Synthetic Dollar Funding

March 2025

Abstract

Global banks rely heavily on US money markets for short-term dollar funding. Yet, post-financial crisis regulations — designed to shield domestic investors from default risk — have constrained banks' access to this crucial funding source. This paper uses novel quantities data to show that foreign exchange (FX) swaps emerge as alternative ("synthetic") funding instruments when US money market funds reduce wholesale funding to banks. The resulting shift in banks' demand for FX swaps leads to substantial deviations from covered interest parity (CIP) – the breakdown of a fundamental no-arbitrage pricing condition. Using an instrumental variables strategy that exploits idiosyncratic variation in the availability of wholesale dollars to banks, I show that (i) banks' swap demand causes CIP deviations to worsen, and (ii) non-bank investors' inelastic demand triggers spillover effects on their FX hedging costs. I use my empirical estimates to calibrate a model in which global banks optimally choose FX swaps to offset shortfalls in wholesale funding, generating CIP deviations in equilibrium. My model provides two quantitative insights. First, CIP deviations could be halved by increasing banks' access to wholesale dollars, but with a 40% increase in default risk for money market funds. Second, a sharp drop in wholesale funding can disrupt global dollar credit as the marginal cost of synthetic dollars quickly outpaces the marginal revenue on bank assets. My findings suggest that regulations aimed at reducing domestic investors' default risk have contributed to the growth of synthetic dollar market, creating externalities in the form of CIP deviations and frictions in bank lending.

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

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

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 global supply of US dollars disrupt asset markets (Avdjiev, Du, Koch, and Shin, 2019, Du and Schreger, 2022) as well as the real economy (Ivashina, Scharfstein, and Stein, 2015, Barajas, Deghi, Raddatz, Seneviratne, Xie, and Xu, 2020), with episodes of severe dollar shortage often requiring Federal Reserve intervention (Bahaj and Reis, 2022). Strikingly, a majority of US dollar lending is conducted by *non-US* banks that have limited access to stable funding sources such as insured dollar deposits, making them particularly vulnerable to disruptions in dollar liquidity. In this paper, I show that global banks turn to off-balance sheet instruments to compensate for a decline in on-balance sheet dollar funding, resulting in violations of no-arbitrage asset pricing conditions and broader implications on international financial markets.

Historically, US money markets have been the primary source of short-term dollar funding for non-US banks, providing liquidity through instruments such as repo, commercial paper, and certificates of deposit (collectively, on-balance sheet wholesale funding). However, excessive risk-taking by major investors in these products, such as money market funds (MMFs), led to investor runs during the 2008 financial crisis (Kacperczyk and Schnabl, 2013). In response, several post-crisis regulations were introduced to shield MMFs from default risk, limiting their investments in risky banks (Rime, Schrimpf, and Syrstad, 2022) and increasing volatility in investor flows.

Despite ample evidence that large funding shortfalls to banks can threaten financial stability, we know very little about how banks compensate for these shortfalls and whether their actions create externalities in other financial markets. The key challenge in studying this issue is that we often do not observe the full composition of banks' dollar funding sources, particularly the use of instruments such as foreign exchange (FX) swaps that allow banks to raise dollars without reporting them as debt (known as *off-balance sheet* synthetic funding). Moreover, since FX swaps are predominantly traded over-the-counter, visibility into the quantities traded by swap users is generally limited.

Using a comprehensive dataset that links large banks' FX swap transactions with their wholesale dollar funding, this paper makes three key contributions. First, I show that globally active dealer banks turn to FX swaps for synthetic dollar funding when wholesale funding from US money market funds declines. Under this arrangement, banks first raise funds in a foreign currency, e.g., the euro, and then enter into an FX swap to temporarily exchange them for dollars. The

[1] Additionally, 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 dollars (Committee on the Global Financial System, 2020), and foreign investors derive convenience yield from holding US dollar assets (Jiang, Krishnamurthy, and Lustig, 2021).

instrument resembles a collateralized revolving credit facility, but does not appear on the balance sheet as a dollar debt. This enables banks with access to multiple money markets to easily raise marginal dollars in response to the limited scalability of funding from US money markets. Banks' substitution from wholesale to synthetic funding also highlights one reason why FX swaps - with over $60 trillion in outstanding notional and $3.8 trillion in daily turnover - are among the most heavily traded financial instruments in the world (Bank for International Settlements, 2022).[2]

My second contribution is to show that banks' demand for FX swaps widens deviations from covered interest parity (CIP). CIP deviations (measured as cross-currency bases) represent the breakdown of a fundamental no-arbitrage pricing condition in international finance, implying a wedge between wholesale and synthetic dollar funding costs.[3] Figure 1 shows a strong negative correlation between non-US banks' dollar funding gap and cross-currency bases. However, establishing a causal link has been challenging due to the lack of FX swaps data, which my paper overcomes. I instrument for swap demand using idiosyncratic shocks to the wholesale dollars available to banks, and causally show that cross-currency bases turn more negative (i.e., synthetic dollars become costlier) when banks increase swap demand. 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.

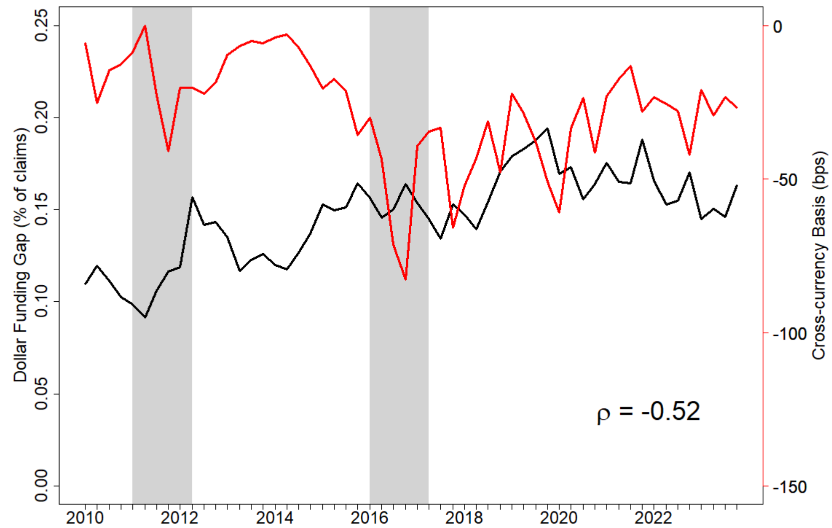
My third contribution is to quantitatively assess the limits of synthetic dollar funding in offsetting sharp reductions in wholesale dollars. While post-crisis regulations aim to reduce default risk in US money market funds (MMFs), it is not clear whether tighter limits on wholesale funding can ultimately hamper the global availability of US dollar credit. Following Ivashina, Scharfstein, and Stein (2015), I build a model where banks offset a decline in wholesale dollars using FX swaps to the extent that the marginal cost of swaps equals the marginal revenue from dollar assets. My key innovation to the model is incorporating a constrained arbitrageur, which allows banks to endogenize the price impact of their swap demand. I calibrate the model using my empirical estimates, and show that CIP deviations rapidly increase as MMFs are further constrained from lending to risky banks. As a result, a sharp reduction in wholesale funding can contract US dollar credit in the economy because the marginal cost of swaps quickly exceeds the marginal revenue on assets.

My analysis leverages a comprehensive dataset of cross-sector FX swap and forward transac-

[2]Borio et al. (2022) estimate that up to two-thirds of non-US banks' dollar debt may be via FX swaps, whose off-balance sheet nature complicates regulatory oversight and macro-prudential policy design.

[3]Recent studies suggest that CIP deviations reflect the shadow cost of swap arbitrageurs' balance sheet constraints (Du, Tepper, and Verdelhan, 2018, Du and Schreger, 2022), with real economic impact on corporate investments (Ippolito, Peydro, Karapetyan, Juelsrud, and Syrstad, 2024), cross-border capital flows (Kubitza, Sigaux, and Vandeweyer, 2024), and bank lending in partially-dollarized economies (Keller, 2024).

Figure 1: 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 black) and average cross-currency basis across all USD-facing currencies (in red) 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 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. Data source: BIS Locational Banking Statistics and BIS Consolidated Banking Statistics.

tions, merged with monthly bank-level holdings of US money market funds, that together allow me to jointly study these two major short-term funding markets. Synthetic dollar funding is facilitated by FX swaps, that are among the most heavily traded financial instruments 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.

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 major regulatory changes such as the 2016 money market fund reform. 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 evidence of substitution from wholesale to synthetic markets. Synthetic dollar funding is concentrated in the overnight to three-month tenors of the term structure, 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.[4] I analyze the evolution of global banks' synthetic dollar borrowing against changes in money market fund (MMF) holdings of bank securities, and find a strong and robust 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 costlier synthetic funding as an alternative.

I rule out a number of alternative explanations for my findings. 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 banks' dollar purchase in FX forwards (that entail a single set of cash flows) does not react to changes in MMF holdings, and that the shift in demand is specific to FX swaps (that entail two sets of cash flows), which indicates that currency risk hedging cannot explain my findings. Third, using the quarterly aggregate balance sheet line items of US branches and agencies of foreign banks, I confirm that banks, when faced with a decline in MMF investments, do not meaningfully tap other funding sources such as balances with depository institutions or Federal Reserve banks.

Synthetic dollar funding compensates banks for a decline in wholesale dollars but creates two major externalities. First, it widens deviations from covered interest parity (CIP). I find that an increase in banks' swap demand turns the cross-currency basis more negative across funding currencies and for maturities of 1 week to 3 months where the vast majority of swaps are traded. Specifically, for a \$100 billion increase in demand, the 1-month basis declines by about 10% of the sample average of -26 bps. My finding implies that demand for synthetic 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 time-varying constraints of swap arbitrageurs that could lead to omitted variable bias. To investigate if the price impact is causal, I employ an instrumental variables strategy that exploits plausibly exogenous variation in the availability of wholesale dollars to individual non-US banks.

[4] 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.

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. In my setting, three institutional features support the existence of idiosyncratic shocks to banks' wholesale funding from MMFs: (i) fund-specific investor flows that affect banks based on their *ex ante* exposure to funds (akin to a shift-share instrument), (ii) differential distance of banks from the regulatorily-imposed 5% concentration limits on MMFs, and (iii) bank-specific credit downgrades that reduce MMF investments in the affected banks only. These factors create variation in the availability of wholesale dollars to banks, and can be aggregated across banks to instrument for currency-level synthetic dollar funding demand. Moreover, borrowers from MMFs represent a concentrated set of large global banks (Aldasoro, Ehlers, and Eren, 2022), which ensures that idiosyncratic shocks do not wash out in the aggregate.[5]

Following Gabaix and Koijen (2024), I construct the currency-specific instrument as the size-weighted sum of idiosyncratic shocks to bank-level MMF flows, extracted after removing common shocks and time trends, and term it "excess wholesale funding".[6] I find that an increase in excess wholesale funding leads to reduced demand for synthetic dollars (first stage) and narrower cross-currency bases (second stage), providing causal evidence of price impact. Crucially, my results are not confined to quarter-ends and reflect ongoing dynamics in funding shocks faced by global banks.

The second externality of banks' use of synthetic dollars is increased FX hedging cost borne by non-bank investors - investment "funds", non-financial corporations, and non-bank financial intermediaries (NBFIs). Using my instrument, I estimate their demand elasticity to wider CIP deviations, which they either absorb as higher hedging costs (price inelastic) or offset by adjusting traded volumes to maintain overall costs (price elastic). I find that, while all non-bank sectors are generally price inelastic, funds show the highest sensitivity to CIP deviations in a direction consistent with 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% and buy-sell swaps by 0.62%, while corporations and NBFIs do not react significantly. These estimates imply 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 \$2.6 billion in FX hedging costs per annum.

My results indicate that banks face additional costs when substituting from wholesale to synthetic markets. Given the regulatory objective of limiting default risk in domestic money markets, this raises an important question: can synthetic markets fully offset a decline in wholesale funding

[5]Relative to other settings that leverage granular instrumental variables, my instrumentation for swap quantities adds an additional layer of exogeneity because I use shocks in a different but related market.

[6]I adjust for heterogeneous loadings on common factors, that are the first three principal components of bank-level changes in MMF flows, and for potential heteroskedasticity in the extracted residuals.

without hampering dollar credit availability? To address this question, I develop a model where global banks lend dollars using a combination of wholesale and synthetic funding. My framework builds on Ivashina, Scharfstein, and Stein (2015), with three important distinctions. First, because cross-currency basis has generally been negative after 2008, banks in my model exhaust wholesale funding first and use swaps only to bridge any shortfalls. Second, I introduce an arbitrageur sector that makes CIP deviations an equilibrium object (Iida, Kimura, and Sudo, 2018), allowing banks to endogenize the price impact of their swap demand. Third, I calibrate the model using my data, empirical estimates, and a sample of non-US banks' dollar assets to derive quantitative implications.

I find that CIP deviations and MMF default risk exhibit a strong inverse relationship. For example, increased wholesale funding from MMFs to banks could halve the cross-currency basis from -30 bps to -15 bps, but with an additional default risk of 40% for MMFs. This trade-off is more pronounced when I allow swap arbitrageurs' balance sheet constraints to positively co-move with the availability of wholesale dollars (Rime et al., 2022). The sharp impact of tighter MMF constraints on prices ultimately reduces the total dollars lent by banks because their marginal funding cost quickly outpaces the marginal revenue on assets. Under such conditions, dollar funding from outside the system, e.g., through central bank swap lines, becomes necessary.

Taken together, my results offer a first evidence of demand substitution across funding markets arising out of frictions in the wholesale supply of dollars. These frictions provide a demand-side explanation for persistent CIP deviations, with potential implications on the global availability of dollar credit. My results also complement 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 a distinct economic force - *quantitative* limits on wholesale investors - that 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 and banks' ability to hold dollar assets.

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 wholesale markets, where money market funds remain major investors in foreign banks' short-term dollar debt. 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 instruments that enable global banks to reduce dollar funding constraints. In doing so, my research also contributes to the literature on banks' short-term capital management under market frictions: Cetorelli and Goldberg (2012) show that global banks manage liquidity using cross-border funding that insulates them from local monetary policy shocks; 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; 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; Aldasoro, Ehlers, and Eren (2022) highlight money market funds' bargaining power in providing funding to banks. 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) and 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 that lead banks to substitute (cheaper) wholesale funding with (costlier) synthetic funding.

Studies that link money market funds (MMFs) with CIP deviations include Anderson, Du, and Schlusche (2021), who argue that reduction in MMF investment affects banks' arbitrage capital, and Rime, Schrimpf, and Syrstad (2022) who correlate MMF concentration limits with banks' inability to arbitrage CIP deviations. My study complements their narrative by distinguishing banks that *demand* dollars via FX swaps, in a direction inconsistent with arbitrage activity but consistent with bridging dollar funding gaps as in Ivashina, Scharfstein, and Stein (2015). The key feature of my paper that allows for such distinction is the use of actual swaps transaction data. Other studies on banks' assets in this context include Becker, Schmeling, and Schrimpf (2023) and Bippus, Lloyd, and Ostry (2023) who show that cross-border lending affects CIP deviations and USD strength.

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 during these periods, and Kloks, Mattille, and Ranaldo (2024) document that Euro-area 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 calendar dates 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' end-of-quarter 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 the impact of market frictions on institutional investors' financial risk management. 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. Using *cross-sector* swap transactions data, my paper estimates the FX hedging demand elasticity of multiple non-bank sectors, and quantifies the spillover impact of banks' synthetic dollar funding on non-bank investors' hedging costs.

Finally, my paper quantitatively estimates the limits of synthetic dollar funding in meeting global dollar credit demand. Eguren-Martin et al. (2024) empirically link UK banks' synthetic funding costs to their cross-border lending; Ivashina et al. (2015) provide an early theoretical framework, extended by Iida et al. (2018) to include arbitrageurs. Moskowitz et al. (2024) further incorporate multiple risk sources, introducing cross-sectional variation in CIP deviations. My paper is the first to calibrate key model parameters using banks' swaps and assets data, enabling me to quantify the linkages between MMF default risk, CIP deviations, and dollar credit availability.

This paper proceeds as follows. Section 2 provides the institutional background and hypotheses development. Section 3 discusses the data, and Section 4 analyzes the demand for synthetic dollar funding. Section 5 shows the causal impact on prices and spillover impact on non-banks. Section 6 calibrates the model to provide analytical and quantitative insights. Section 7 concludes.

