Synthetic Dollar Funding

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Abstract

Off-balance sheet foreign exchange (FX) swaps are a major source of US dollar funding for non-US banks that provide over half of global dollar credit. However, the frictions that lead banks to rely on these instruments and their broader impact on the financial system are not well understood. This paper shows that FX swaps emerge as alternative ("synthetic") funding instruments when banks face negative funding shocks from cash-market investors, such as US money market funds. The resulting increase in swap demand, combined with limits to arbitrage, leads to substantial deviations from covered interest parity (CIP) – the breakdown of a fundamental no-arbitrage pricing condition. I show a causal impact of banks' swap demand on CIP deviations using an instrumental variables strategy that exploits idiosyncratic variation in money market funds' investment in bank-level debt. 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 swap prices and find only a partial adjustment in quantities traded. My results indicate that frictions in the global market for the US dollar can provide a demand-based explanation for CIP deviations.

Keywords: FX swaps, US dollar, currency hedging, covered interest rate parity, financial frictions.
JEL classification: F31, G11, G12, G15, G20

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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 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 dollar intermediation, funding constraints faced by large global banks can significantly impact international financial stability.

Global banks are increasingly reliant on off-balance sheet foreign exchange (FX) swaps, that facilitate "synthetic" dollar funding by temporarily converting foreign currency into US dollars.[2] These instruments represent one of the most active segments of financial markets with over $60 trillion in outstanding notional, with non-US banks holding upwards of $35 trillion (Bank for International Settlements, 2022). However, synthetic funding instruments are not only costlier than conventional debt products, but their off-balance sheet nature also creates "hidden leverage" for borrowers, making it challenging for regulators to monitor such debt and design macro-prudential policies (Borio, McCauley, and McGuire, 2022). Despite its large size and crucial role in the international financial system, we do not know (i) what specific frictions lead banks to borrow dollars synthetically, (ii) how it affects asset prices, and (iii) what is the spillover impact on other investors active in global capital markets. These questions are important to understand how various funding markets are interlinked, 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 dataset of daily FX swap transactions, I show that globally active dealer banks turn to synthetic dollar funding in response to a decline in wholesale (i.e., cash-market) supply of dollars, particularly from US money market funds. This shift in demand increases swap prices, widening covered

[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.

[2]Under this arrangement, the borrower first raises funds in its local currency, e.g., the Euro, and then enters into an FX swap transaction to borrow US dollars for the maturity of the contract. The instrument effectively works like a collateralized term loan but does not appear on the balance sheet as a dollar debt. Borio et al. (2022) report that two-thirds of the total dollar debt of non-US banks was via FX swaps in 2022.

interest parity (CIP) deviations across tenors from one week to three months.[3] To provide a causal interpretation to these results, I instrument for swap demand using idiosyncratic shocks to the wholesale dollar funding available to foreign banks in a granular dataset of US money market fund holdings. To understand the broader implications of banks' substitution between wholesale and synthetic funding markets, I estimate the demand elasticities of non-bank investors to CIP deviations and find that investors largely absorb higher prices by way 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 the limited scalability of dollar funding from US MMFs pushes global banks to raise dollars via FX swaps, pointing towards a substitution pattern. On the supply side, recent studies emphasize limits to arbitrage in the swap market that create upward-sloping supply curves (Du, Tepper, and Verdelhan, 2018).[4] Therefore, the net impact of increased demand pressure in the swap market is higher prices, i.e. more negative cross-currency bases, borne by non-bank investors in the form of increased FX hedging cost of USD assets. Figure 1 illustrates these relationships in the context of Euro-area banks: when a larger fraction of Euro-area banks is constrained from accessing additional wholesale market funding, EURUSD cross-currency basis turns more negative.

I provide empirical support for these channels using a comprehensive dataset of cross-sector FX derivative transactions. Synthetic dollar funding is facilitated by FX swaps, that are among the most heavily traded financial derivatives in the world. Despite its central role in the international financial architecture, limited research exists on this market due to its over-the-counter nature that limits visibility on the quantities traded by various participants. My analysis leverages daily aggregated dealer-to-client transactions from CLSMarketData, 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 FX swaps across seven tenors and nine major currency pairs that together represent over 90% of the trading volume. I estimate that these data cover about a quarter of global dealer-to-client swap transactions.

[3]Covered interest parity (CIP) deviations represent the breakdown of a fundamental no-arbitrage pricing condition in international financial markets, implying the existence of a wedge between direct and synthetic dollar funding costs. Recent literature has focused on "limits to arbitrage" that allow these deviations to persist (Du et al., 2018). My results documented here provide a demand-side counterpart.

[4]Du and Schreger (2022) suggest that CIP deviations (measured as cross-currency bases) represent a compensation for suppliers of dollars in the FX swap market.

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 at a daily frequency, which allows me to quantify high-frequency dollar borrowing and connect it to indicators of dollar funding shortage. Second, I observe trades contracted between core dealers and all other sectors put together, as well as between market-makers 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 investors. 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 events such as the 2016 money market fund reform. Finally, I complement the CLS data with monthly bank-level holdings of US money market funds, which allows me to jointly study substitution patterns between these two funding markets. To my knowledge, this is one of the most comprehensive databases covering the flow of FX swaps utilized in academic research to date.

I start by documenting stylized facts and correlative evidence of funding market substitution. Synthetic dollar funding is concentrated in the overnight to one-month tenors of the swap curve, and is primarily undertaken against the Euro (EUR), the Japanese yen (JPY), the Swiss franc (CHF), and the British pound (GBP). Further, global dealer banks are the largest dollar borrowers in this market, while non-dealer banks act as suppliers.[5] I analyze the evolution of global banks' synthetic dollar borrowing against changes in money market fund (MMF) holdings of bank securities, both for a panel of currencies and for the 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 the count of trades, as well as different measures of wholesale funding, such as the value-weighted maturity of MMF holdings. Furthermore, I rule out two alternative explanations. First, I find that a decline in MMF holdings affects swap trades between dealers and non-dealer banks only, which suggests that intermediation for non-bank 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 currency risk hedging cannot explain my findings.

Synthetic dollar funding via FX swaps widens covered interest parity (CIP) deviations. I find that an increase in net dollar borrowing by global banks turns the cross-currency basis more negative across all funding currencies and maturities of 1 week to 3 months where the majority of FX

[5]While global banks, particularly those domiciled outside of the US, borrow USD from non-dealer banks (e.g., the Northern Trust company), they supply USD to other end-users such as funds and corporations.

derivatives are traded. An implication of this finding is that demand for dollars interacts with 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 changing supply constraints in the swap market that could lead to omitted variable bias. To address endogeneity concerns, I employ a granular instrumental variables (GIV) strategy that exploits variation in money market funds' holdings in bank-specific debt.

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 from US money market funds (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, global banks' synthetic dollar funding demand 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 wholesale 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 faces 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 construct the currency-specific instrument as the size-weighted sum of idiosyncratic shocks to bank-level MMF flows, extracted after removing shocks that are common to all banks as well as time trends.[6] I find that an increase in the size-weighted sum of idiosyncratic shocks to banks' MMF funding leads to reduced synthetic dollar borrowing and narrower cross-currency basis. This implies that an increased availability of wholesale funding allows banks to reduce their reliance on FX swaps, leading to a narrowing of CIP deviations for that currency against the US dollar. My results are statistically and economically strong even after allowing for potential increase in the demand for credit by banks' end-borrowers, which would induce a positive correlation between banks' wholesale and synthetic dollar funding demand. Importantly, my results are not confined to only quarter-ends, and reflect ongoing dynamics in funding shocks faced by global banks.

To gain further insights into the mechanism behind the price effect, I estimate the impact of instrumented CIP deviations on non-bank users of FX derivatives: investment managers ("funds"), non-financial corporations, and non-bank financial intermediaries (NBFIs). Each investor in this

[6] I allow banks to have heterogeneous loadings to common factors, that are the first three principal components of bank-level changes in MMF flows. I also account for potential heteroskedasticity in residuals.

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 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 0.26% in the panel of all currencies and by 0.29% against the Euro. Likewise, funds reduce buy-sell USD swaps by 0.62% in the panel and by 0.52% against the Euro. In both the products, corporations and NBFIs do not react significantly. These estimates suggest relatively inelastic demand, implying that foreign investors largely absorb price shocks in the form of increased hedging costs. 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.

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 cash-rich US institutional investors. Existing literature documents that traditional arbitrageurs such as dealer banks face limits to arbitrage, while the Federal Reserve supplies dollars via swap lines mainly during market-wide disruptions (e.g., the COVID-19 pandemic). I complement my 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 derivatives to hedge the FX risk. I find that while insurers increase their holding of FX forwards and swaps when the cross-currency basis turns more negative, the elasticity is well under one and therefore their marginal dollars are not large enough to fully offset the impact of demand shifts from global banks.

Taken together, my results provide a first evidence of demand substitution across funding markets arising out of quantitative constraints on large wholesale market investors, providing a demand-side explanation for persistent CIP deviations. My results complement the contemporaneous work of Kloks, Mattille, and Ranaldo (2024), who exploit jurisdictional differences in regulatory reporting requirements and find that Euro-area banks substitute from repo to FX swaps at quarter-ends to reduce balance sheet costs. In contrast, my study focuses on *quantitative* constraints, that represent different economic forces, and create ongoing reliance on FX swaps by banks. Furthermore, my identification strategy focuses on the price impact of this demand, that holds outside of quarter-ends and across currencies, with real spillover effects on non-bank investors' hedging costs.

My work also informs regulatory discussions on the fragility of short-term funding markets and prudential policies to safeguard the system. Post-financial crisis regulations have increased frictions in banks' ability to source dollars in the cash market. As I show in this paper, part of this demand has shifted to FX swaps, an off-balance sheet product that is more difficult to track and can add to financial opacity (Barajas et al., 2020). As a result, macro-prudential policies such as central banks swap lines are set "in fog" (Borio et al., 2022). To this end, my paper presents an early step in understanding the linkage between wholesale and synthetic funding markets, which can help to assess the impact of domestic liquidity policies on the globally interconnected financial system.

Related literature. This paper contributes to the literature that emphasizes the importance of financial intermediaries to asset prices (Haddad and Muir, 2021, Du, Hebert, and Huber, 2022).

Recent studies highlight the scarcity of intermediary banks' balance sheet space (Siriwardane, 2019, Fleckenstein and Longstaff, 2020). My unique contribution is to analyze the growth of off-balance sheet derivatives that enable global banks to reduce dollar funding constraints. In doing so, my research also contributes 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; Correa, Du, and Liao (2020) find that large US banks drain reserves parked with the Federal Reserve to finance short-term lending; Anderson, Du, and Schlusche (2021) show that banks use unsecured borrowing to conduct arbitrage; Du and Schreger (2022) argue that non-US banks face barriers in accessing dollar cash markets; 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 study builds on this literature by jointly assessing two major funding sources – wholesale cash markets and foreign exchange swaps – offering 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 CIP deviations. Several studies document that supply-side frictions create limits to arbitrage: Du, Tepper, and Verdelhan (2018), Du, Hébert, and Li (2023) focus on post-financial crisis regulatory regime shifts, Rime, Schrimpf, and Syrstad (2022) on funding costs, and Barbiero, Bräuning, Joaquim, and Stein (2024) on risk limits. 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 Ben Zeev and Nathan (2024) who study institutional investors' demand under limits to arbitrage. While each of these sources of demand is important, they abstract away from analyzing systematic variation in the supply of dollars to global banks. Focusing on the largest set of institutions that regularly bear on-balance sheet dollar funding gap, my paper provides a causal link between their swap demand and CIP deviations, and traces the source of this activity to frictions in the wholesale dollar funding market. Relatedly, Becker, Schmeling, and Schrimpf (2023) and Bippus, Lloyd, and

Ostry (2023) show that cross-border bank lending affects CIP deviations and USD strength. My analysis differs in that it highlights the role of frictions that lead banks to substitute (cheaper) wholesale funding with (costlier) synthetic funding, with large asset pricing consequences.

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, Syrstad and Viswanath-Natraj (2022) find that customer order flow affects swap prices around quarter-ends, and Kloks, Mattille, and Ranaldo (2024) document that European banks substitute repo funding with FX swaps at quarter-ends. My paper focuses on persistent limits to wholesale dollar funding that are not restricted to quarter-ends and are, therefore, generalizable across periods. This distinction is important because there are different dynamics at play at quarter-ends. First, regulations around leverage ratios make it particularly costly for dealers to price FX derivatives at quarter-ends, sharply affecting the supply curve (Cenedese, Della Corte, and Wang, 2021). Second, Abbassi and Bräuning (2021) argue that foreign banks' quarter-end dollar demand reflects regulatory arbitrage, which is distinct from the ongoing wholesale funding shocks that I focus on. Third, Wallen (2020) shows that US banks exercise market power at quarter-ends which can explain a significant part of CIP deviations on these dates. Finally, non-bank end-users may also face end-of-period liquidity shocks, due to "dash for cash" for institutional investors (Etula, Rinne, Suominen, and Vaittinen, 2020) or "settlement breaks" for corporations (Khetan and Sinagl, 2023), which may not reflect funding market frictions.

