightly adjust their portfolios to benefit from wider cross-currency basis, providing limited offset to the demand from global banks. Overall, this paper highlights demand-side determinants of CIP deviations and estimates its real effects on institutional investors' cost of hedging and composition of asset portfolios.

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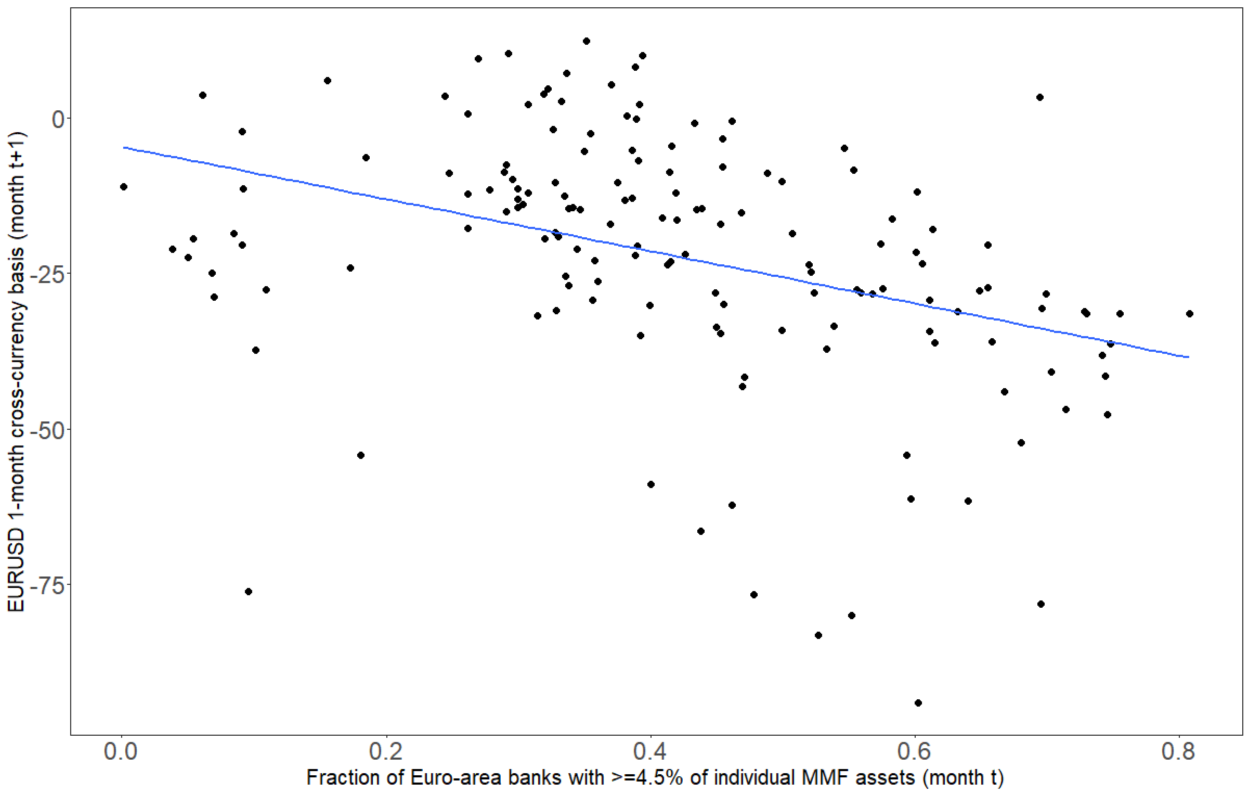
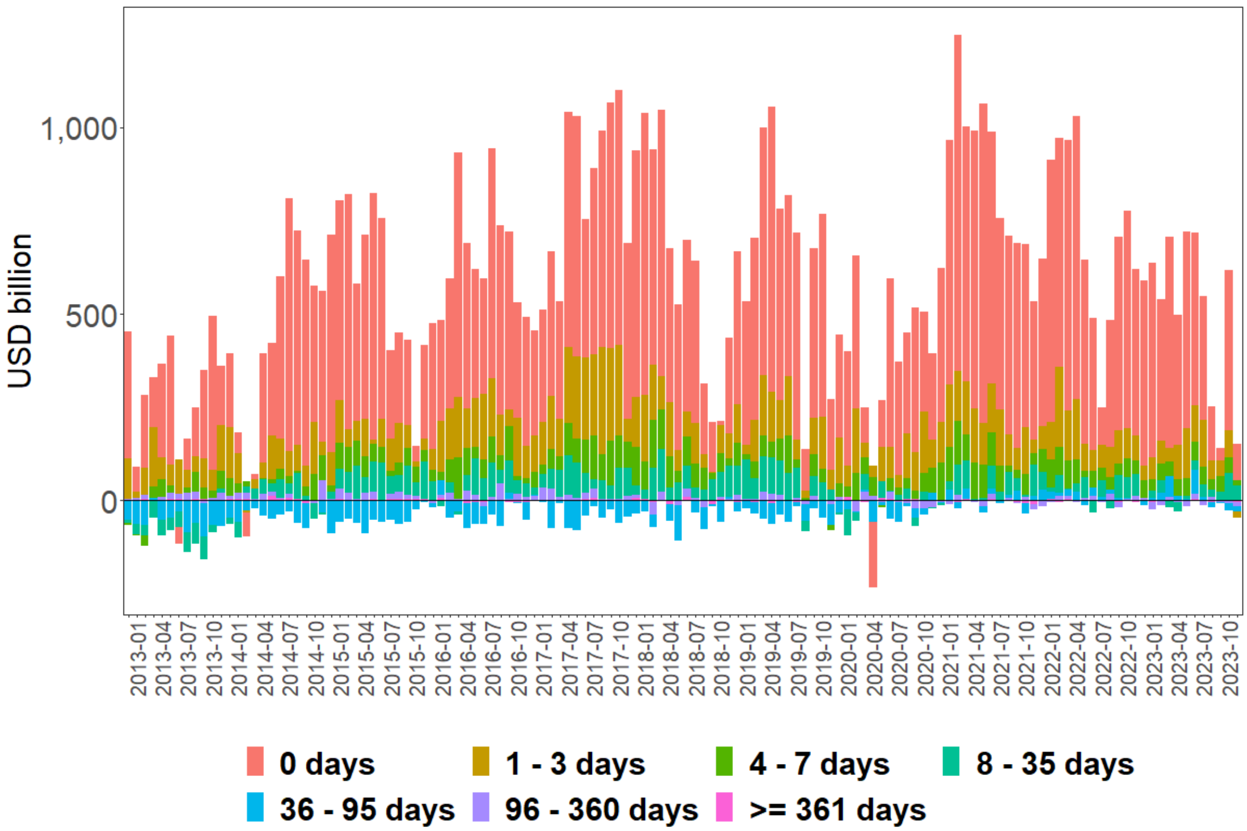
Figure 1: Banks' Wholesale Funding Constraints and Cross-currency Basis



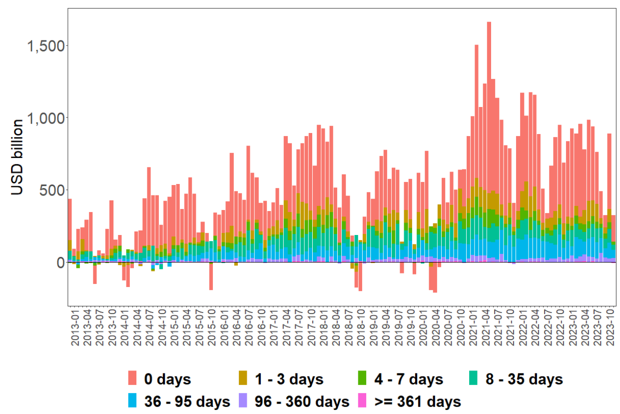
Notes: This figure correlates Euro-area banks' wholesale funding constraints with 1-month EURUSD cross-currency basis. Each dot in the scatterplot constitutes a monthly observation between December 2010 and December 2023. The x-axis represents the fraction of Euro-area banks that had borrowed at least 4.5% of the total assets of a US money market fund, weighted by the total borrowing by that bank in that month. (The concentration limit on US MMFs on lending to individual borrowers is 5% of total assets.) The y-axis represents the EURUSD 1-month cross-currency basis in month $t + 1$, with outliers below -150 bps trimmed. A linear trend is represented by the blue line. MMF holdings data are sourced from the SEC's N-MFP filings.

Figure 2: Synthetic Dollar Funding of Global Banks against EUR

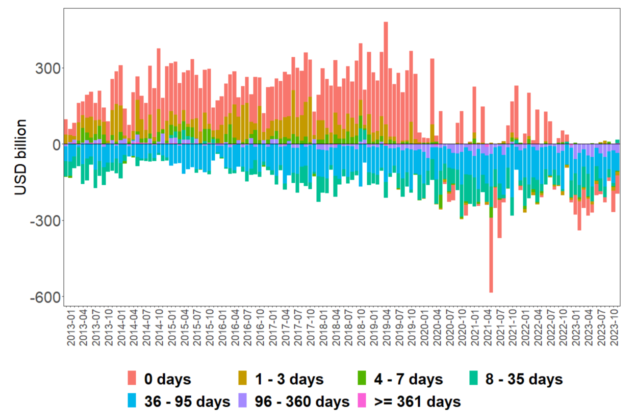


Notes: This figure plots the quantity of USD borrowed (positive y-axis) or lent (negative y-axis) against EUR by globally active dealer banks from/to all other counterparty sectors put together. USD is borrowed against EUR for settlement at the near leg of the swap and exchanged back at the far end. Bar colors represent 7 maturity buckets, with "0 days" corresponding to overnight borrowing. The near date for all other tenors is the spot date. The time series is at a monthly frequency from January 2013 through December 2023. This figure is constructed using daily signed FX swap order flow sourced from CLSMarketData and aggregated at a monthly level.

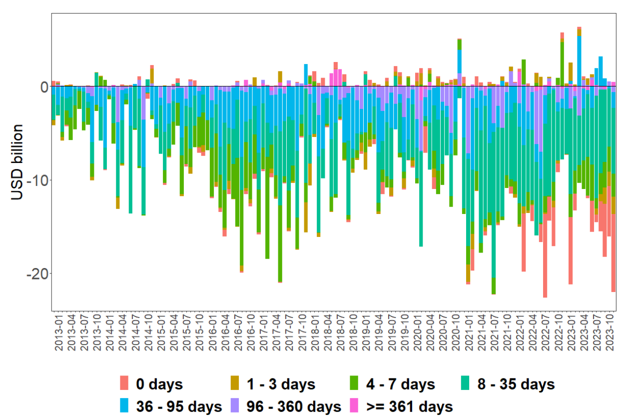
Figure 3: Sector-level Synthetic Dollar Funding of Global Banks against EUR