2. Institutional background

With over 14 trillion in US dollar-denominated assets (panel (a) of Figure 2), non-US global banks play a pivotal role in supplying dollars to various segments of the world economy. Many of these assets consist of short-term working capital loans and credit lines extended to firms engaged in cross-border trade and capital flows. Despite large asset holdings, foreign and US branches of non-US banks do not have direct access to FDIC-insured retail dollar deposits. As a result, a large portion of non-US banks' dollar assets is not matched by equivalent liabilities, creating a dollar funding gap on their balance sheets (Ivashina, Scharfstein, and Stein, 2015, Abbassi and Bräuning, 2021).[7] One of the primary ways in which non-US banks finance dollar assets is through borrowing in short-term wholesale funding markets, where the major investors are US money market funds (MMFs) such as Vanguard and Fidelity.

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 US MMFs are crucial for banks to fund dollar assets, they have increasingly become subject to tight regulatory controls on liquidity and default risk.

For example, 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 them from providing additional funding even to credit-worthy borrowers. Further, the 2016 MMF regulatory reform allowed prime MMFs to float their NAVs, which increased volatility in fund flows from end-investors, in turn affecting the stability of dollar funding to borrower banks. (Committee on the Global Financial System (2020) provides a detailed account of the historical evolution of US dollar funding sources.) In contrast to direct US dollar funding, non-US banks typically have

[7] 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; Correa, Sapriza, and Zlate (2021) provide a corresponding analysis for foreign banks' dollar lending to US firms; Sun (2023) documents the prevalence of dollar funding crises across countries.

easier access to local currency funding, e.g., in the euro, especially when their home country central banks keep liquidity conditions loose.

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.[8] The investors most likely to benefit from synthetic funding instruments are those with access to multiple money markets, e.g., global banks.[9] Given that MMFs are important but constrained suppliers of dollars to global banks, my first hypothesis tests whether banks borrow dollars via FX swaps when MMF investments decline.

The foreign exchange derivatives market facilitates synthetic dollar borrowing. Bank for International Settlements (2022) reports 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. 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. Panel (b) of Figure 2 shows that cross-currency bases deviate from zero across multiple currencies, and turns sharply negative during periods of economic contraction.

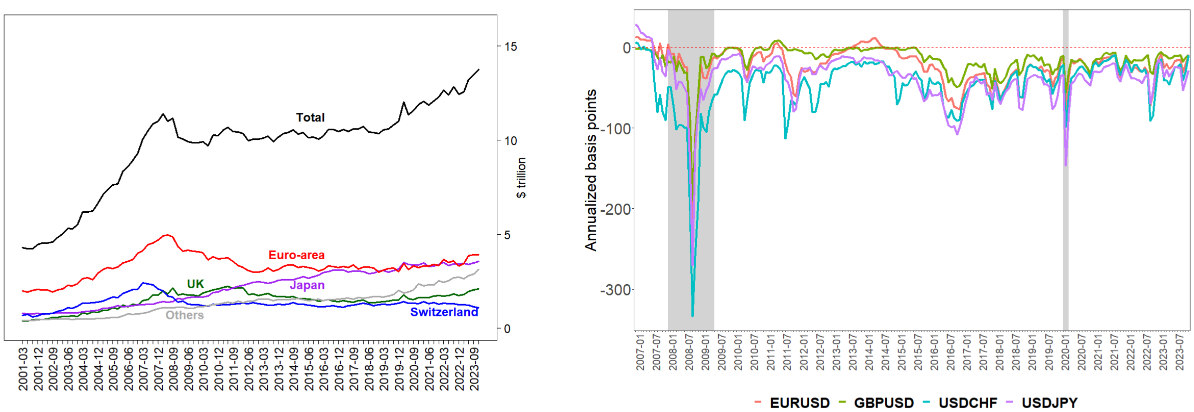
Figure 1 illustrates a strong negative correlation between the on-balance sheet dollar funding gap of non-US banks, and the average cross-currency basis across currency pairs. Figure 1 shows

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

[9] Microstructure studies of the FX swap market include Krohn and Sushko (2022) and Ranaldo (2022).

[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.

Figure 2: Non-US Banks' Dollar Assets and Cross-Section of CIP Deviations



(a) US Dollar Assets

(b) CIP Deviations

Notes: Panel (a) plots the time series of aggregate US dollar-denominated bank assets ("claims") by banks' country of domicile or nationality. The underlying data are sourced from the Bank of International Settlements' Locational Banking Statistics and Consolidated Banking Statistics. Panel (b) shows deviations of the 3-month cross-currency basis from zero for the Euro (EUR), British pound (GBP), Swiss franc (CHF), and Japanese yen (JPY), all facing the US dollar. Shaded region indicates NBER-dated recessions.

that the dollar funding gap has ranged between 15-20% of outstanding claims in recent years, which translates to $1.2 trillion - $2 trillion. Further, 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 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. Hence, the second hypothesis in this paper links banks' swap demand to negative cross-currency basis. Through the lens of a quantitative model, my paper then tests whether a potential price impact of banks' synthetic dollar demand ultimately affects their ability to provide US dollar credit to the global economy.

[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 (tomorrow/next) 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.[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, Table A1 estimates that my data cover between a quarter to a third of the global OTC swaps turnover between dealers and various types of clients. 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 CLS data with regulatory filings of US money market fund holdings, and price variables from public sources.

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 are split by 6 buckets (forwards exclude the overnight tenor). Further, swaps entail two sets of cash-

[12] Other studies that use CLS data include Hasbrouck and Levich (2021), Ranaldo and Somogyi (2021), Khetan and Sinagl (2023), Roussanov and Wang (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), An and Huber (2025) 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).

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 banks 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 demand 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 a compensation.

A vast majority of borrowing takes place in the short tenor of currency term structure. Panel B of Table 1 shows that overnight ("0 days (tom/next)") 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] Correa, Du, and Liao (2020) and Kloks, Mattille, and Ranaldo (2024) suggest that US Global Systemically Important Banks (GSIBs) lend USD via swaps to non-US GSIBs, especially at quarter-ends.

Table 1: Descriptive Statistics for Daily Swap $ 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 (tom/next)	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 (tom/next)" 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.

While dollar funding activity via FX swaps is concentrated between global banks and non-dealer banks, and for tenors up to one week, Table A2 shows that FX forwards are largely traded by end-users such as funds (net USD sellers) and corporations (net USD buyers), with volumes more uniformly distributed up to the 3-month tenor.

For my empirical analysis, I convert the raw transaction volume variable into a percentage change in stock measure to address two issues with raw transactions. First, transaction volumes are non-stationary. Autocorrelation plots in Figure A2 show that transaction volumes are strongly persistent, while the percentage change in stock is not. Second, aggregate transaction volumes across tenors hide the potential change in the composition of maturities over which banks borrow dollars. To address these issues, first I construct a stock variable that captures the outstanding synthetic dollars held by banks on each day, taking into account the maturity of swaps contracted up to that date. New trades get added to the stock, while maturing swaps get deducted from the stock. Then, I average the daily stock to a monthly level, and construct month-on-month percentage changes. Since the stock can be negative (implying dollars lent rather than borrowed), I calculate the approximate percentage change as the difference in stock from month $t-1$ to t, divided by the average absolute stock in each month. This results in a scaled variable bounded between -/+ 2 and mitigates the effect of outliers (Davis and Haltiwanger, 1992).

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.

[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.

Panel A of Table 2 provides descriptive statistics on both the level and changes in monthly holdings of US MMFs. The average monthly holdings of MMFs in non-US bank securities during my sample period was $963 billion, with a standard deviation of $155.8 billion. Euro-area banks were the largest foreign beneficiaries of MMF investment, at an average of $345.5 billion per month, followed by Japanese banks at $163.7 billion. These facts are consistent with Aldasoro and Doerr (2023) who show that banks are the largest non-government borrowers from US MMFs.

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

Panel A: Money market fund holding	Mean	SD	p25	p50	p75	N
All non-US banks ($ billion)	963.0	155.8	866.5	978.7	1051.4	132
Δ All non-US banks ($ billion)	-0.3	133.3	-85.6	2.6	76.6	131
EUR banks ($ billion)	345.5	80.2	289.7	340.6	407.7	132
Δ EUR banks ($ billion)	0.1	86.4	-52.9	4.2	48.1	131
JPY banks ($ billion)	163.7	30.3	139.8	154.1	187.4	132
Δ JPY banks ($ billion)	-0.1	3.7	-2.2	0.1	1.6	131
Panel B: EURUSD prices and controls	**Mean**	**SD**	**p25**	**p50**	**p75**	**N**
Cross-currency basis (1 week, bps)	-19.40	22.76	-24.50	-14.46	-7.05	132
Cross-currency basis (1 month, bps)	-26.08	27.65	-33.87	-20.71	-10.21	132
Cross-currency basis (3 months, bps)	-25.30	20.42	-34.40	-23.98	-11.43	132
Δ Spot price (bps)	-16.73	196.16	-139.52	-15.81	97.27	132
Δ Swap price (overnight, bps)	0.08	3.14	-0.87	-0.02	0.74	132
Assets ($ billion)	3,291.6	199.9	3,181.5	3,260.0	3,349.5	132
Gross position ($ billion)	138.78	18.62	123.68	136.33	151.88	132
ILRS (log)	5.57	0.30	5.35	5.59	5.76	132
CBBS/GDP	0.10	0.11	-0.00	0.13	0.19	132
US 1-month OIS	1.22	1.53	0.13	0.42	1.96	132

Notes: This table describes money market fund holdings in panel A, and price and market variables in panel B. Panel A shows US money market fund (MMF) holdings in non-US banks (in levels and changes) in $ billion. Holdings shown are aggregated across all non-US banks and specifically for EUR and JPY banks. Panel B summarizes the EURUSD cross-currency bases across tenors from 1-week to 3-months, expressed in basis points. Panel B also describes the control variables: EUR banks' USD assets, EURUSD gross swap position, intermediary leverage ratio squared (ILRS), the difference between Euro-area and US central bank balance sheet sizes scaled by GDP (CBBS/GDP), US 1-month OIS yield, and EURUSD spot and swap price changes. All variables are at a monthly frequency. MMF data are sourced from the SEC's N-MFP filings, and prices from Bloomberg.

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 deviations 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 three 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 swaps.[16]

Panel B of Table 2 shows that the average monthly EURUSD cross-currency bases are 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 3-month tenor. The EURUSD spot rate declined about 17 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. Finally, in addition to spot and swap prices, I construct a number of variables to control for confounders in my analysis: (i) "Assets", the sum of country-level quarterly dollar assets, linearly interpolated to monthly;[17] (ii) "Gross position", the sum of buy and sell volume of swaps that could affect balance sheet costs (Bahaj et al., 2024); (iii) "ILRS (log)", log of the intermediary leverage ratio (squared) provided by He, Kelly, and Manela (2017); (iv) "CBBS/GDP", the difference between the European Central Bank and the Federal Reserve Bank's balance sheet size as a percentage of (linearly interpolated) GDP (Rime et al., 2022); and (v) "US 1-month OIS" for US 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.

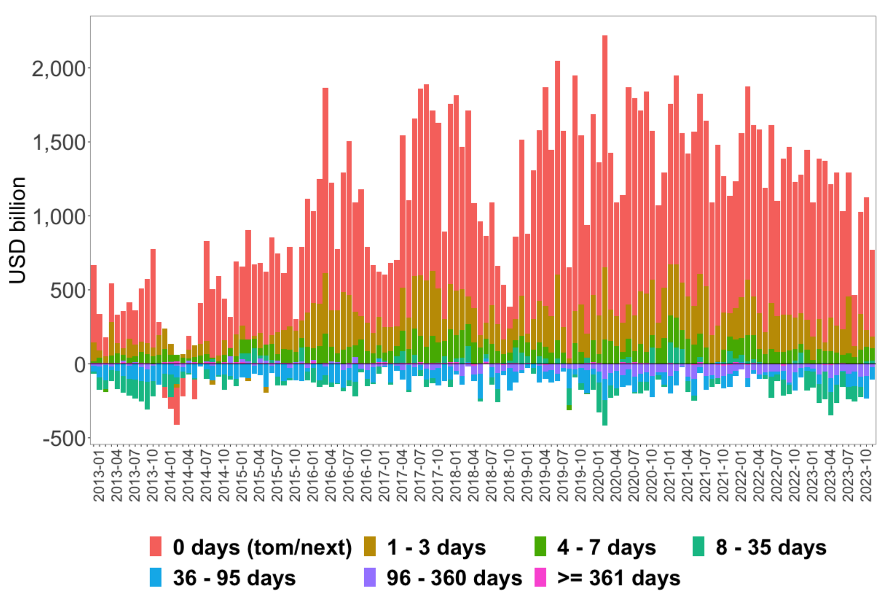
[17] Data on aggregate dollar assets by bank nationality are available from the BIS locational banking statistics, but they do not separate short-term and long-term assets.

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 3 plots the time series of monthly net USD borrowing by global banks (i.e., sell-side institutions in the CLS data) against all 9 currencies in my sample put together. Strikingly, global banks are net dollar borrowers in almost every month from January 2013 through December 2023, with the magnitude frequently exceeding \$1.5 trillion.[18] Dis-aggregating by individual currencies, Figure A3 shows that banks borrow USD primarily against EUR and JPY. In terms of counterparty sectors, panel (a) of Figure 4 shows that this demand is almost entirely supplied by non-dealer banks. In contrast, funds lend USD for short term and borrow over longer term, resembling carry trades. Corporations are consistently net borrowers, and non-bank financial institutions traded significant volumes in my sample only in the months following the onset of the COVID-19 pandemic.

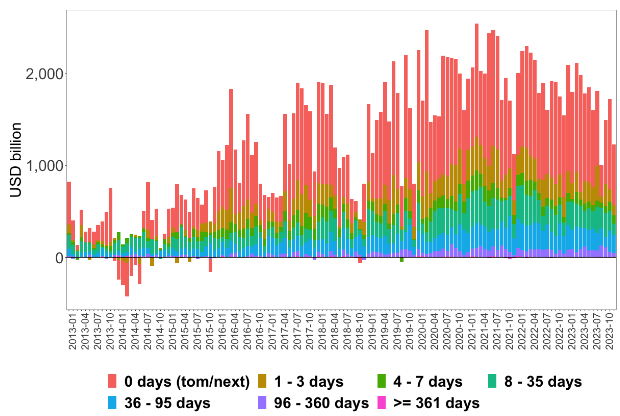
Figure 3: Synthetic Dollars Borrowed by Global Banks



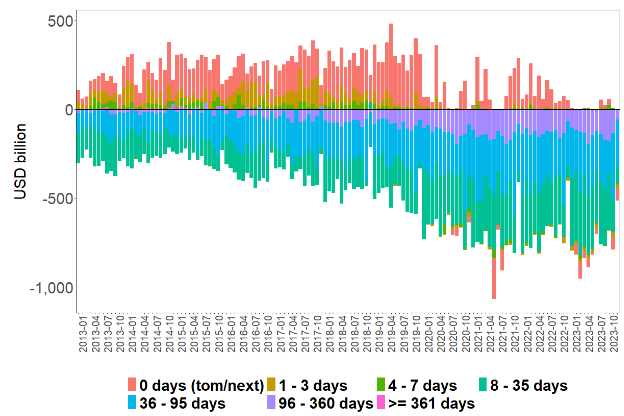
Notes: This figure plots the quantity of USD borrowed (positive y-axis) or lent (negative y-axis) by globally active dealer banks from/to all other counterparty sectors and against all 9 currencies put together. USD is borrowed for settlement at the near leg of the swap and exchanged back at the far end. Bar colors represent 7 maturity buckets, with "0 days (tom/next)" corresponding to overnight borrowing whose near leg settles one day after the trade date (T+1). The near date for all other tenors is the spot (T+2) 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.

[18]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.

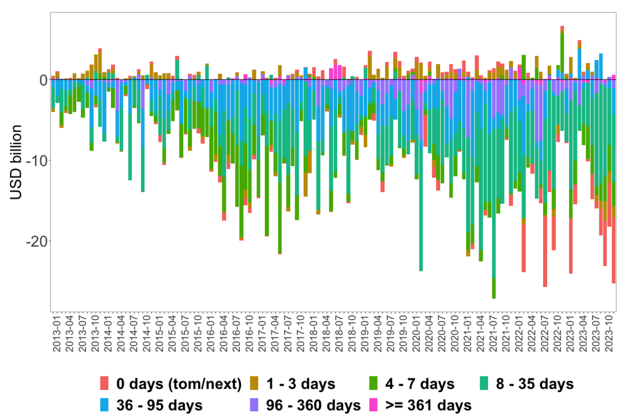
Figure 4: Sector-wise Synthetic Dollars Borrowed by Global Banks



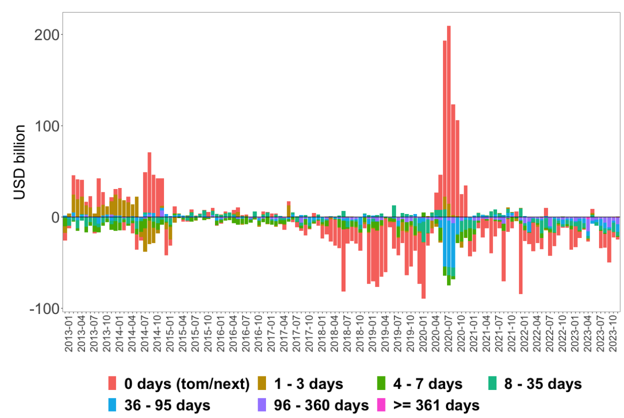
(a) Non-dealer banks



(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) 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 all 9 currencies put together, and 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 (tom/next)" corresponding to overnight borrowing whose near leg settles one day after the trade date (T+1). The near date for all other tenors is the spot (T+2) 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.

