Synthetic Dollar Funding

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August 2025

Abstract

I study how funding market frictions shape the pricing and availability of U.S. dollar credit. Firms around the world rely on large global banks to obtain dollar credit. Yet, post-financial crisis regulations have restricted banks' access to conventional wholesale funding markets. Using comprehensive transaction-level data across major funding markets, I show that foreign exchange swaps emerge as a key alternative when wholesale funding dries up. Swaps allow banks to convert foreign currency funds into U.S. dollars, creating a supply of "synthetic" dollars while hedging currency risk. However, this workaround is not costless: as suppliers of synthetic dollars face balance sheet costs, swap prices increase with demand. I find that a 10% rise in banks' demand raises the relative price of synthetic dollars by 7 bps, providing a novel demand-driven mechanism for persistent violations of covered interest parity – a fundamental no-arbitrage condition. Through the lens of a bank funding model calibrated to my estimates, I show that the resulting increase in intermediation costs ultimately disrupts the availability of dollar credit. My findings illustrate how funding frictions can threaten dollar dominance in the international financial system.

Keywords: U.S. dollar, global banks, FX swaps, covered interest rate parity, financial frictions.

JEL classification: E44, F31, F36, G01, G11, G15, G20

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I am grateful to Tong Yao, Ishita Sen, Fotis Grigoris, Petra Sinagl, and the late David Bates for guidance and feedback. This paper benefited from helpful comments by Iñaki Aldasoro, Adolfo Barajas (discussant), Falk Bräuning, Ricardo Correa (discussant), Filipe Correia, Wenxin Du, Zhiyu Fu, Xavier Gabaix, Marco Graziano (discussant), Bryan Gutierrez, Ingomar Krohn (discussant), Victoria Ivashina, Jetson Leder-Luis, Thomas A. Maurer (discussant), Ioana Neamțu, Charlotte Østergaard (discussant), Jonathan Parker, Richard Peter, Fabiola Ravazzolo, Marco Sammon, Fabricius Somogyi, Hillary Stein, Jeremy Stein, Adi Sunderam, Olav Syrstad, Judit Temesvary (discussant), Ashish Tiwari, Philippe van der Beck, Andrea Vedolin, Jonathan Wallen, Anthony Lee Zhang, and participants at the American Finance Association (PhD poster), Bank for International Settlements - University of Basel, CFTC, European Finance Association (doctoral tutorial), Midwest Finance Association, Office of Financial Research PhD Symposium, Federal Reserve Bank of Atlanta - Georgia State University, Federal Reserve Board Short-Term Funding Markets Conference, University of Iowa, and University of Zurich. I thank Mark Socha and Femi Opeodu at the Continuous Linked Settlement Group (CLS) for data access and for answering my numerous questions. The findings and conclusions in this paper do not necessarily reflect the views of CLS. All errors and omissions are my own. This paper is scheduled to be presented at: Northern FA, FMA, European Central Bank.

The recent escalation in cross-border trade tensions has raised concerns about disruptions to U.S. dollar liquidity in the international financial system.[1] A large number of financial and non-financial firms worldwide seek access to U.S. dollar credit, and constraints in dollar supply are known to destabilize asset markets and the real economy, often necessitating central bank intervention (Avdjiev, Du, Koch, and Shin, 2019, Bahaj and Reis, 2022).[2] At the heart of this system are large global banks that facilitate cross-border dollar flows. Strikingly, a majority of dollar credit is provided by *non-U.S.* banks that have limited access to stable funding sources such as insured deposits, making them particularly vulnerable to dollar liquidity disruptions.

Global banks rely on two major short-term dollar funding markets. The first is the on-balance sheet wholesale market (e.g., repurchase agreements, commercial paper, and certificates of deposit), accounting for $5 trillion in global funding (Committee on the Global Financial System, 2020). Although large and systemically important, wholesale markets are subject to regulatory constraints and policy levers that can limit access, especially for non-U.S. borrowers. For example, following a series of destabilizing runs during the 2008 financial crisis, regulations significantly curtailed wholesale investors' exposure to risky banks (Kacperczyk and Schnabl, 2013). While existing research shows that such restrictions affect banks' access to dollar liquidity, it often considers wholesale markets in isolation, overlooking their interaction with and spillovers to alternative funding sources.