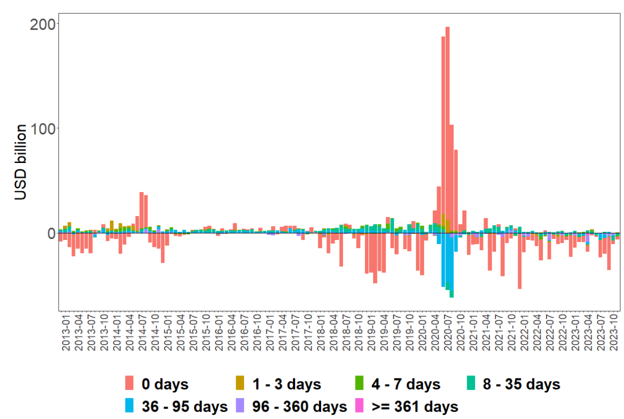
(a) Non-dealer banks



(b) Fund



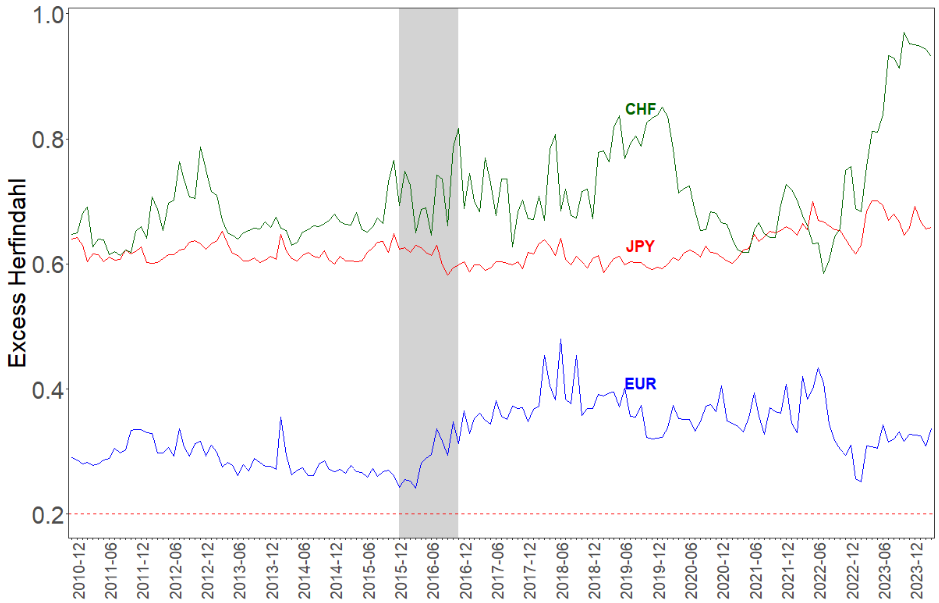
(c) Non-financial corporate



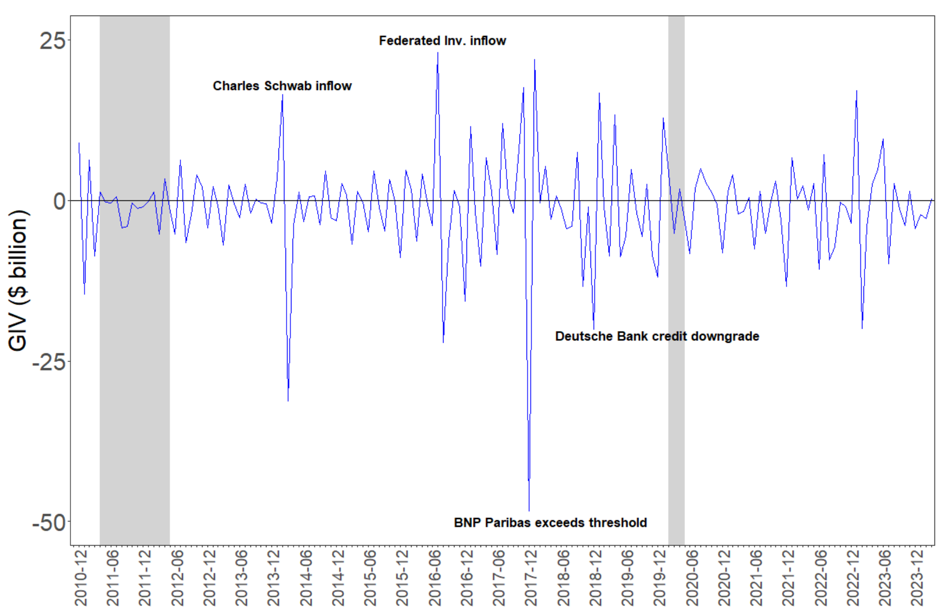
(d) Non-bank financial institutions

Notes: This figure plots the quantity of USD borrowed (positive y-axis) or lent (negative y-axis) against EUR by globally active dealer banks from/to non-dealer banks in panel (a), funds in panel (b), non-financial corporations in panel (c), and non-bank financial institutions in panel (d). USD is borrowed against EUR for settlement at the near leg of the swap and exchanged back at the far end. Bar colors represent 7 maturity buckets, with "0 days" corresponding to overnight borrowing. The near date for all other tenors is the spot date. The time series is at a monthly frequency from January 2013 through December 2023. This figure is constructed using daily signed FX swap order flow sourced from CLSMarketData and aggregated at a monthly level.

Figure 4: GIV Diagnostics – Concentration and Idiosyncratic Shocks



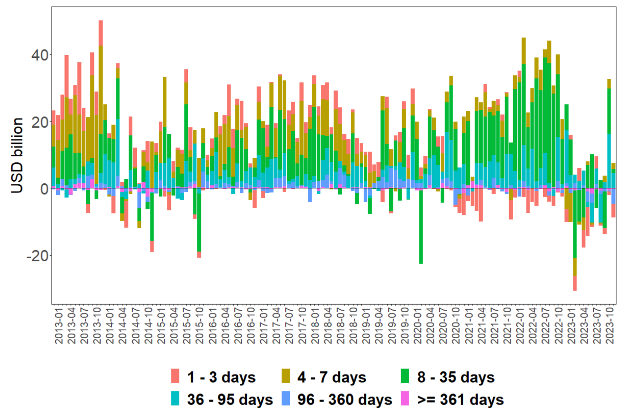
(a) High excess Herfindahl



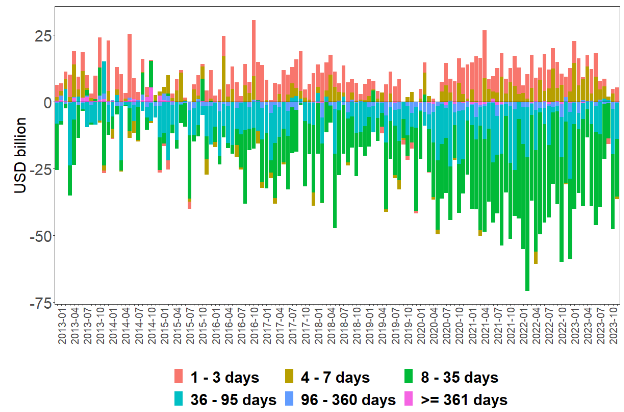
(b) Large idiosyncratic shocks

Notes: This figure demonstrates the validity of granular instrumental variables (GIV) in the context of money market fund investments. Panel (a) plots the time-series of excess Herfindahl index for banks headquartered in three currency areas. Shaded area represents the transition period of the 2016 MMF reform in the US. Panel (b) plots the time-series of the instrument for EURUSD and shows the presence of large idiosyncratic shocks. Shaded areas represent the Euro-area debt crisis in 2011 and the COVID-19 pandemic in 2020.

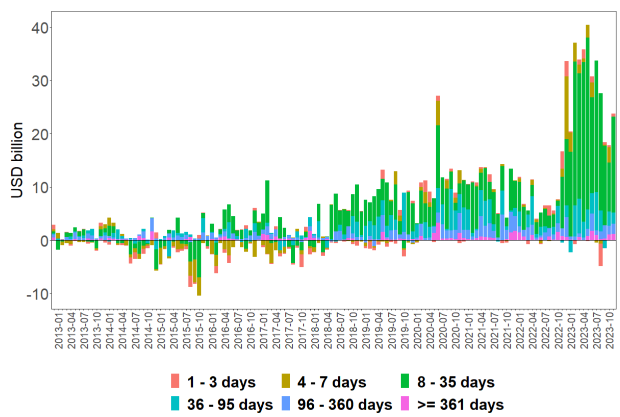
Figure 5: Sector-level EURUSD FX Forward Dollar Purchase



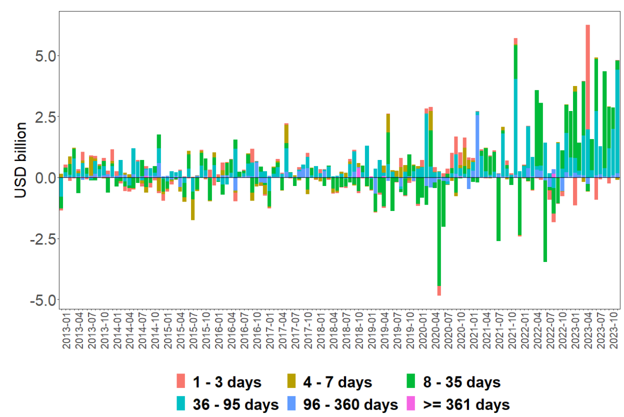
(a) Non-dealer banks



(b) Fund



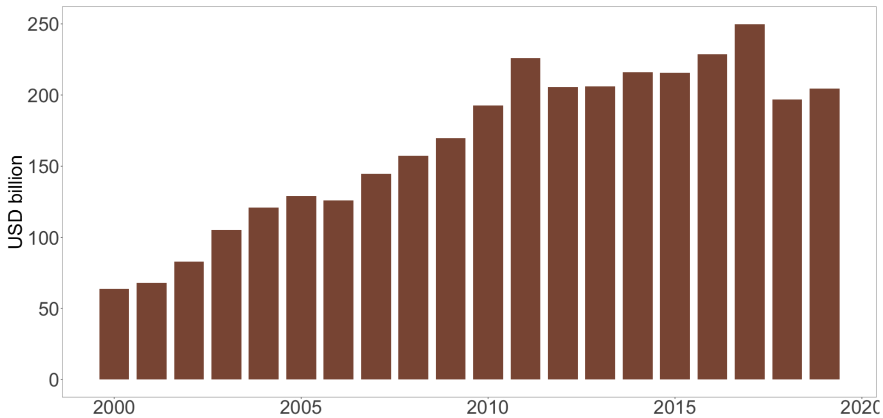
(c) Non-financial corporate



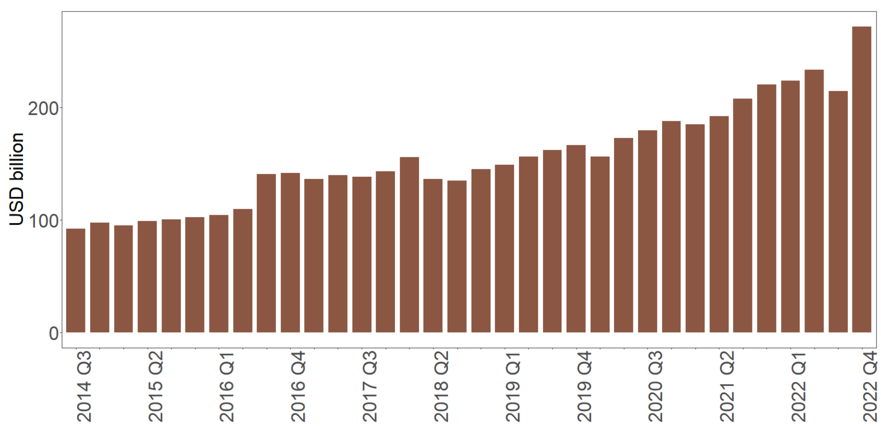
(d) Non-bank financial institutions

Notes: This figure plots the quantity of USD bought (positive y-axis) or sold (negative y-axis) against EUR by non-dealer banks in panel (a), funds in panel (b), non-financial corporations in panel (c), and non-bank financial institutions in panel (d) at the far leg of FX forward contracts. The time series is at a monthly frequency from January 2013 through December 2023. Bar colors represent 6 maturity buckets. The near date for all tenors is the spot date but no cash flow takes place on the near date. This figure is constructed using daily signed FX forward order flow sourced from CLSMarketData and aggregated at a monthly level.

Figure 6: US Insurers' Foreign Bond and Derivative Holdings



(a) Annual bond holdings



(b) Quarterly outstanding FX derivatives

Notes: This figure plots the outstanding notional of foreign bonds held by US life insurance companies in panel (a), and FX derivatives in panel (b). The time series is constructed from Schedule D regulatory filings for bonds and Schedule DB filings for derivatives, sourced from the National Association of Insurance Commissioners (NAICS).