Two notable events during my sample period sharply affected banks' synthetic dollar funding. First, panel (a) of Figure A4 uses daily data to show that in March 2020, global banks reduced their reliance on swaps after the Federal Reserve activated emergency swap lines with foreign central banks in the aftermath of the disruption caused by the COVID-19 pandemic. Second, panel (b) of Figure A4 uses *hourly* data to show that on 10 March 2023, when Silicon Valley Bank in the US was declared insolvent, global banks became net dollar lenders in the swap market because of stress in the domestic banking sector, potentially hampering non-dealer banks' ability to supply dollars. These events highlight that the synthetic dollar market is sensitive to external supply shocks.

4.2. Constrained Wholesale Funding

Given that synthetic dollars are costlier than wholesale dollars due to negative cross-currency basis, this section presents evidence to support the substitution hypothesis: global banks demand dollars via FX swaps in response to reduced wholesale supply from US money market funds. Using the monthly time series of net dollars borrowed by global banks against each foreign currency, I construct a currency-month panel and estimate a model of the form:

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

The dependent variable, Net \$ Borrowing$_{C,t}$, is the percentage change in the stock of synthetic dollars held by global banks in my sample against foreign currency C in month t. I use the count of net buy trades (referred to as the "order flow" in microstructure literature) as an alternate dependent variable for robustness. The regressor of interest, ΔMMF Holdings$_{C,t}$, is the change in the total MMF holdings in banks headquartered in currency (country) C in month t.

I control for other factors that are known to affect swap markets: (i) foreign banks' dollar assets that could co-move with MMF holdings; (ii) aggregate gross swap positions and intermediary leverage ratio squared (ILRS) that affect dealers' capital constraints, (iii) the difference between the balance sheet size of the European Central Bank and the Federal Reserve Bank scaled by GDP (CBBS/GDP), (iv) US 1-month interest rates, (v) spot price, and (vi) overnight swap price. All control variables are expressed as month-on-month changes and I include them in all the analyses henceforth. I add currency fixed effects to capture currency-specific time invariant features, and cluster standard errors by currency. Table 3 reports estimation results for both the dependent variables: percent change in stock in panel A, and count of net buy trades in panel B.

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 β coefficient on the change in MMF holdings. Column (2) adds controls, column (3) adds currency fixed effects, and column (4) additionally adds year-quarter fixed effects to account for correlations across currencies within a quarter. A strong negative association between dollars borrowed by global banks via swaps and changes in MMF holdings holds across all specifications.

In economic terms, a \$100 billion (about one standard deviation) decline in MMF holdings in month t associates with a 22% increase in synthetic dollar borrowing by global banks. Note that the use of percentage changes in swap quantities ensures that the coefficient is not biased due to the fact that my data captures the universe of MMF holdings but only a quarter of swap transaction volume. Panel B of Table 3 repeats the estimation using count of net buy trades as the dependent variable, and reports consistent results. Both the dependent variables support the interpretation of substitution between supply of dollars from MMFs and FX swap markets.[19]

I report two additional robustness exercises in Table A4. First, panel A of Table A4 uses *lagged* changes in MMF holdings to address simultaneity concerns. I continue to find that banks substitute into swaps in month t when MMF holdings decline in month $t-1$, although with an expectedly smaller coefficient. Second, using heteroskedasticity- and autocorrelation-adjusted standard errors (Newey and West, 1986), panel B of Table A4 shows that the negative relationship also holds specifically for the EURUSD pair, the largest segment of the FX swaps market.

Ruling out alternate interpretations. A potential alternate explanation for the substitution effect documented above could be that the increased swap demand by global banks reflects intermediation on behalf of other end-users of currency derivatives, not banks' own funding needs. As Figure 4 shows, non-dealer banks are the main suppliers of synthetic dollars to global banks. If FX intermediation is the driver behind the results in Table 3, we would expect banks' swap trading with non-bank end-users to also be affected by their 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 confirms that only non-dealer banks increase their supply of synthetic dollars to global banks when money market fund holdings decline, with neither statistically nor economically significant impact on banks' trading with funds, corporations or non-bank financial institutions (NBFIs). This suggests that a decline in MMF investments affects global banks' demand for synthetic dollar funding and does not reflect intermediation for non-bank investors.

[19] 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.

Table 3: Synthetic Dollar Funding and Money Market Fund Holdings

	Net \$ Borrowing by global banks			
Panel A: % change in stock	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.221**	-0.236***	-0.237***	-0.236***
	(0.070)	(0.055)	(0.054)	(0.055)
Δ Assets		0.020	0.028	0.046
		(0.060)	(0.055)	(0.087)
Δ Gross position		0.037	-0.158	-0.651**
		(0.032)	(0.089)	(0.249)
Δ ILRS (log)		-3.340	-2.144	12.557
		(29.844)	(30.134)	(30.906)
Δ CBBS/GDP		5.156	5.104	8.199
		(3.162)	(3.117)	(7.099)
Δ US 1-month OIS		-0.112	-0.114	-0.091
		(0.237)	(0.237)	(0.429)
Δ Spot		-1.317***	-0.815***	-1.160
		(0.135)	(0.141)	(0.961)
Δ Swap (overnight)		-0.784***	-0.792***	-0.846***
		(0.112)	(0.108)	(0.131)
N	1,048	780	780	780
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y
Panel B: Count of net buy trades	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.047**	-0.066***	-0.065**	-0.075**
	(0.019)	(0.014)	(0.017)	(0.020)
N	1,056	786	786	786
Controls	N	Y	Y	Y
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Notes: This table reports estimates for a model of the form in Equation 1. The dependent variable in panel A is the % change in the stock of synthetic dollars held by global banks, and in panel B it is the count of net buy trades. The regressor of interest is the change in money market fund holdings in banks located in each currency (country), denoted as Δ MMF holdings and expressed in \$ billion. Columns (3) and (4) include currency fixed effects, and column (4) includes time (year-quarter) fixed effects. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Furthermore, I address a potential concern that swap transactions may be correlated with FX hedging needs of intermediaries. Swaps are used as inputs into other hedging products, such as forwards, and therefore any correlation between currency hedging 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* trading is not affected by changes in money market funds' holdings. I estimate the below model using percentage changes in the stock of signed FX forwards as the dependent variable, with rest of the specification analogous to Equation 1:

$$\text{Net \$ Bought Forward}_{C,t} = \beta \Delta \text{MMF Holdings}_{C,t} + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t}. \tag{2}$$

Table A6 collects the estimation results. I find no significant impact of changes in MMF holdings on banks' use of FX forwards, across all combinations of controls and fixed effects. Therefore, currency hedging cannot explain the negative relation between MMF holdings and banks' swap demand.

Interest rates. I show that the interest rate environment partly governs banks' substitution from wholesale to synthetic dollar funding markets. The intuition is that at higher interest rates, households shift their savings from lower-yielding bank deposits to money market funds (Aldasoro and Doerr, 2023). As a result, the increased availability of wholesale dollars during periods of tighter monetary policy should reduce banks' reliance on synthetic funding. For example, Figure 3 shows a decline in net dollar borrowing via swaps during the 2022-23 tightening cycle.

I construct a variable, *Fraction Synthetic*, defined as the volume of net synthetic dollars borrowed by global banks (aggregated across tenors) in each currency, scaled by the dollar assets of non-US banks located in that currency (country). Scaling by assets also accounts for the co-movement between the overall demand for dollar credit and interest rates. Then, I estimate:

$$\Delta \text{Fraction Synthetic}_{C,t} = \beta \Delta \text{US 1-month OIS}_t + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t}, \tag{3}$$

where I regress changes in *Fraction Synthetic* on changes in US 1-month OIS rate, with other controls and fixed effects as before. 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. Note that bank assets typically decline at higher rates. Hence, the negative β coefficient in Table A7 cannot be attributed to a decline in the denominator.

Other funding sources. I confirm that banks' other *on-balance sheet* assets and liabilities do not compensate for a decline in MMF investment. To do this exercise, I source quarterly aggregated balance sheet line items for US branches and agencies of non-US banks.[20] The advantage of this dataset is the availability of granular line items such as deposits with the Federal Reserve Bank and borrowing from other foreign banks. However, unlike CLS swaps data, this dataset is not split by the domicile country of non-US banks, and the time frequency is lower.

I estimate a time series version of Equation 1 on each asset and liability in turn as the dependent variable, and plot the coefficients in Figure A5. On the assets side, I find that only non-treasury trading assets decline with MMF investments. On the liabilities side, there is a slight increase in funds borrowed from nonrelated foreign banks when MMF investments decline. However, the magnitude of impact is much smaller compared to Table 3. Other items such as funds with depository institutions show wide confidence intervals. Overall, relative to swaps, there is much smaller adjustment to on-balance sheet items on account of changes in dollar funding from money markets.

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 FX forward market remained unaffected.

5. Asset Pricing and Spillover Impact

In this section, I show that synthetic dollar demand contributes to increased deviations from the covered interest parity (CIP). In addition to being of independent interest as a major asset pricing phenomenon, a causal impact on prices forms an important input to my model setup in Section 6. Following Du et al. (2018), I calculate 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

[20] The quarterly aggregated balance sheet data are available from Federal Reserve website.

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 three different tenors (n) that together cover the vast majority of trading in the FX derivatives market: 1 week, 1 month, and 3 months, as well as the first principal component of the basis at these tenors. FX swap premium is the percentage premium over the prevailing spot rate at time t. I average the annualized bases to a monthly frequency.

Table 2 shows that the average EURUSD basis, $x_{t,t+n}$, is negative across the term structure. A negative cross-currency basis indicates that it is costlier to borrow dollars synthetically using FX swaps compared to direct borrowing in the US money market. Under perfectly integrated markets, borrowing dollars through either option would cost approximately 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. However, recent studies show the existence of limits to arbitrage. In the below analysis, I test the demand channel: when global banks are compelled to use FX swaps for dollar funding, CIP deviations worsen. I estimate the model:

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

where the dependent variable is the change in cross-currency basis in currency C in month t for tenor n. I regress the change in basis on the change in monthly stock of synthetic dollars held by global banks in currency C and month t. Analogous to Equation 1, I include controls for both supply-side factors and other confounding variables, additionally including the previous month's cross-currency basis (Rime et al., 2022). I include currency fixed effects, cluster standard errors by currency, and estimate Equation 5 in turn for maturities of 1-week, 1-month, and 3-months, as well as for their first principal component. Table 4 reports the estimation result for all specifications.

Synthetic dollar borrowing through FX swaps turns cross-currency basis significantly more negative. Table 4 reports negative and statistically significant coefficients on the net \$ borrowing variable across all tenors and their first principal component. The economic magnitude of price impact is also large: if global banks demand an additional daily average of \$100 billion in a month, the 1-month cross-currency basis declines by about 2.7 basis points, which is 10.4% of the full sample average of negative 26 basis points.[21]

[21] 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 A8 provides suggestive evidence that investment "funds" supply USD in the short tenor (up to 1 month) and simultaneously borrow USD in the medium tenor (1 - 3 months). 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.

Table 4: **Synthetic Dollar Funding and Covered Interest Parity Deviations**

	Δ Cross-currency basis ($\Delta x_{t,t+n}$)			
	PC1 (1W, 1M, 3M)		1W	1M
	(1)	(2)	(3)	(4)
Net \$ Borrowing	-3.101**	-3.031**	-2.550***	-2.232*
	(1.010)	(1.200)	(0.469)	(0.908)
Δ Assets	-0.010	-0.003	-0.009	0.015
	(0.088)	(0.089)	(0.051)	(0.071)
Δ Gross position	-0.004	-0.100	-0.103**	-0.063
	(0.003)	(0.061)	(0.035)	(0.055)
Δ ILRS (log)	-43.021**	-42.274**	-17.182*	-33.334***
	(11.528)	(11.679)	(7.888)	(8.157)
Δ CBBS/GDP	-4.508***	-4.530***	-2.472**	-2.113**
	(1.007)	(0.993)	(0.645)	(0.614)
Δ US 1-month OIS	0.247*	0.248*	0.173**	0.139
	(0.108)	(0.108)	(0.066)	(0.078)
Δ Spot price	0.512**	0.564**	0.686***	0.866**
	(0.160)	(0.203)	(0.112)	(0.217)
Δ Swap price (overnight)	0.994**	0.989**	0.615***	0.764**
	(0.255)	(0.257)	(0.148)	(0.201)
Cross-currency basis (t-1)	-0.443***	-0.448***	-0.647***	-0.587***
	(0.061)	(0.060)	(0.079)	(0.078)
N	776	776	778	780
Currency FE	N	Y	Y	Y

Notes: This table reports 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 currencies. Column (1) uses the first principal component of 1-week, 1-month, and 3-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 change in the stock of synthetic dollars held by global banks in the respective currency. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

My reduced-form results suggest that the substitution of global banks' dollar funding from wholesale to synthetic markets can significantly impact asset prices. However, quantities and prices are simultaneously determined in equilibrium, potentially 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* (potential swap arbitrageurs), not demand shifts of foreign banks. In the following sub-section, I sharpen the identification of my proposed channels using granular data on MMF investments in non-US banks' short-term debt. My identification strategy serves two goals: First, I confirm a causal impact of banks' swap demand on CIP deviations. Second, I estimate non-bank investors' demand elasticity to instrumented CIP deviations and examine the spillover effects of banks' synthetic dollar funding demand.

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 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.

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. This identification technique is well-suited to my question because it allows me to focus on funding shocks faced by non-US banks only, and leverages the institutional features of short-term funding markets such as stickiness in MMF-bank relationships, described in detail below. Further, my setting adds another layer of exogeneity because I use shocks in a *different* but related market to instrument for swap quantities.

Identification strategy. I extract shocks to the availability of wholesale dollar funding from US money market funds to individual non-US banks, and aggregate them at a currency-level to 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 sources 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. MMF-specific inflows/outflows: MMFs frequently face large but heterogeneous inflows or outflows from their end investors due to their differential product features and expense ratios (Schmidt, Timmermann, and Wermers, 2016). These flows differentially impact the banks that MMFs specialize in lending to because MMF-to-bank lending does not resemble a perfect competition market. For example, panels (a) and (b) of Figure A6 show that while a typical bank borrows from about 9 MMFs throughout my sample period, the top 3 funds provide it with 90% of the total investment, resulting in a very high concentration and heterogeneity in exposure to end-investor flows.
2. Concentration limits: SEC regulations prohibit MMFs from lending more than 5% of their assets (unsecured) to a single issuer (Hanson, Scharfstein, and Sunderam, 2015). Banks closer to this limit may attract a smaller fraction of additional flows compared to those further away from the limit. As an illustration, panel (c) of Figure A6 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, suggesting that these limits are occasionally binding.
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, several episodes of bank-specific credit downgrades associate with large declines in MMF investment in the affected banks. For example, panel (d) of Figure A6 shows a sharp decline in MMF investments in Deutsche Bank that suffered multiple credit rating downgrades in late 2014, while other major Euro-area banks were not affected.[22]

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:

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

[22] www.dw.com/en/moodys-downgrades-deutsche-bank-as-lenders-net-profit-falls/a-17816791

where $\Delta y_{i,t}$ is the change in bank i's MMF funding in month t, scaled by the moving average of past 6 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, $z_{C,t}$, is the difference between the size-weighted and equally-weighted sums of idiosyncratic shocks in each currency area C:

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

In the estimation procedure, I relax two assumptions to ensure that $z_{C,t}$ 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 $\Delta y_{i,t}$.[23,24]

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

[23] 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).

[24] Table A9 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.

residuals, and re-estimate Equation 9 to construct the instrument $z_{C,t}$.