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, Bräuer and Hau (2022) and Ben Zeev and Nathan (2022) study the hedging behavior of institutional investors, Du and Huber (2023) estimate the dollar holdings and hedge ratios of non-US investors, Sialm and Zhu (2024) focus on fixed-income mutual funds, and Kubitza, Sigaux, and Vandeweyer (2024) study the impact of CIP deviations on Euro-area investors' portfolios.[7] Using *cross-sector* swap transactions data, my paper estimates the FX hedging demand elasticity of multiple non-bank sectors, and provides a first quantification of the spillover impact of synthetic dollar funding 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 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 links synthetic dollar funding with CIP deviations, Section 5 details the identification strategy and spillover impact on non-banks, and Section 6 concludes.

[7]Studies on the real effects of CIP deviations include Ippolito, Peydro, Karapetyan, Juelsrud, and Syrstad (2024) for non-financial corporations, and Keller (2024) for bank lending in partially-dollarized economies.

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.[8] 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 cash-market investors 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 investment in banks is 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.[9] The investors most likely to benefit from

[8] 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.

[9] 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, e.g., 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.[10]

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.[11] 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.

[10] 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.

[11] 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.[12]

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 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.[13] Both the swaps and forwards data are structured similarly except that swaps are split by 7 tenor buckets, while forwards

[12]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.

[13]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).

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. One limitation of this dataset is that I do not observe "inter-dealer" trading activity. Thus, my estimated quantities of global dealer banks' net synthetic dollar funding could be understated to the extent that dealers offset this demand among themselves.[14]

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, followed by the Japanese yen (USDJPY pair) at $12.2 billion, with the Swiss franc (USDCHF pair) and other currencies in low single digits.

[14] Kloks et al. (2024) find that US Global Systemically Important Banks lend USD to non-US banks.

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 asset-backed commercial paper) and unsecured (commercial paper and certificate of deposit) instruments.[15] 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 MMFs. 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 during

[15] 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.

the 2022-23 high-interest rate regime). Euro-area banks were the largest foreign beneficiaries 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 facts are consistent with Aldasoro and Doerr (2023) who show that banks are the largest non-government borrowers from MMFs. Further, Panel B reports that the median synthetic dollar funding as a fraction of total (synthetic + MMF) ranges from 34% to 85% across major currencies.

I confirm that the largest bank borrowers from US money market funds are also CLS settlement members, that are likely global dealer banks in FX markets. Table A3 shows that all the 30 largest commercial banks borrowing from US MMFs are CLS settlement members, and collectively hold about half of all non-government MMF investments. Further, 25 of these 30 banks are headquartered outside of the US, and hold 70% of all the MMF investment into the banking sector.

3.3. Prices and Market Variables

The relevant measure of price in my 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) rates from Bloomberg. Then, I calculate the annualized difference between USD OIS rate (direct borrowing) and the corresponding synthetic borrowing rate (foreign currency OIS rate 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.[16]

Panel C of Table 2 shows that the average monthly CIP deviation in EURUSD is negative across the term structure. Between 2013 and 2023, the mean 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, which suggests that swaps may be preferred over outright spot or forwards for borrowing dollars due to 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 rate for interest rates.

[16] Overnight indexed swap rates for the Swiss franc (CHF) are unavailable prior to 2017. Hence, I use the CHF LIBOR series to construct USDCHF cross-currency basis.

4. Demand for Synthetic Dollar Funding

4.1. Stylized Facts

The market for synthetic dollar funding is large and dominated by banks and institutional investors. 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.[17] Figure A5 shows a similar pattern for USDJPY and USDCHF pairs. Moreover, panel (a) of Figure 3 shows that this demand is almost entirely supplied by non-dealer banks. In contrast, funds supplied under $200 billion each month until end-2019, and borrowed about $250 billion monthly thereafter. Corporations are consistently net borrowers, and non-bank financial institutions traded significant volumes only in the months following the onset of the pandemic.

There are two notable exceptions in the time series of synthetic dollar borrowing by global banks. First, in the month of April 2020, 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. Second, in the week following the collapse of the Silicon Valley Bank in March 2023, non-dealer banks reduced the supply of dollars in swap markets. Figure A6 zooms in on these two events using daily frequency of the data.

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 the rest of 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.

4.2. 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 swaps, which represents the largest segment of the FX swaps market (Table 1). Specifically, I estimate the model:

[17] While CLS data combines US and foreign dealer banks into one sector, a subset of the sample shows that 70% of the net USD borrowed via EURUSD overnight swaps is by banks headquartered outside the US.

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

The dependent variable, Net \$ Borrowing_t, is the average daily flow of net dollars borrowed by global banks against EUR in month t, aggregated across all tenors. I average the borrowing amount within the month to mitigate the influence of month-ends or quarter-ends that are documented in the literature to have special dynamics. Further, I use both the net volume in dollars and the net count of trades as two alternative dependent variables. The regressor of interest, $\Delta\text{MMF Holdings}_{t-1}$, is the change in the total non-government MMF holdings in bank debt. 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 the European Central Bank and the Federal Reserve Bank scaled by GDP (CBBS/GDP), (iii) US 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 strong negative association between dollars borrowed by global banks via swaps and changes in MMF holdings. In dollar terms, a one-standard-deviation decline in MMF holdings in month $t-1$ associates with a \$9.8 billion additional synthetic dollar funding per day in month t (556.47×17.7 / 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.[18]

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 A4. Similar to Table 3, all

[18]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.

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 another potential explanation that the increased swap demand by global banks reflects intermediation on behalf of other end-users of currency derivatives. As Figure 3 shows, non-dealer banks are the main suppliers of swap dollars to global banks. If FX intermediation is the driver behind the results in Table 3, we would expect banks' trading with other end-users to also be affected by wholesale funding constraints. 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 A5 shows that only non-dealer banks increase their supply of swap dollars to global banks when money market fund holdings decline, with no impact on trading between banks and funds, corporations and non-bank financial institutions (NBFIs). This suggests that a decline in MMF investments most severely affects global banks' dollar funding needs.

I broaden the scope of my analysis to include other currency areas where large global banks are located. Using the granular holdings of MMFs in debt securities of banks headquartered in these countries, I construct a currency-month panel that allows me to control for currency-specific time-invariant and common time trends. I estimate the below model using fixed-effects regression:

$$\text{Net \$ Borrowing}_{C,t} = \beta \Delta \text{MMF Holdings}_{C,t-1} + \text{Controls}_{C,t} + \alpha_C + \alpha_t + \varepsilon_{C,t}. \tag{2}$$

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.

Furthermore, 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.

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

The dependent variable in this equation is the average daily quantity of dollars bought forward by global banks in month t in the panel of currencies (aggregated across maturities), with rest of the specification analogous to Equation 2. Table A6 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 significant impact of changes in MMF holdings on the forward market order flow. Hence, hedging demand does not appear to be correlated with MMF holdings, and any change in swap trades is likely because of funding demand only.

Interest rates. I find further support for banks' substitution between wholesale and synthetic dollar funding markets using changes in the interest rate environment. At higher interest rates, households shift their savings from lower-yielding bank deposits to money market funds (Aldasoro and Doerr, 2023). I hypothesize that the increased availability of wholesale dollars during periods of tighter monetary policy reduces banks' reliance on synthetic markets. For example, Figure 2 shows a decline in net dollar borrowing via swaps during the 2022-23 tightening cycle.

I formally test this hypothesis by regressing banks' synthetic dollar funding demand on changes in the US 1-month OIS rate. Since the overall demand for dollar credit can also shrink during periods of tighter monetary policy, I regress changes in the fraction of synthetic to total (synthetic + MMF) dollar funding on changes in interest rates, while controlling for changes in cross-currency bases that co-move with interest rates (Lee, 2024). Table A7 reports that banks reduce their dependence on FX swaps when interest rates rise, supporting the argument that at least a part of synthetic dollar funding demand reflects quantitative limits on the availability of wholesale dollars.

Regulatory shock. 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 MMF 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 in 2016. I find that global banks' swap borrowing significantly increased in the quarters following the transition phase of the reform, while the other sectors as well as the forwards market were unaffected.

4.3. 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 EURUSD 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 approximately 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 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:

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

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 the scaled balance sheet sizes of the European Central Bank and the Federal Reserve Bank, 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, and 3-months, as well as for the first principal component. I also estimate this equation separately for EURUSD, given the large share of EURUSD swaps in this market. 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, where the bulk of FX swaps are traded. These results hold 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 decline in 3-month cross-currency basis is about 3.6 basis points (0.036 $\times$ 100), which is 10.3% of the full sample average of negative 35 basis points (Figure A3).

I repeat the estimation of Equation 5 at a weekly frequency and find consistent results in Table A8. 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.[19]

5. Identification and spillover impact

The previous section presented evidence suggesting 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. However, quantities and prices are simultaneously determined in equilibrium, inducing estimation bias. Furthermore, it is possible that the impact of swap quantities on CIP deviations reflects tightening of supply-side constraints of US banks, not demand shifts of foreign banks from wholesale to synthetic market.

In this section, I sharpen the identification of my proposed channels using granular data on MMF investments in non-US banks' short-term debt. I construct a time series of aggregated shocks to banks' MMF funding to achieve two goals: First, I confirm that a negative wholesale funding shock to non-US banks widens CIP deviations due to a rightward shift in the demand for FX swaps. Second, I estimate the demand elasticity of non-bank investors to instrumented CIP deviations, and assess the portfolio implications of frictions in the international supply of the 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 economic aggregates. It confers three advantages in my setting: (i) addresses simultaneity in swap quantities and cross-currency basis, as well as endogeneity from omitted

[19]While the vast majority of swap borrowing is in the short tenor ($\leq$1 month), we see CIP deviations impacted for tenors up to three months. A likely explanation for this price transmission is long-short carry trades, similar to the framework in Vayanos and Vila (2021). Table A9 provides suggestive evidence that "funds" supply USD in the short tenor (up to 1 month) and simultaneously borrow USD in the medium tenor (1 - 3 months). The negative coefficient in Table A9 implies that for every dollar supplied in the short-tenor swap, funds borrow about 30 cents in the 1 - 3 month tenor swaps, which transmits CIP deviations to that segment of the curve. Consistent with the results above, the carry trade does not extend beyond 3 months.

variables by netting out "common shocks" such as macro-economic factors; (ii) 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 global banks' synthetic dollar borrowing and the price; and (iii) allows me to directly shock the price to estimate of demand elasticities of non-bank investors and, with it, the spillover impact of synthetic dollar funding.[20]

Identification strategy. I use shocks to individual non-US banks' supply of dollar funding from US money market funds, aggregated at a currency-level, as an instrument for quantities demanded by global banks in the FX swap market. The key identifying assumption is that global banks cannot always optimize the cost of borrowing between these funding sources, and at least part of the swap demand is driven by quantitative constraints on additional borrowing from money market funds. I micro-found the source of these constraints below.

Gabaix and Koijen (2024) argue that in economies dominated by a few but large agents, idiosyncratic shocks to 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), Swiss franc (CHF), and the British pound (GBP). On one hand, aggregate MMF borrowing by the banking sector may co-move with swap demand for reasons other than MMF supply frictions (e.g., interest rate changes). On the other hand, when a subset of banks obtains differential investment compared to the overall sector, it could affect their FX swaps activity and thereby the cross-currency basis. Below reasons motivate the presence of idiosyncratic shocks.

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. As an illustration, Figure 1 reports a strong negative correlation between the fraction of Euro-area banks that are at or close to this 5% concentration threshold, and the EURUSD basis.
2. MMF-specific inflows/outflows: some MMFs may face larger inflows or outflows from their investors, differentially impacting the banks they specialize in lending to. This effect can be exacerbated when there is a high concentration among the MMFs that lend to a single bank. Figure A7 shows that while a typical bank borrows from about 9 money market funds throughout my sample period, the top 3 funds provide it with 90% of the total investment.
3. Credit rating changes: MMFs invest only in highly rated securities, which exposes banks to funding shocks on account of idiosyncratic credit rating changes. During my sample period,

[20] In related studies, Ben Zeev and Nathan (2024) use granular instruments to study the impact of institutional investors' demand on USDILS CIP deviations, and Becker et al. (2023) construct granular instruments from the syndicated loan market to study the impact of bank lending on exchange rates.

several episodes of bank-specific credit downgrades associate with large declines in MMF investment in the affected banks.

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

$$\Delta y_{i,t} = \underbrace{\phi^d p_t}_{\text{price effect}} + \underbrace{\boldsymbol{\lambda}_i \boldsymbol{\eta}_t}_{\text{common shock effect}} + \underbrace{u_{i,t}}_{\text{idiosyncratic shock}}, \tag{6}$$

where $\Delta y_{i,t}$ is the change in bank i's MMF funding in month t, scaled by the moving average of past 12 months' average MMF funding in that bank. Further, price p_t is the relative cost of wholesale versus synthetic funding in currency C against the US dollar, expressed as the cross-currency basis, and $\boldsymbol{\eta_t}$ is the vector of common shocks that all banks are exposed to.