Table 1: Descriptive Statistics of Daily Dollar Borrowing by Global Banks

Panel A: By supplier sector	Mean	SD	p25	p50	p75	N
All non-dealers	43.28	35.08	17.24	41.43	67.67	2,853
NBFI	-0.52	2.20	-1.52	-0.42	0.42	2,853
Fund	-14.00	21.62	-24.92	-11.48	-0.38	2,853
Corporate	-0.45	1.00	-0.78	-0.29	0.00	2,853
Non-dealer Banks	58.25	40.89	26.54	56.63	88.46	2,853
Panel B: By tenor						
0 days	35.60	25.20	16.90	35.40	53.40	2,853
1 - 3 days	9.30	9.60	2.40	8.30	15.50	2,853
4 - 7 days	4.10	5.70	0.40	3.50	7.10	2,853
8 - 35 days	-1.20	12.20	-7.20	-0.60	5.50	2,853
36 - 95 days	-3.30	6.50	-7.10	-2.80	0.80	2,853
96 - 360 days	-1.50	3.70	-3.40	-1.00	0.80	2,853
>= 361 days	0.10	0.80	-0.30	0.10	0.60	2,853
Panel C: By currency pair						
AUDUSD	-0.90	6.20	-4.80	-0.60	3.00	2,853
EURUSD	25.80	20.30	11.40	25.00	39.10	2,853
GBPUSD	1.80	11.10	-4.80	1.50	8.70	2,853
NZDUSD	-0.30	2.30	-1.80	-0.30	1.20	2,853
USDCAD	0.50	4.50	-2.20	0.20	2.90	2,853
USDCHF	3.20	8.40	-2.20	2.30	8.10	2,853
USDJPY	12.20	14.20	2.10	11.60	21.40	2,853
USDNOK	-0.50	2.80	-2.30	-0.30	1.30	2,853
USDSEK	1.50	3.40	-0.70	1.30	3.80	2,853

Notes: This table presents summary statistics of daily net dollar borrowing by global banks using FX swaps. USD is borrowed for settlement at the near leg of the swap and exchanged back at the far end. The near date for all tenors is the spot date, except for tenor "0 days" where it is T+1 for all currencies and T+0 for USDCAD. The time series is at a daily frequency from January 2013 through December 2023. Units are in $ billion. Panel A shows that non-dealer banks are the main suppliers of USD, panel B indicates that 0 days (overnight) is the most common tenor, and panel C reflects the dominance of EURUSD pair. This table is constructed using daily signed FX swap order flow sourced from CLSMarketData.

Table 2: Descriptive Statistics of Money Market Fund Holdings and Prices

Panel A: Money market fund holding	Mean	SD	p25	p50	p75	N
Total (non-govt., $ billion)	2,665.34	556.47	2,341.35	2,489.38	2,785.63	132
Δ Total (non-govt., $ billion)	10.18	134.66	-53.58	-0.73	73.71	131
Total (EUR banks, $ billion)	391.71	116.72	301.85	382.09	480.46	132
Δ Total (EUR banks, $ billion)	1.57	124.32	-58.32	0.87	59.42	131
Weighted maturity (days)	75.06	9.00	70.25	75.10	81.32	132
Δ Weighted maturity (days)	0.06	2.24	-1.50	0.00	1.60	131
Panel B: Price and market variables	**Mean**	**SD**	**p25**	**p50**	**p75**	**N**
Cross-currency basis (1 week, %)	-0.19	0.23	-0.24	-0.14	-0.07	132
Cross-currency basis (1 month, %)	-0.26	0.28	-0.34	-0.21	-0.10	132
Cross-currency basis (3 months, %)	-0.25	0.20	-0.34	-0.24	-0.12	132
Cross-currency basis (6 months, %)	-0.25	0.18	-0.37	-0.24	-0.14	132
Δ Spot price (bps)	-18.20	196.18	-139.52	-16.86	93.28	131
Δ Swap price (overnight, bps)	0.00	0.12	-0.04	0.00	0.05	131
CBBS/GDP	0.10	0.11	0.00	0.13	0.18	132
ILRS	275.66	86.74	211.06	268.98	315.75	132
US 1-month OIS (%)	1.22	1.53	0.13	0.42	1.95	132

Notes: This table describes money market fund holdings in panel A, and price and market variables in panel B. Panel A shows the overall and Euro-area bank-specific US money market fund (MMF) holdings (in levels and changes) in $ billion. It also describes the value-weighted average maturity and its changes in number of days. Panel B summarizes the EURUSD cross-currency bases across tenors from 1-week to 6-months, expressed in percentage. In panel B, ILRS refers to the intermediary leverage ratio squared (He et al., 2017), and CBBS/GDP refers to the difference between Euro-area and US central bank balance sheet sizes scaled by GDP. All variables are at a monthly frequency. MMF data are sourced from the SEC's N-MFP filings, and prices from Bloomberg.

Table 3: Synthetic Dollar Funding (EURUSD) and Money Market Fund Holdings

	Dollars borrowed by Global Banks			
	$ million		Count of trades	
	(1)	(2)	(3)	(4)
Δ MMF holdings (t-1)	-21.1***	-17.2**	-0.036***	-0.030***
	(5.53)	(6.60)	(0.009)	(0.010)
Δ ILRS		-5.48		0.020
		(18.0)		(0.032)
Δ CBBS/GDP		1,301.8		2.72**
		(799.4)		(1.23)
Δ US 1-month OIS		2,767.4		6.33
		(4,243.6)		(8.11)
Δ Spot		-1.19		0.017**
		(4.02)		(0.007)
Δ Swap (overnight)		-3,874.7		-6.18
		(7,589.1)		(13.4)
N	132	131	132	131
Adj. R^2	0.08	0.06	0.06	0.08

Notes: This table reports ordinary least squares estimates for a model of the form in Equation 1. The dependent variable is daily average dollar borrowing at the near leg of overnight EURUSD swaps by global banks from all other sectors. Columns (1) and (2) consider the net dollar amounts borrowed, while columns (3) and (4) consider the net number of buy trades. The regressor of interest is the change in previous month's money market fund holdings of all non-government securities, denoted as Δ MMF holdings (t-1) and expressed in $ billion. Controls in columns (2) and (4) include the monthly change in intermediary leverage ratio squared (Δ ILRS), monthly change in the difference between Euro-area and US central bank balance sheet sizes scaled by GDP (Δ CBBS/GDP), and monthly changes in the rates of US 1-month OIS, EURUSD spot, and EURUSD overnight swap. Newey-West standard errors (lags=3) are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 4: Synthetic Dollar Funding (FX Panel) and Money Market Fund Holdings

	Dollars borrowed by Global Banks			
	(1)	(2)	(3)	(4)
Δ MMF holdings (t-1)	-3.77**	-3.77**	-4.73***	-5.84***
	(1.19)	(1.16)	(1.23)	(1.05)
Δ ILRS		2.35	2.63	
		(2.44)	(2.38)	
Δ CBBS/GDP		384.9	379.0	
		(296.0)	(291.8)	
Δ US 1-month OIS		-338.4	-342.7	
		(1,308.3)	(1,259.4)	
Δ Spot		0.018	-0.002	0.006
		(0.016)	(0.003)	(0.008)
Δ Swap (overnight)		311.4	133.4	-119.9
		(265.0)	(169.4)	(194.5)
N	1,056	1,048	1,048	1,048
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Notes: This table reports ordinary least squares estimates for a fixed-effects panel regression of the form in Equation 3. The dependent variable is daily average dollar borrowing at the near leg of the overnight FX swaps by global banks from all other sectors, expressed in $ million. The regressor of interest is the change in previous month's money market fund holdings of all bank securities in the respective currency-area, denoted as Δ MMF holdings (t-1) and expressed in $ billion. Column (1) does not include controls and fixed effects, column (2) includes controls, column (3) includes controls and currency fixed effects, and column (4) includes controls, currency, and time fixed effects. Controls include the monthly change in intermediary leverage ratio squared (Δ ILRS), monthly change in the difference between Euro-area and US central bank balance sheet sizes scaled by GDP (Δ CBBS/GDP), and monthly changes in the rates of US 1-month OIS, EURUSD spot, and EURUSD overnight swap. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 5: Synthetic Dollar Funding and Covered Interest Parity Deviations

	Δ Cross-currency basis ($\Delta x_{t,t+n}$)			
Panel	PC1 (1W, 1M, 3M, 6M)	1W	1M	3M
	(1)	(2)	(3)	(4)
Net \$ Borrowing	-0.006**	-0.007***	-0.004*	-0.002
	(0.002)	(0.0010)	(0.002)	(0.001)
Δ Spot price	1.16***	0.930**	0.702**	0.031
	(0.111)	(0.173)	(0.184)	(0.200)
Δ Swap price (overnight)	10.8	8.56	7.08	-1.90
	(5.59)	(3.83)	(4.43)	(1.29)
Cross-currency basis (t-1)	-0.512***	-0.778***	-0.621***	-0.199***
	(0.077)	(0.111)	(0.069)	(0.015)
N	469	469	469	469
Currency FE	Y	Y	Y	Y
Time FE	Y	Y	Y	Y
EURUSD	PC1 (1W, 1M, 3M, 6M)	1W	1M	3M
	(1)	(2)	(3)	(4)
Net \$ Borrowing	-0.015**	-0.011**	-0.011*	-0.007*
	(0.008)	(0.004)	(0.006)	(0.004)
N	131	131	131	131
Controls	Y	Y	Y	Y
Adj. R^2	0.38	0.49	0.42	0.20

Notes: This table reports ordinary least squares estimates for a model of the form in Equation 5. The dependent variable is monthly change in CIP deviations (i.e., cross-currency basis) for a panel of EURUSD, USDJPY, USDCHF, and GBPUSD in the top panel, and for EURUSD in the bottom panel. Column (1) uses the first principal component of 1-week, 1-month, 3-month and 6-month cross-currency basis, while columns (2) through (4) consider individual tenors. CIP deviations are calculated using the daily overnight index swap yields at the respective tenors, the spot rate, and the forward premium. The regressor of interest is the monthly net dollar borrowing by global banks using FX swaps in the respective currency. The panel version clusters standard errors by currency and the time-series version uses Newey-West standard errors (lags=3), all reported in parantheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 6: Relevance of the Instrument to Cross-currency Basis (GIV first-stage)

Panel (EUR, JPY, CHF)	PC1 (1W, 1M, 3M, 6M)		1W	1M
	(1)	(2)	(3)	(4)
$z_{C,t}$	0.020***	0.018***	0.012***	0.016***
	(0.004)	(0.005)	(0.004)	(0.005)
N	340	338	338	338
Instrument F-statistic	26.75	10.85	11.98	11.03
Currency FE	Y	Y	Y	Y
Controls	N	Y	Y	Y
EURUSD	**PC1 (1W, 1M, 3M, 6M)**		**1W**	**1M**
	(1)	(2)	(3)	(4)
z_t	0.022***	0.020***	0.013***	0.018***
	(0.007)	(0.006)	(0.004)	(0.005)
N	132	131	131	131
Instrument F-statistic	10.91	11.52	10.32	14.95
Controls	N	Y	Y	Y

Notes: This table reports the first-stage results of Equation 10 from a two-stage least squares estimation. The dependent variable is monthly change in cross-currency basis, with the first principal component of 1-week, 1-month, 3-month, and 6-month tenors in columns (1) and (2), 1-week tenor in column (3), and 1-month tenor in column (4). The regressor of interest is the granular instrumental variable, with additional controls in columns (2) through (4). The panel version considers EURUSD, USDJPY, and USDCHF currencies, with currency fixed-effects and standard errors clustered by currency. The time-series version considers EURUSD, with Newey-West standard errors (lags=3) reported in parantheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 7: Impact of CIP Deviations on Hedging Demand (GIV second-stage)

Panel (EUR, JPY, CHF)	Forwards			Swaps		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}\ \text{basis}_{C,t}$ (1M)	-9.989***	0.087	0.373	-31.267***	0.387	2.396***
	(1.693)	(0.798)	(0.233)	(9.268)	(0.487)	(0.222)
N	338	338	338	338	338	338
Adj. R^2	0.32	0.02	0.12	0.13	0.44	0.47
Currency FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
EURUSD	**Forwards**			**Swaps**		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}\ \text{basis}_{t}$ (1M)	-10.899**	-0.587	0.447	-40.848**	-0.278	2.999**
	(4.341)	(0.472)	(3.064)	(16.870)	(1.074)	(1.421)
N	131	131	131	131	131	131
Adj. R^2	0.32	0.05	0.03	0.04	0.01	0.04
Controls	Y	Y	Y	Y	Y	Y