With these adjustments to the basic GIV framework, I construct $z_{C,t}$ using data on monthly bilateral flows from MMFs to individual banks' legal entities, sourced from the SEC N-MFP filings. I term the instrument "excess wholesale funding" because a higher value of $z_{C,t}$ represents greater availability of MMF investments to larger banks in currency C relative to the sector-level average. 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 5 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 5 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. Most of these shocks can be traced to one of three sources mentioned earlier. For example, (i) In 2017, several MMFs had 5% of their assets invested into BNP Paribas, which led to a sharp decline in its subsequent additional funding; (ii) In 2014, Deutsche Bank's credit downgrade contracted its MMF funding compared to other Euro-area banks; (iii) Large inflows experienced by Charles Schwab in 2016 disproportionately benefited some banks. In contrast, common shocks that affect all banks, such as the COVID-19 pandemic, do not reflect as major outliers.

Third, Table A10 confirms that the instrument 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. However, one alternative explanation for the differential MMF flows to banks could be that the borrower banks have differential underlying demand for dollar credit (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. Instead, 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 dollar credit demand.

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 1, the endogenous variable Net \$ Borrowing$_{C,t}$ represents the change in the stock of synthetic dollars held by global banks against currency C in month t. All control variables are also consistent with Equation 1 and additionally include the first three principal components and lagged basis. The regressor of interest is $z_{C,t}$ that captures the component of swap quantities demanded by global banks due to constrained availability of wholesale dollar funding. Table 5 presents the estimation results, with univariate analysis in column (1), controls added in columns (2) through (4), and currency fixed effects in columns (3) and (4). Column (4) uses the instrument constructed without heteroskedasticity adjustment for robustness.

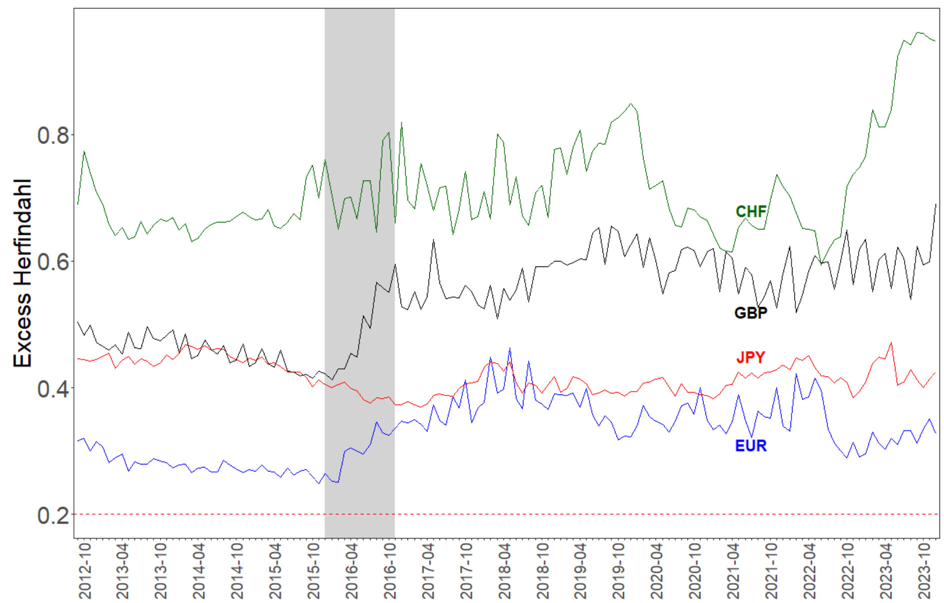
All four columns of Table 5 show that the instrument is relevant to explaining variations in swap quantities in a direction consistent with the substitution hypothesis: a greater flow of wholesale funding to large foreign banks associates with reduced synthetic dollar borrowing in that currency.[25] With the relevance confirmed, I estimate the below second stage model:

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

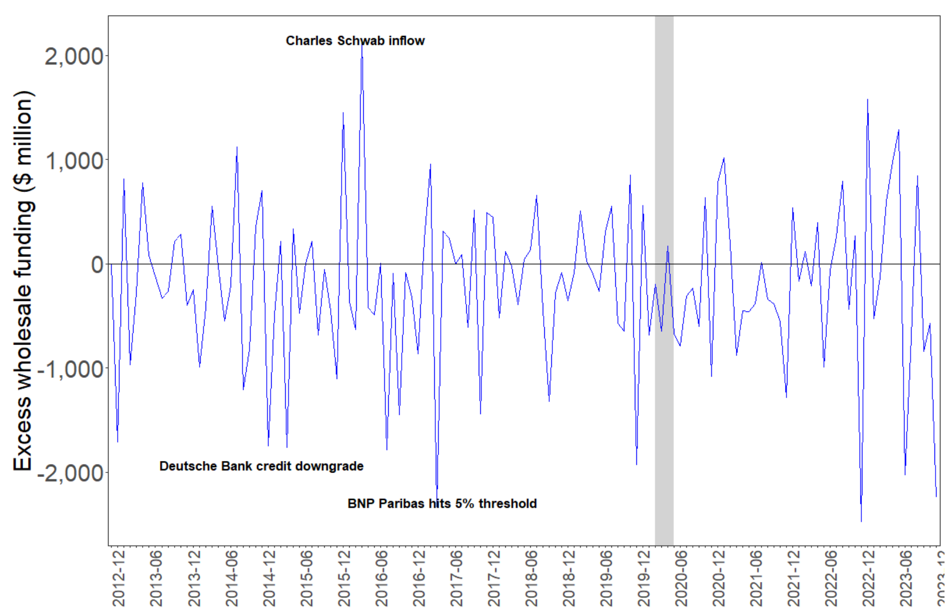
Panel A of Table 6 reports the estimation results, with a negative β coefficient on the instrumented net dollar borrowing through swaps. These results provide a causal interpretation to the price impact reported in Table 4. Further, the coefficient β is larger than the OLS estimate in Table 4, suggesting the reduction of simultaneity bias. Panel B of Table 6 shows robustness of the price impact to exclusion of quarter-end months from my sample (March, June, September, and December). While the statistical significance is lower than in panel A because of smaller sample, the coefficient on instrumented net dollar borrowing itself is smaller, consistent with supply curves steepening during quarter-ends.

[25] A negative association between my instrument and swap quantities confirms that it does not capture swap arbitrageurs' constraints. If arbitrageurs get more MMF funding, swap quantities should increase.

Figure 5: 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 (unscaled) instrument for EURUSD and shows the presence of large shocks that can be traced to idiosyncratic economic factors. Shaded area represents the COVID-19 pandemic in 2020.

Table 5: Instrumented Swap Quantities (First Stage)

	Net \$ Borrowing$_{C,t}$			
	(1)	(2)	(3)	(4)
Excess wholesale funding ($z_{C,t}$)	-0.787***	-0.809***	-0.743***	-0.755***
	(0.218)	(0.220)	(0.226)	(0.230)
Δ Assets		0.020	0.028	0.046
		(0.060)	(0.055)	(0.087)
Δ Gross position		0.037	-0.158	-0.651**
		(0.032)	(0.089)	(0.249)
Δ ILRS (log)		-3.340	-2.144	12.557
		(29.844)	(30.134)	(30.906)
Δ CBBS/GDP		5.156	5.104	8.199
		(3.162)	(3.117)	(7.099)
Δ US 1-month OIS		-0.112	-0.114	-0.091
		(0.237)	(0.237)	(0.429)
Δ Spot		-1.317***	-0.815***	-1.160
		(0.135)	(0.141)	(0.961)
Δ Swap (overnight)		-0.784***	-0.792***	-0.846***
		(0.112)	(0.108)	(0.131)
PC1		0.009	0.002	-0.694
		(0.076)	(0.071)	(0.327)
PC2		3.047***	3.162***	3.082***
		(0.324)	(0.322)	(0.387)
PC3		3.398	3.769	3.747
		(6.944)	(6.530)	(6.634)
N	786	648	648	648
Instrument F-statistic	13.03	13.52	10.81	10.78
Currency FE	N	N	Y	Y

Notes: This table reports the first-stage estimates from a two-stage least squares regression for a model of the form in Equation 10. The dependent variable is the change in the stock of synthetic dollars borrowed by global banks in a panel of currencies. The regressor of interest is the granular instrumental variable "Excess wholesale funding ($z_{C,t}$)". Columns (2) through (4) add controls, and columns (3) and (4) include currency fixed effects. Column (4) uses the instrument that is constructed without heteroskedasticity adjustment, to show robustness. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 6: Causal Impact on CIP Deviations (Second Stage)

	ΔCross-currency basis$_{C,t}$			
Panel A: full sample	PC1 (1W, 1M, 3M)		1W	1M
	(1)	(2)	(3)	(4)
Net \$ $\widehat{\text{Borrowing}}_{C,t}$	-4.073***	-4.235***	-3.897***	-3.047**
	(0.674)	(0.718)	(1.015)	(1.240)
N	646	646	648	650
Controls	Y	Y	Y	Y
Currency FE	N	Y	Y	Y
Panel B: ex. quarter-end months	PC1 (1W, 1M, 3M)		1W	1M
	(1)	(2)	(3)	(4)
Net \$ $\widehat{\text{Borrowing}}_{C,t}$	-3.510**	-3.700**	-2.107**	-2.019*
	(1.507)	(1.699)	(0.998)	(1.159)
N	483	483	483	485
Controls	Y	Y	Y	Y
Currency FE	N	Y	Y	Y

Notes: This table reports the second-stage estimates from a two-stage least squares regression for a model of the form in Equation 11. The dependent variable is the monthly change in currency-specific cross-currency basis, with the first principal component of 1-week, 1-month, and 3-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 change in the stock of synthetic dollars borrowed by global banks in a panel of currencies from the first stage (Table 5). All control variables are consistent with the first stage table. Panel A uses the full sample period, while Panel B drops months corresponding to quarter-ends: March, June, September, and December. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

5.2. Spillover to Non-banks Investors' Hedging Cost

In addition to banks, investors such as funds, corporations, and non-bank financial institutions (NBFIs) are major users of FX derivatives. Figure 4 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. On the other hand, Figure 6 shows that funds sell dollars using FX forwards, implying that they are net holders of USD assets, while corporations buy dollars forward. In this section, I investigate the impact of global banks' synthetic dollar funding on the FX hedging activity of non-bank investors.

To do this, first I test the relevance of the instrument, excess wholesale funding ($z_{C,t}$), to explaining the variation in cross-currency basis. I estimate a first stage model of the form:

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

The specification mirrors Equation 12 in terms of controls and fixed effects, and I estimate it in turn for cross-currency bases calculated using the first principal component of 1-week, 1-month, and 3-month tenors, as well as for the 1-week and 1-month tenors separately. Panel A of Table 7 reports the estimation results.

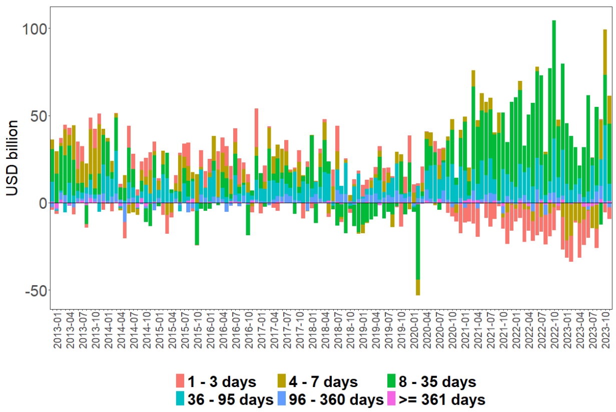
Cross-currency bases across all tenors strongly correlate with my instrument. In all the columns of Table 7 panel A, there is a positive and statistically significant relation between the $z_{C,t}$ and cross-currency basis, which implies that when relatively larger banks receive wholesale funding in excess of the currency-level average, the cross-currency basis for that currency becomes *less* negative. The strong link between the instrument and cross-currency basis also confirms that the results in Table 6 are not attributable to a problem of weak instrument.

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 the spillover effects of dollar supply frictions on FX risk management (whether quantities adjust or the cost changes). 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' asset portfolios. On the other hand, if demand is inelastic, then investors pay a higher hedging cost and realize lower *returns* on such assets.[26] I estimate the below second stage model to test which effect dominates:

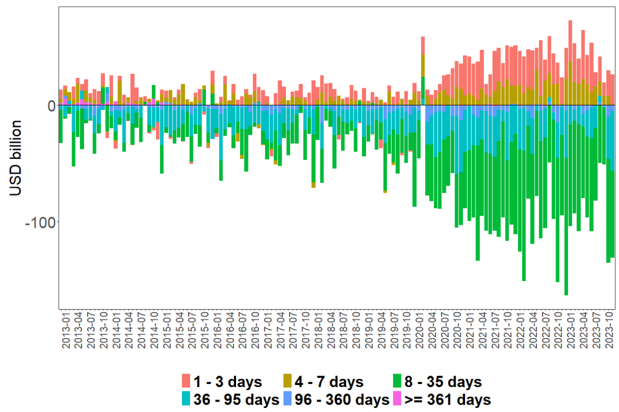
$$\text{Hedging Demand}^S_{C,t} = \beta \Delta\widehat{\text{Cross-currency}}\ \text{basis}_{C,t} + \text{Controls}_{C,t} + \alpha_C + \varepsilon_{C,t}. \tag{13}$$

[26] Dávila, Graves, and Parlatore (2024) provide a framework for welfare gains from closing arbitrage gaps.

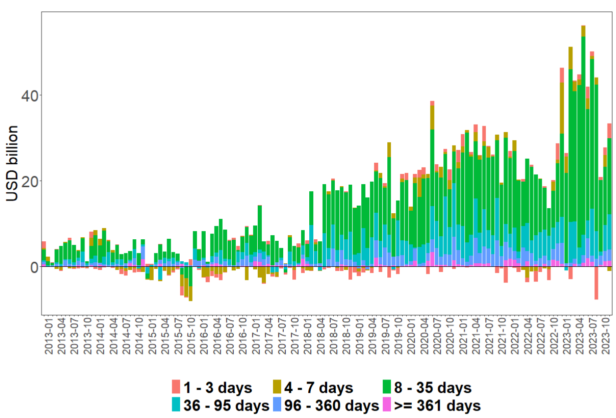
Figure 6: Sector-wise FX Forward Dollar Purchase



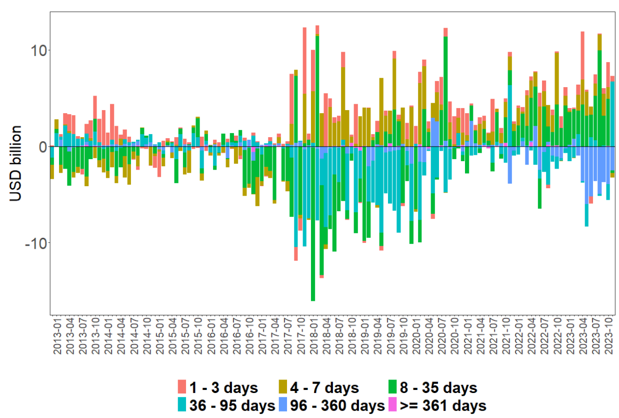
(a) Non-dealer banks



(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 all 9 currencies in my sample put together 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.

I measure hedging demand in two separate products: net sale of USD in the forward market, and net buy-sell USD trades in the swap market. The dependent variable, Hedging Demand$^{S}_{C,t}$, represents the change in the stock of forwards or swaps held by sector S in currency C in month t. The different non-bank sectors I estimate the model for are: funds, non-bank financial institutions (NBFIs), and non-financial corporations. Panel B of Table 7 reports the estimation results for parameter β for both the products as well as each of the three sectors.

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 currencies. Interpreting as elasticities, for a 1% reduction in cross-currency basis, funds reduce forward sale of the dollar by 0.26% and buy-sell USD swaps by 0.62%. 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 corporations do not show a statistically significant reaction for any of the products. These estimates 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.[27] 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 26 basis points across major currencies, these investors pay an estimated additional \$2.6 billion in FX hedging costs per annum (\$2 trillion $\times$ 0.0026/2).