In the basic setup, assume that (i) all banks trade at a common price p_t with equal elasticities ϕ^d, and (ii) all banks within a country have the same loadings on the common factors that affect their demand (i.e., $\boldsymbol{\lambda_i} = \boldsymbol{\lambda}$). Further, let each bank's share in MMF funding in month $t-1$ be $S_{i,t-1}$ (potentially time-varying). Then, the size-weighted change in MMF funding :=

$$\Delta y_{S,t} = \sum_i S_{i,t-1} \Delta y_{i,t} = \phi^d p_t + \boldsymbol{\lambda \eta_t} + u_{S,t}, \tag{7}$$

and, under the assumption of homoskedastic residuals, the equal-weighted change in MMF funding:

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

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:

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

In the estimation procedure, I relax two assumptions to ensure that z_t captures only the idiosyncratic component of banks' MMF funding shocks. First, motivated by the possibility that even within a currency-area or country, banks may react differently to common factors (represented by $\boldsymbol{\eta}$), I allow for heterogeneity in their factor loadings, $\boldsymbol{\lambda_i}$. To do this, I follow Gabaix and Koijen (2021) and extract the first three principal components of the monthly change in de-meaned MMF flows across all banks in currency-area C, and then use the residuals from a bank-by-bank regression on these three principal components that wash out any common components in $\Delta y_{i,t}$.[21,22]

Second, I adjust for heteroskedasticity in the residuals extracted above. Heteroskedasticity arises when, for example, the residuals correlate with bank size, thereby biasing the construction of equal-weighted changes represented in Equation 8. To accurately estimate the equal-weighted changes, I weight the observations in Equation 8 by the inverse of the bank-level variance of residuals, and re-estimate Equation 9 to construct the instrument z_t.

With these adjustments to the basic GIV framework, 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. Note that I drop Nordic currencies when constructing the GIV because there are only a few banks headquartered in these countries which makes the size- and equal-weighted components identical.

Diagnostics. A valid GIV requires that the economy be constituted by large players, i.e. has a high concentration, that idiosyncratic shocks are large enough to matter in the aggregate, and that the instrument is not correlated with confounding factors. I find support for all three conditions.

First, panel (a) of Figure 4 shows a high level of concentration (excess Herfindahl > 0.2) across all the four currencies against which global banks borrow dollars synthetically. For the Euro (EUR), British pound (GBP), 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 (expressed in dollars) can be economically significant: there are large and frequent deviations in the size-weighted changes in MMF holdings from equal-weighted changes.[23] Most of these shocks can be traced to one of three sources mentioned earlier. For example, (i) In November 2017, large MMFs 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

[21] I de-mean the variable using residuals from a time fixed-effects regression, which is equivalent to subtracting the equal-weighted change in MMF funding (Equation 8).

[22] Table A10 shows that the first three principal components explain 80% of the common variation in Euro-area banks, 75% in Japanese banks, 96% in Swiss banks, and 88% in British banks. Using principal components instead of observable factors also helps to attenuate omitted variable bias.

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

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.

Third, Table A11 confirms that the instrument z_t does not correlate with confounding factors such as changes in aggregate money market fund flows, interest rates, quarter-end dates, and measures of dealer sector's balance sheet constraints. Table A11 also shows that the residuals $u_{i,t}$ in Equation 6 are orthogonal to how much a bank borrows from MMFs. However, one alternative explanation for the differential MMF flows to banks could be that the borrower banks 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 a substitution impact on swap market. 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 the cross-currency bases. As I show below, a higher value of the instrument negatively associates with swap quantities but positively with CIP deviations. Overall, my instrument plausibly satisfies the exclusion criteria, with its strength potentially attenuated by changes in underlying demand for dollar credit.

Causal impact of swap demand on CIP deviations. I confirm that the instrument is relevant to explaining variation in FX swap quantities (first-stage) and then test the impact of instrumented swap quantities on CIP deviations (second-stage). I estimate the below first-stage model:

$$\text{Net \$ Borrowing}_{C,t} = \beta z_{C,t} + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t,t+n}. \tag{10}$$

Analogous to the ordinary least squares set up in Equation 2, the endogenous variable Net \$ Borrowing$_{C,t}$ represents the average daily net USD borrowed by global banks against currency C in month t across all maturities. All control variables are also consistent with Equation 2 and additionally include the first three principal components and lagged CIP deviations. The above equation includes $z_{C,t}$ to capture the component of swap quantities demanded by global banks due to constrained availability of wholesale dollar funding. Then, I estimate the second-stage equation as:

$$\Delta\text{Cross-currency basis}_{C,t,t+n} = \beta \text{Net \$ } \widehat{\text{Borrowing}}_{C,t} + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t}. \tag{11}$$

The top panel of Table 6 presents the first-stage results showing the relevance of the instrument to synthetic dollar funding in a panel of EUR, JPY, CHF, and GBP swaps. The first-stage supports the relevance of the granular instrument for FX swap quantities: a greater flow of MMF-based wholesale funding to large foreign banks associates with reduced synthetic dollar borrowing in that currency against the dollar. The lower panel of Table 6 reports the second-stage results on cross-currency bases, with a negative coefficient on the instrumented net dollar borrowing through swaps, also consistent with the reduced form results in Table 5. The coefficient β is larger than the OLS estimate in Table 5, suggesting the reduction of simultaneity bias.

Table A12 shows two sets of robustness checks to the causal impact of swap demand on CIP deviations. First, it confirms that increased synthetic dollar funding demand leads to more negative cross-currency basis even when I exclude quarter-end months from my sample (March, June, September, and December). The statistical significance is lower than in Table 6 because one-third of the sample is dropped. The coefficient on instrumented net dollar borrowing is also smaller, consistent with supply curves steepening during quarter-ends. Second, Table A12 confirms that the causal impact is also visible on EURUSD swaps that are traded most heavily in this market.

Next, I test the relevance of the instrument directly on price changes (cross-currency basis) in the month when idiosyncratic shocks are realized. I estimate the below first-stage model for a panel of four currency pairs (EUR, JPY, CHF, GBP), and separately for EURUSD:

$$\Delta\text{Cross-currency basis}_{C,t} = \beta z_{C,t} + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t}. \tag{12}$$

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. Table 7 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 7, 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. In sum, I find that negative shocks to wholesale funding faced by foreign banks are sufficient to move the cross-currency bases deeper into the negative territory. The strong link between the instrument and cross-currency basis also confirms that the results in Table 6 are not on account of a weak instrument problem.

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.[24] I estimate the below model to test which effect dominates:

$$\text{Hedging Demand}^{S}_{C,t} = \beta \Delta \widehat{\text{Cross-currency}} \text{ basis}_{C,t} + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t}. \tag{13}$$

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. Further, I scale the dependent variable by the sector-specific average quantity during the sample period, such that the β coefficient measures percentage change in quantities for 1 basis point change in cross-currency basis. 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 8 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 bps reduction in cross-currency basis (i.e., synthetic dollars are more expensive), funds reduce the forward sale of the dollar by 0.73% in the panel of all currencies and by 1.13% against the Euro. Interpreting using percentage changes, for a 1% reduction in cross-currency basis, funds reduce forward sale of the dollar by 0.26% in the panel of all currencies and by 0.29% against the Euro. Further, funds reduce buy-sell USD swaps by 0.62% in the panel and by 0.52% against the Euro.[25] 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 and

[24] Dávila, Graves, and Parlatore (2024) provide a theoretical framework to measure the welfare gains from closing arbitrage gaps.

[25] A 1% reduction in CIP deviations equals -0.36 bps for the panel and -0.26 bps for EURUSD.

Corporations do not show a statistically significant reaction for any of the products or currencies. These estimates are consistent when considering cross-currency basis over a 1-week tenor in Table A13, and are also 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.

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.[26] 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 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).

Next, I assess the spillover impact of synthetic dollar funding on cash-rich US institutional investors. 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). To complement these findings, I present novel evidence on the reaction of real-money institutional investors who face distinct incentives and constraints compared to other participants: US life insurance companies.

US life insurers are among the largest holders of foreign fixed income securities. Figure 6 shows that the foreign bond holdings of US life insurers have quadrupled between the years 2000 and 2020, accompanied by a large increase in the stock of FX derivatives. These institutions represent a large 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 empirically test to what extent insurers react to wider cross-currency basis using granular, entity-level transactions data at a quarterly frequency sourced from the National

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

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.

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:

$$\Delta \text{Net Exposure}_{i,t} = \beta \Delta \text{Cross-}\widehat{\text{currency}} \text{ basis}_t + \gamma \text{Demand factors}_{i,t} + \alpha_i + \varepsilon_{i,t} \tag{14}$$

where Net 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.[27] 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 9 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 9 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 14 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 A14. 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.

[27] 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 and global banks play a particularly important role in its intermediation. This paper shows that frictions in the wholesale 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 US money market funds, 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 increased cost of hedging. Overall, this paper highlights demand-side determinants of CIP deviations and estimates their real effects on institutional investors' asset portfolios.

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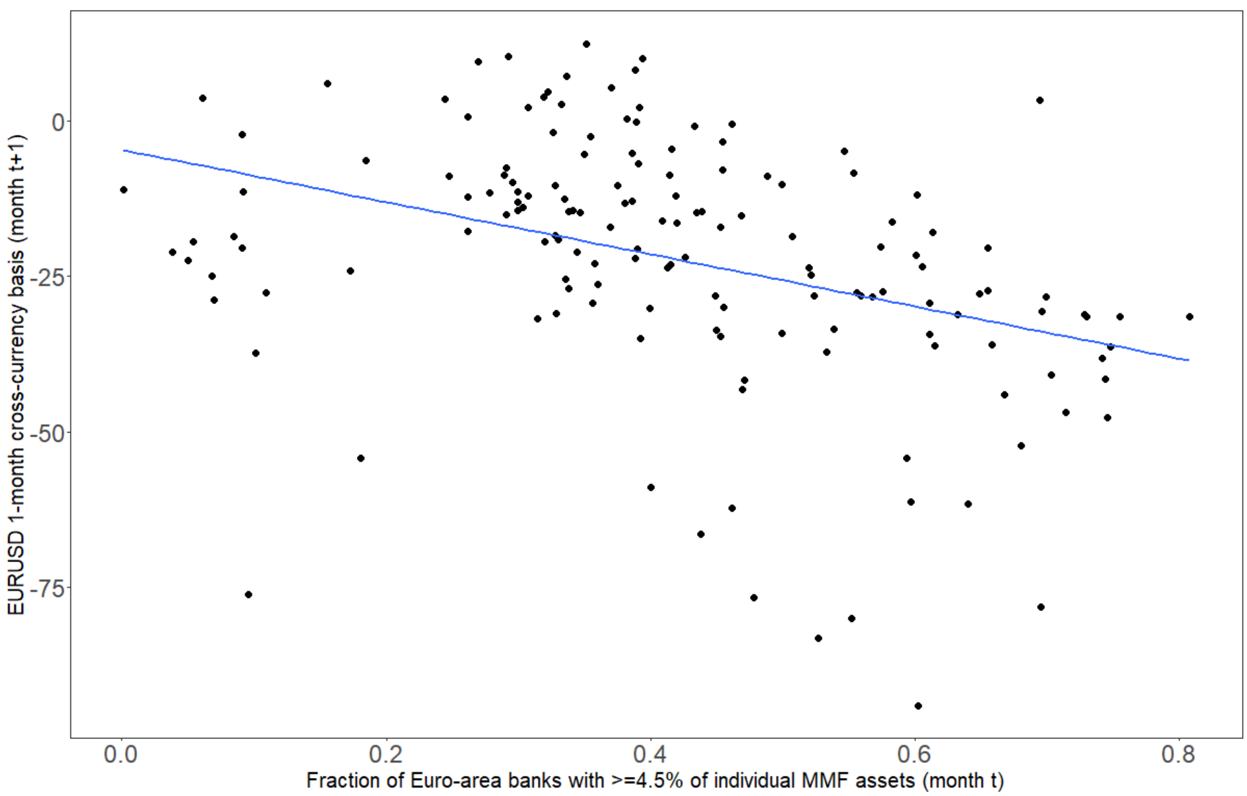
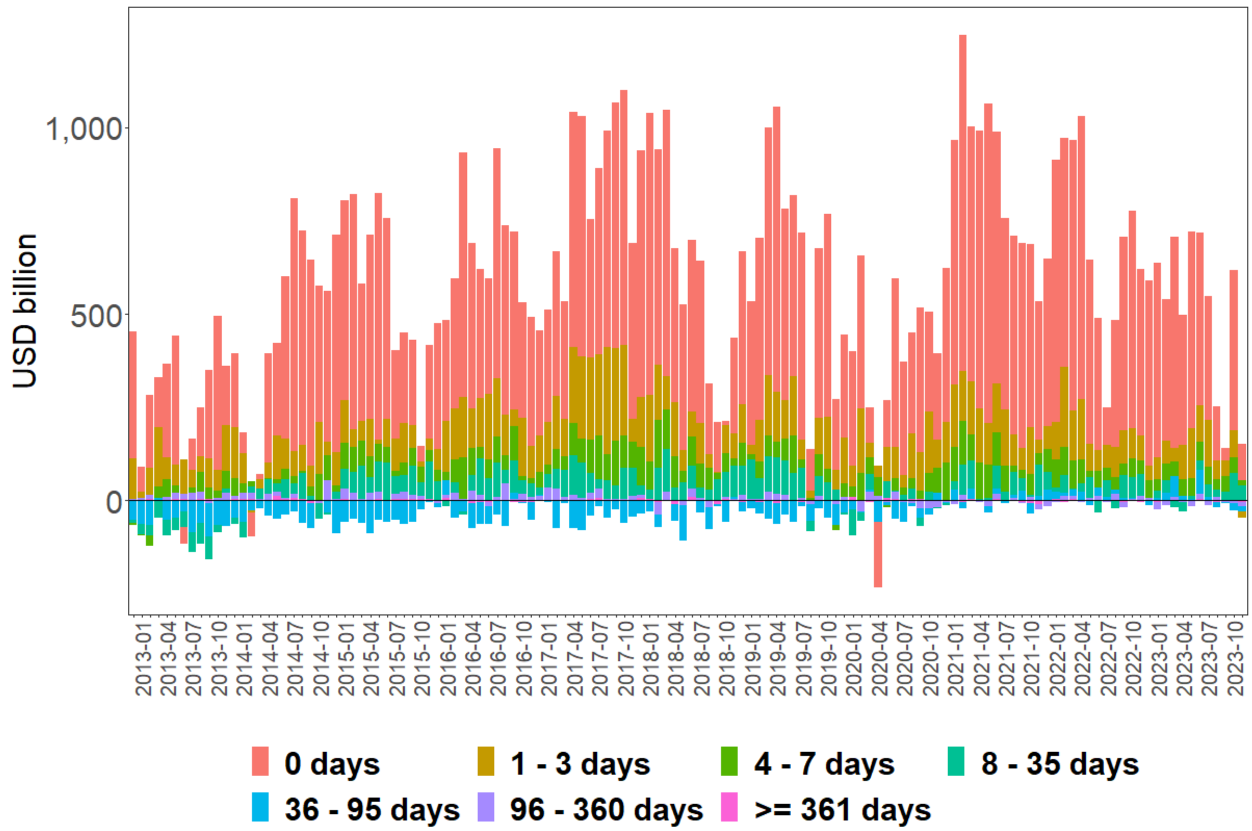
Figure 1: Banks' Wholesale Funding Constraints and Cross-currency Basis