Notes: This table reports the second-stage results of Equation 11 from a two-stage least squares estimation. The dependent variable is the monthly net USD forward purchase in the first three columns, and net USD sell-buy swaps in the last three columns, all for a 1-month tenor. The regressor of interest is the instrumented change in 1-month cross-currency basis. Standard errors are reported in parantheses, and are clustered by currency in the panel version. The time-series version for EURUSD uses Newey-West standard errors (lags=3). $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 8: Impact of CIP Deviations on US Insurers' Hedging Demand

	% Change in EURUSD Swaps and Forwards			
	(1)	(2)	(3)	(4)
$\Delta\widehat{\text{Cross-currency basis}}$ (PC 1)	-3.478**	-3.513**		
	(1.702)	(1.691)		
$\Delta\widehat{\text{Cross-currency basis}}$ (1 month)			-2.137**	
			(0.937)	
$\Delta\widehat{\text{Cross-currency basis}}$ (3 months)				-1.018**
				(0.446)
5Y US-EU Yield Differential		0.104**	0.078**	0.067**
		(0.043)	(0.031)	(0.030)
EURUSD 3M Implied Vol		-0.043***	-0.024**	-0.028**
		(0.016)	(0.012)	(0.012)
N	1,813	1,813	1,813	1,813
Investor FE	Y	Y	Y	Y

Notes: This table reports the second-stage results of Equation 12 from a two-stage least squares estimation. The dependent variable is the quarterly percentage change in the net outstanding USD forward purchase or sell-buy USD swap (against the EUR), for each firm in the US life insurance industry. The regressor of interest is the instrumented change in cross-currency basis, using the first principal component of 1-week, 1-month, 3-month, and 6-month tenors in columns (1) and (2), 1-month tenor separately in column (3), and 3-month tenor in column (4). All columns include investor (firm) fixed effects, and columns (2) through (4) include additional controls. Standard errors clustered by firm are reported in parantheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Internet Appendix

“Synthetic Dollar Funding”

Umang Khetan

July 2024

A. DATA APPENDIX

A.1. CLS Data Collection

The dataset used in this paper consists of daily FX swap and forward signed volumes that are settled by the CLS Group (“CLS”), aggregated and anonymized at a sector-level. CLS operates the world’s largest multi-currency cash settlement system under which it settles FX transactions on a payment-versus-payment (PvP) basis for 18 eligible currencies. PVP mitigates settlement or *Herstatt* risk by ensuring that each counterparty to a trade makes its payment first and only then receives its share of the cash flow. To enable this, CLS acts as a clearing house which facilitates payments to and from each counterparty to a trade. Glowka and Nilsson (2022) estimate that about half of global FX turnover across spot, forwards, and swaps in 2022 was settled through risk-mitigation mechanisms including PvP. Settlements through CLS form the largest component of these risk-mitigating mechanisms with a volume share of 72%.

Similar to a clearing house for over-the-counter derivatives, CLS has direct members that comprise of large banks, and indirect members who settle through CLS with the help of member banks. This model is followed by other clearing houses such as the LCH Ltd. (formerly London Clearing House) and the Chicago Mercantile Exchange (CME). At the time of writing, 76 financial institutions were direct members of CLS, primarily FX market-making banks.[18] Indirect members access CLS settlement service through direct members, and include smaller banks, non-bank financial institutions (NBFIs) and non-financial corporations (CLS, 2022). This ensures that CLS data not only reflect trades *among* direct members, but also between direct members and other clients that access CLS services. It is the latter group of dealer-to-client trades that this paper focuses on.

The CLS FX forward and swap datasets provide information on the executed trade volume submitted to the CLSSettlement services. Both the parties to a trade submit transaction details

[18] The list of settlement members is available here.

to CLS, which then matches these trades, identifies the product type (spot, forward, or swap) and constructs daily sector-level aggregated datasets after dropping duplicate reports. CLS receives confirmation on the majority of trades from settlement members within 2 minutes of trade execution, and uses the earlier of two reports to determine the transaction timestamp. The underlying data is adjusted to follow the reporting convention used by the Bank for International Settlements (e.g., report the volume in terms of the base currency, and report only one leg of the trade to avoid double counting).

The FX forward and swap flow datasets that this paper uses contain executed buy and sell contracts in terms of number of trades (trade count) and total value in the base currency of the respective currency pair. However, as part of CLS' client confidentiality policy, there must be a minimum of 2 trades in the currency-maturity bucket over the day for CLS to publish the data. The final CLS dataset includes all matched trades in the eligible currencies between CLS (direct or indirect) members, with at least two trades over the reporting period.[19]

A.2. CLS Data Coverage

I estimate that CLS swaps data cover between a quarter to a third of global dealer-to-client swaps turnover, based on the April 2022 BIS benchmark (Bank for International Settlements, 2022). Further, the data are representative of the market both in terms of the tenors and currencies across which trading takes place. Table A1 reports the estimated coverage of average daily volume observed in CLS data in April 2022. For external comparison, Hasbrouck and Levich (2017) estimate that CLS data cover about 37.2% of global spot FX turnover, 14.4% of forwards, and 35.1% of FX swaps and provide corroborating evidence of representation by currency. Note that these comparisons are likely lower bound because both Hasbrouck and Levich (2017) and Cespa, Gargano, Riddiough, and Sarno (2022) show that a non-trivial fraction of the volume reported by the BIS is related to interbank trading across desks, and double-counts prime-brokered trades.

I make several adjustments to the CLS data to enable comparison with BIS benchmarks. Between the two datasets, there is no exact match for sectors and tenors, but approximations are close. For BIS reported trades between reporting dealers and all other counterparties, I use Sell-side and Buy-side categorization in CLS data. For BIS reported trades between Dealers and Other financial institutions, I use the combined volume of Fund and NBFI in CLS data. Finally, Non-financial corporations are directly identified in my data. For tenors, the buckets are: overnight (defined the same way in both reports); up to 7 days in BIS is up to 8 days in CLS, one month in BIS is 35 days in CLS, and over 3 months in BIS is 96 days and above in CLS. The BIS also reports that 90% of

[19]More details are available on CLSMarketData.

swaps involve the USD, and therefore I focus only on the currency pairs that include the USD for my analyses.

A.3. Variable Construction

I construct measures of dollar borrowing from the daily flow data by sector, tenor, and currency.

Sectors. Sector-level data are constructed in two (potentially overlapping) cuts. In the first cut, trades are reported between sell-side and buy-side parties. Most of these sell-side banks are in the globally systemically important banks (GSIBs) category that are able to access multiple money markets, that I term "Global Banks". For the currencies in my sample, the majority of sell-side banks are tier-one international investment and largest custodian banks, which are headquartered in the US, UK, Euro-area, and Asia. As of February 2022, there are 24 sell-side entities for EURUSD, 20 for GBPUSD, 23 for AUDUSD, 20 for NZDUSD, 21 for USDJPY, 23 for USDCAD, 18 for USDCHF, 12 for USDSEK, and 11 for USDNOK. On the other hand, buy-side includes all other entities such as non-dealer banks, as well as end-users such as funds, non-banking financial institutions, and corporations.

CLS categorizes investors in this market into sell-side or buy-side using a statistical network analysis that is based upon the behavior of the entity within the FX ecosystem. In this network, "nodes" represent trade parties, and "links" are connections between parties and counterparties, which are established within each currency pair based on their trading behavior. Once CLS creates the network for each currency, the nodes are separated into two groups using the concept of "coreness" which is a measure that identifies tightly interlinked groups within a network. The sell-side parties are represented by nodes that maintain a consistently high coreness over time, and are considered to be market-makers. All other parties are included in the second group, the buy-side. The network analysis is performed independently for each currency pair using 24 months of latest historical data, with a generally stable categorization over time.

The second cut of the data reports trades between banks of all kinds and three end-users: (i) non-bank financial institutions (NBFI) that are not banks but primarily engage in the provision of financial services, (ii) non-financial corporations, and (iii) funds that includes hedge funds, pension funds, and asset managers.

I impute trades between dealer or global banks and non-dealer banks by combining the two cuts of the data. The categorization of non-dealer banks is a close approximation and proceeds as follows. I start with tabulating the net flows for each sector within the currency, maturity, and trade date. Then, under the assumption that all end-users trade with dealers, I impute non-dealer bank flows as the total buy-side flow minus fund minus corporate minus NBFI flow. The noise in this process comes from the possibility that some end-user trades could be executed with non-dealer banks. However, based on the list of CLS clearing members available on their website (most of whom would be classified as market-making sell-side institutions), the share of non-dealer banks as market-makers is not likely to be large.

Tenors. There are 7 tenor buckets (6 for forwards), ranging from overnight to over one year. Within both forwards and swaps datasets, tenor is defined as the difference between the settlement date of the far leg, and the spot settlement day. For the overnight tenor swaps (called "0 days"), the far leg is the tomorrow next day for all currencies except USDCAD for which it is the overnight next day. All volumes in the raw data are reported as on the far leg of a swap. For calculating the near-leg dollar borrowing, I assume that an equivalent amount of opposite-side cash flow occurs.

Volume. The raw data reports buy and sell volumes from the perspective of price-taker in both the data cuts. For the purpose of analyzing dollars borrowed by financial intermediaries, I flip the direction and analyze it from the perspective of global banks that are on the price-making side.

Finally, the notional values in raw data are expressed as number of base currency units. In five out of the nine pairs, USD is the base currency. However, four currency pairs are expressed in terms of number of dollars per unit of foreign currency (EURUSD, GBPUSD, AUDUSD, and NZDUSD). I convert the notionals in these four pairs into the number of dollars to remain consistent with the other five pairs. I use daily FX spot rates sourced from Bloomberg for the conversion.

A.4. Money Market Fund Data

US Money Market Funds (MMFs) are required to report their detailed holdings as at the end of a month within five business days of the following month using the SEC'S EDGAR system. This database is publicly available starting with holdings as of December 2010. I download, clean, and merge three sets of files from this database for the full sample period, described below.

1. Security-level holdings (form "NMFP_SCHPORTFOLIOSECURITIES"): This is the most detailed account of each fund's holdings in individual securities, many of which are issued by the same borrower. I first condense the security-level investments by individual funds into "issuer-level" borrowing at the issuer's legal entity identifier (LEI) level. Note that the LEI filed started to populate only in later part of the sample. Hence, I back-fill the LEIs using issuer names available in the earlier part of the sample. Then, I map the issuer to its parent entity and the location of its domicile using the Global Legal Entity Identifier Foundation

(GLEIF) database. For example, I am able to aggregate all the MMF investments of Deutsche Bank subsidiaries into the parent bank, and tag the currency-area it is located in as Euro. This report does not contain the filing date or the information on the fund family/adviser, for which I use the below reports and merge them using the field "Accession Number".

2. Filing information (form "NMFP_SUBMISSION"): This form contains the filing date, which is typically the month following the holdings month. I use the "Accession Number" to merge the filing date with the issuer-level holdings generated above.
3. Fund information (form "NMFP_ADVISER"): This form contains the fund adviser name, which I merge in with the issuer-month-level dataset using the "Accession Number". I do not collapse the data at a fund level, except to narrative check the granular instrumental variables and identify the share of assets invested by individual funds into single issuers.

A.5. US Life Insurance Data

US insurance firms are required to report their assets and derivative holdings at a quarterly frequency. These data are then compiled by the National Association of Insurance Commissioners (NAIC) and made publicly available. I closely follow Sen (2023) to clean these datasets and compute entity-level exposures from two types of forms.

The Schedule DB form provides data on derivatives at a transaction level. I focus on files that contain forwards and swaps, and filter the risk categories that relate to foreign exchange. The variables contained in these files include: NAIC company code, description of the hedge, trade date and maturity date, notional amount, fair value at the reporting date, rate/price, and counterparty institution. In some cases, the description mentions the direction of the trade i.e. purchase or sale of USD. I use those when available. In other cases, I infer the direction by comparing the implied fair value (using market rates between the trade date and reporting date) and the reported fair value. In most cases, the currencies involved in the trade are specified and available to use.