This paper examines the second major source of dollar funding: the off-balance sheet *synthetic* market via foreign exchange (FX) swaps. Under this arrangement, banks first raise funds in a foreign currency, e.g., the euro, and then temporarily exchange them for dollars while hedging the currency risk. As a measure of its importance, outstanding swap notional held by banks exceeds $60 trillion – potentially comprising up to two-thirds of some banks' total dollar debt (Borio et al., 2022). Yet, despite its size and relevance, the role of synthetic markets in banks' funding portfolio remains poorly understood. A key challenge is that swap quantities are rarely observed, leaving fundamental questions unanswered: Do swaps allow banks to offset declines in wholesale dollar liquidity? If so, what are the implications for the pricing and global availability of dollar credit?

Using a comprehensive dataset linking banks' swap transactions with their wholesale funding activity, this paper makes three contributions. First, I show that global banks turn to synthetic dollar funding when the availability of wholesale dollars declines. FX swaps, resembling collateralized revolving credit facilities, are facilitated by *foreign* depositors and specialized intermediaries, i.e.,

[1] For example, *"European banks exposed to risk of US dollar shortfall"*–Financial Times (April 2025), and *"EU firms fear dollar liquidity becoming tariff bargaining chip"*– Risk.net (April 2025).

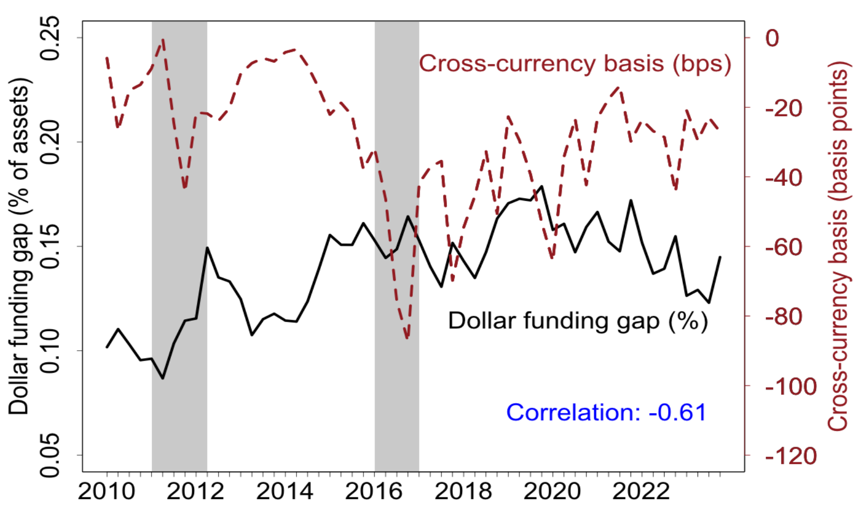
[2] Firms around the world rely on dollar funding for trade credit, working capital, and long-term debt. This "dollar dominance" is reflected in 75% of cross-border trade invoicing, 67% of foreign currency debt, 60% of central bank reserves, and 40% of international payments (Bertaut et al., 2021, Jiang et al., 2021, Gopinath and Stein, 2021). As a result, disruptions in dollar funding can trigger widespread economic distress.

swap arbitrageurs. This allows banks operating in multiple money markets to raise dollars synthetically when wholesale funding cannot scale. A direct implication of my finding is that banks' dollar lending may appear insulated from wholesale funding frictions if the role of swaps is overlooked. At the same time, reliance on swaps obscures the true size of banks' dollar debt, which is not fully captured by conventional on-balance sheet sources. By leveraging transactions data directly from the swap market, I provide new evidence of this hidden dimension of banks' dollar debt.

My second contribution is to show that banks' demand distorts swap prices from their fundamental no-arbitrage values, leading to violations of covered interest parity (CIP). When CIP holds, the "cross-currency basis" - gap between wholesale and synthetic funding costs - is near zero. In practice, however, bases are often negative, implying that synthetic dollar funding is more expensive. Such deviations are known to have real economic consequences on credit allocation (Keller, 2024), cross-border capital flows (Kubitza et al., 2024), and corporate investment (Ippolito et al., 2024). A common explanation emphasizes balance sheet costs faced by dollar suppliers in the swap market. For example, post-crisis regulations such as the Basel III leverage ratio have raised the cost of risk-free arbitrage (Du, Tepper, and Verdelhan, 2018, Rime, Schrimpf, and Syrstad, 2022).

I complement this view by showing that banks' *demand* is a central driver of negative bases. As a starting point, Figure 1 shows a strong negative correlation between non-U.S. banks' dollar funding gaps and the basis, consistent with banks turning to swaps to bridge funding shortfalls.