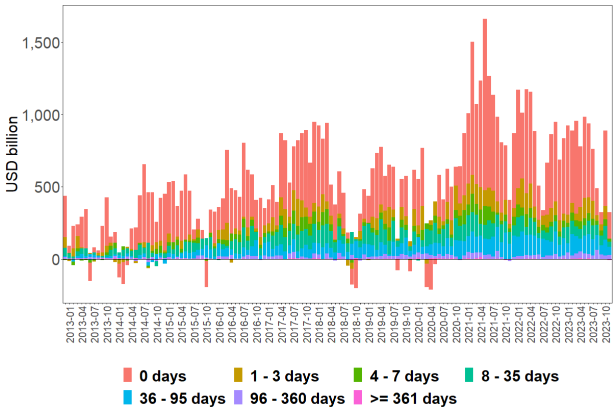
Notes: This figure correlates Euro-area banks' wholesale funding constraints with 1-month EURUSD cross-currency basis. Each dot in the scatterplot constitutes a monthly observation between December 2010 and December 2023. The x-axis represents the fraction of Euro-area banks that had borrowed at least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

Figure 2: Synthetic Dollar Borrowing by Global Banks against EUR

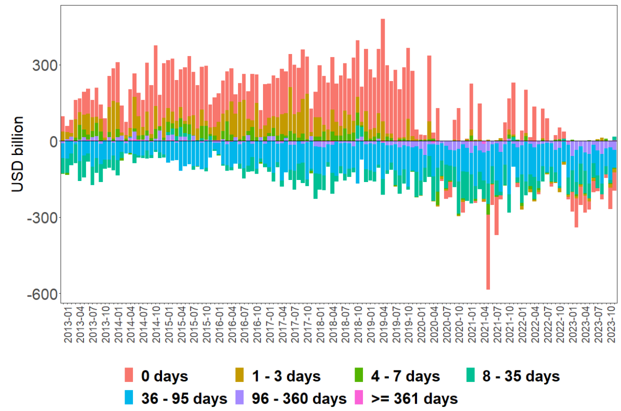


Notes: This figure plots the quantity of USD borrowed (positive y-axis) or lent (negative y-axis) against EUR by globally active dealer banks from/to all other counterparty sectors put together. USD is borrowed against EUR for settlement at the near leg of the swap and exchanged back at the far end. 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.

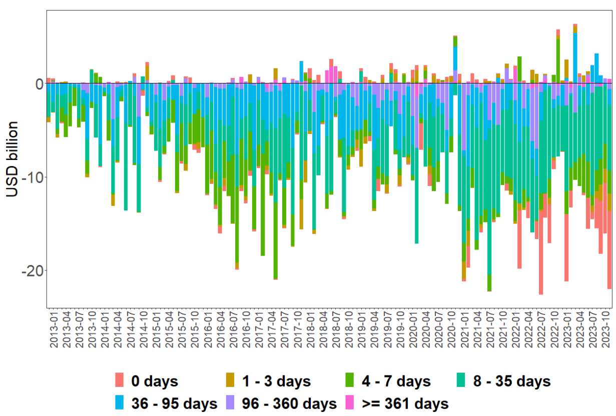
Figure 3: Sector-level Synthetic Dollar Borrowing by Global Banks against EUR



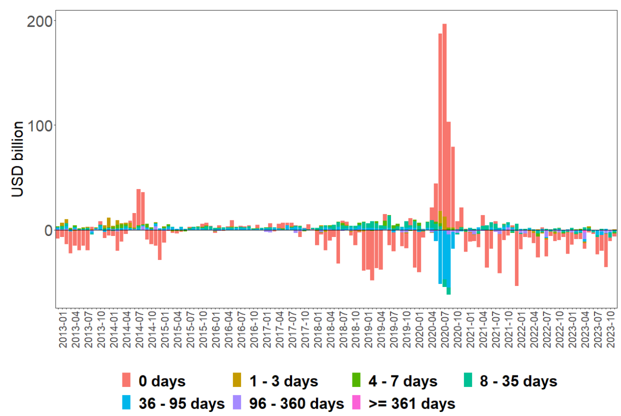
(a) Non-dealer banks



(b) Fund



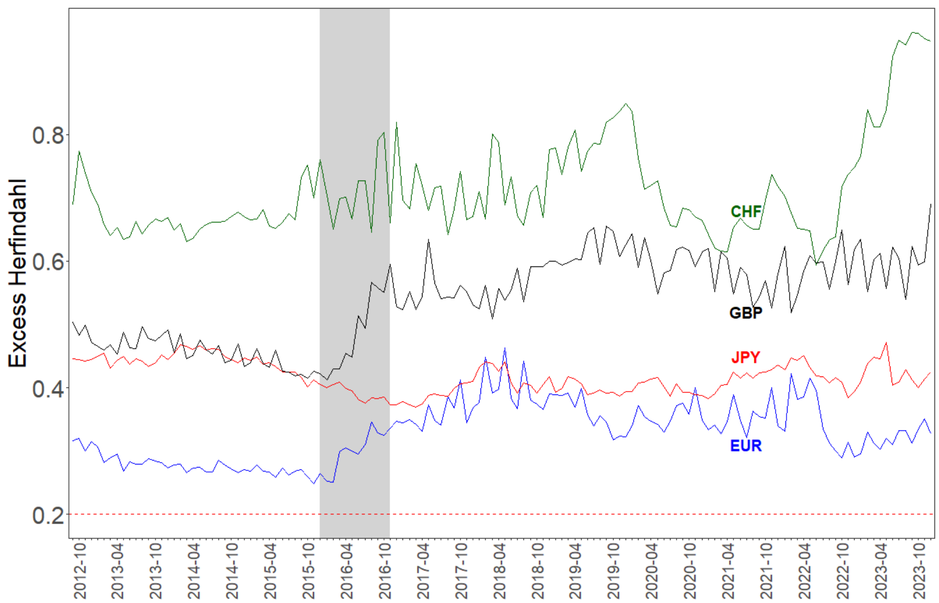
(c) Non-financial corporate



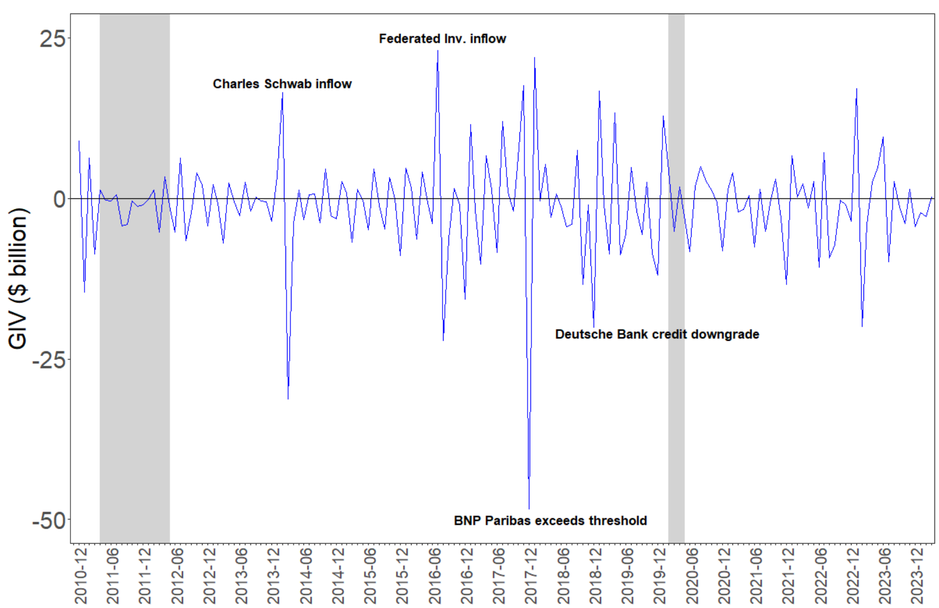
(d) Non-bank financial institutions

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



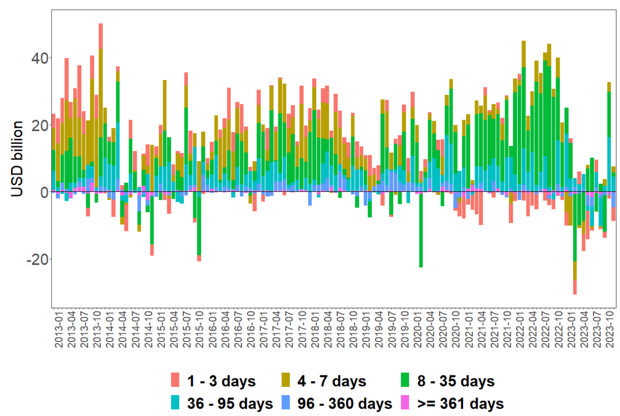
(a) High excess Herfindahl



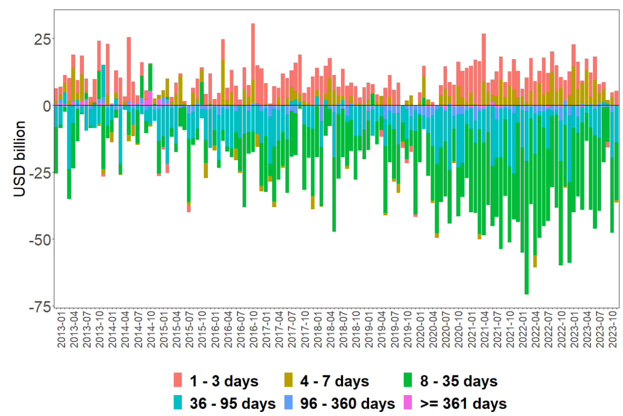
(b) Large idiosyncratic shocks

Notes: This figure demonstrates the validity of granular instrumental variables (GIV) for extracting idiosyncratic shocks to global banks' wholesale funding from US money market funds. Panel (a) plots the time-series of excess Herfindahl index for banks headquartered in four 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.