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

Table 7: Elasticity of Non-Bank Investors' Hedging Demand

Panel A: First stage	ΔCross-currency basis$_{C,t}$			
	PC1 (1W, 1M, 3M)		1W	1M
	(1)	(2)	(3)	(4)
Excess wholesale funding ($z_{C,t}$)	5.615***	5.246***	6.442***	7.992***
	(1.336)	(1.485)	(2.010)	(2.167)
N	651	651	653	655
Instrument F-statistic	17.66	12.48	10.27	13.60
Controls	N	Y	Y	Y
Currency FE	Y	Y	Y	Y

Panel B: Second stage	Hedging Demand$^{S}_{C,t}$					
	Forwards			Swaps		
	Fund	NBFI	Corp.	Fund	NBFI	Corp.
$\Delta\widehat{\text{Cross-currency}}$ basis$_{C,t}$	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
Controls	Y	Y	Y	Y	Y	Y
Currency FE	Y	Y	Y	Y	Y	Y

Notes: This table reports estimates of a two-stage least squares regression for models of the form in Equation 12 (first stage) and Equation 13 (second stage). In Panel A, the dependent variable is monthly change in cross-currency basis, with the first principal component of 1-week, 1-month, and 3-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, "Excess wholesale funding ($z_{C,t}$)" with additional controls in columns (2) through (4) consistent with Table 5. Panel B reports the second-stage results where the dependent variable is the monthly change in net USD forward purchase in the first three columns, and net USD sell-buy swaps in the last three columns, aggregated across all tenors. The regressor of interest is the instrumented change in the first principal component of cross-currency basis (column (2) in panel (a)). All columns include currency fixed effects. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

6. Model and Counterfactuals

Several post-financial crisis regulations have sought to mitigate default risk in US money market funds (MMFs) that took on excessive risk leading up to the crisis (Kacperczyk and Schnabl, 2013, Chernenko and Sunderam, 2014). Given this regulatory objective, my next goal is to assess the extent to which synthetic dollar funding can offset a decline in wholesale funding, beyond which the global availability of US dollar credit could suffer. To this end, first I need to quantify the trade-off between MMF default risk and the cross-currency basis, and then compare the basis to banks' marginal revenue on dollar assets. Achieving these goals requires a model that rationalizes my empirical results and can be calibrated using my data.

I present a tractable model that closely builds on Ivashina et al. (2015), where non-US banks optimally choose synthetic dollar funding in the presence of limited scalability of wholesale funding. My model departs in three important ways. First, banks in my model face occasionally binding quantitative limits on how much they can borrow from MMFs, which creates a demand *shift* in favor of FX swaps. Second, motivated by my empirical results, I add an arbitrageur sector to close the model which makes CIP deviations an equilibrium object. Third, I calibrate the model using observed data and indirect inference from my empirical results to present counterfactual estimates.

6.1. Model Setup

The economy. Consider a two-country economy, the US and Europe, with a global bank that has lending opportunities in USD and is able to borrow dollars both directly in US wholesale markets and synthetically in the FX swap market. The bank funds its synthetic borrowing via European money markets or euro deposits. If it lends an amount L^D in dollars at time 0, it earns an expected gross return of $g(L^D)$ at time 1, where $g(.)$ is a concave function. As in Ivashina et al. (2015), I assume that the riskless rates in the US and Europe are both equal to r.[28]

US money market funds are the primary investors in wholesale funding market.[29] Their corpus scales linearly with interest rates, with the sensitivity parameter η. Further, funds are subject to mean-zero flow shocks from end-investors, σ_X. However, to mitigate exposure to default risk, funds lend only a fraction, α, to banks. A literal interpretation of the parameter α is the 5% regulatory concentration limit that MMFs are subject to. Thus, MMFs' total lendable corpus is given by:

[28]The assumption of equal riskless rates in both economies is without loss of generality. Different interest rates have the effect of generating a time-varying FX spot risk. However, CIP deviations are near-risk free arbitrage opportunities and FX spot risk does not enter any agent's problem. Hence, I assume equal rates.

[29]Other wholesale investors, such as federal home loan banks, do not significantly lend to non-US banks. Other funding sources, such as bonds, are typically used by banks for *long-term* lending.

$$L^W = \alpha[\overline{L^W}(1 + \eta(1 + r) + \sigma_X)], \tag{14}$$

where $\overline{L^W}$ is a steady state value. MMFs earn a constant return of r on funds lent to banks.[30] Finally, funds incur a default risk on their lending to banks:

$$\text{Default Risk} = \beta(L^W)^2, \tag{15}$$

where the parameter β captures the default sensitivity (probability of and loss given default) and the squared term on the amount lent is meant to reflect convex risk that arises, for example, out of increased correlations during crises.

The third agent in the economy is a swap arbitrageur who is subject to leverage ratio constraints on its balance sheet. In the FX swap market, the arbitrageur lends US dollar and earns the riskless rate r plus the (negative) cross-currency basis S. The arbitrageur does not face default risk because swaps are effectively collateralized. As a result, banks' substitution from wholesale to synthetic funding transfers default risk out of US money market funds to European depositors or investors that provide the foreign currency to the bank for swapping against the dollar.

Basic assumptions. The bank faces an overall demand constraint on lending, such that aggregate lending is capped by $L^D \leq N$. This constraint, which I assume is not correlated with funding market frictions, reflects the aggregate demand for short-term dollar loans from bank-dependent borrowers. I further assume that (i) the bank does not leave open FX mismatch on its dollar funding gaps for both economic and regulatory reasons (Abbassi and Bräuning, 2021), and (ii) the bank cannot "create" money due to lack of significant dollar deposit franchise (Lee, 2024).

Unlike in the wholesale market, the bank faces no direct constraint on raising dollars synthetically because it can frictionlessly expand its euro borrowing, especially when European monetary conditions are loose. Even if the bank cannot immediately expand its retail deposit base beyond some baseline level, it can always resort to local money markets and drain European Central Bank reserves when the dollar investment opportunity is profitable enough. I make this assumption to keep the focus on constraints in the dollar funding markets, but the key predictions go through even if the bank faces limited scalability of euro funding as in Ivashina et al. (2015).

[30] It is an important feature of the model that r does not scale with the amount lent because it creates a pecking order of dollar funding sources. At a constant r, banks will always prefer to borrow in wholesale markets, as opposed to synthetic markets where the cost scales non-linearly. I confirm in the data that the interest rate charged by MMFs is not increasing with the amount lent, holding fixed the issuer and time.

6.1.1. Demand for Dollar Funding

Following the assumption of no unhedged FX exposure, the bank matches its total dollar lending, L^D, with funding from the wholesale market, L^W, and the synthetic market, L^S:

$$L^D = L^W + L^S. \tag{16}$$

The bank prefers the cheaper wholesale funding but is constrained in that it can raise at most L^W dollars. The leftover quantity, $L^D - L^W$, is then diverted to the synthetic market, where the bank pays a price of $r + S$. In equilibrium, detailed in next sub-section, the cross-currency basis S is also a function of the aggregate banking sector demand. For now, consider a price-taking bank whose optimization problem is to choose L^S to maximize its profit:

$$\max_{\{L^S\}} \left[g(L^W + L^S) - r \cdot L^W - (r + S) \cdot L^S \right] \tag{17}$$

subject to the total lending and wholesale funding constraints:

$$L^W + L^S \leq N$$

$$L^W \leq \alpha[\overline{L}^W (1 + \eta(1 + r) + \sigma_X)]$$

The first order condition of Equation 17 with respect to L^S is given by

$$-(r + S) + g'(L^W + L^S) = 0, \tag{18}$$

implying that the bank raises just enough synthetic dollars to equate the marginal cost $r + S$ with the marginal revenue $g'(L^S)$. Intuitively, the bank's actions can be grouped into three scenarios.

1. The overall dollar demand, N, is within the available wholesale funding, L^W, such that $N = L^D$ and $L^D \leq \alpha[\overline{L}^W (1 + \eta(1 + r) + \sigma_X)]$. The bank will not borrow at all using FX swaps: $L^S = 0$.
2. The overall dollar demand is higher than what MMFs can meet: $L^D > \alpha[\overline{L}^W (1 + \eta(1 + r) + \sigma_X)]$. However, the marginal revenue on lending is still greater than synthetic funding cost $r + S$. Hence, the bank fulfills its residual demand using FX swaps: $L^S = N - L^W$.
3. The overall dollar demand is higher than what MMFs can meet and the cost of marginal dollars, $r + S$, exceeds marginal returns, $g'(L^S)$. Hence, the bank does not meet the total dollar demand: $L^D < N$. A severe shortage of dollars in both the wholesale and synthetic markets necessitates a reduction in dollars lent by the bank, or reliance on an outside source of dollar supply, such as central bank swap lines.

These scenarios show that the relative pricing of swaps and dollar assets lies at the heart of banks' decision problem. I now parametrize the concave revenue function, $g(L^D)$ as

$$g(L^D) = aL^D - b(L^D)^2 \tag{19}$$

Plugging Equation 19 into Equation 18, and recognizing that $L^S \leq N - L^W$, where $L^W = \alpha[\overline{L^W}(1 + \eta(1 + r) + \sigma_X)]$, we arrive at the first proposition.

$$\underbrace{N - \alpha[\overline{L^W}(1 + \eta(1 + r) + \sigma_X)]}_{\text{Swap quantity}(L^S)} \geq \underbrace{\frac{a - (r + S)}{2b}}_{\text{Marginal revenue over cost}} \tag{20}$$

Proposition 1. *To the extent that the marginal revenue from lending exceeds cross-currency bases, quantitative limits on wholesale dollars force banks to meet the residual demand through FX swaps.*

$$\frac{\partial L^S}{\partial \alpha} > 0 \tag{21}$$

This proposition focuses on the most interesting case, i.e. scenario 2 above, where returns on dollar assets exceed the marginal cost so the bank has an incentive to use swaps. In the counterfactual exercise, I analyze the conditions under which scenario 3 materializes. Given that global banks run persistent dollar funding gaps (Figure 1), I do not focus on scenario 1 henceforth.

An interesting extension of this proposition is that interest rates modulate the extent of wholesale dollar funding available to banks because higher rates attract flows into money market funds (Aldasoro and Doerr, 2023). Hence, when the monetary authority exogenously sets a higher riskless rate r, banks rely less on FX swaps to raise dollars (Table A7). This effect is amplified when the end-user demand for dollars, N, also reduces under a tighter monetary policy regime.

I now close the model by introducing a balance-sheet constrained arbitrageur in the FX swap market and derive equilibrium price and swap quantities.

6.1.2. Constrained Supply of Swaps

The swap arbitrageur takes advantage of negative cross-currency basis but faces convex balance sheet costs (e.g., leverage ratios). I follow Moskowitz et al. (2024) to express the arbitrageur's problem as below, abstracting away from counterparty costs and asset scarcity risks for simplicity:

$$\max_{\{Z^S\}} \left[(r + S) \cdot Z^S - r \cdot Z^S - \frac{1}{2}\lambda(Z^S)^2 \right], \tag{22}$$

where Z^S is the quantity supplied by the arbitrageur and λ is a parameter modulating the strength of the quadratic balance sheet cost. When the basis is negative, arbitrageurs have an incentive to borrow at the riskless dollar rate and supply them via FX swaps. However, convex balance sheet costs imply an upward sloping supply curve and limit the scalability of arbitrage.[31]

Equilibrium price and quantity. I impose market clearing to solve for the equilibrium price, i.e. the cross-currency basis. Since swaps are in net zero supply, the aggregate synthetic dollar demand of the banking sector must equal the supply from arbitrageurs to clear the market.

$$L^S + Z^S = 0 \tag{23}$$

We take the first order condition of Equation 22 with respect to Z^S and plug the above market clearing condition to write the price impact as:

$$\mathrm{S} = \lambda L^S \tag{24}$$

Proposition 2. *Greater aggregate demand for synthetic dollar funding interacts with limits to arbitrage to turn the cross-currency bases negative (i.e., increases the price of synthetic dollars).*

$$\frac{\partial S}{\partial L^S} > 0 \tag{25}$$

The equilibrium quantity of swaps is given by plugging Equation 24 into the RHS of Equation 20:

$$L^S = \frac{a - r}{2b + \lambda} \tag{26}$$

Next, I link MMF default risk with CIP deviations. To do so, re-write Equation 15 as Default Risk $= \beta(N - L^S)^2$, and then plug Equation 24 to get:

$$\text{Default Risk} = \beta \left[N - \frac{S}{\lambda} \right]^2 \tag{27}$$

Proposition 3. *A reduction in money market funds' default risk is accompanied by greater deviations from covered interest parity.*

$$\frac{\partial S}{\partial \text{Default Risk}} < 0 \tag{28}$$

The main channel that links MMF default risk with CIP deviations is the parameter α. A higher α simultaneously increases MMF default risk while lowering banks' dependence on swaps, thereby narrowing cross-currency bases.

[31] Note that it is possible that the constraints in wholesale funding market, α, correlate with arbitrageurs' balance sheet costs, λ, such that there is an additional supply-side effect of wholesale funding constraints (Anderson et al., 2021, Rime et al., 2022). I account for the potential correlation in the calibration exercise.

6.2. Calibration

I match the model to empirical estimates and key moments in the data to quantify the co-movement between CIP deviations and money market funds' default risk. Table 8 summarizes the model calibration using the average values during my sample period.

There are three state variables that I assume are exogenously specified. First, interest rates r_t follow the Cox, Ingersoll, and Ross (1985) mean-reverting process.[32] Based on the US-1 month OIS rates from 2013-2023, I set the mean rate $\bar{r}$ at 1.5%, speed of mean reversion Γ at 0.1, and the volatility parameter σ_r at 1.5%. I derive Γ and σ_r from the period before 2022 because interest rates were no longer stationary after 2022. The second variable is the correlation between money market fund flows and arbitrageurs' balance sheet constraint ψ which I set to 0 in the baseline calibration and to 0.5 for sensitivity analysis. The third variable is the correlation between interest rates and the overall demand for US dollar funding ρ which I set to -0.1, based on my estimates from banks' short-term dollar assets data.

The representative bank faces a credit demand of N dollars, which it tries to meet by raising as much wholesale funding is available L^W and the rest through FX swaps L^S. The bank earns a marginal revenue on lending which is a concave function. I leverage the collateral data available in the N-MFP filings to calculate the profits on short-term assets as a function of loan size, and calibrate the parameters attached to the linear term $a = 2.18$ and the squared term $b = -1.96e{-}04$. These two parameters enter the optimization function of banks as they try to equalize marginal cost with marginal revenue (Equation 20).

Money market funds manage a corpus of investments, a fraction on which is invested in risky bank securities (Equation 14). I set the sample average $\overline{L^W} = \$2,000$ billion as observed in the data (this figure excludes funds that invest exclusively in US Treasuries). The corpus increases with interest rates; I set the sensitivity parameter $\eta = 0.15$ based on a time-series regression coefficient. MMFs are also exposed to other mean-zero normally distributed flow shocks, whose standard deviation is $\sigma_X = 200$ in the data.

MMFs can lend only a fraction α to (risky) banks, which can be viewed as the regulatorily-imposed concentration limit. A lower realization of α can also result from MMFs' risk aversion. I set $\alpha = 0.05 \times 8 = 0.4$, because a typical MMF on average lends to 8 foreign banks. I vary this parameter in the counterfactual exercises to estimate the impact on prices and quantities borrowed via swaps. I assume that an outside borrower (e.g., US government) is willing to absorb the leftover MMF corpus, but do not model it explicitly to keep the focus on MMF-bank flows. I place a non-negativity constraint on MMF corpus as well as on bank lending.

[32] Note that the model is static, but I use time-varying rates only to show the dynamics of key parameters.

Money market funds face default risk on their lending to banks. I model the default risk as increasing in the squared term of the amount lent (Equation 15). The squared term in default risk is meant to capture the plausible scenario where defaults are correlated across issuers. Following Collins and Gallagher (2014), I calculate the sensitivity parameter β as the value-weighted credit default swap (CDS) premium on dollars lent to risky banks. During my sample period, CDS premium averages 50 bps for a \$100 notional. Hence, I set $\beta = 0.005$.[33]

Table 8: Calibration

Parameter	Definition	Source or Target
State variables		
$\overline{r} = 0.015$	Mean interest rate in US	Data
$\Gamma = 0.1$	Speed of mean reversion	Data
$\sigma_r = 0.015$	Standard deviation of rates	Data
$\psi = 0$ (baseline)	Correlation between MMF flows and arbitrageur constraints	Assumption ($\psi = 0.5$ for sensitivity)
Bank funding and lending		
$N \geq L^W + L^S$	Total funding need	Assumption
$a = 2.18$	Revenue scaler	Regression coefficient
$b = -1.96e-04$	Quadratic term for concavity	Regression coefficient
Money market funds		
$\eta = 0.15$	Sensitivity of corpus to interest rates	Regression coefficient
$\sigma_X = 200$	Volatility in fund flows	Data
$\overline{L^W} = 2,000$	Mean corpus of funds	Data
$\alpha = 0.4$	Fraction of corpus lendable	Regulations and data
$\beta = 0.005$	Default risk sensitivity	CDS spreads (Collins and Gallagher, 2014)
Arbitrageurs		
$\lambda = 0.0006$	Balance sheet cost scaler	Indirect inference from Table 6

Notes: This table summarizes the values of model parameters and their empirical counterparts.