Figure 1: Dollar Funding Gap of Non-U.S. Banks and Cross-Currency Basis



Notes: This figure plots the quarterly time series of non-U.S. banks' dollar funding gap (solid line in black) and 1-month cross-currency basis across all USD-facing currencies (dashed line in brown). Dollar funding gap is defined as the difference between on-balance sheet dollar assets and liabilities, scaled by total assets, 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 U.S. money market fund reforms in 2016. Data source: BIS Locational Banking Statistics and BIS Consolidated Banking Statistics.

I provide the first causal evidence that banks' synthetic dollar demand is a key driver of CIP deviations. Leveraging institutional features of wholesale funding markets, I construct an instrument for swap demand that exploits bank-specific shocks to wholesale dollar availability. Using this instrument, I show that the cross-currency basis becomes significantly more negative, i.e., synthetic dollars become costlier, as banks' swap demand rises. My results identify an important demand-side determinant of CIP deviations, one not confined to specific calendar dates. Importantly, I show that more negative bases directly increase banks' effective cost of dollar intermediation.

My third contribution is to quantify the limits of the synthetic market in offsetting sharp wholesale funding shortfalls. If U.S. regulators further restrict non-U.S. banks' access to wholesale markets, how much of that shortfall could FX swaps replace? To answer this counterfactual question, I follow Ivashina, Scharfstein, and Stein (2015) and build a model in which banks use synthetic funding until the marginal cost (cross-currency basis) equals the marginal return on dollar assets. My key innovation is to incorporate a constrained swap arbitrageur, allowing the basis to respond endogenously to banks' demand. Calibrating the model to my empirical estimates, I show that the basis widens sharply as wholesale funding constraints tighten. Two implications follow. First, severe wholesale funding shocks ultimately curtail U.S. dollar credit as the marginal cost of swaps exceeds banks' asset returns. Second, I reconcile contrasting findings in the literature by quantifying the conditions under which wholesale funding shocks translate into lending effects.

FX swaps are among the most heavily traded financial instruments, but their over-the-counter nature limits visibility into quantities traded by participants. To overcome this challenge, I leverage a novel dataset of daily dealer-to-client FX swap transactions from CLSMarketData, compiled by the CLS Group, which operates the largest multi-currency cash settlement system in the world. My sample spans seven tenors and nine major currency pairs that together represent over 90% of swaps trading, and covers a quarter of dealer-to-client volume. This enables granular, high-frequency measurement of synthetic dollar funding and its connection to wholesale markets. Notably, the dataset disaggregates transactions by different sectors, and over an 11-year period from 2013 through 2023, encompassing the entire business cycle. To my knowledge, it is one of the most comprehensive datasets on the flow of FX swaps used in academic research to date.

To measure global banks' wholesale funding, I focus on U.S. money market funds (MMFs), e.g., Vanguard and Blackrock, which provide a useful setting to study wholesale funding frictions for three reasons. First, with $1.2 trillion invested in 2023, MMFs have been among the largest holders of short-term dollar debt issued by non-U.S. banks, both pre- and post-crisis (Aldasoro and Doerr, 2023). Second, MMFs face regulatory investment constraints—such as concentration limits on unsecured credit—making them a realistic setting for my counterfactual analysis (Chernenko and Sunderam, 2014). Third, granular and non-anonymized regulatory data on the universe of

U.S. MMF holdings in banks are available, that allow me to jointly analyze wholesale and synthetic funding markets, and construct instruments to identify the price impact of demand shifts.

I begin by characterizing the demand for synthetic dollar funding. Banks raise dollars via swaps at overnight to three-month tenors, primarily against the euro (EUR) and the Japanese yen (JPY). Global dealer banks are the largest borrowers in this market, and non-dealer banks act as suppliers.[3] I construct a currency-month panel of money market fund (MMF) investments in banks domiciled in a given country, alongside banks' synthetic dollar borrowing against the local currency. I find that a standard deviation decline in wholesale funding is associated with a 22% increase in banks' demand for synthetic dollars. This characterization aligns with a pecking order of funding sources: banks turn to (costlier) synthetic dollars when (cheaper) wholesale funding dries up.