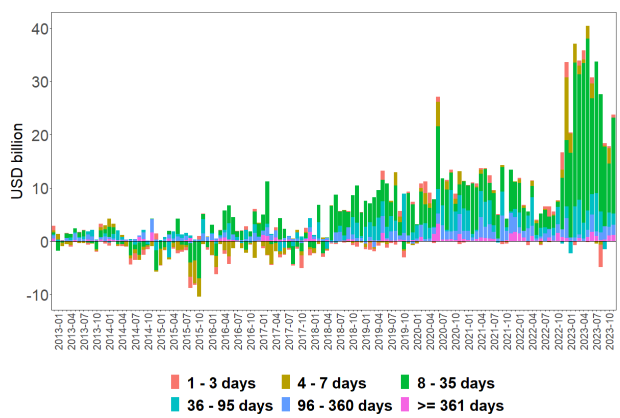
Figure 5: Sector-level EURUSD FX Forward Dollar Purchase



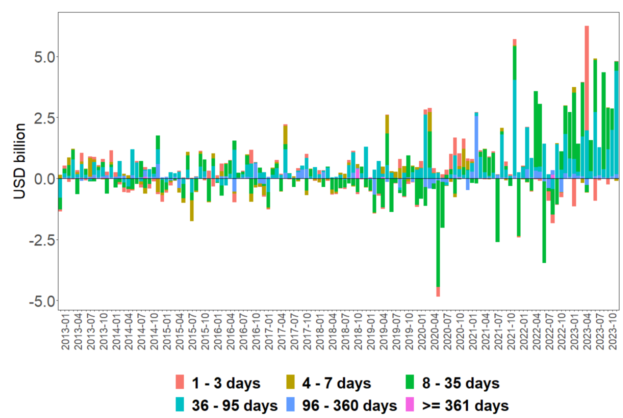
(a) Non-dealer banks



(b) Fund



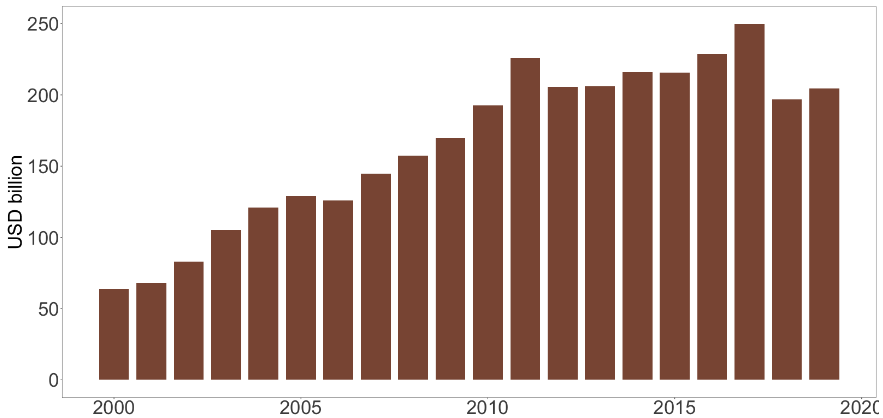
(c) Non-financial corporate



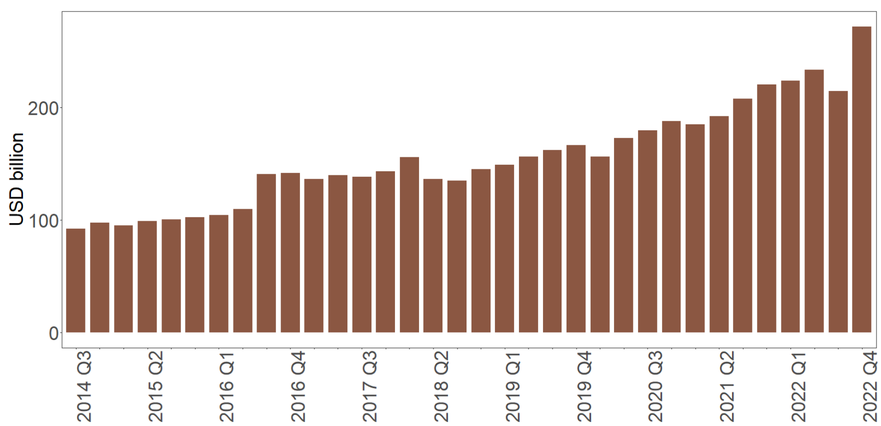
(d) Non-bank financial institutions

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 foreign 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 for 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	**Mean**	**SD**	**p25**	**p50**	**p75**	**N**
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	**Mean**	**SD**	**p25**	**p50**	**p75**	**N**
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 for 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: Fraction of synthetic funding	**Mean**	**SD**	**p25**	**p50**	**p75**	**N**
EURUSD	0.55	0.20	0.50	0.58	0.67	132
GBPUSD	0.09	7.10	-0.18	0.34	0.59	132
USDCHF	1.59	8.46	0.52	0.85	0.95	132
USDJPY	1.28	8.36	0.48	0.61	0.70	132
Panel C: 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, the fraction of synthetic dollar funding in panel B, and price and market variables in panel C. 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 describes the fraction of synthetic to total (synthetic + MMF) dollar funding by major currencies. Panel C summarizes the EURUSD cross-currency bases across tenors from 1-week to 6-months, expressed in percentage. In panel C, 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)	-23.9***	-17.7**	-0.036***	-0.030***
	(7.19)	(8.77)	(0.009)	(0.010)
Δ ILRS		-11.8		0.020
		(23.3)		(0.032)
Δ CBBS/GDP		2,216.5*		2.72**
		(1,317.6)		(1.23)
Δ US 1-month OIS		2,975.2		6.33
		(5,676.1)		(8.11)
Δ Spot		1.11		0.017**
		(5.39)		(0.007)
Δ Swap (overnight)		-6,404.9		-6.18
		(9,816.4)		(13.4)
N	132	131	132	131
Adj. R^2	0.05	0.04	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 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)	-4.13**	-3.72**	-5.04**	-4.97***
	(1.53)	(1.54)	(1.74)	(1.24)
Δ ILRS		0.958	1.43	
		(3.24)	(3.19)	
Δ CBBS/GDP		834.6*	823.5*	
		(420.7)	(414.5)	
Δ US 1-month OIS		-186.7	-225.1	
		(1,910.8)	(1,850.1)	
Δ Spot		0.013	-0.018***	-0.005
		(0.025)	(0.003)	(0.008)
Δ Swap (overnight)		574.0	260.8	-218.5
		(415.3)	(252.7)	(257.2)
N	924	917	917	917
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 2. The dependent variable is daily average dollar borrowing at the near leg of 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, spot, and 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	-0.115**	-0.126*	-0.078**	-0.036**
	(0.047)	(0.059)	(0.034)	(0.009)
Δ Spot price	0.788***	0.595***	0.520***	0.151
	(0.086)	(0.075)	(0.045)	(0.163)
Δ Swap price (overnight)	0.811*	0.503*	0.519	0.187
	(0.369)	(0.236)	(0.299)	(0.088)
Cross-currency basis (t-1)	-0.497***	-0.722***	-0.624***	-0.250***
	(0.095)	(0.130)	(0.081)	(0.031)
N	653	653	653	653
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	-0.311*	-0.234**	-0.219*	-0.151*
	(0.170)	(0.101)	(0.128)	(0.086)
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, USDSEK, 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: Instrumented Swap Borrowing and Cross-currency Basis

First-stage	Net \$ Borrowing$_{C,t}$	
	(1)	(2)
$z_{C,t}$	-0.330***	-0.327***
	(0.091)	(0.095)
N	528	524
Instrument F-statistic	15.37	10.64
Currency FE	Y	Y
Controls	N	Y

Second-stage	ΔCross-currency basis$_{C,t}$			
	PC1 (1W, 1M, 3M, 6M)		1W	1M
	(1)	(2)	(3)	(4)
Net \$ $\widehat{\text{Borrowing}}_{C,t}$	-0.175***	-0.149***	-0.087***	-0.131***
	(0.061)	(0.033)	(0.020)	(0.031)
N	528	524	524	524
Currency FE	Y	Y	Y	Y
Controls	N	Y	Y	Y

Notes: This table reports estimates from a two-stage least squares regression for models of the form in Equation 10 and Equation 11. The endogenous variable is the net dollar borrowing in a panel of EURUSD, USDJPY, USDCHF, and GBPUSD swaps. 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 the monthly change in currency-specific 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 via FX swaps from the first stage. Standard errors clustered by currency are reported in parantheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 7: **Relevance of the Instrument to Cross-currency Basis**

Panel (EUR, JPY, CHF, GBP)	PC1 (1W, 1M, 3M, 6M)		1W	1M
	(1)	(2)	(3)	(4)
$z_{C,t}$	0.033***	0.031***	0.018***	0.027***
	(0.008)	(0.009)	(0.005)	(0.007)
N	528	524	524	524
Instrument F-statistic	15.78	10.86	11.96	12.94
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	0.041***	0.048***	0.032***	0.039***
	(0.008)	(0.012)	(0.009)	(0.009)
N	132	131	131	131
Instrument F-statistic	24.63	17.06	13.73	19.04
Controls	N	Y	Y	Y

Notes: This table reports the first-stage results of Equation 12 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). All control variables are consistent with the OLS estimates of Table 5, and additionally include the first three principal components of the monthly changes in bank-level MMF funding used to construct the GIV. The panel version considers EURUSD, USDJPY, USDCHF and GBPUSD, 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 8: Impact of CIP Deviations on Hedging Demand

Panel (EUR, JPY, CHF, GBP)	Forwards			Swaps		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}$ basis$_{C,t}$ (1M)	0.729**	-0.428	0.947	1.727***	-0.406	-0.116
	(0.245)	(2.300)	(1.082)	(0.436)	(0.445)	(1.057)
N	524	524	524	524	524	524
Adj. R^2	0.07	0.01	0.02	0.02	0.01	0.01
Currency FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
EURUSD	Forwards			Swaps		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}$ basis$_{t}$ (1M)	1.125**	-0.152	1.090	2.001**	1.008	0.226
	(0.493)	(0.833)	(1.176)	(0.921)	(1.640)	(0.570)
N	131	131	131	131	131	131
Adj. R^2	0.14	0.06	0.04	0.02	0.03	0.01
Controls	Y	Y	Y	Y	Y	Y

Notes: This table reports the second-stage results of Equation 13 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. All control variables are consistent with the OLS estimates of Table 5, and additionally include the first three principal components of the monthly changes in bank-level MMF funding used to construct the GIV. 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 9: 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 14 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. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Appendix

"Synthetic Dollar Funding"

Umang Khetan

October 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.[28] 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

[28]The list of settlement members is available at www.cls-group.com/communities/settlement-members/.

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.[29]

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 for major sectors, 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 sectors in the 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

[29]More details are available on CLSMarketData: www.cls-group.com/products/data/clsmarketdata/.

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 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, 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 report 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 report date, which is typically the last date of a month for which the holdings are reported. I use the "Accession Number" to merge the report 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.[30]

Figure A8 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 A8 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:

[30] 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.

$$\text{Net \$ Borrowed}_{s,p,t} = \sum_{\substack{\tau \in -4,3, \\ \tau \neq -1}} \beta_\tau \times Reltime_\tau + \Delta Price_{p,t} + \alpha_{s,p} + \alpha_t + \varepsilon_{s,p,t}, \tag{15}$$

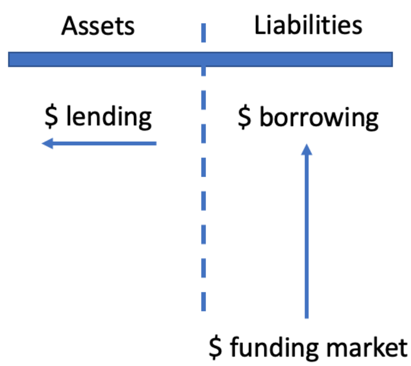
where the dependent variable is the quantity of swap dollars borrowed by sector s in product p in quarter t. I define "product" as the currency and tenor combination, for a total of $9 \times 7 = 63$ products. Since only bank funding suffered a decline due to MMF outflows, the treated sector is global 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 A8. 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 A9 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 A9 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 A9, 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.

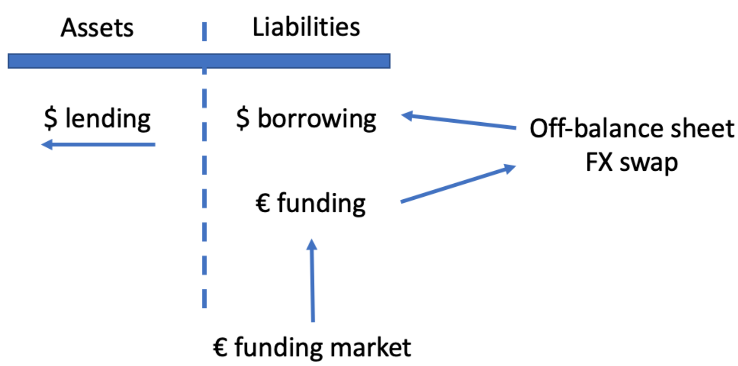
My interpretation of funding substitution is also complementary to Anderson, Du, and Schlusche (2021), who show that global banks reduced their arbitrage positions in USDJPY in response to the decline in MMF investments after the regulatory reform. The direction of the effect (increase in net borrowing) 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