[33] Say MMFs lend \$100. The default risk on this lending is \$0.5 ($0.005 \times (100)^2/100$). However, if they lend \$500, the default risk rises in a convex manner to \$12.5 ($0.005 \times (500)^2/100$).

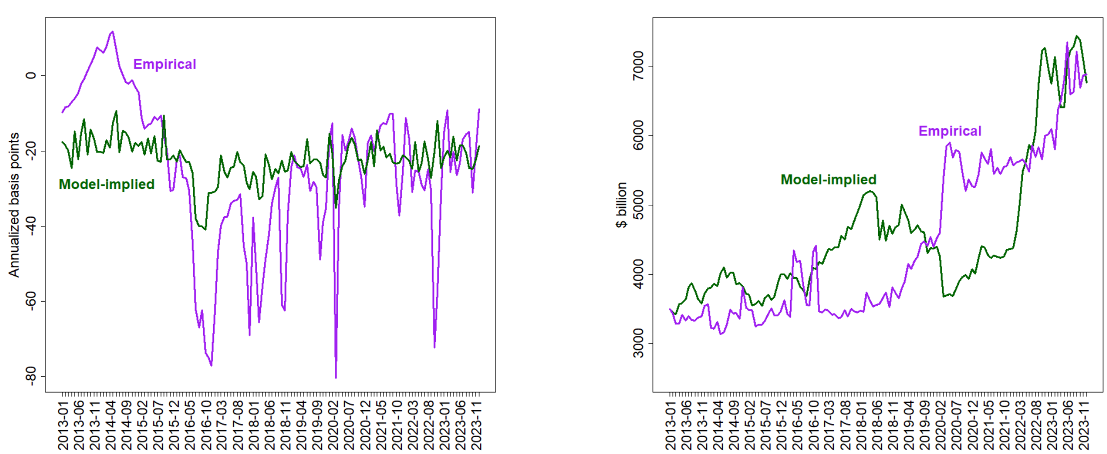
The last agent in my model is the swap arbitrageur. Post-financial crisis regulations penalize the expansion of balance sheet size, for example through leverage ratio requirements, even for risk-free activities such as arbitraging CIP deviations. This cost is captured by the parameter λ in Equation 22. However, I do not directly observe λ in my data. Instead, I observe the price impact of banks' synthetic dollar funding demand, detailed in Section 5. I apply an indirect inference approach to estimate λ such that I can match empirically observed price impact from the GIV second stage. Table 6 shows that for a \$100 billion increase in quantities demanded, cross-currency basis turns negative by about 3 bps. This allows me to set $\lambda = 0.0006$.

6.2.1. Results

I confirm that the above calibration matches key patterns in the data. Panel (a) of Figure 7 shows that the model-implied path of CIP deviations shows variation that is comparable to the empirical patterns in the data during my sample period. However, unlike in the data, the model-implied CIP deviations do not spike down during quarter-ends because arbitrageurs' balance sheet constraints are not time varying in my model.

Panel (b) of Figure 7 shows that the evolution of MMF corpus matches the observed time series. Two periods where a divergence exists are (i) the late-2016 MMF reform that led to large fund outflows, and (ii) the aftermath of COVID-19 pandemic during which the model-predicted MMF corpus declines with interest rates. On the contrary, MMF corpus increased in the data, as the special dynamics of this period led to a large drop in aggregate consumption.

Figure 7: Model-implied vs. Empirical CIP Deviations and MMF Corpus



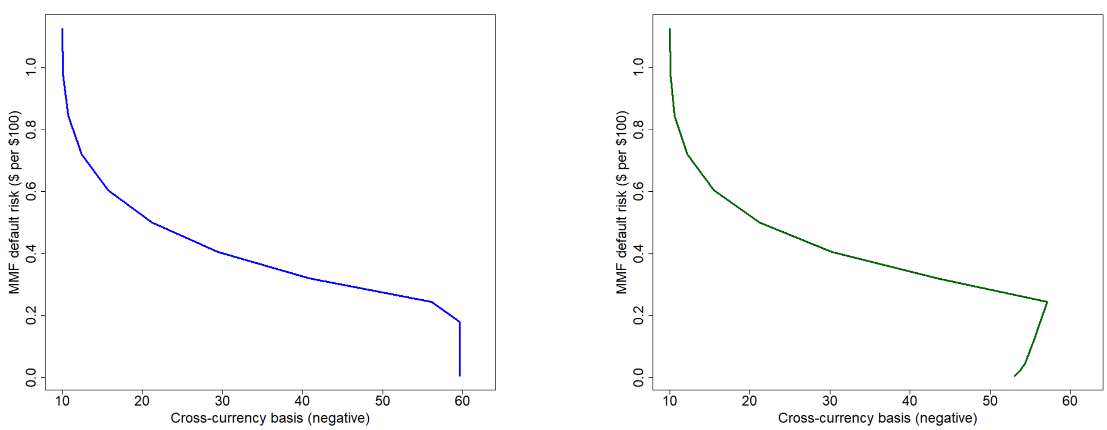
(a) CIP deviations (b) Money market fund corpus

Notes: This figure compares the empirical and model-implied CIP deviations in panel (a) and money market fund corpus in panel (b). Table 8 lists the parameters used to generate the model-implied time series.

I apply my model to study the externalities of domestic money market regulations that seek to shield MMFs from default risk (Kacperczyk and Schnabl, 2013, Chernenko and Sunderam, 2014). As a first step, I quantify the trade-off between reducing default risk in MMFs and increasing CIP deviations. To do this, I fix all the model parameters to the values shown in Table 8, and vary only α, the fraction of corpus that MMFs invest in risky bank debt. Figure 8 plots the trade-off, where panel (a) assumes that swap arbitrageur constraints λ do not vary with MMF funding ($\psi = 0$), while panel (b) allows for a simultaneous tightening of arbitrageur constraints at lower α ($\psi = 0.5$).

Default risk and CIP deviations exhibit a strong inverse relationship. For example, reducing CIP deviations from -30 bps to -15 bps would require additional wholesale funding to banks, increasing the default risk in MMFs by around 40%. Note that the default risk shown on y axis is scaled by the total corpus so it can be interpreted as expected dollar loss for a \$100 lending. Interestingly, at around -60 bps cross-currency basis, the curve turns vertical. This is because, as per the model, banks stop borrowing more via swaps when the marginal cost exceeds their marginal returns. This reflects the joint dynamics of CIP deviations and dollar asset profitability, which I detail in the next sub-section. Panel (b), which allows for steepening of arbitrageurs' supply curve with tighter MMF constraints, shows a slightly more convex relationship than panel (a).

Figure 8: Money Market Fund Default Risk and CIP Deviations



(a) Baseline ($\psi = 0$)

(b) Correlated arbitrageur cost ($\psi = 0.5$)

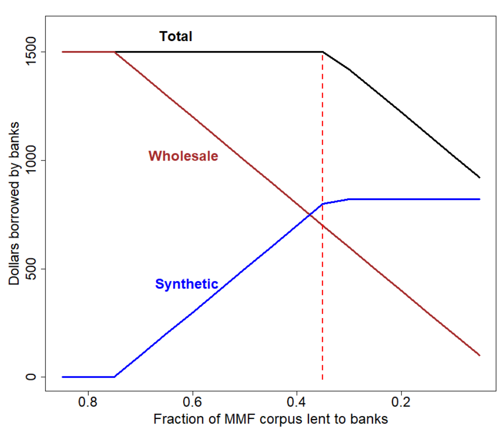
Notes: This figure compares the counterfactual limits on money market fund lending to banks (i.e., parameter α on y axis) and the resulting CIP deviations (x axis) through the channel of banks' synthetic dollar funding demand. CIP deviations are represented as the (negative) of the price impact resulting from banks' substitution from wholesale to synthetic funding for a given level of end-user demand for dollar credit. Panel (a) considers the baseline where arbitrageurs' balance sheet cost, λ, does not tighten with money market fund lending limits. Panel (b) considers the case where λ positively co-moves with α.

6.4. *Counterfactual Decline in Lending*

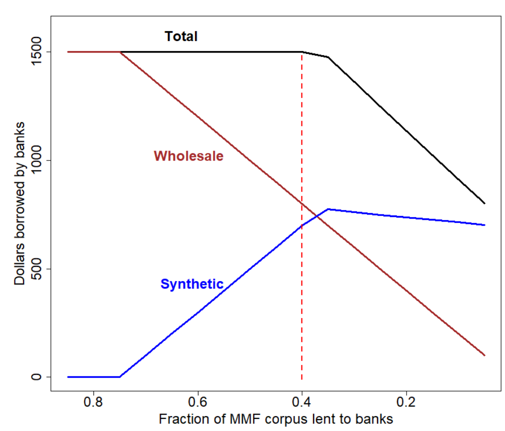
I quantify the thresholds at which tighter constraints on MMFs' wholesale lending to banks ultimately reduces banks' ability to supply global dollar credit. The key intuition in this counterfactual exercise is that banks endogenize the expected price impact of marginal synthetic dollars and do not borrow in excess of their marginal returns. Figure 9 plots the dollars borrowed by banks through wholesale (L^W) and synthetic (L^S) routes on the y axis, and the corresponding fraction of MMF corpus that can be lent to banks (α) on the x axis (going from looser to tighter constraints).

Panel (a) considers the baseline ($\psi = 0$) and shows that the total dollar borrowing by banks, holding fixed end-user demand, begins to shrink once $\alpha < 0.35$. After this point, while wholesale funding continues to decline, synthetic funding no longer increases as CIP deviations become prohibitively expensive for banks. The 2011 European sovereign debt crisis serves as an illustrative case, when US MMFs declined their lending to European banks, turning cross-currency basis sharply negative while also decreasing USD lending in the Euro-area (Ivashina et al., 2015). Panel (b), which allows arbitrageur constraints to co-vary with α, shows that the threshold at which bank lending declines arrives sooner, at $\alpha = 0.4$. These counterfactual exercises quantify the trade-off between funding constraints and the global availability of US dollar, through the channel of prices.

Figure 9: Banks' Funding Composition and Lendable Dollars



(a) Baseline ($\psi = 0$)



(b) Correlated arbitrageur cost ($\psi = 0.5$)

Notes: This figure plots the quantitative impact of tighter wholesale funding constraints on banks' lendable dollars. The x axis represents the fraction of MMF corpus that can be lent to banks, and the y axis represents the quantity borrowed by banks from MMFs (brown line), FX swaps (blue line), and the total of the two (black line). The vertical dashed line in red marks the point beyond which tighter MMF constraints could lead to a reduction in banks' dollar assets because the marginal cost of swaps exceeds the marginal revenue from assets. Panel (a) considers the baseline where arbitrageurs' balance sheet cost, λ, does not tighten with money market fund lending limits. Panel (b) considers the case where λ positively co-moves with α.

Extensions. In ongoing work, I relax two assumptions currently embedded in the baseline calibration. First, I allow end-borrowers' demand for dollars (N in the model) to be correlated with funding market frictions. These situations may arise during global economic slowdown when MMFs face higher risk aversion in lending to banks, while firms that borrow dollars simultaneously experience a decline in underlying business activity. Second, I consider the possibility that banks pass on the increased cost of dollar funding to end-borrowers. Under a non-zero pass-through of the marginal cost of swaps to the rates that banks charge on dollar credit, the impact of wholesale funding frictions may be felt on the global price of dollars as opposed to its quantitative availability.

7. 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 investors in the form of increased hedging costs. My quantitative framework shows that the higher cost of synthetic dollar funding can ultimately restrict banks' ability to provide US dollar credit when their marginal revenue on dollar assets does not expand with wider cross-currency bases.

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Appendix

“Synthetic Dollar Funding”

Umang Khetan

March 2025

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.[34] 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 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

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

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.[35]

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 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

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

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 (tom/next)”), 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.

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.[36]

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

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

$$\text{Net \$ Borrowed}_{s,p,t} = \sum_{\substack{\tau \in -4,3, \\ \tau \neq -1}} \beta_\tau \times \mathit{Reltime}_\tau + \Delta \mathit{Price}_{p,t} + \alpha_{s,p} + \alpha_t + \varepsilon_{s,p,t}, \tag{29}$$

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

[36] 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.

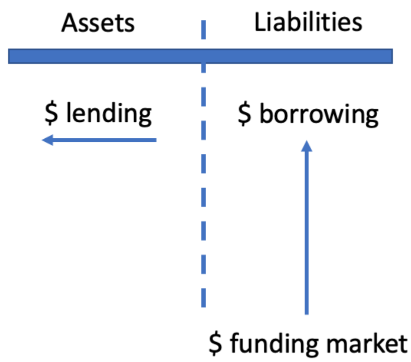
sector is global banks' borrowing from non-dealer banks, and control sectors are funds, non-financial corporations, and non-bank financial institutions. "Reltime" is the relative number of quarters since 2016Q1 when outflows from MMFs began to accelerate, as shown in Figure A7. The β_τ coefficient identifies the treatment effect in each of the eight quarters from 2015Q1 through 2016Q4, with 2015Q4 as the base. I control for the change in price in each currency-tenor combination as a covariate, and include interactive fixed effects for the sector-product combination, and time fixed effects. I estimate this specification at a quarterly level to smooth the noise arising out of quarter-end spike in volumes. Finally, I also run this specification separately on FX forwards as a placebo for robustness. Figure A8 plots the event studies for both swaps and forwards.

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

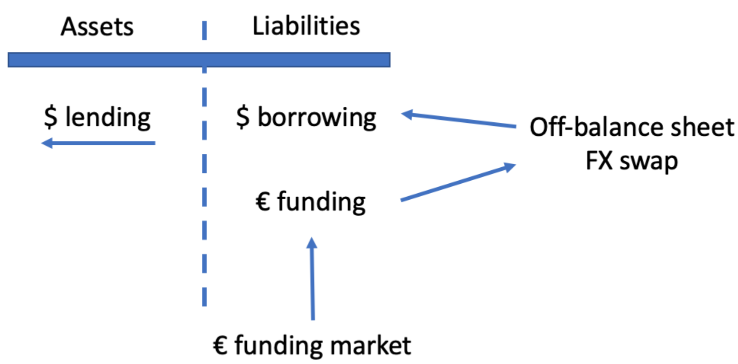
My interpretation of funding substitution is also complementary to Anderson, Du, and Schlusche (2021), who show that global banks reduced their arbitrage positions in USDJPY in response to the decline in MMF investments after the regulatory reform. The direction of the effect (increase in net borrowing)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