An alternate explanation for my results could be that banks choose the cheaper of two funding sources, rather than respond to *quantitative* constraints in wholesale funding. To show that cost differential is not the underlying mechanism, I exploit a major regulatory reform that triggered a sharp contraction in MMF assets. In 2016, the Securities and Exchange Commission implemented structural changes to MMFs for improving their financial stability. Provisions of this reform (e.g., a shift from fixed to floating net asset value) led to investor outflows from "prime funds", that largely invested in unsecured bank debt. As a result, global banks lost over $250 billion in wholesale funding. Using a difference-in-differences approach with non-bank swap users as controls, I find that banks significantly increased their reliance on synthetic dollars in the months following the reform. This shift was both immediate and persistent, and not driven by pre-trends.

Banks' use of synthetic dollars to offset wholesale funding declines has important asset pricing implications. I show that an increase in banks' demand for swaps turns cross-currency bases more negative, i.e., makes synthetic dollars costlier. A 10% rise in net demand lowers the 1-month basis by about 7 bps, which is economically meaningful compared to a sample average of -26 bps. Since quantities and prices are jointly determined in equilibrium, I identify the price impact using an instrumental variables strategy that exploits plausibly exogenous variation in the availability of wholesale dollars to banks, which shifts their swap demand independently of confounding factors.

The key idea of my identification strategy is to isolate *idiosyncratic shocks* to banks' wholesale funding from broad market shifts, that may be correlated with confounding factors such as macroeconomic volatility or swap arbitrageurs' constraints. These shocks arise from several sources: (i) MMF-specific investor flows that impact banks based on their *ex ante* exposure to those funds (akin to a shift-share instrument), (ii) banks' differential proximity to regulatory concentration limits on MMFs, and (iii) bank-specific credit downgrades that reduce MMF investments in the

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

affected banks only. I exploit these sources of variation using the granular instrumental variables framework of Gabaix and Koijen (2024), who show that in economies dominated by a few large agents, idiosyncratic shocks to those agents can aggregate into significant macro-level fluctuations.

I construct my currency-specific instrument as the size-weighted sum of bank-level MMF flows, purged of common factors and time trends, and term it “excess wholesale funding.” A higher value of my instrument strongly associates with lower net synthetic dollar demand, confirming its relevance. The segmentation in MMF flows across borrower types also ensures that my instrument satisfies the key exclusion criteria - wholesale funding shocks to non-U.S. banks do not correlate with other factors that could independently affect the basis. Using this instrument, I confirm that synthetic dollar demand causes cross-currency bases to turn more negative. Importantly, the price effect is not confined to quarter-ends, and reflects persistent funding constraints faced by banks.

When banks face additional costs in raising dollar funding, it raises an important question in the current policy backdrop: can synthetic markets fully offset a decline in wholesale funding without hampering dollar credit provision? To address this question, I develop a model in which global banks source dollar funding from wholesale and synthetic markets, building on Ivashina et al. (2015) with three key extensions. First, given that cross-currency bases have been persistently negative since 2008, banks exhaust available wholesale funding before turning to swaps to cover any shortfall. Second, I introduce a swap arbitrageur to makes the basis an equilibrium object, allowing banks to endogenize the price impact of their swap demand. Third, I calibrate the model to my data and empirical estimates to derive counterfactual results.

I find that a reduction of more than 20% in wholesale funding beyond current limits can hamper dollar lending by global banks. At this threshold, the marginal cross-currency bases exceed the marginal returns on banks’ assets, prompting them to either scale back lending or raise the cost of dollar credit. This threshold arrives earlier when swap arbitrageurs’ balance sheet costs co-move with the availability of wholesale dollars. Under such conditions, funding from outside the system, e.g., through central bank swap lines, becomes necessary to alleviate dollar shortages. On the other hand, increased wholesale funding to banks could halve the basis from -26 bps to -13 bps, with minimal additional default risk borne by U.S. wholesale investors.

My work 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. As I show in this paper, part of this demand has shifted to FX swaps, an off-balance sheet product that can add to financial opacity, complicating the implementation of macro-prudential policies (Barajas et al., 2020, Borio et al., 2022). To this end, my paper presents an early step in understanding the linkages across funding markets, which can help to assess the impact of domestic liquidity policies on the price, availability, and ultimately the dominance of U.S. dollar in the global economic system.