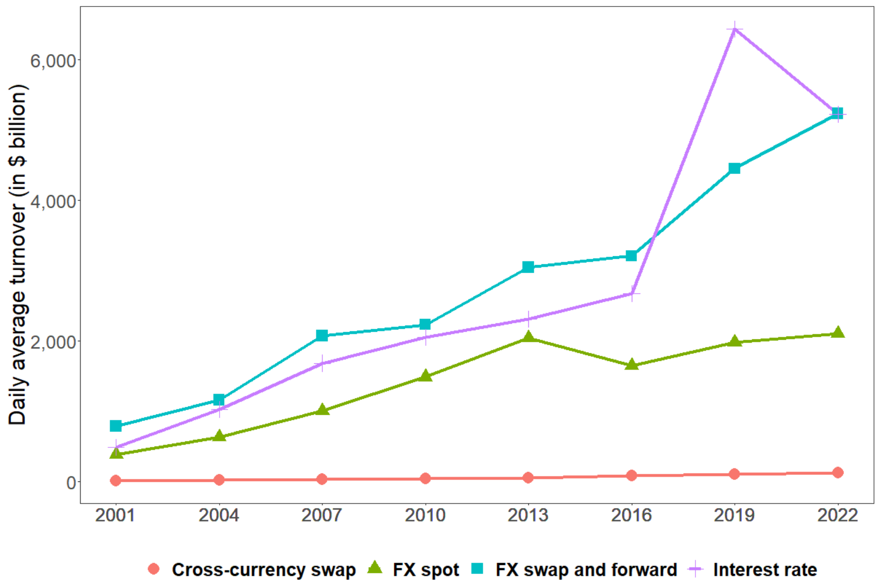
(a) Direct dollar funding



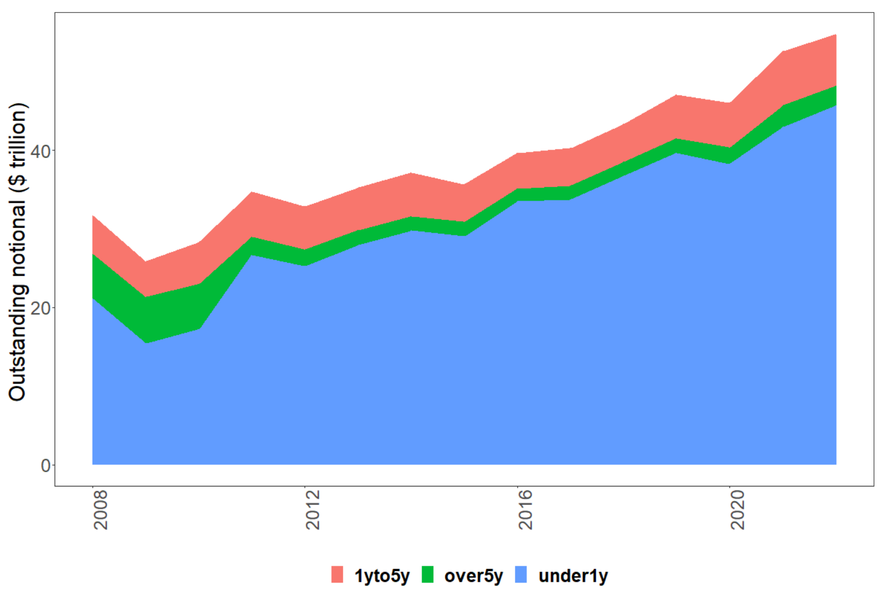
(b) Synthetic dollar funding

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



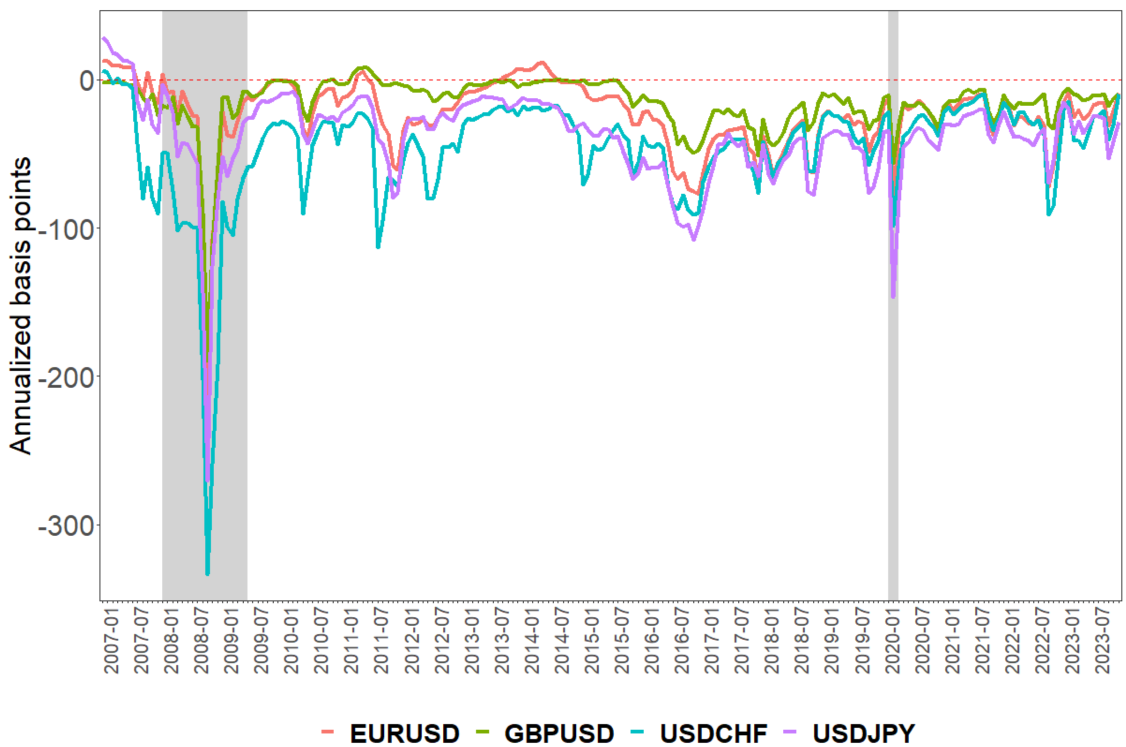
(a) Daily turnover



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

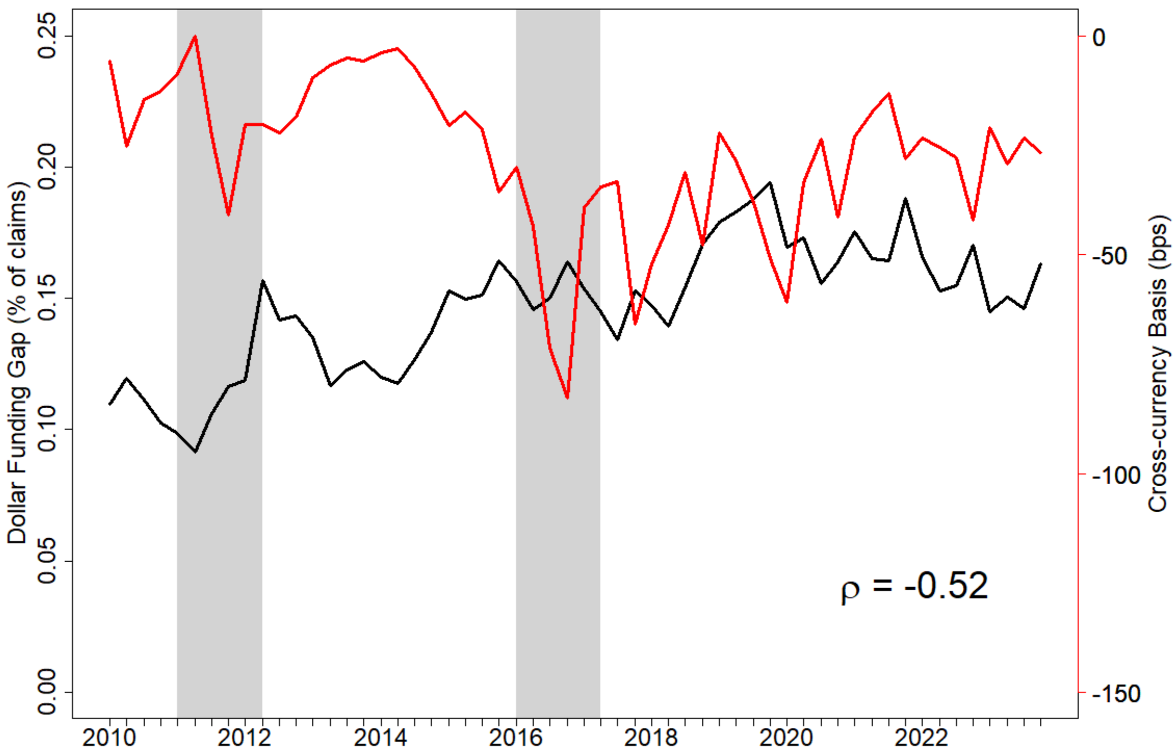
Notes: This figure shows that FX swaps are among the most heavily traded financial derivatives, with typical maturities of less than one year. Panel (a) plots the average daily turnover of four OTC instruments - cross-currency swaps, FX spot, FX swaps and forwards, and interest rate derivatives. The 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 Bases



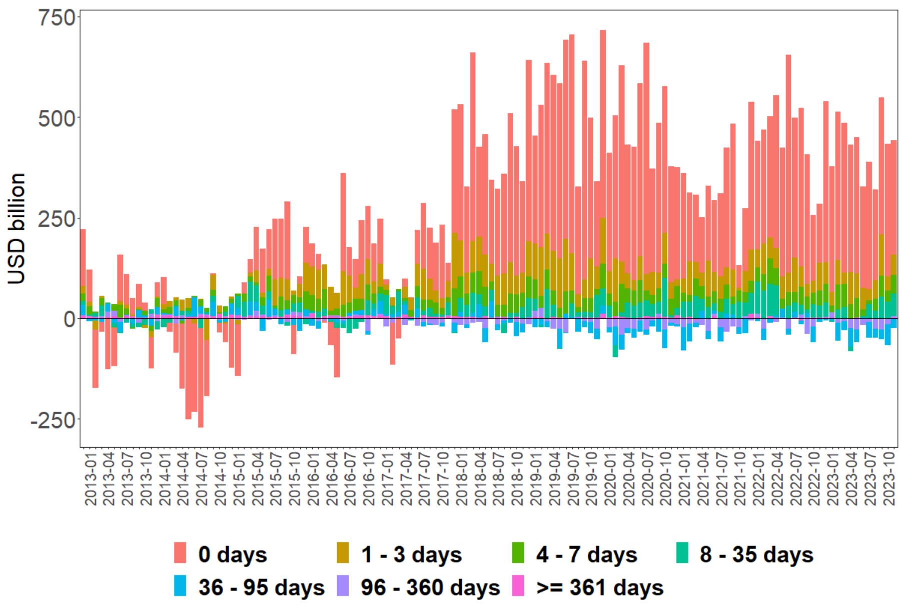
Notes: This figure shows persistent deviations of the 3-month cross-currency basis from zero for four currencies: the Euro (EUR), British pound (GBP), Swiss franc (CHF), and Japanese yen (JPY), all facing the US dollar. Cross-currency basis is computed using overnight indexed swap rates (LIBOR for CHF),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

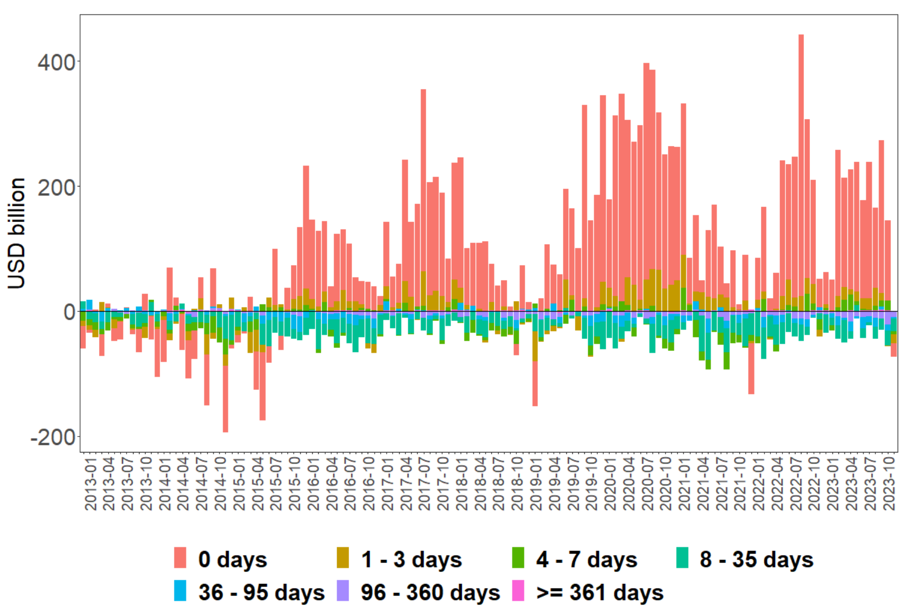


Notes: This figure plots the time-series of dollar funding gap of non-US banks (in red) and average cross-currency basis across all USD-facing currencies (in black) at a quarterly frequency. Dollar funding gap is defined as the difference between on-balance sheet dollar claims and liabilities, scaled 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 Borrowing by Global Banks against JPY and CHF



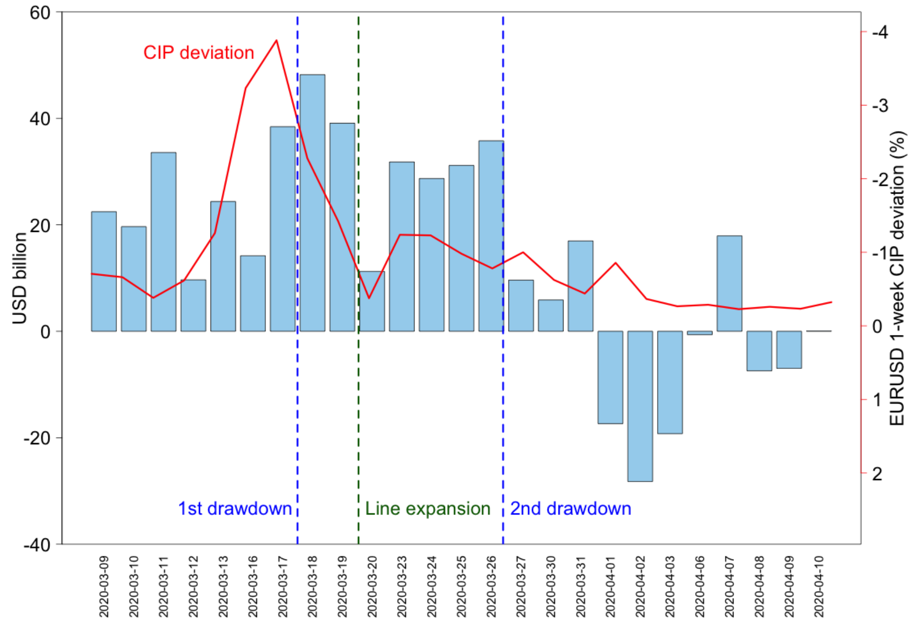
(a) USD borrowing against JPY



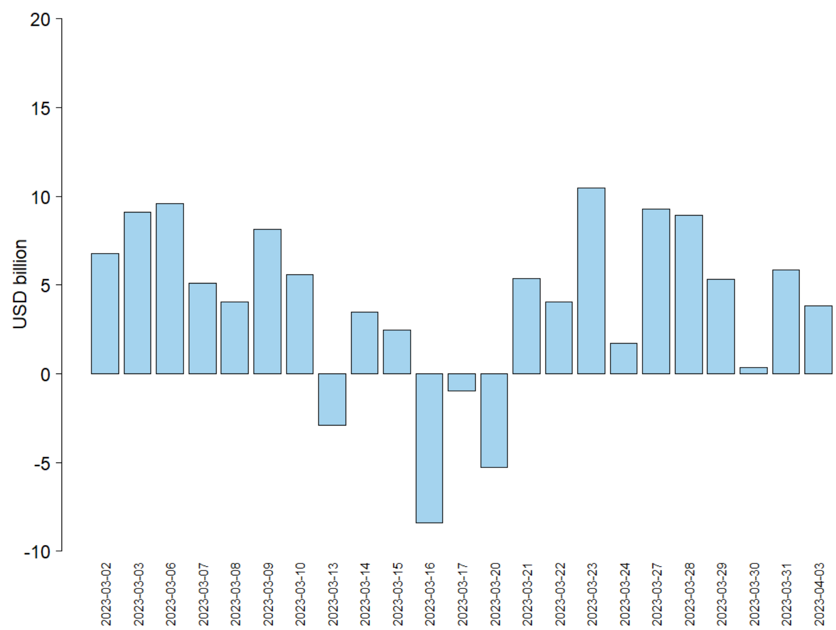
(b) USD borrowing against CHF

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: Synthetic Dollar Funding during Macro-economic Disruptions