The Schedule D form provides data on investment assets. I focus on bonds, and retain foreign bonds using their CUSIP. Even though there is a field that categorizes the bond type, it splits only sovereign bonds by country of issuer (domestic or foreign) but does not identify the country of issuance for corporate bonds. I leverage the fact that all foreign bond CUSIPs begin with an alphabetical letter that identifies the country of issuance, while domestic US-issued bonds start with a number. However, one drawback of this method is that even if the issuer is based out of a foreign country, the bond may be USD denominated. I use the bond CUSIPs to identify the currency of denomination using the S&P Capital IQ database.

B. The 2016 Money Market Fund Reform

In this appendix, I sharpen the identification of the link between the wholesale and synthetic funding markets by using changes in money market fund (MMF) holdings around the time of a major regulatory reform that took effect in 2016. The key identifying assumption is that the introduction of this reform impacted FX swaps through no channel other than the change in holdings of the MMF that were subject to its provisions.

In 2014, the Securities and Exchange Commission (SEC) proposed a major regulatory change that would mainly affect non-government US money market funds (prime funds in particular) and was scheduled to be implemented in October 2016. The provisions of this reform would require prime MMFs to move away from "fixed net asset value (NAV)" to "floating NAV", which made it difficult for investors to redeem their shares at par. Further, the reform allowed prime funds to introduce liquidity restrictions on investors, such as redemption gates and liquidity fees, while leaving government funds mostly untouched by these provisions. The intention behind this reform was to improve the resilience and financial stability of MMFs that had come under severe liquidity pressure during the global financial crisis.[20]

Figure A7 shows that this reform represented an economically significant negative wholesale funding shock to non-government borrowers. The total non-government holdings of US MMFs declined from around \$2.6 trillion in the beginning of 2016 to about \$1.9 trillion in mid-2017. Banks were the most severely affected borrowers due to this decline: panel (b) of Figure A7 shows that MMF holdings of certificate of deposits dropped by \$400 billion, with large declines also visible for commercial paper instruments. Note that while the provisions of this reform took effect from October 2016, its rules were widely known almost a year in advance, and therefore the decline in holdings is visible from the first quarter of 2016 itself. Anderson, Du, and Schlusche (2021) report that global banks lost altogether \$800 billion in capital from MMFs due to this regulatory change.

This shock provides me with a natural experiment to causally establish FX swaps as alternatives to local US dollar funding markets. I employ a difference-in-differences estimation technique using a two-way fixed effects model. My outcome variable is the quantity of dollars borrowed by each sector in each currency and tenor combination. My specification examines the outcome variable in each of the 4 quarters before and since the outflows from MMFs began to take place (2016Q1) in anticipation of the reform implementation, saturating the model with sector-product and time fixed effects. I estimate the model:

[20] Hanson, Scharfstein, and Sunderam (2015) evaluate these reforms prior to their implementation, Cipriani and La Spada (2021) show that the reforms triggered large flows of AUM from prime to government funds, and Li, Li, Macchiavelli, and Zhou (2021) argue that liquidity restrictions imposed by the reforms exacerbated run on prime funds during the COVID-19 pandemic.

$$\text{Net \$ Borrowed}_{s,p,t} = \sum_{\substack{\tau \in -4,3, \\ \tau \neq -1}} \beta_\tau \times Reltime_\tau + \Delta Price_{p,t} + \alpha_{s,p} + \alpha_t + \varepsilon_{s,p,t}, \tag{13}$$

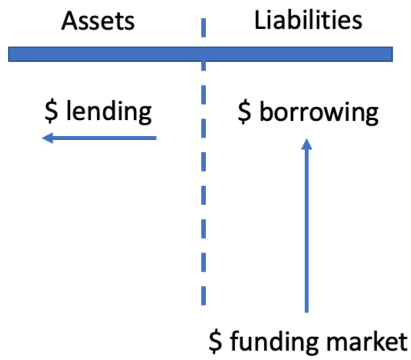
where the dependent variable is the quantity of swap dollars borrowed by sector s in product p in quarter t. I define "product" as the currency and tenor combination, for a total of $9 \times 7 = 63$ products. Since only bank funding suffered a decline due to MMF outflows, the treated sector is global banks' borrowing from non-dealer banks, and control sectors are funds, non-financial corporations, and non-bank financial institutions. "Reltime" is the relative number of quarters since 2016Q1 when outflows from MMFs began to accelerate, as shown in Figure A7. The β_τ coefficient identifies the treatment effect in each of the eight quarters from 2015Q1 through 2016Q4, with 2015Q4 as the base. I control for the change in price in each currency-tenor combination as a covariate, and include interactive fixed effects for the sector-product combination, and time fixed effects. I estimate this specification at a quarterly level to smooth the noise arising out of quarter-end spike in volumes. Finally, I also run this specification separately on FX forwards as a placebo for robustness. Figure A8 plots the event studies for both swaps and forwards.

A negative exogenous shock to MMF holdings resulted in significantly higher dollar borrowing through FX swaps by global banks. Panel (a) of Figure A8 shows a sharp and persistent increase in net dollars borrowed by global banks starting in 2016Q1. Note that this increase is relative to both their own pre-reform borrowing, and after controlling for trends exhibited by all other sectors that were not affected by this reform. The figure also supports the parallel trends assumption in the quarters before the reform: the net borrowing in quarters -4 through -2 were not statistically different from that in quarter -1. Finally, in panel (b) of Figure A8, we do not see any change in the net dollars bought through FX forwards, supporting the interpretation of funding substitution between US money markets and the global FX swap markets.

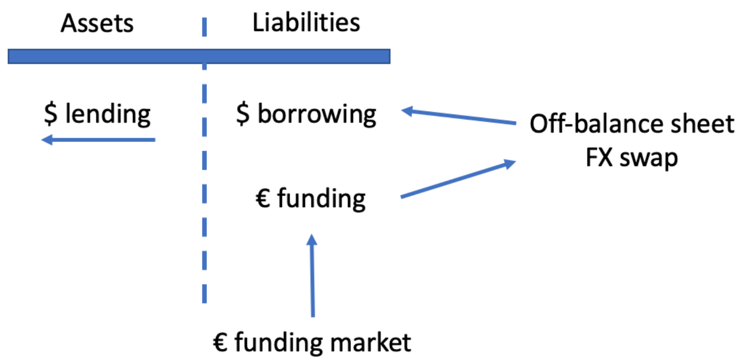
My interpretation of funding substitution is also complementary to Anderson, Du, and Schlusche (2021), who show that global banks reduced their arbitrage positions in USDJPY in response to the decline in MMF investments after the regulatory reform. The direction of the effect (increase in net borrowing) is consistent in both the studies, but my focus is on *increase* in US dollar borrowing by banks who resort to FX swaps to reduce their dollar funding constraints.

The results in this appendix provide further evidence of substitution between two funding sources: US money markets and global FX swap markets. This substitution explains both, why huge quantities are traded in short-term FX swaps, and how changes in local monetary conditions transmit to global asset markets.

Figure A1: Direct and Synthetic Dollar Funding



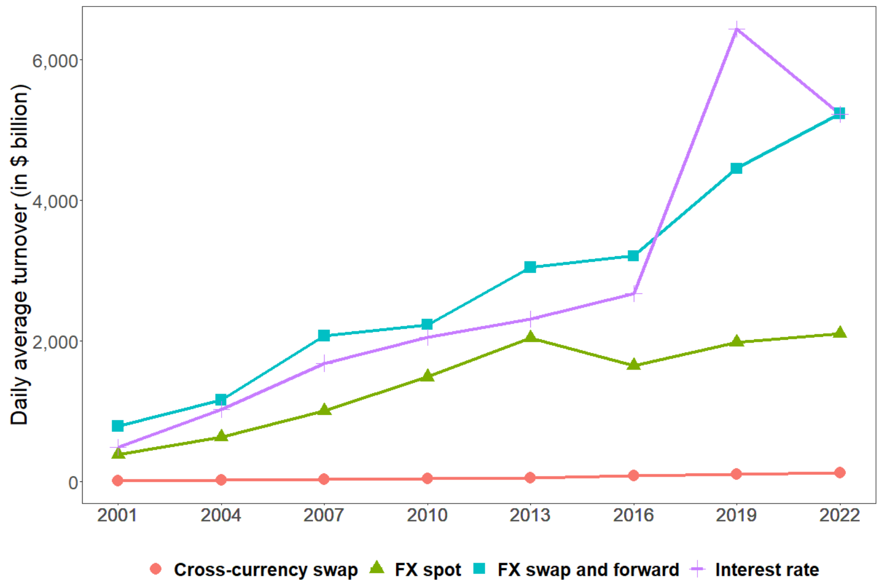
(a) Direct dollar funding



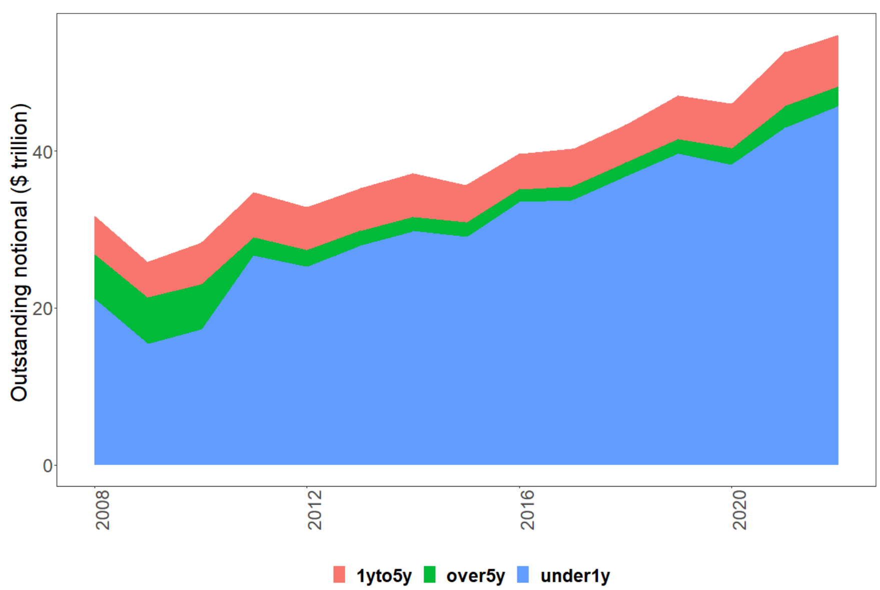
(b) Synthetic dollar funding

Notes: This figure shows the balance sheet flows associated with direct dollar borrowing in panel (a) and synthetic dollar borrowing in panel (b). Direct borrowing in USD or EUR is a liability that appears on the balance sheet, while its conversion into another currency is an off-balance sheet transaction. As a result, large global financial institutions who are able to access multiple money markets are most likely to use FX swaps for synthetic dollar funding.