More broadly, my results provide a useful framework for analyzing markets where different regulations intersect to determine the distribution of risks. When banks raise dollars synthetically, default risk shifts from U.S. investors to foreign depositors. However, regulations that increase the cost of renting swap arbitrageurs' balance sheets limit banks' ability to swap foreign currency into dollars. Similar trade-offs arise in other markets. For example, central bank bond purchase can push investors into using derivatives for gaining duration exposure, but dealers' balance sheet constraints limit their capacity to absorb this flow, resulting in mispricing (Khetan et al., 2023). These frictions call for a coordinated approach to regulations that interact in major financial markets.

Related literature. This paper contributes to the literatures on short-term funding markets, international asset pricing, and cross-border bank lending.

A large body of work recognizes that frictions in short-term wholesale funding markets have increased the cost of bank balance sheets and exposed them to funding dry-ups (Schmidt, Timmermann, and Wermers, 2016, Pérignon, Thesmar, and Vuillemey, 2018, Andersen, Duffie, and Song, 2019, Fleckenstein and Longstaff, 2020). My unique contribution is to analyze the growth of off-balance sheet derivatives that enable global banks to sidestep wholesale funding constraints. Relative to other studies that indirectly hint at banks' use of derivatives (Iida et al., 2018, Barajas et al., 2020), my ability to observe executed swap transactions is key to providing direct evidence of demand substitution from on- to off-balance sheet instruments.

In doing so, my research contributes to the literature on banks' internal capital management under funding frictions: Cetorelli and Goldberg (2012) show that global banks manage liquidity using cross-border funding that insulates them from local monetary policy shocks; Correa, Du, and Liao (2020) find that large U.S. banks drain reserves parked with the Federal Reserve to finance short-term lending; Du and Schreger (2022) argue that non-U.S. banks face barriers in accessing dollar cash markets; Siriwardane, Sunderam, and Wallen (2022) document segmentation in banks' internal funding sources; and Keller (2024) focuses on the currency composition of bank lending in partially dollarized economies. My study adds to 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 deviations from covered interest parity (CIP). Several studies document that supply-side frictions create limits to swap 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-U.S. 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 systematic variation in global banks' dollar liabilities. 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 wholesale funding with synthetic funding.

Studies that link money market funds (MMFs) with CIP deviations include Anderson, Du, and Schlusche (2021), who argue that a 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 et al. (2015). The key feature of my paper that allows for such distinction is the use of actual swaps transaction data. These data also enable the measurement of demand shifts, that I use to estimate the steepness of swap arbitrageurs' supply curve. Related studies on banks' cross-border lending and USD strength include Becker, Schmeling, and Schrimpf (2023) and Bippus, Lloyd, and Ostry (2023).

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 et al. (2024) document that Euro-area banks substitute repo funding with FX swaps at quarter-ends. My paper focuses on persistent limits to wholesale 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, leverage ratio regulations make it particularly costly for arbitrageurs to price FX derivatives at quarter-ends, sharply affecting the supply curve (Cenedese et al., 2021).[4] Second, Abbassi and Bräuning (2021) argue that banks' end-of-quarter demand reflects regulatory arbitrage, which is distinct from the ongoing wholesale funding frictions that I focus on. Third, Wallen (2020) shows that U.S. banks exercise market power at quarter-ends which can explain a significant part of CIP deviations. Finally, non-bank end-users may also face end-of-period liquidity shocks, due to "dash for cash" for institutional investors (Etula et al., 2020) or "settlement breaks" for corporations (Khetan and Sinagl, 2023), which may not reflect funding market frictions.

[4] Global Systemically Important Banks (GSIBs) also face year-end capital surcharge (Favara et al., 2021).

I contribute to the literature linking funding frictions to cross-border bank lending by focusing on the role of large but often overlooked synthetic markets. While recent work has examined the fragility of deposit funding—particularly after the Silicon Valley Bank collapse (e.g., Blickle et al. (2024))—my paper highlights the behavior of banks that lack dollar deposits yet remain key providers of dollar credit. Ivashina et al. (2015) offer an early theoretical framework for non-U.S. banks' dollar lending, extended by Iida et al. (2018) to include swap arbitrageurs. My paper is the first to calibrate key parameters of these models, enabling me to quantitatively link funding frictions to real economic outcomes. My counterfactual estimates speak to important policy questions, such as the impact of domestic liquidity restrictions on global dollar availability, allowing me to extend the discussion on cross-border trade tensions from physical goods to encompass capital flows.

Outline. This paper proceeds as follows. Section 1 provides the institutional background and discusses the data. Section 2 analyzes the demand for synthetic dollar funding. Section 3 shows the causal impact on prices and spillover impact on non-banks. Section 4 calibrates the model to provide analytical and quantitative insights. Section 5 concludes.