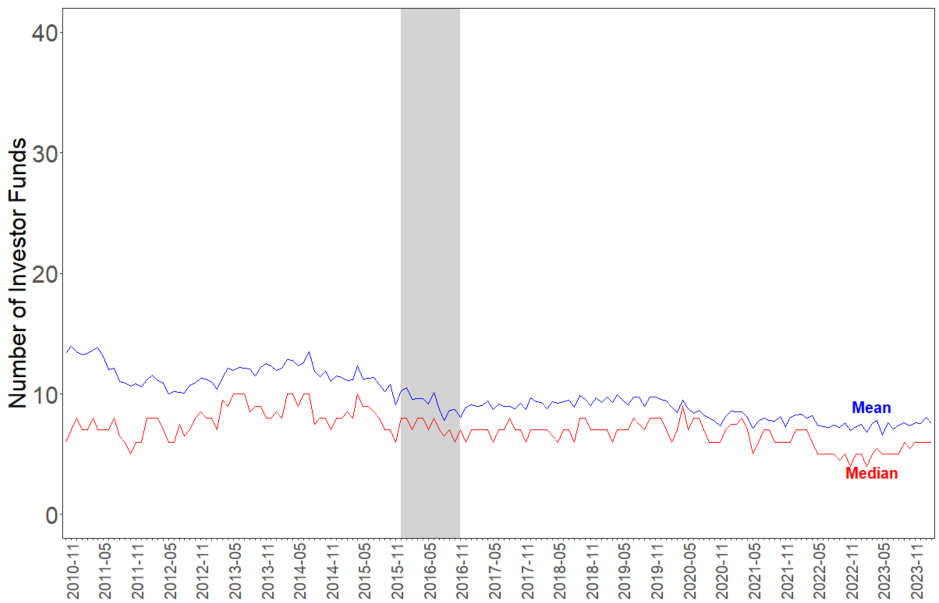
(a) Borrowing against EUR during COVID-19



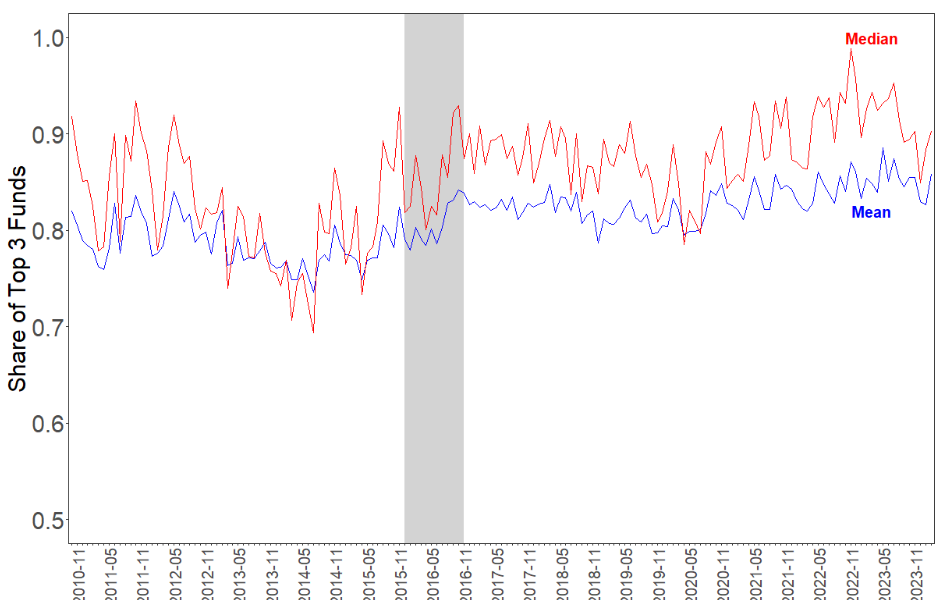
(b) Borrowing against EUR during SVB/Credit Suisse Collapse

Notes: This figure plots the daily net dollar borrowing by global banks against the EUR during the onset of the COVID-19 pandemic in panel (a) and around the time of Silicon Valley Bank (SVB) and Credit Suisse collapse in panel (b). Panel (a) additionally plots the EURUSD 1-week cross-currency basis in red, and denotes the timing of the drawdown of central bank swap lines by the European Central Bank using vertical dashed lines. Panel (b) shows that the supply of synthetic dollars was sharply curtailed in the week after SVB collapsed.

Figure A7: Concentration in Money Market Fund Flows



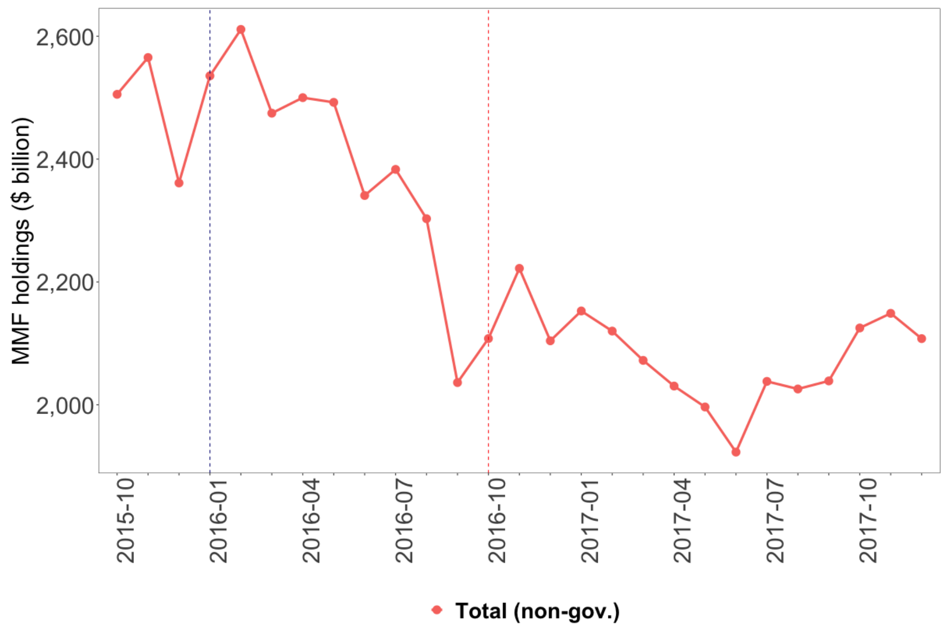
(a) Number of Money Market Fund Investors in a Foreign Bank



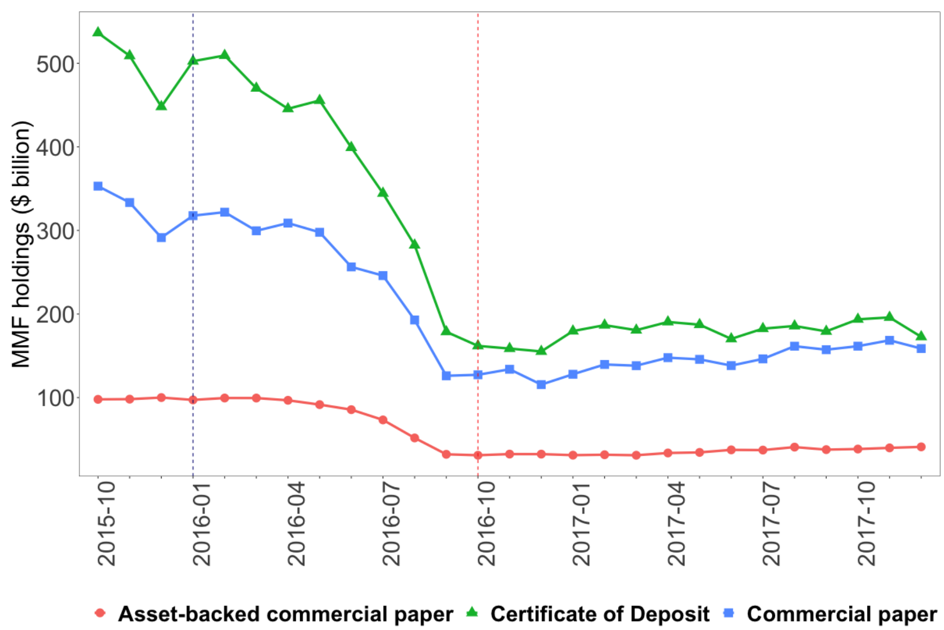
(b) Share of Top 3 Money Market Funds in a Foreign Bank

Notes: This figure shows that money market fund (MMF) represent a concentrated set of investors in bank securities. Panel (a) plots the mean (in blue) and median (in red) number of MMFs that invest in banks headquartered in the Euro-area (EUR), Switzerland (CHF), Japan (JPY), and the UK (GBP). Panel (b) plots the mean (in blue) and median (in red) share of top three MMFs in the holdings of these banks. Shaded areas represent the 2016 Money Market Fund reform period.

Figure A8: The 2016 Money Market Fund Reform Shock



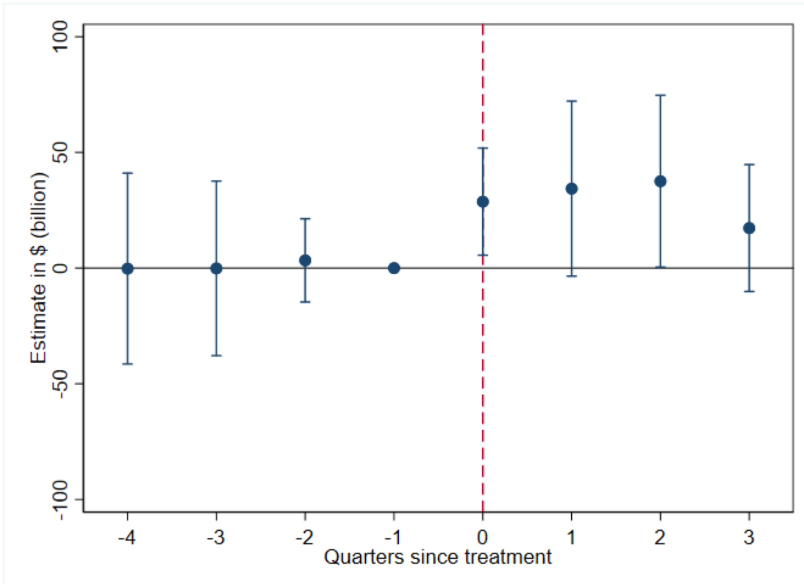
(a) Total non-government holdings



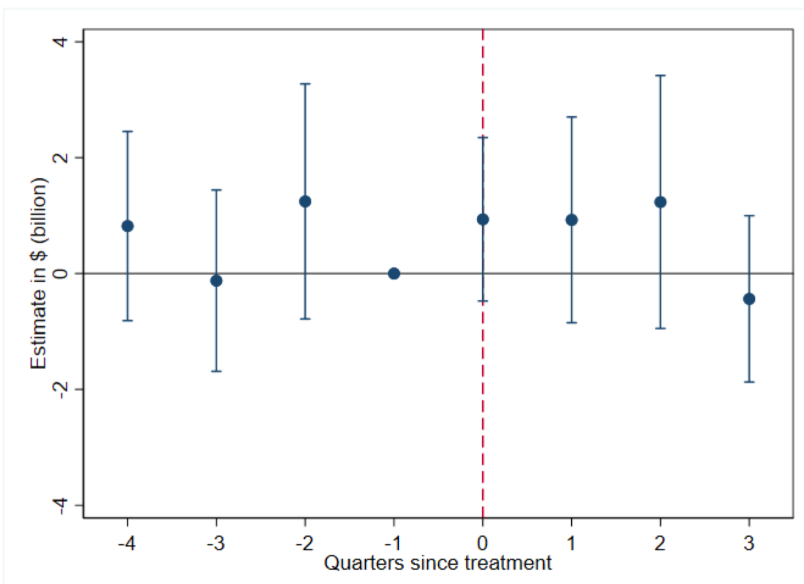
(b) Major bank-issued instruments

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 A9: 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 A8. The β_τ coefficients from Equation 15 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 (%)**
≤ 7 days	71	61
> 7 days & ≤ 1 month	11	22
> 1 month & ≤ 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	**Mean**	**SD**	**p25**	**p50**	**p75**	**N**
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	**Mean**	**SD**	**p25**	**p50**	**p75**	**N**
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: CLS Classification of Top Bank Borrowers from Money Market Funds