Figure A2: Over-the-counter Financial Instruments



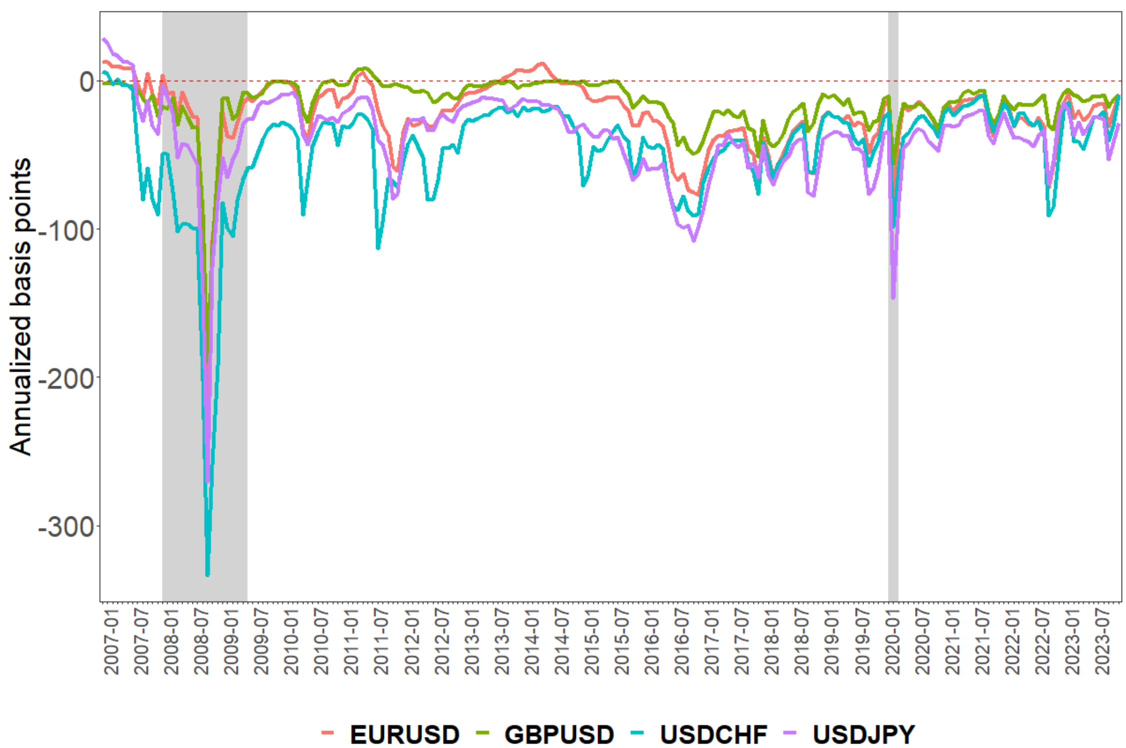
(a) Daily turnover



(b) Outstanding FX swap maturity (excluding inter-dealer)

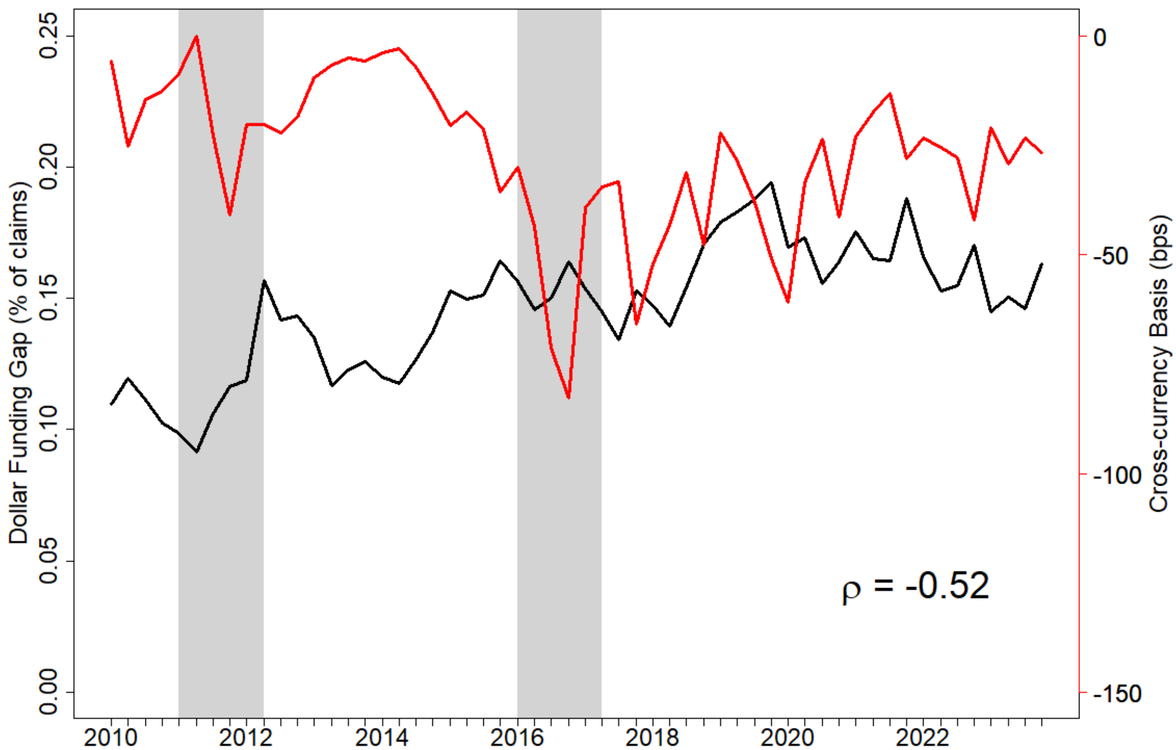
Notes: This figure shows that FX swaps are among the most heavily traded financial derivatives, with typical maturities of less than one year. Panel (a) plots the average daily turnover of four OTC instruments - cross-currency swaps, FX spot, FX swaps and forwards, and interest rate derivatives. The data are sourced from the BIS triennial survey (Bank for International Settlements, 2022). Panel (b) shows outstanding FX swaps between dealers and other financial institutions across three maturity buckets - under 1 year, 1 year to 5 years, and over 5 years. These data are sourced from the BIS data portal that can be accessed here.

Figure A3: Cross-currency Basis



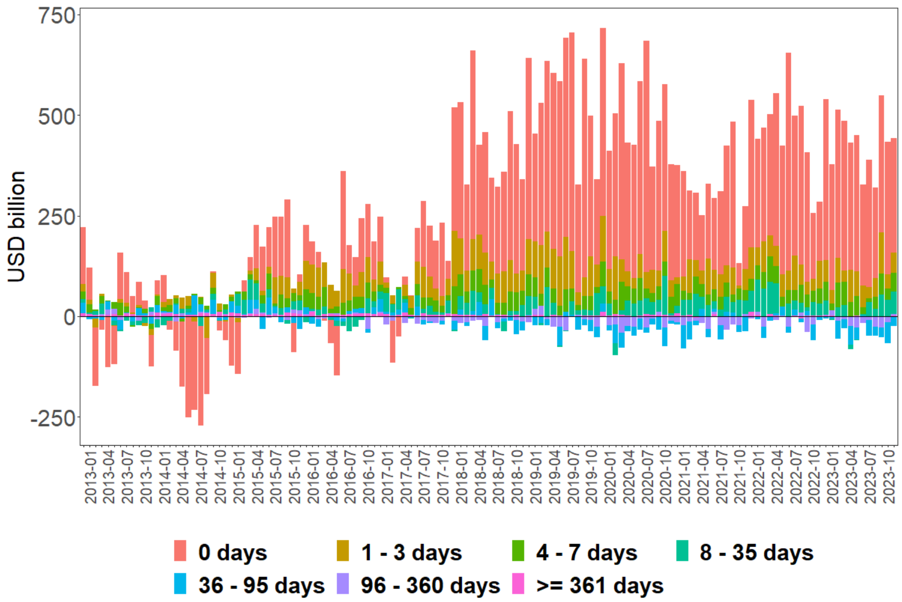
Notes: This figure shows persistent deviations of the 3-month cross-currency basis from zero for four currencies: the Euro (EUR), British pound (GBP), Swiss franc (CHF), and Japanese yen (JPY), all facing the US dollar. Cross-currency basis is computed using overnight indexed swap rates, and FX spot and forward rates. Shaded region indicates NBER-dated recessions.

Figure A4: Dollar Funding Gap of Non-US Banks and Cross-currency Basis

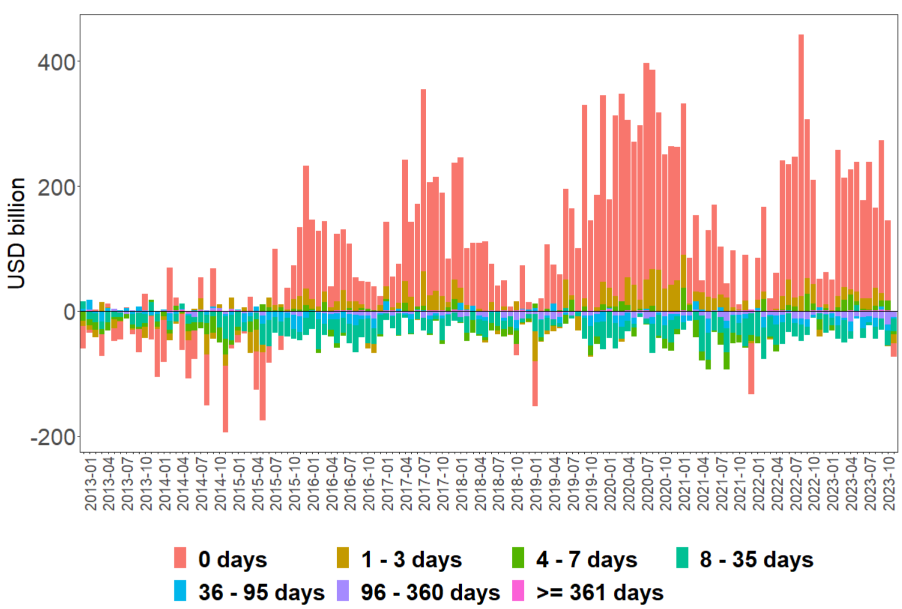


Notes: This figure plots the time-series of dollar funding gap of non-US banks (in red) and average cross-currency basis across all USD-facing currencies (in black) at a quarterly frequency. Dollar funding gap is defined as the difference between on-balance sheet dollar claims and liabilities, scaled by total claims, and represented as a percentage on the left axis. Cross-currency basis is annualized and reported in basis points on the right axis. Shaded areas represent Euro-area debt crisis in 2011 and the implementation of US money market fund reforms in 2016. The data on dollar funding gap is sourced from the Bank of International Settlements' Locational Banking Statistics and Consolidated Banking Statistics.