1. Institutional Background and Data

With over 14 trillion in U.S. dollar-denominated assets (panel (a) of Figure A1), non-U.S. global banks play a pivotal role in supplying dollar credit to various segments of the world economy. Much of this credit takes the form of short-term working capital loans and credit lines to firms engaged in cross-border trade and capital flows.[5] Despite their large asset holdings, branches of non-U.S. banks do not have direct access to FDIC-insured retail deposits. In the absence of deposits, banks rely on wholesale money markets for on-balance sheet funding (Aldasoro et al., 2022), and on foreign exchange swaps for off-balance sheet funding (Borio et al., 2022). This section describes the construction of my sample that jointly covers these two major short-term funding markets.

1.1. Wholesale Funding via Money Market Funds

To analyze banks' wholesale funding activity, I focus on U.S. money market funds (MMFs), including major institutions such as Vanguard and BlackRock. MMFs are tightly regulated investment vehicles that invest in short-term fixed income securities issued by governments, banks, and non-bank financial institutions, with capital preservation as their primary objective. They offer an ideal setting for analyzing wholesale funding markets for three key reasons. First, MMFs disclose granular, non-anonymized security-level holdings data, that is central to my identification strategy.

[5] Iida et al. (2018) report that non-U.S. banks have a larger market share in international USD lending than U.S. banks and Correa et al. (2021) show that non-U.S. banks are also active lenders to U.S. firms.

Second, they are among the largest investors in bank debt: as of 2023, U.S. MMFs managed over $5 trillion in assets, with nearly half allocated to bank-issued secured and unsecured debt securities. Third, MMFs are both risk-averse and subject to external regulatory levers, making them well suited for studying policy-induced shifts in funding flows. I elaborate on these features below.

1.1.1. Money Market Fund Holdings Data

U.S. MMFs disclose their holdings at a monthly frequency. I source these records from the N-MFP filings 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.[6] Following Chernenko and Sunderam (2014) and Cipriani and La Spada (2021) in the merging and cleaning of these data, I compute bilateral exposures between MMFs and banks at a legal entity identifier (LEI) level. 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 deposits for raising dollars synthetically. Using these data, I construct the monthly time series of the total MMF holdings in each bank, mapped to the currency of its parent's domicile country. Appendix A provides additional details on the data processing steps.

The N-MFP filings also report the collateral pledged by borrower banks to MMFs against secured borrowing. The collateral includes not only marketable securities (e.g., U.S. Treasuries), but also bank-held corporate debt, along with loan characteristics such as the amount lent and the interest rate charged. I use this granular data to capture non-U.S. banks' dollar assets, and estimate their revenue function, which anchors key asset-side parameters in my calibration.

1.1.2. Large Investments in (non-U.S.) Bank Debt

U.S. MMFs are a key source of short-term wholesale funding for non-U.S. banks. Panel A of Table 1 reports descriptive statistics on the level of and changes in monthly MMF holdings. On average, U.S. MMFs held $964 billion in non-U.S. bank securities each month during my sample period, with a standard deviation of $155.7 billion. Roughly half of this funding was unsecured, though the share reached as high as 70% in the early part of the sample and fluctuates considerably over time. Euro-area banks were the largest recipients, averaging $346 billion per month, followed by Japanese banks at $163.7 billion. Panel B shows that, outside of U.S. Treasuries ("Govt. & Others"), non-U.S. banks constitute the single largest share of MMF portfolios.

[6] N-MFP data are available from the SEC data catalog. They cover the universe of U.S. MMF holdings, but exclude foreign-domiciled offshore MMFs that provide eurodollar deposits. Aldasoro et al. (2021) report that under 15% of total MMF dollar funding of non-U.S. banks was from offshore funds between 2013-20. Note that the eurodollar market has significantly shrunk since the financial crisis (New York Fed, 2024).