Borrower bank	Mean borrowing ($ billion)	CLS classification	Domicile (Parent)
BNP Paribas	101	Settlement Member	Non-US
Sumitomo Mitsui	74	Settlement Member	Non-US
Royal Bank of Canada	70	Settlement Member	Non-US
Barclays	61	Settlement Member	Non-US
JP Morgan	54	Settlement Member	US
Citibank	53	Settlement Member	US
Wells Fargo	52	Settlement Member	US
Bank of America	49	Settlement Member	US
Credit Agricole	49	Settlement Member	Non-US
Societe Generale	44	Settlement Member	Non-US
Bank of Nova Scotia	39	Settlement Member	Non-US
Bank of Montreal	38	Settlement Member	Non-US
Natixis	36	Settlement Member	Non-US
Nomura	36	Settlement Member	Non-US
Toronto-Dominion Bank	35	Settlement Member	Non-US
HSBC	34	Settlement Member	Non-US
Goldman Sachs	33	Settlement Member	US
Bank of Tokyo-Mitsubishi (MUFJ)	31	Settlement Member	Non-US
Mizuho	30	Settlement Member	Non-US
ING Bank	29	Settlement Member	Non-US
Canadian Imperial Bank	27	Settlement Member	Non-US
Deutsche Bank	26	Settlement Member	Non-US
Credit Suisse	25	Settlement Member	Non-US
Svenska Handelsbanken	21	Settlement Member	Non-US
Westpac Bank	17	Settlement Member	Non-US
Australia and New Zealand Bank	17	Settlement Member	Non-US
National Australia Bank	16	Settlement Member	Non-US
Skandinaviska Enskilda Banken	16	Settlement Member	Non-US
DNB Bank ASA	15	Settlement Member	Non-US
Swedbank AB	14	Settlement Member	Non-US

Notes: This table lists the top 30 bank borrowers from US money market funds and reports their average monthly borrowing in $ billion, their classification in the CLS database, and the domicile of parent entity. CLS settlement members are large market-making financial institutions in foreign exchange.

Table A4: 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)	-1,183.1**	-1,148.1**	-2.59***	-2.55***
	(479.4)	(541.5)	(0.642)	(0.701)
Δ ILRS		-25.1		-0.011
		(25.4)		(0.033)
Δ CBBS/GDP		2,671.7**		3.27***
		(1,315.7)		(1.23)
Δ US 1-month OIS		-342.5		-1.85
		(6,488.1)		(9.34)
Δ Spot		-0.123		0.015**
		(5.39)		(0.007)
Δ Swap (overnight)		-5,215.9		-2.68
		(10,551.3)		(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 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 A5: 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)	-21.9**	3.31	0.035	0.802
	(10.2)	(7.13)	(0.150)	(0.778)
Δ ILRS	21.1	-29.0	-0.449	-3.50*
	(29.7)	(18.5)	(0.526)	(1.84)
Δ CBBS/GDP	875.6	915.0	-43.8*	469.7**
	(1,282.7)	(832.1)	(22.2)	(196.0)
Δ US 1-month OIS	15,722.9**	-11,571.5***	-261.0*	-915.2**
	(7,202.2)	(3,935.6)	(136.5)	(405.0)
Δ Spot	8.51	-8.44***	0.013	1.02*
	(5.83)	(3.21)	(0.102)	(0.581)
Δ Swap (overnight)	-12,195.7	5,295.6	293.2*	202.0
	(10,046.4)	(6,201.0)	(165.5)	(624.6)
N	131	131	131	131
Adj. R^2	0.04	0.05	0.03	0.18

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 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 A6: Forward Purchase of USD (FX Panel) and MMF Holdings

	Dollars purchased forward by Global Banks			
	$ million		Count of trades	
	(1)	(2)	(3)	(4)
Δ MMF holdings (t-1)	-0.010	-0.047	-0.069	-0.090
	(0.090)	(0.074)	(0.072)	(0.125)
Δ ILRS		0.256	0.254	
		(0.315)	(0.316)	
Δ CBBS/GDP		-23.3	-23.6	
		(16.0)	(16.1)	
Δ US 1-month OIS		56.2	49.6	
		(73.6)	(75.0)	
Δ Spot		0.0008	0.002***	0.0007
		(0.0005)	(0.0001)	(0.0007)
Δ Swap (overnight)		7.55	1.95	-5.06
		(7.35)	(8.03)	(11.9)
N	924	917	917	917
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 net USD bought forward against a panel of currencies by global banks from all other sectors. 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, spot, and overnight swap. Newey-West standard errors (lags=3) are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A7: Interest Rates and the Fraction of Synthetic Dollar Funding

	Δ Fraction of Synthetic Dollar Funding			
	(1)	(2)	(3)	(4)
Δ US 1-month OIS	-0.167**	-0.167**	-1.73*	-1.73*
	(0.057)	(0.057)	(0.978)	(0.978)
Δ ILRS			-0.020	-0.020
			(0.013)	(0.013)
Δ CBBS/GDP			0.211	0.211
			(0.194)	(0.194)
Δ Spot (in bps)			−9.59*	−9.83*
			(3.9)	(3.87)
Δ Swap (overnight)			0.429	0.436
			(1.17)	(1.17)
Δ Cross-currency basis (1M)			-3.45*	-3.34*
			(1.67)	(1.66)
N	524	524	524	524
Currency FE	N	Y	N	Y

Notes: This table reports ordinary least squares estimates for a model that tests the impact of interest rate changes on banks' synthetic dollar funding demand. The dependent variable is the change in the fraction of dollars borrowed by global banks via FX swaps to total dollars borrowed by them via both swaps and money market funds in month t. The regressor of interest is the change in US 1-month OIS rate in month t. Column (1) does not include controls and fixed effects, column (2) includes currency fixed effects, column (3) includes controls, and column (4) includes controls and currency 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), monthly changes in the spot rate, overnight swap rate, and 1-month cross-currency basis. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A8: 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	-0.080*	-0.084**	-0.027**	-0.009*
	(0.043)	(0.042)	(0.013)	(0.006)
Δ Spot price	-1.11***	-0.884**	-0.549**	-0.142
	(0.202)	(0.214)	(0.140)	(0.088)
Δ Swap price (overnight)	1.37***	1.38***	0.344***	0.096**
	(0.296)	(0.276)	(0.060)	(0.024)
Cross-currency basis (t-1)	-0.401***	-0.620***	-0.284***	-0.109**
	(0.055)	(0.059)	(0.041)	(0.025)
N	2,860	2,860	2,860	2,860
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	-0.146**	-0.067	-0.144***	-0.032*
	(0.059)	(0.060)	(0.047)	(0.018)
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, USDSEK, 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 A9: Investment Funds' Carry Trade

Panel (EUR, JPY, CHF, GBP)	Net \$ Supply ($\leq$1 month)			
	(1)	(2)	(3)	(4)
Net \$ Supply (1 - 3 months)	-0.297**	-0.414**		
	(0.085)	(0.082)		
Net \$ Supply (>3 months)			0.181	0.353
			(0.315)	(0.720)
N	11,412	2,312	11,412	2,312
Adj. R^2	0.36	0.46	0.35	0.45
Currency FE	Y	Y	Y	Y
Time FE	Y	Y	Y	Y
Frequency	Daily	Weekly	Daily	Weekly
EURUSD	Net \$ Supply ($\leq$1 month)			
	(1)	(2)	(3)	(4)
Net \$ Supply (1 - 3 months)	-0.311***	-0.261*		
	(0.079)	(0.151)		
Net \$ Supply (>3 months)			0.925***	1.95***
			(0.114)	(0.248)
Constant	4.02***	20.9***	5.77***	30.7***
	(0.348)	(3.18)	(0.254)	(1.85)
N	2,853	578	2,853	578
Adj. R^2	0.01	0.00	0.02	0.08
Frequency	Daily	Weekly	Daily	Weekly

Notes: This table shows that funds in CLS data appear to execute long-short carry trades across the term structure of CIP deviations. The table reports ordinary least squares estimates for a model of the form:

$$\text{Net \$ Supply } (\leq 1 \text{ month})_{C.t} = \beta \text{Net \$ Supply } (1 \text{ - } 3 \text{ months}) + \alpha_C + \alpha_t + \varepsilon_{C,t}, \quad (16)$$

where the dependent variable is funds' net dollar supply in the short-tenor FX swaps, and the regressor of interest is their net dollar supply in the medium-tenor (1 - 3 months) in columns (1) and (2), and long-tenor (>3 months) in columns (3) and (4). Columns (1) and (3) run the estimation using daily data, while columns (2) and (4) aggregate the time-series to a weekly frequency. The panel version includes currency and time fixed effects, and clusters standard errors by currency, while 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 A10: Common Variation in Bank-level Money Market Fund Flows

	% of variation explained			
	EUR	JPY	CHF	GBP
PC1	54	36	63	63
PC2	20	26	28	17
PC3	6	13	5	8
Cumulative	80	75	96	88

Notes: This table reports the percentage of variation explained by the first three principal components of the monthly changes in bank-level money market fund investments within each currency-area. Principal components are extracted from a panel of all banks that had outstanding investments from US MMFs within a given month, constructed using the issuer-level holdings data made available under the SEC's N-MFP filings.

Table A11: Instrument Correlations with Confounding Variables

	All currencies	EURUSD
Δ Money Market Fund holdings	-0.001	-0.009
Δ US 1-month OIS	0.005	0.008
Δ Intermediary Leverage Ratio (Squared)	0.072	0.096
Quarter-end indicator (1/0)	0.031	0.027
Serial correlation	0.039	0.046
Bank size (average borrowing from MMFs)	-0.062	-0.063

Notes: This table reports the correlations between the granular instrumental variable and other potentially confounding variables. The last row reports the correlation between the variance of idiosyncratic shocks at a bank level and the size of the bank measured using the average outstanding investment from US money market funds. The "All currencies" column pools all four currencies while the EURUSD column separately considers banks headquartered in the Euro-area. The table confirms orthogonality of the instrument with variables that are expected to co-move with FX swap quantities and cross-currency basis.

Table A12: Instrumented Swap Borrowing for Non-quarter-ends and EURUSD

Panel (excluding quarter-end months)	ΔCross-currency basis$_{C,t}$			
	PC1 (1W, 1M, 3M, 6M)		1W	1M
	(1)	(2)	(3)	(4)
Net \$ $\widehat{\text{Borrowing}}_{C,t}$	-0.093***	-0.083**	-0.043*	-0.059**
	(0.031)	(0.040)	(0.025)	(0.030)
N	344	344	344	344
Instrument F-statistic	10.33	10.76	10.76	10.76
Currency FE	Y	Y	Y	Y
Controls	N	Y	Y	Y

EURUSD	ΔCross-currency basis$_t$			
	PC1 (1W, 1M, 3M, 6M)		1W	1M
	(1)	(2)	(3)	(4)
Net \$ $\widehat{\text{Borrowing}}_t$	-0.375***	-0.249***	-0.287**	-0.131**
	(0.101)	(0.093)	(0.138)	(0.056)
N	132	131	131	131
Controls	N	Y	Y	Y
Instrument F-statistic	26.01	16.07	16.07	16.07
Adj. R^2	0.15	0.13	0.27	0.11

Notes: This table reports estimates from a two-stage least squares regression for a model of the form in Equation 11. The endogenous variable is the net dollar borrowing in a panel of EURUSD, USDJPY, USDCHF, and GBPUSD swaps, excluding the quarter-end months of March, June, September and December. The table also reports second-stage results for EURUSD specifically. The dependent variable is the monthly change in currency-specific 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 via FX swaps from the first stage. 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 A13: Impact of 1-Week CIP Deviations on Hedging Demand

Panel (EUR, JPY, CHF, GBP)	Forwards			Swaps		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}$ $\text{basis}_{C,t}$ (1W)	1.052**	-0.620	0.136	2.546***	-0.599	-0.260
	(0.415)	(3.203)	(0.158)	(0.751)	(0.681)	(1.545)
N	524	524	524	524	524	524
Adj. R^2	0.07	0.01	0.02	0.05	0.01	0.01
Currency FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y

EURUSD	Forwards			Swaps		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}$ basis_{t} (1W)	1.324*	-0.189	1.285	2.506**	1.040	0.289
	(0.721)	(0.120)	(1.448)	(1.256)	(1.959)	(0.716)
N	131	131	131	131	131	131
Adj. R^2	0.12	0.05	0.03	0.14	0.01	0.01
Controls	Y	Y	Y	Y	Y	Y

Notes: This table reports the second-stage results of Equation 13 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. All control variables are consistent with the OLS estimates of Table 5, and additionally include the first three principal components of the monthly changes in bank-level MMF funding used to construct the GIV. 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 A14: 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 14. 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. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.