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

Figure A1: Direct and Synthetic Dollar Funding



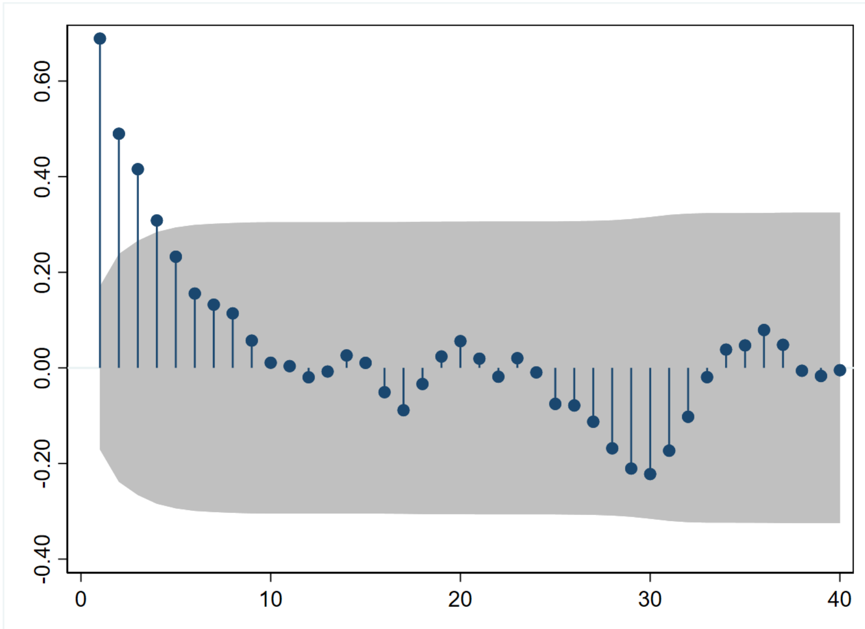
(a) Direct dollar funding



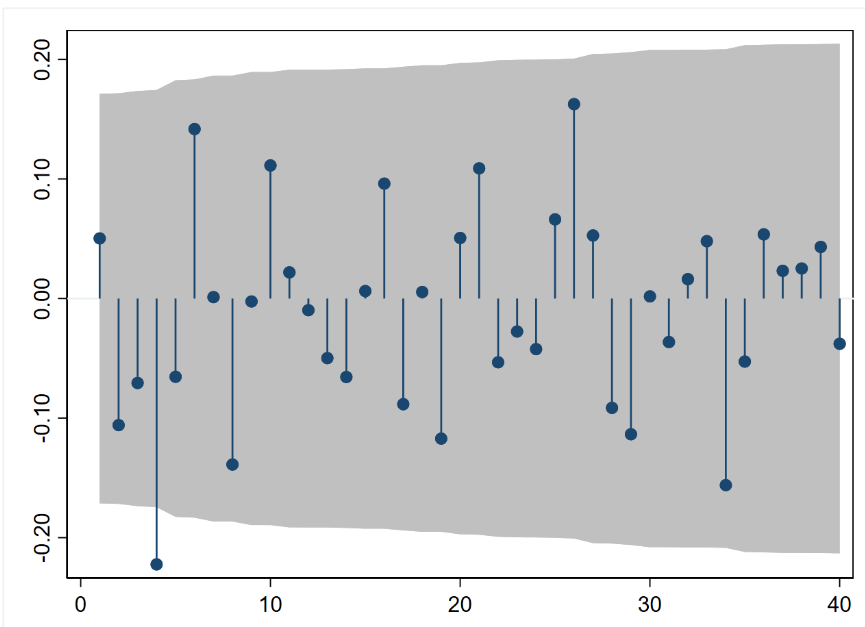
(b) Synthetic dollar funding

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

Figure A2: Autocorrelation Functions



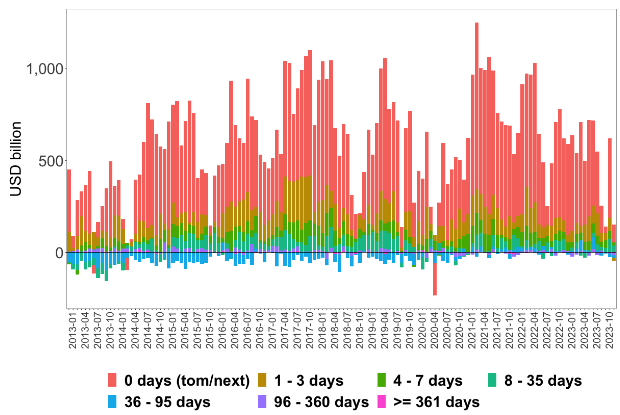
(a) Transaction Amount



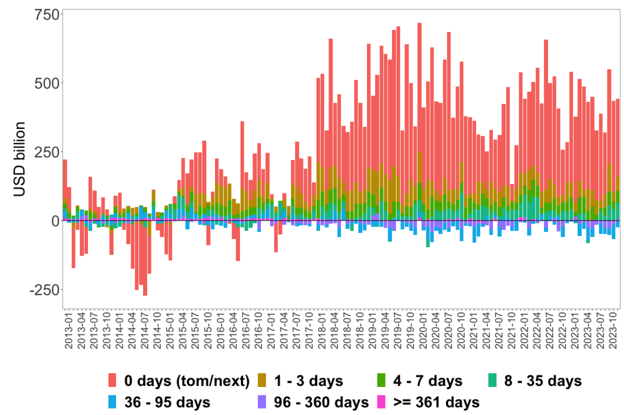
(b) % Change in Stock

Notes: This figure plots the autocorrelation functions for net $ borrowed by global banks using FX swaps. Panel (a) considers the net transaction amount, calculated as the dollar value of buy minus sell trades aggregated across all maturity buckets, counterparty sectors and days in a month. Panel (b) considers the monthly percentage change in the stock of dollars borrowed. The x axis in both plots reflects the number of lags, and the shaded region represents 95% confidence interval.

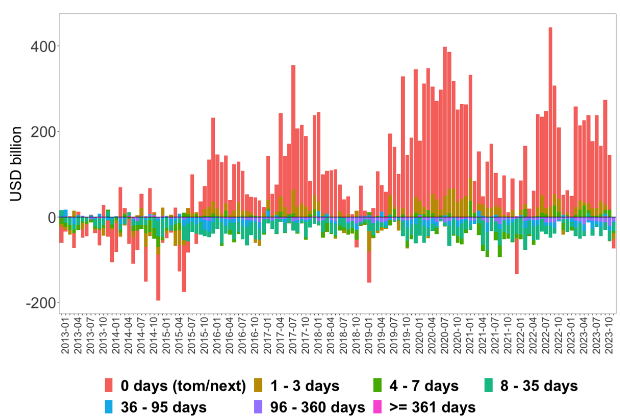
Figure A3: Currency-wise Synthetic Dollars Borrowed by Global Banks



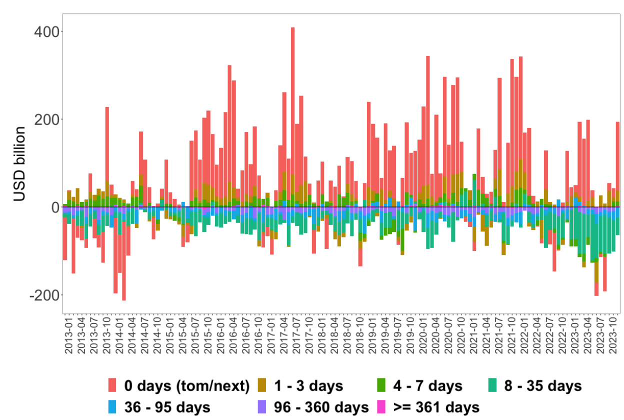
(a) Against EUR



(b) Against JPY



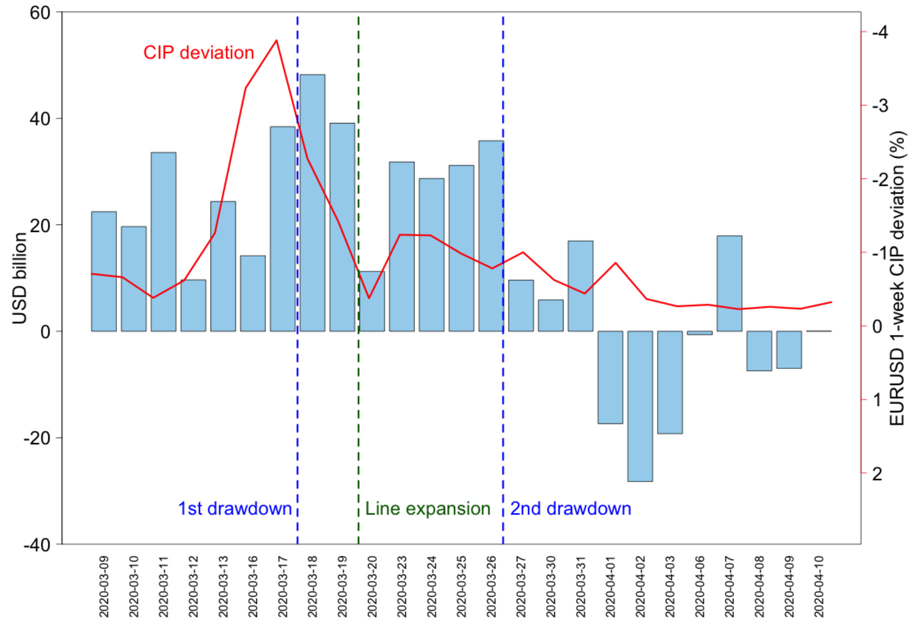
(c) Against CHF



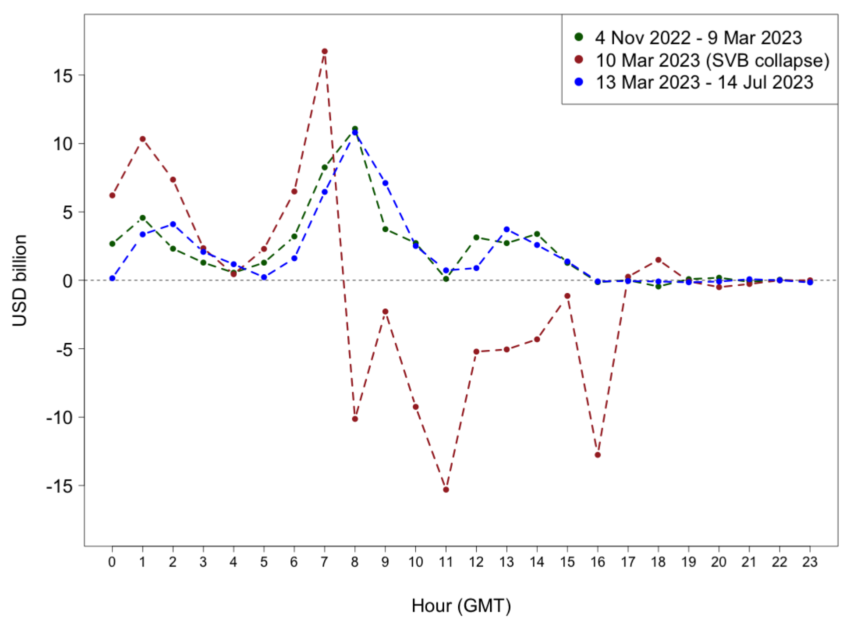
(d) Against GBP

Notes: This figure plots the quantity of USD borrowed (positive y-axis) or lent (negative y-axis) against the Euro (EUR) in panel (a), the Japanese yen (JPY) in panel (b), the Swiss franc (CHF) in panel (c), and the British pound (GBP) in panel (d), by globally active dealer banks from/to all other counterparty sectors put together. USD is borrowed 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 (tom/next)" corresponding to overnight borrowing whose near leg settles one day after trade date (T+1). 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 A4: Synthetic Dollar Funding during Macro-economic Disruptions



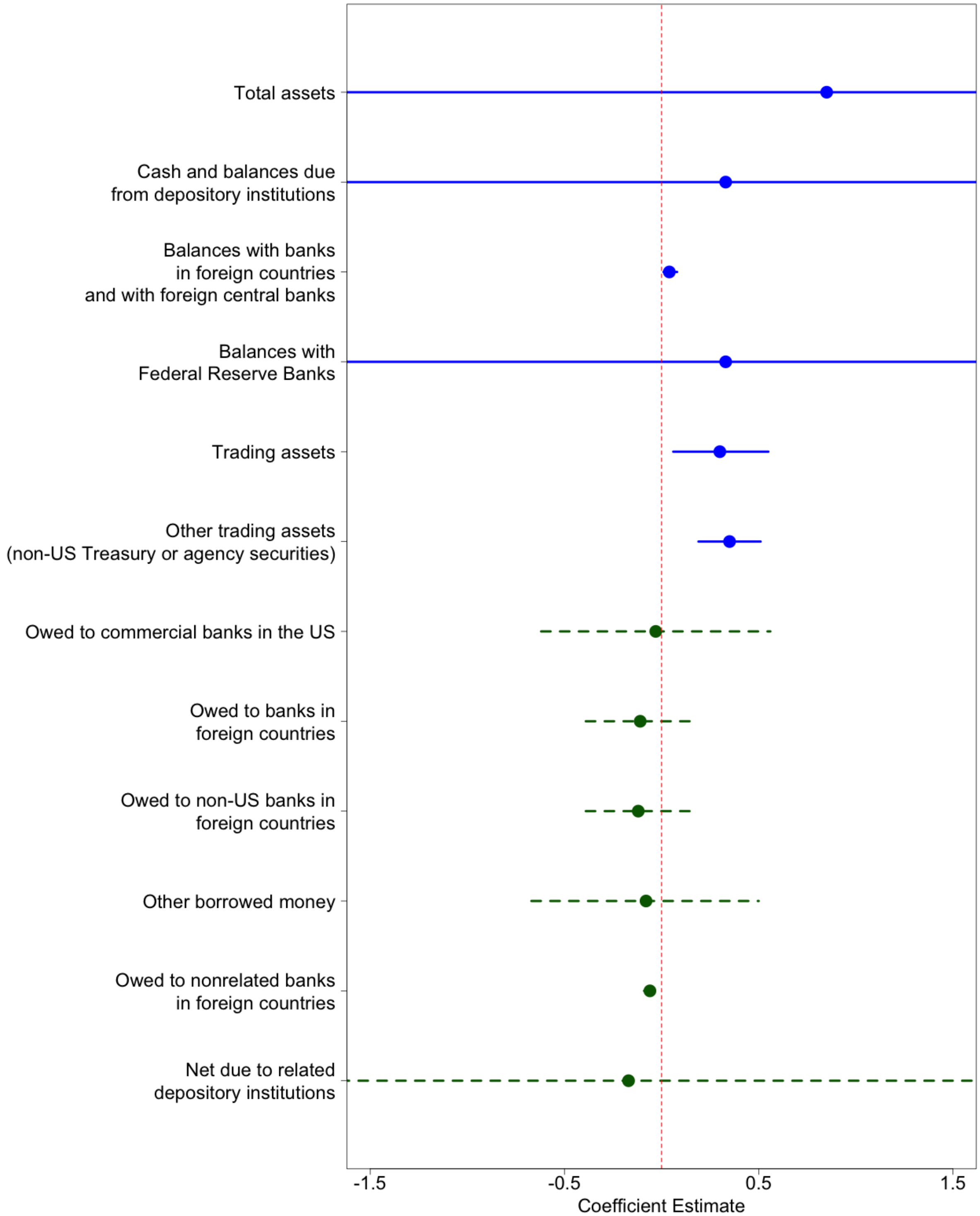
(a) March 2020 COVID-19 Pandemic and Central Bank Swap Lines



(b) Intra-day Pattern during Silicon Valley Bank Collapse

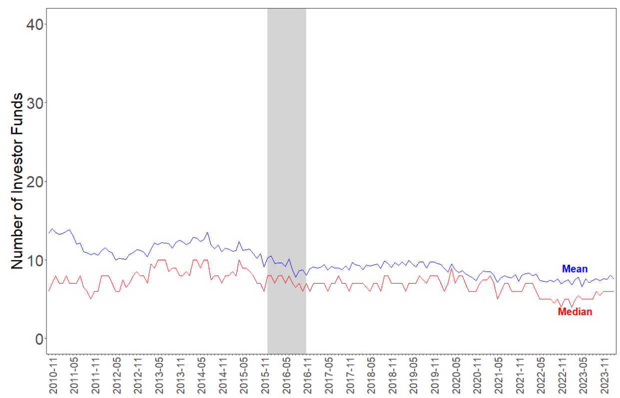
Notes: This figure plots the daily net synthetic dollars borrowed by global banks against EUR around the onset of the COVID-19 pandemic in panel (a), and intra-day hourly borrowing on the day of Silicon Valley Bank (SVB) collapse in panel (b). Panel (a) additionally plots the EURUSD 1-week cross-currency basis in red, and denotes the timing of central bank swap line drawdown by the European Central Bank using vertical dashed lines. Panel (b) shows that global banks were net lenders of dollars on the day of SVB collapse, relative to one quarter before and after the event.

Figure A5: MMF Investment and Balance Sheet of Foreign Banks' US Branches

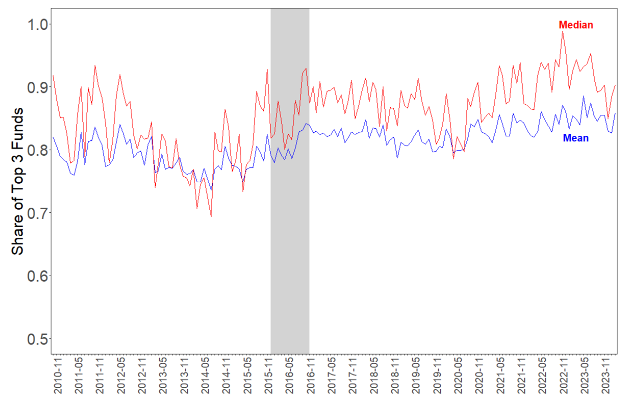


Notes: This figure plots estimates of Equation 1, where the dependent variables are each of the major line items on the balance sheets of US branches and agencies of non-US banks. Dots indicate point estimates and horizontal lines indicate 95% confidence intervals. Blue dots with solid lines are assets, and green dots with dashed lines are liabilities. Y axis is censored at -1.5/+1.5 for expositional clarity.