Table 1: Descriptive Statistics for Money Market Fund Holdings

Panel A: MMF holdings ($ billion)	Mean	SD	p25	p50	p75	N
All non-U.S. banks	963.9	155.7	867.4	979.8	1051.8	132
– of which, uncollateralized	495.8	181.7	351.7	422.6	679.3	132
Δ All non-U.S. banks	-0.4	133.3	-85.6	2.5	76.7	131
EUR banks	346.0	80.1	290.1	340.8	408.7	132
Δ EUR banks	0.1	86.3	-52.5	4.0	48.4	132
JPY banks	163.7	30.3	139.8	154.1	187.4	132
Δ JPY banks	0.6	14.0	-7.0	-0.1	8.3	132

Panel B: Share of portfolio	Non-U.S. Banks	U.S. Banks	Govt. & Others
All MMFs mean holding	23.2%	15.5%	60.5%
– Change, conditional on outflow	-0.3%	0.0%	0.3%
Non-exclusive MMFs mean holding	29.1%	19.4%	50.7%
– Change, conditional on outflow	-0.2%	0.0%	0.1%
Vanguard mean holding	20.4%	14.8%	62.6%
– Change, conditional on outflow	-0.5%	0.0%	0.4%
Blackrock mean holding	26.4%	10.8%	62.4%
– Change, conditional on outflow	-0.5%	-0.1%	0.6%

Notes: This table summarizes U.S. money market fund (MMF) holdings. Panel A reports monthly MMF holdings in non-U.S. banks (in levels and changes) in $ billion. Holdings shown are aggregated across all non-U.S. banks and separately for EUR and JPY banks. Panel B disaggregates mean holdings by issuer type, with changes (conditional on outflow from MMFs) shown separately. Data source: SEC N-MFP filings.

1.1.3. Differential Risk Appetite and Regulatory Constraints

MMFs view non-U.S. banks as relatively riskier counterparties. Panel B of Table 1 shows the average monthly change in portfolio shares allocated to non-U.S. banks, U.S. banks, and other borrowers (including the U.S. Treasury) *conditional* on net outflows from MMFs in that month. During such periods, MMFs systematically reduce exposure to non-U.S. banks, while allocations to U.S. banks remain largely stable and those to the U.S. Treasury increase. This pattern holds not only in the aggregate, but also within key subgroups — including MMFs that lend to diverse borrower types ("non-exclusive MMFs") and the largest fund families such as Vanguard and BlackRock.

Beyond their own risk preferences, MMFs operate under occasionally binding regulatory constraints on both liquidity and credit risk. For example, SEC Rule 2a-7 prohibits MMFs from investing more than 5% of total assets in any A-1/P-1-rated issuer on unsecured basis, which constrains them from lending even to credit-worthy borrowers. The 2016 regulatory reform further tightened these constraints by allowing prime MMFs to float their net asset values, increasing volatility in end-investor flows and reducing the stability of dollar funding for risky borrowers.

1.2. Synthetic Funding via Swaps and Forwards

Foreign exchange swaps and forwards enable banks to leverage foreign currency deposits to raise U.S. dollars synthetically. In a typical swap, the bank exchanges foreign currency for dollars at the spot date, with the transaction reversing at a predetermined future date.[7] Forwards function similarly but involve a single cash flow at maturity rather than two legs. Unlike repo transactions, these instruments are effectively collateralized without requiring dollar-denominated collateral, offering banks operational flexibility and reducing dependence on constrained wholesale investors. I study this market using transactions data that cover a large share of activity across major participants.

1.2.1. Transactions Data

I source daily records of 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.[8] I source the data from CLSMarketData, a platform owned by the CLS Group which operates the world's largest multi-currency cash settlement system.[9]

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 shows that my data cover between a quarter to a third of the global OTC swaps turnover between

[7] Figure A2 depicts the balance sheet implications of wholesale dollar debt in panel (a) and synthetic debt in panel (b). Even though the cash flow profile of swaps resembles that of a collateralized term loan, accounting conventions imply that the resulting "dollar" debt is not reported as a balance sheet liability.

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

[9] Other studies using CLS data include Hasbrouck and Levich (2021), Ranaldo and Somogyi (2021), Khetan and Sinagl (2023), Roussanov and Wang (2023), Cespa, Gargano, Riddiough, and Sarno (2022), Ranaldo (2022), Bräuer and Hau (2022), Kloks, Mattille, and Ranaldo (2023), Kloks, McGuire, Ranaldo, and Sushko (2023), Loualiche, Reggi Pecora, Somogyi, and Ward (2024).

dealer banks facing other banks and end users. 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.

1.2.2. Summary statistics

I begin by calculating the daily net dollars borrowed at the near leg of swap trades, defined as the signed difference between buy and sell volumes from the perspective of the market-maker, within each currency pair and tenor bucket. All volumes are expressed in terms of U.S. dollars borrowed at the near leg by market-making banks, which are primarily large global dealer banks. Appendix A outlines the variable construction in detail, and Table 2 presents descriptive statistics on net dollar borrowing from the perspective of these global banks.