Figure A5: Synthetic Dollar Funding by Global Banks against JPY and CHF



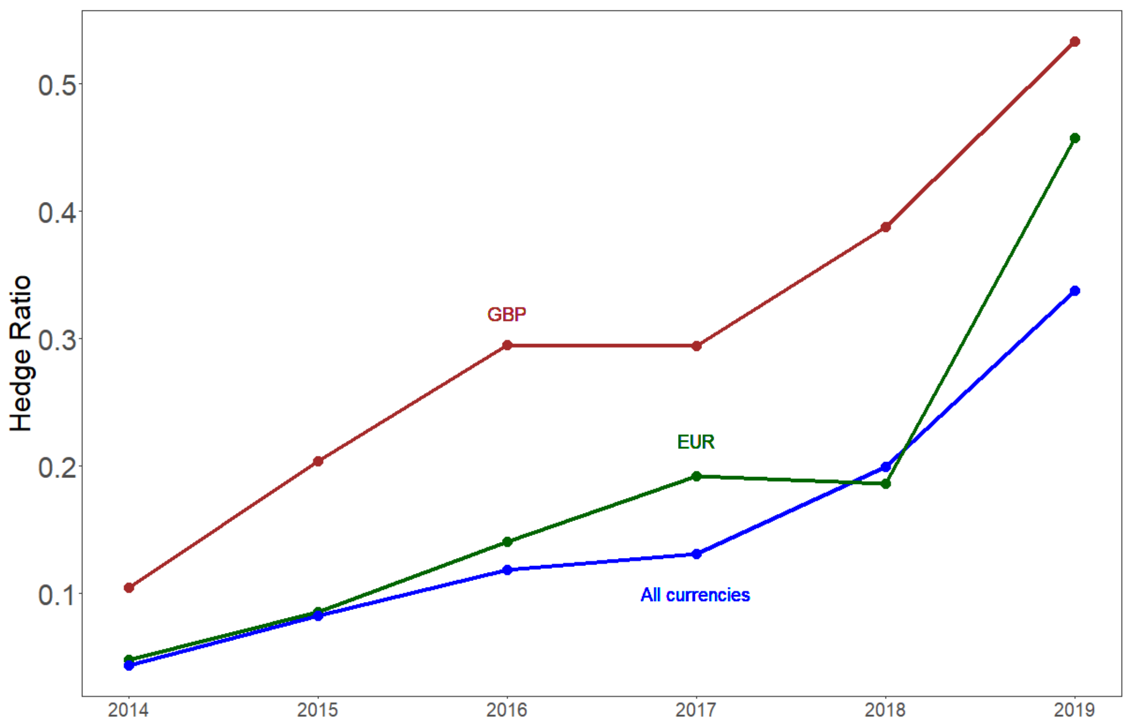
(a) USD borrowing against JPY



(b) USD borrowing against CHF

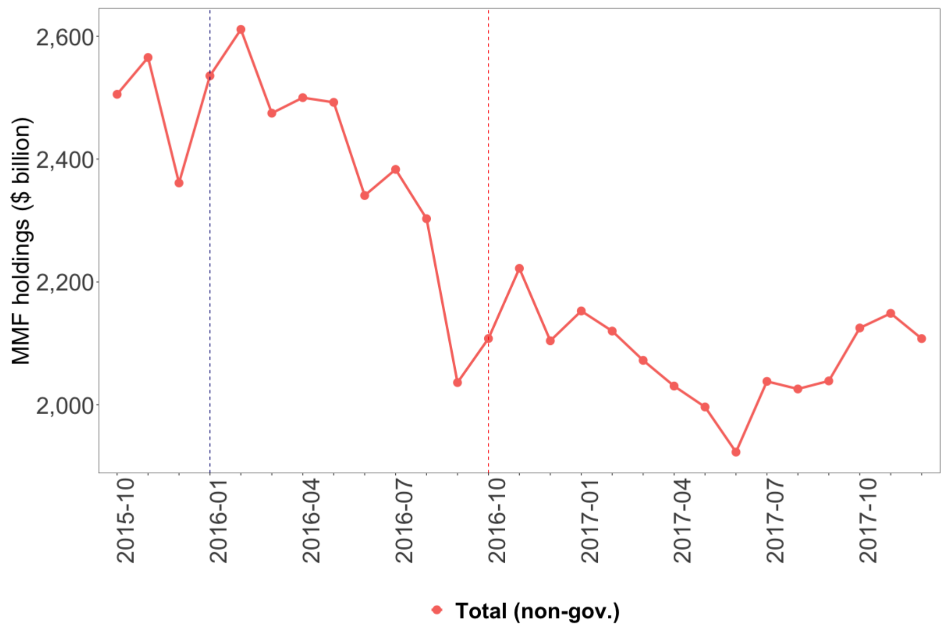
Notes: This figure plots the quantity of USD borrowed (positive y-axis) or lent (negative y-axis) against the Japanese yen (JPY) in panel (a) and the Swiss franc (CHF) in panel (b) by globally active dealer banks from/to all other counterparty sectors put together. USD is borrowed against JPY or CHF for settlement at the near leg of the swap and exchanged back at the far end. Bar colors represent 7 maturity buckets, with "0 days" corresponding to overnight borrowing. The near date for all other tenors is the spot date. The time series is at a monthly frequency from January 2013 through December 2023. This figure is constructed using daily signed FX swap order flow sourced from CLSMarketData and aggregated at a monthly level.

Figure A6: US Insurers' FX Hedge Ratio

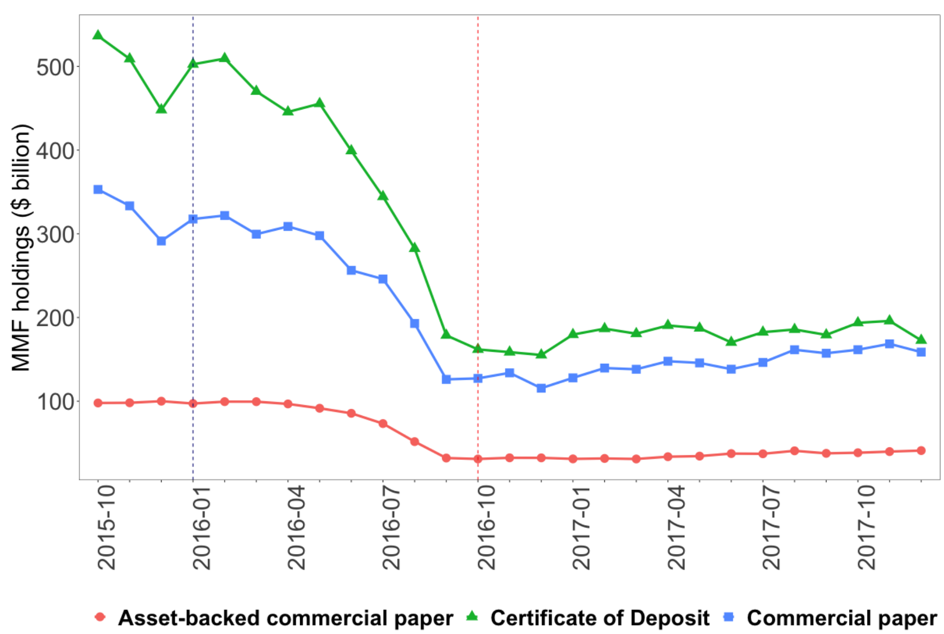


Notes: This figure plots the fraction of foreign bond holdings in notional terms that are FX hedged by all the firms in the US life insurance sector. The time series is constructed from Schedule D regulatory filings for bonds and Schedule DB filings for derivatives, sourced from the National Association of Insurance Commissioners (NAICS).

Figure A7: The 2016 Money Market Fund Reform Shock



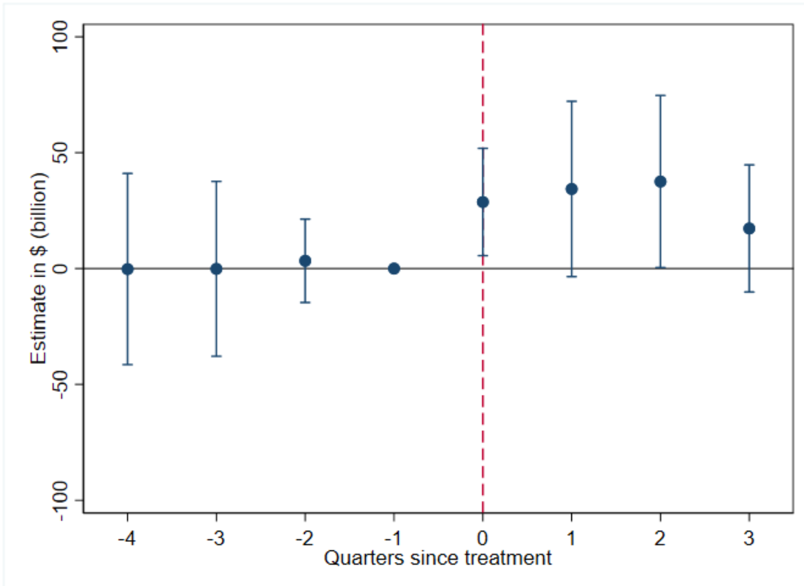
(a) Total non-government holdings



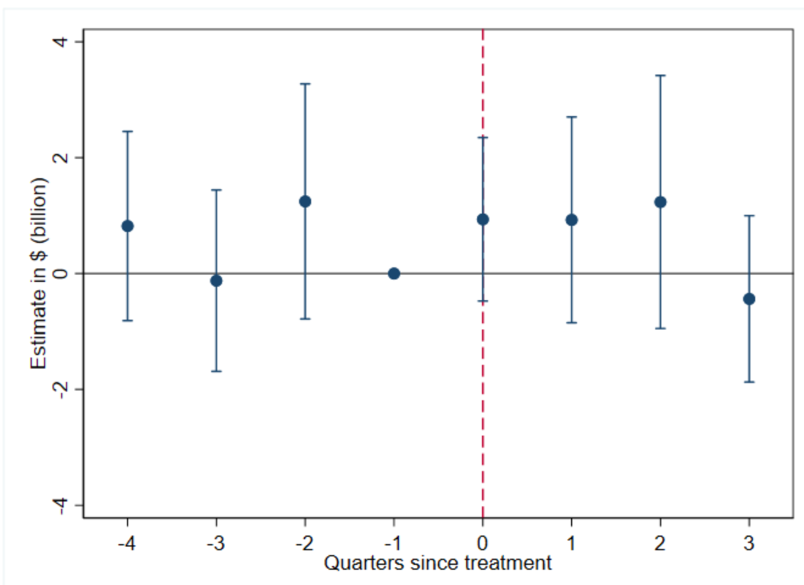
(b) Major bank-issued instruments

Notes: This figure shows that US money market fund (MMF) holdings sharply declined around the time of the 2016 regulatory reforms. Panel (a) plots the total holdings of US MMFs and panel (b) plots their instrument-specific holdings. The vertical dashed lines in blue indicate the start of the transition period when the proposed reforms were known to the market, and the dashed lines in red indicate the month of implementation of reforms.

Figure A8: Treatment Effects of 2016 Money Market Fund Shock



(a) Swaps



(b) Forwards

Notes: This figure shows that global banks' dollar borrowing through FX swaps sharply increased after the implementation of the 2016 money market fund reforms. Both panels show the treatment effects in $ billion for the quarters around 2016Q1 when the transition period began, as shown in Figure A7. The β_τ coefficients from Equation 13 and 95% confidence intervals are displayed in blue. Panel (a) considers FX swaps where the effect is visible, whereas panel (b) considers FX forwards as a placebo where no treatment effect is visible. This figure also confirms the existence of parallel trends before treatment.

Table A1: Data Coverage and Representativeness

Panel A: Trading between dealers and	BIS ($ billion)	CLS Share (%)
Non-reporting entities (Buy-side)	1,768	23
Financial institutions (Buy-side - Corporate)	1,620	25
Non-reporting banks (Buy-side - Fund - NBFI - Corporate)	909	31
Institutional investors (Fund + NBFI)	650	18
Non-financial institutions (Corporate)	148	2
Panel B: Share of volume by tenor	**BIS (%)**	**CLS (%)**
$\leq$ 7 days	71	61
$>$ 7 days & $\leq$ 1 month	11	22
$>$ 1 month & $\leq$ 3 months	11	11
$>$ 3 months	7	5
Panel C: Share of volume involving currency	**BIS (%)**	**CLS (%)**
EUR	33	33
JPY	15	21
GBP	15	16
AUD	6	9
CAD	7	7
CHF	6	7

Notes: This table reports the estimated coverage and representativeness of FX swap transactions observed in CLS data against the April 2022 Bank for International Settlements (BIS) over-the-counter FX turnover survey. Panel A reports the gross volume of transactions between reporting dealers and various end-users as reported by the BIS, and the approximate share of this volume covered by the CLS data. (The CLS-equivalent sector names are in parentheses.) Panel B compares the share of each maturity bucket in the FX swaps turnover as reported by the BIS and observed in CLS data. Panel C compares the share of each currency in the FX swaps turnover as reported by the BIS and observed in CLS data. Note that the match between sectors and tenor definitions are approximate and detailed in Appendix A. BIS data can be accessed here. CLS data are averaged across all trading days in April 2022.

Table A2: Descriptive Statistics of FX Forward Dollar Purchase by Global Banks

Panel A: By sector	Mean	SD	p25	p50	p75	N
All non-dealers	-0.29	3.89	-2.19	-0.28	1.43	2,853
NBFI	0.01	0.76	-0.16	-0.03	0.12	2,853
Fund	1.56	4.19	-0.30	1.08	2.83	2,853
Corporate	-0.68	1.81	-0.71	-0.21	0.00	2,853
Non-dealer Banks	-1.18	3.25	-2.81	-1.02	0.53	2,853
Panel B: By tenor						
1 - 3 days	-0.60	1.60	-1.10	-0.30	0.20	2,853
4 - 7 days	-0.60	1.30	-1.00	-0.30	0.10	2,853
8 - 35 days	0.50	3.40	-0.90	0.20	1.40	2,853
36 - 95 days	0.30	1.70	-0.50	0.30	1.10	2,853
96 - 360 days	0.00	0.70	-0.30	0.00	0.30	2,853
>= 361 days	-0.00	0.20	-0.10	-0.00	0.00	2,853
Panel C: By currency pair						
AUDUSD	0.10	0.80	-0.20	0.10	0.40	2,853
EURUSD	-0.40	2.40	-1.40	-0.40	0.70	2,853
GBPUSD	-0.10	1.70	-0.80	-0.20	0.40	2,853
NZDUSD	0.00	0.40	-0.10	0.00	0.10	2,853
USDCAD	-0.10	0.80	-0.40	-0.00	0.30	2,853
USDCHF	0.10	0.60	-0.10	0.10	0.30	2,853
USDJPY	0.10	1.30	-0.40	0.00	0.50	2,853
USDNOK	-0.00	0.20	-0.10	-0.00	0.10	2,853
USDSEK	-0.00	0.30	-0.10	-0.00	0.10	2,853

Notes: This table presents summary statistics of daily net dollars bought by global banks using FX forwards. USD is bought for settlement at the far leg of the contract. The time series is at a daily frequency from January 2013 through December 2023. Units are in $ billion. Panel A shows that funds are the main sellers of USD, panel B indicates that tenors up to one quarter are most common, and panel C reflects the dominance of EURUSD pair. This table is constructed using daily signed FX forward order flow sourced from CLSMarketData.