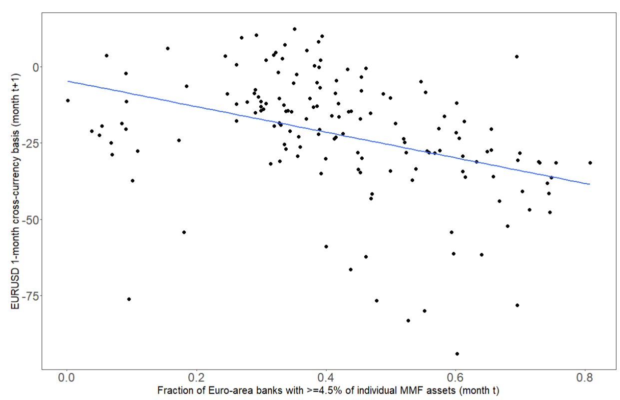
Figure A6: Drivers of Idiosyncratic Shocks to Money Market Fund Investments



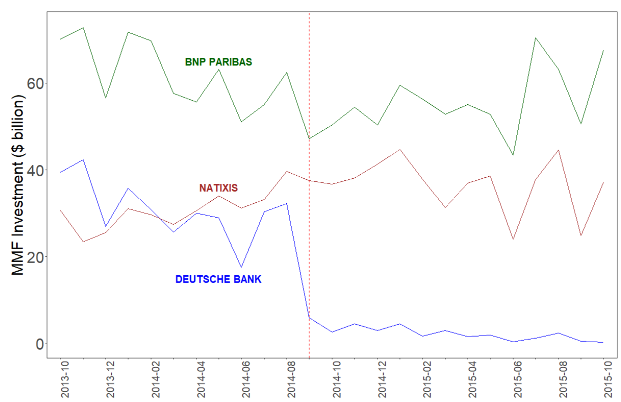
(a) Number of MMF Investors in a Foreign Bank



(b) Share of Top 3 MMFs in a Foreign Bank



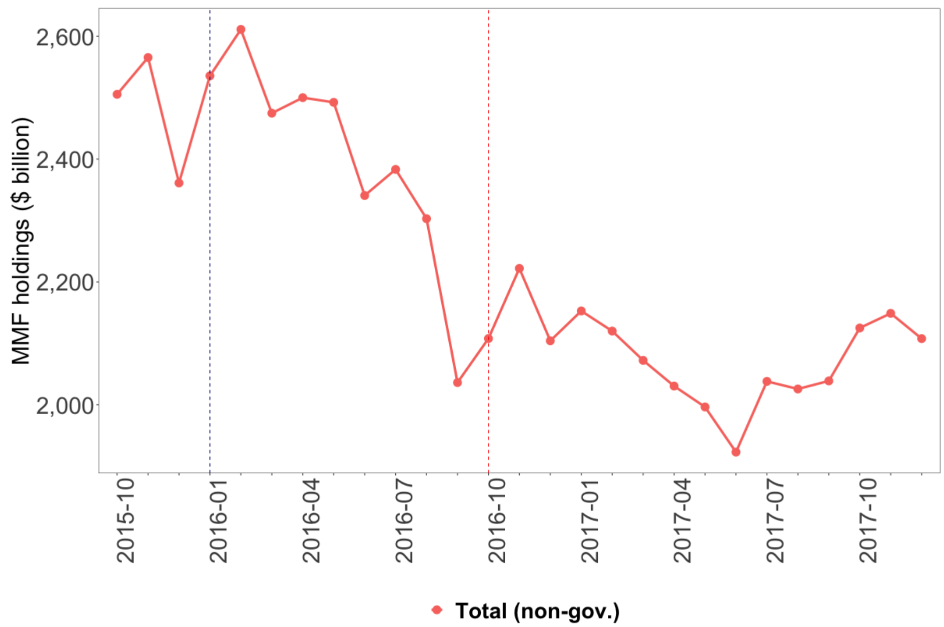
(c) Concentration limit vs. CIP deviations



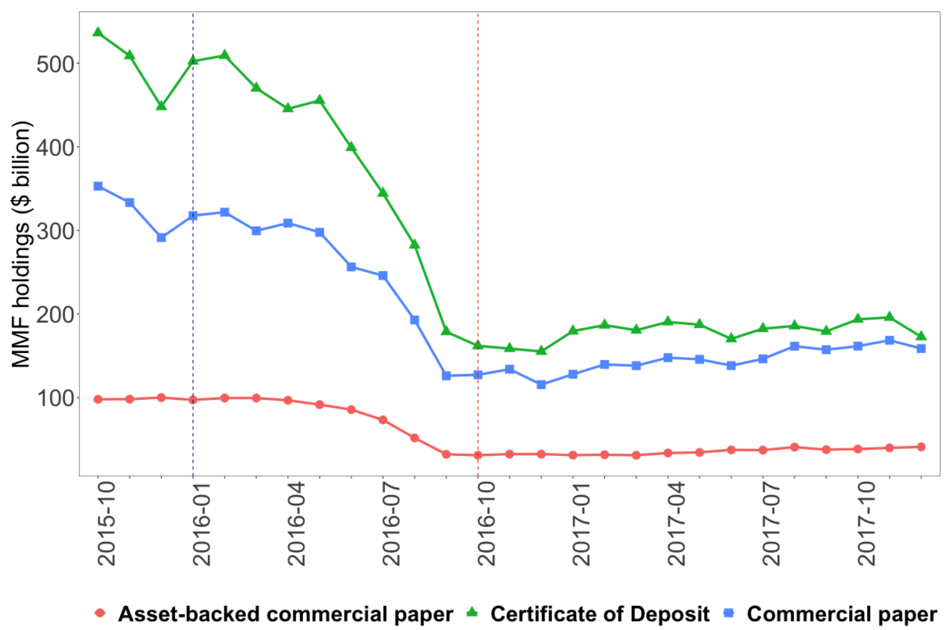
(d) Credit downgrade and MMF investment

Notes: This figure shows that (i) money market funds (MMF) represent a concentrated set of investors in bank securities, (ii) regulatory concentration limits on MMFs can occasionally bind, and (iii) MMFs sharply reduce investment in response to bank-specific credit downgrades. 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. Panel (c) correlates Euro-area banks' wholesale funding constraints with 1-month EURUSD cross-currency basis, where each dot in the scatterplot constitutes a monthly observation between December 2010 and December 2023. (The concentration limit on US MMFs' unsecured lending to individual borrowers is 5% of total assets.) Panel (d) shows a drop in MMF investments in Deutsche Bank in 2014 due to multiple credit rating downgrades with no impact on other Euro-area banks.

Figure A7: The 2016 Money Market Fund Reform Shock



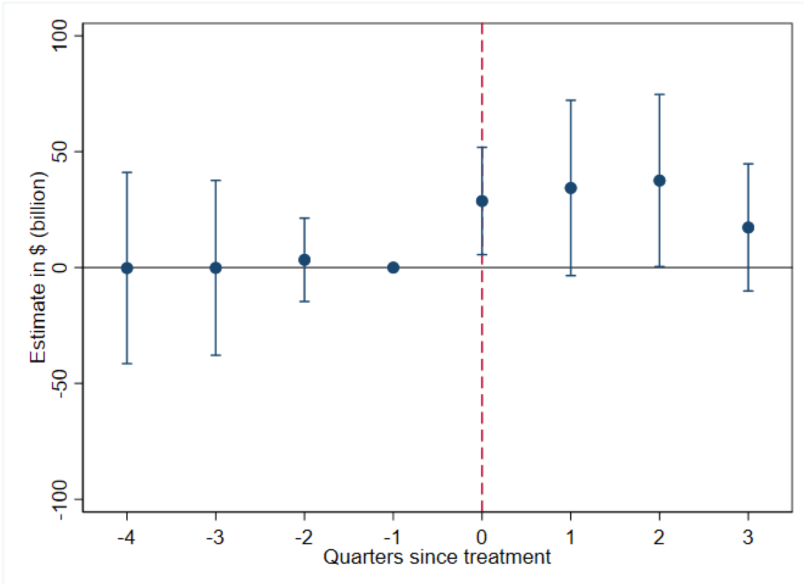
(a) Total non-government holdings



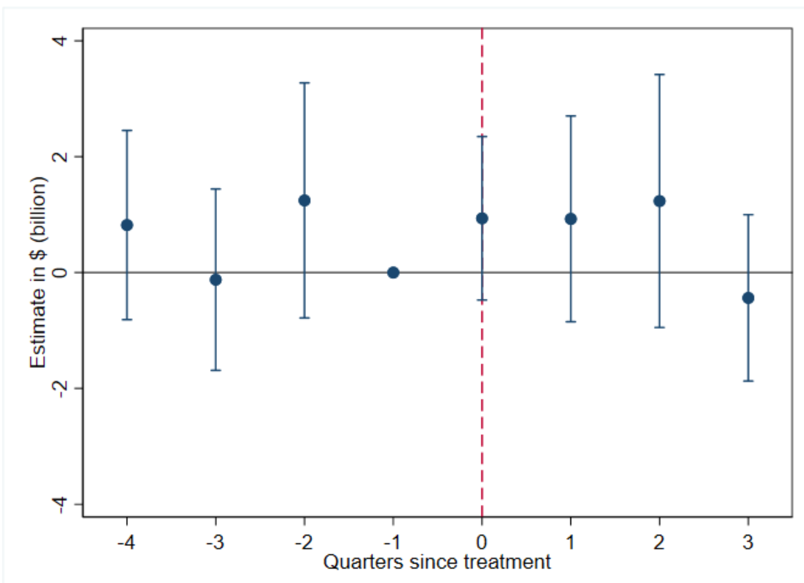
(b) Major bank-issued instruments

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

Figure A8: Treatment Effects of 2016 Money Market Fund Shock



(a) Swaps



(b) Forwards

Notes: This figure shows that global banks' dollar borrowing through FX swaps sharply increased after the implementation of the 2016 money market fund reforms. Both panels show the treatment effects in $ billion for the quarters around 2016Q1 when the transition period began, as shown in Figure A7. The β_τ coefficients from Equation 29 and 95% confidence intervals are displayed in blue. Panel (a) considers FX swaps where the effect is visible, whereas panel (b) considers FX forwards as a placebo where no treatment effect is visible. This figure also confirms the existence of parallel trends before treatment.

Table A1: Data Coverage and Representativeness

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

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

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

Panel A: By sector	Mean	SD	p25	p50	p75	N
All non-dealers	-0.29	3.89	-2.19	-0.28	1.43	2,853
NBFI	0.01	0.76	-0.16	-0.03	0.12	2,853
Fund	1.56	4.19	-0.30	1.08	2.83	2,853
Corporate	-0.68	1.81	-0.71	-0.21	0.00	2,853
Non-dealer Banks	-1.18	3.25	-2.81	-1.02	0.53	2,853
Panel B: By tenor	**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: 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 and MMF Holdings (Robustness)

Panel A: Lagged MMF flows	Net $ Borrowing by global banks			
	(1)	(2)	(3)	(4)
Δ MMF holdings (t-1)	-0.078	-0.091**	-0.092**	-0.084**
	(0.042)	(0.033)	(0.033)	(0.026)
Δ Assets		-0.024	-0.016	0.008
		(0.067)	(0.062)	(0.082)
Δ Gross position		0.039	-0.155	-0.605*
		(0.034)	(0.102)	(0.284)
Δ ILRS (log)		10.001	11.237	34.830
		(30.827)	(31.060)	(34.372)
Δ CBBS/GDP		4.986	4.934	7.394
		(3.159)	(3.108)	(7.148)
Δ US 1-month OIS		-0.089	-0.091	0.005
		(0.239)	(0.239)	(0.432)
Δ Spot		-1.367***	-0.875***	-1.290
		(0.125)	(0.113)	(0.908)
Δ Swap (overnight)		-0.772***	-0.780***	-0.805***
		(0.162)	(0.157)	(0.177)
N	1,048	780	780	780
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Panel B: EURUSD	% change in stock		count of net buy trades	
	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.180**	-0.171	-0.067**	-0.086*
	(0.077)	(0.127)	(0.034)	(0.046)
N	131	130	132	131
Controls	N	Y	N	Y

Notes: This table reports robustness of Table 3 to using lagged changes in money market fund flows, and considering only EURUSD swaps. Panel A re-estimates Equation 1 using lagged changes in MMF flows to global banks, with rest of the specification analogous to Table 3. Panel B repeats the estimation of Equation 1 for EURUSD swaps only, which forms the largest segment of swaps market. In panel A, standard errors clustered by currency are reported in parentheses. In panel B, Newey-West standard errors (lags=3) are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A5: Sector-wise Synthetic Dollar Funding and MMF Holdings

	Net $ Borrowing by global banks from			
	Non-dealer Banks	Fund	Corporate	NBFI
	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.293***	-0.020	-0.038	-0.014
	(0.084)	(0.013)	(0.077)	(0.072)
Δ Assets	0.029	-0.012	-0.148	-0.113
	(0.066)	(0.045)	(0.099)	(0.090)
Δ Gross position	-0.212	0.075**	0.232	0.150*
	(0.188)	(0.021)	(0.187)	(0.067)
Δ ILRS (log)	-2.765	-4.208	-17.551	-9.427
	(19.090)	(9.259)	(18.106)	(31.265)
Δ CBBS/GDP	6.765	1.242	-7.792	-0.103
	(8.911)	(1.283)	(3.893)	(3.137)
Δ US 1-month OIS	-0.098	0.019	-0.113	-0.037
	(0.171)	(0.362)	(0.128)	(0.0896)
Δ Spot	-0.951***	-0.595***	-1.673**	4.696***
	(0.210)	(0.076)	(0.428)	(0.132)
Δ Swap (overnight)	-0.896***	-0.023	-0.458***	0.016
	(0.120)	(0.020)	(0.065)	(0.107)
N	780	780	775	779
Currency FE	Y	Y	Y	Y

Notes: This table reports estimates for a model of the form in Equation 1, separately estimated for swap trades between dealer banks and other sectors. The dependent variable is the percentage change in the stock of synthetic dollars held by global banks facing non-dealer banks in column (1), funds in column (2), corporate entities in column (3), and non-bank financial institutions in column (4). Rest of the specification is analogous to column (3) of Table 3. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A6: Forward Purchase of US Dollar and MMF Holdings

	Dollars purchased forward by global banks			
	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.046	-0.058	-0.058	-0.082
	(0.052)	(0.062)	(0.061)	(0.055)
Δ Assets		0.116	0.100	0.026
		(0.223)	(0.231)	(0.152)
Δ Gross position		0.052**	0.485	0.559*
		(0.017)	(0.259)	(0.250)
Δ ILRS (log)		37.362	34.430	7.749
		(25.687)	(25.983)	(41.655)
Δ CBBS/GDP		9.360*	9.457*	11.915*
		(4.133)	(4.077)	(5.464)
Δ US 1-month OIS		-0.084	-0.0889	-0.627
		(0.147)	(0.148)	(0.367)
Δ Spot		5.623***	6.104***	4.784**
		(0.822)	(0.929)	(1.453)
Δ Swap (overnight)		0.435***	0.438***	0.350***
		(0.081)	(0.078)	(0.066)
N	1,048	780	780	780
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Notes: This table reports estimates of Equation 2 where the dependent variable is the change in the stock of net dollars bought forward by global banks from all other sectors. The regressor of interest is the change in money market fund holdings of banks located in the respective currency, denoted as Δ MMF holdings and expressed in $ billion. Columns (2) through (4) include controls, columns (3) and (4) include currency fixed effects, and column (4) includes time (year-quarter) fixed effects. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A7: Synthetic Dollar Funding and Interest Rates

	Δ Fraction Synthetic			
	(1)	(2)	(3)	(4)
Δ US 1-month OIS	-0.029***	-0.028**	-0.028**	-0.044*
	(0.007)	(0.009)	(0.009)	(0.019)
Δ ILRS (log)		4.269	4.273	2.956
		(3.098)	(3.099)	(3.416)
Δ CBBS/GDP		0.414	0.414	0.862
		(0.212)	(0.211)	(0.557)
Δ Spot		-0.282*	-0.285*	-0.201*
		(0.137)	(0.139)	(0.097)
Δ Swap (overnight)		-0.047**	-0.046**	-0.050**
		(0.016)	(0.016)	(0.013)
N	786	786	786	786
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Notes: This table reports estimates of Equation 3. The dependent variable is the change in the fraction of dollars borrowed by global banks via FX swaps to total dollar assets 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, columns (2) through (4) include controls, columns (3) and (4) include currency fixed effects, and column (4) includes time (year-quarter) fixed effects. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A8: Investment Funds' Carry Trade

Panel (EUR, JPY, CHF, GBP)	Net \$ Supply (≤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 (≤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:

$$\text{Net \$ Supply } (\leq 1 \text{ month})_{C.t} = \beta \text{Net \$ Supply } (1 \text{ - } 3 \text{ months}) + \alpha_C + \alpha_t + \varepsilon_{C,t}, \quad (30)$$

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 A9: 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 A10: 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.