Table A3: Synthetic Dollar Funding (EURUSD) and MMF Holdings (Tenor)

	Dollars borrowed by Global Banks			
	$ million		Count of trades	
	(1)	(2)	(3)	(4)
Δ MMF holdings (avg. tenor, t-1)	-1,024.2***	-979.5**	-2.59***	-2.55***
	(349.9)	(404.5)	(0.642)	(0.701)
Δ ILRS		-16.5		-0.011
		(19.7)		(0.033)
Δ CBBS/GDP		1,788.4**		3.27***
		(852.1)		(1.23)
Δ US 1-month OIS		109.0		-1.85
		(4,987.4)		(9.34)
Δ Spot		-2.34		0.015**
		(4.01)		(0.007)
Δ Swap (overnight)		-3,041.2		-2.68
		(8,328.4)		(14.7)
N	132	131	132	131
Adj. R^2	0.05	0.05	0.10	0.12

Notes: This table reports ordinary least squares estimates for a model of the form in Equation 1. The dependent variable is daily average dollar borrowing at the near leg of overnight EURUSD swaps by global banks from all other sectors. Columns (1) and (2) consider the net dollar amounts borrowed, while columns (3) and (4) consider the net number of buy trades. The regressor of interest is the change in the average tenor of previous month's money market fund holdings of all non-government securities, denoted as Δ MMF holdings (avg. tenor, t-1) and expressed in number of days. Controls in columns (2) and (4) include the monthly change in intermediary leverage ratio squared (Δ ILRS), monthly change in the difference between Euro-area and US central bank balance sheet sizes scaled by GDP (Δ CBBS/GDP), and monthly changes in the rates of US 1-month OIS, EURUSD spot, and EURUSD overnight swap. Newey-West standard errors (lags=3) are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A4: Synthetic Dollar Suppliers (EURUSD) and MMF Holdings

	Dollars borrowed by Global Banks from			
	Non-dealer Banks	Fund	Corporate	NBFI
	(1)	(2)	(3)	(4)
Δ MMF holdings (t-1)	-22.9***	4.95	-0.177**	0.988
	(7.37)	(4.30)	(0.086)	(0.838)
Δ ILRS	19.2	-22.1**	0.038	-2.69
	(19.2)	(8.68)	(0.165)	(2.52)
Δ CBBS/GDP	-139.0	814.2	-0.838	627.4***
	(831.1)	(580.6)	(4.23)	(236.8)
Δ US 1-month OIS	9,386.3**	-5,898.3**	-134.9**	-585.7
	(4,719.2)	(2,328.6)	(54.0)	(471.3)
Δ Spot	2.68	-5.36***	0.039	1.46**
	(4.17)	(1.69)	(0.024)	(0.709)
Δ Swap (overnight)	-1,784.8	-1,957.0	91.8*	-224.7
	(7,134.8)	(4,540.9)	(52.4)	(732.4)
N	131	131	131	131
Adj. R^2	0.07	0.08	0.12	0.20

Notes: This table reports ordinary least squares estimates for a model of the form in Equation 1. The dependent variable is daily average dollar borrowing at the near leg of overnight EURUSD swaps by global banks from non-dealer banks in column (1), funds in column (2), corporate entities in column (3), and non-bank financial institutions in column (4). The regressor of interest is the change in the previous month's money market fund holdings of all non-government securities, denoted as Δ MMF holdings (t-1) and expressed in $ billion. Controls include the monthly change in intermediary leverage ratio squared (Δ ILRS), monthly change in the difference between Euro-area and US central bank balance sheet sizes scaled by GDP (Δ CBBS/GDP), and monthly changes in the rates of US 1-month OIS, EURUSD spot, and EURUSD overnight swap. Newey-West standard errors (lags=3) are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A5: Forward Purchase of USD against EUR and MMF Holdings

	Dollars purchased forward by Global Banks			
	$ million		Count of trades	
	(1)	(2)	(3)	(4)
Δ MMF holdings (t-1)	0.084	0.004	0.008	0.006
	(0.084)	(0.101)	(0.007)	(0.009)
Δ ILRS		-0.043		-0.005
		(0.431)		(0.023)
Δ CBBS/GDP		-13.6		-0.397
		(18.6)		(1.48)
Δ US 1-month OIS		-213.2**		-22.3***
		(92.2)		(5.34)
Δ Spot		0.032		-0.004
		(0.074)		(0.008)
Δ Swap (overnight)		49.0		3.23
		(153.2)		(9.93)
N	132	131	132	131
Adj. R^2	0.00	0.00	0.00	0.03

Notes: This table reports ordinary least squares estimates for a model of the form in Equation 2. The dependent variable is daily average net dollar bought forward at the $1-3$ day tenor of EURUSD forwards by global banks. Columns (1) and (2) consider the net dollar amounts bought, while columns (3) and (4) consider the net number of buy trades. The regressor of interest is the change in the previous month's money market fund holdings of all non-government securities, denoted as Δ MMF holdings (t-1) and expressed in $ billion. Controls in columns (2) and (4) include the monthly change in intermediary leverage ratio squared (Δ ILRS), monthly change in the difference between Euro-area and US central bank balance sheet sizes scaled by GDP (Δ CBBS/GDP), and monthly changes in the rates of US 1-month OIS, EURUSD spot, and EURUSD overnight swap. Newey-West standard errors (lags=3) are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A6: Synthetic Dollar Funding (Weekly) and CIP Deviations

	Δ Cross-currency basis ($\Delta x_{t,t+n}$)			
Panel	PC1 (1W, 1M, 3M, 6M)	1W	1M	3M
	(1)	(2)	(3)	(4)
Net $ Borrowing	-0.023**	-0.024*	-0.005**	-0.001
	(0.006)	(0.008)	(0.001)	(0.0010)
Δ Spot price	-0.959**	-0.696*	-0.670**	-0.127
	(0.243)	(0.260)	(0.187)	(0.077)
Δ Swap price (overnight)	3.18	3.26	0.752	0.415
	(1.65)	(1.73)	(0.341)	(0.190)
Cross-currency basis (t-1)	-0.406**	-0.659***	-0.196***	-0.060***
	(0.071)	(0.077)	(0.015)	(0.007)
N	2,061	2,061	2,061	2,061
Currency FE	Y	Y	Y	Y
Time FE	Y	Y	Y	Y
EURUSD	PC1 (1W, 1M, 3M, 6M)	1W	1M	3M
	(1)	(2)	(3)	(4)
Net $ Borrowing	-0.031**	-0.013	-0.030***	-0.007*
	(0.012)	(0.012)	(0.010)	(0.004)
N	576	576	576	576
Controls	Y	Y	Y	Y
Adj. R^2	0.15	0.28	0.11	0.13

Notes: This table reports ordinary least squares estimates for a model of the form in Equation 5. The dependent variable is weekly change in CIP deviations (i.e., cross-currency basis) for a panel of EURUSD, USDJPY, USDCHF, and GBPUSD in the top panel, and for EURUSD in the bottom panel. Column (1) uses the first principal component of 1-week, 1-month, 3-month and 6-month cross-currency basis, while columns (2) through (4) consider individual tenors. CIP deviations are calculated using the daily overnight index swap yields at the respective tenors, the spot rate, and the forward premium. The regressor of interest is the weekly net dollar borrowing by global banks using FX swaps in the respective currency. The panel version clusters standard errors by currency and the time-series version uses Newey-West standard errors (lags=3), all reported in parantheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A7: GIV for EURUSD Swap Borrowing and Cross-currency Basis

First-stage	Net \$ Borrowing			
	(1)		(2)	
z_t	-0.031***		-0.033***	
	(0.009)		(0.011)	
N	132		131	
Instrument F-statistic	12.31		10.70	
Controls	N		Y	
Second-stage	**ΔCross-currency basis$_t$**			
	PC1 (1W, 1M, 3M, 6M)		1W	1M
	(1)	(2)	(3)	(4)
Net \$ $\widehat{\text{Borrowing}}_t$	-0.713**	-0.595**	-0.400*	-0.546**
	(0.313)	(0.295)	(0.211)	(0.248)
N	132	131	131	131
Controls	N	Y	Y	Y

Notes: This table reports estimates from a two-stage least squares regression with net dollar borrowing in EURUSD swaps as the endogenoeus variable. The first-stage reports estimates using the granular instrumental variable as the regressor, with column (2) including additional controls. In the second-stage, the dependent variable is monthly change in EURUSD cross-currency basis, with the first principal component of 1-week, 1-month, 3-month, and 6-month tenors in columns (1) and (2), 1-week tenor in column (3), and 1-month tenor in column (4). The regressor of interest is the instrumented net dollar borrowing in EURUSD swaps from the first stage. Newey-West standard errors are reported in parantheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A8: Impact of 1-Week CIP Deviations on Hedging Demand

Panel (EUR, JPY, CHF)	Forwards			Swaps		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}\ \text{basis}_{C,t}$ (1W)	-13.004***	0.113	0.485	-40.737***	0.504	3.122***
	(1.965)	(1.039)	(0.298)	(12.279)	(0.636)	(0.300)
N	338	338	338	338	338	338
Adj. R^2	0.29	0.02	0.12	0.08	0.44	0.45
Currency FE, Controls	Y	Y	Y	Y	Y	Y
EURUSD	Forwards			Swaps		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}\ \text{basis}_{t}$ (1W)	-14.860**	-0.800	0.609	-55.694**	-0.379	4.089**
	(6.893)	(0.668)	(4.199)	(27.180)	(1.453)	(1.753)
N	131	131	131	131	131	131
Adj. R^2	0.16	0.06	0.03	0.01	0.01	0.04
Controls	Y	Y	Y	Y	Y	Y

Notes: This table reports the second-stage results of Equation 11 from a two-stage least squares estimation. The dependent variable is the monthly net USD forward purchase in the first three columns, and net USD sell-buy swaps in the last three columns, all for a 1-month tenor. The regressor of interest is the instrumented change in 1-week cross-currency basis. Standard errors are reported in parantheses, and are clustered by currency in the panel version. The time-series version for EURUSD uses Newey-West standard errors (lags=3). $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A9: US Insurers' EUR Bond Holdings

	% Change in EUR Bond Holdings			
	(1)	(2)	(3)	(4)
Δ Cross-currency basis (PC1)	-0.071	-0.120**		
	(0.052)	(0.058)		
Δ Cross-currency basis (1 month)			-0.225**	
			(0.106)	
Δ Cross-currency basis (3 months)				-0.304***
				(0.111)
Δ 5Y US-EU Yield Differential		-0.099**	-0.100**	-0.101**
		(0.046)	(0.045)	(0.045)
Δ EURUSD 3M Implied Vol		-0.035***	-0.036***	-0.039***
		(0.010)	(0.010)	(0.010)
N	2,211	2,211	2,211	2,211
Investor FE	Y	Y	Y	Y

Notes: This table reports ordinary least squares estimates of a model of the form in Equation 12. The dependent variable is the annual percentage change in the net outstanding EUR bond holdings for each firm in the US life insurance industry. The regressor of interest is the change in cross-currency basis, using the first principal component of 1-week, 1-month, 3-month, and 6-month tenors in columns (1) and (2), 1-month tenor separately in column (3), and 3-month tenor in column (4). All columns include investor (firm) fixed effects, and columns (2) through (4) include additional controls. Standard errors clustered by firm are reported in parantheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.