Table 2 shows that, on average, global banks borrow over $43 billion per day from all other sectors combined. This demand is met almost entirely by non-dealer banks, while other end users resemble dealer banks in their behavior: investment funds borrow an average of $14 billion daily, and corporate entities and non-bank financial institutions (NBFIs) each borrow about $0.5 billion. These patterns are consistent with global banks having access to multiple money markets, and non-dealer banks' willingness to supply dollars in return for cross-currency basis as a compensation.

A vast majority of synthetic borrowing takes place in the short tenor of currency term structure. Panel B of Table 2 shows that overnight ("0 days (tom/next)") tenor accounts for $35.6 billion 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 regulatory capital requirements. Long-tenor swaps likely support asset purchases, given that banks supply dollars in those tenors to other end users. Finally, panel C shows that most of the dollar borrowing is against the euro (EURUSD) at $25.8 billion per day, followed by the Japanese yen (USDJPY) at $12.2 billion. In contrast to swaps, Table A2 shows that FX forwards are more actively used by funds and corporations, with volumes more evenly distributed across tenors up to three months.

One limitation of this dataset is that it does not identify the individual lender and borrower entities at a transaction level. The data provider's confidentiality policies require transactions to be aggregated to the sector level to preserve anonymity.[10] Such aggregation could introduce

[10] It is possible to split sector level transactions into sector-geography levels, but such disaggregation often yields limited insights. On one hand, some banks may act as both lenders and borrowers of synthetic dollars depending on market conditions (e.g., see Keller (2024) for Peruvian banks). On the other hand, no clear

measurement noise when matching banks' wholesale borrowing from MMFs to their swap-market activity. However, I provide evidence that this noise is limited and unlikely to bias my estimates.

First, in Appendix A, I conduct a variance decomposition exercise using a sample of EURUSD swaps transacted solely by non-U.S. banks. Regressing my main measure of net synthetic dollar funding on the corresponding measure for non-U.S. banks yields a coefficient of 0.80 with an R^2 of 0.74, indicating that 74% of the aggregate variation in swap activity is attributable to non-U.S. banks. Second, I verify that the banks active in wholesale funding markets closely overlap with the ones in CLS sample. Table A3 shows that all 30 of the largest banks borrowing from U.S. MMFs are CLS settlement members—representative of global dealer banks—and collectively account for half of all non-government MMF holdings. Among these, 25 are headquartered outside the U.S. and represent 70% of total MMF exposures to the banking sector. Third, panel B of Table 1 shows that, during episodes of investor redemptions, the share of non-U.S. banks in MMF holdings declines, while the share of U.S. banks remains stable. This asymmetry suggests that the variation in swap-market activity induced by wholesale funding shocks is largely driven by non-U.S. banks.[11]

1.3. Cross-Currency Basis

The FX swap market allows banks to raise dollars synthetically, but pricing in this market frequently violates covered interest parity (CIP) — a fundamental no-arbitrage condition that equates the cost of synthetic and wholesale dollar funding. Under CIP, the price of an FX swap should offset interest rate differentials across currencies, implying a zero cross-currency basis. In practice, however, the basis often deviates from zero. Panel (b) of Figure A1 shows that these deviations are persistent across currencies and become sharply negative during periods of economic stress. Consistent with the literature, I treat the cross-currency basis as the relevant price measure in this setting.

I follow Du et al. (2018) to construct the cross-currency basis for each currency pair and tenor, ranging from one week to three months. Table A4 shows that EURUSD cross-currency bases are negative across the term structure. Between 2013 and 2023, the mean monthly basis was –19 bps for the 1-week tenor and –25 bps for the 3-month tenor, indicating persistent violations of CIP. Importantly, these deviations are present even *outside* of quarter-end months. Table A4 also summarizes the control variables used in my analysis, including banks' dollar asset holdings, central bank liquidity measures, and indicators of swap arbitrageurs' balance sheet constraints.

geographic definition consistently distinguishes borrowers from lenders. For instance, Kloks et al. (2024) find that European banks borrow dollars via swaps from U.S. banks on a nationality basis, while Correa et al. (2021) show that U.S. branches of foreign banks resemble U.S. banks and lend USD to their offshore parents.

[11] Additionally, I show the sensitivity of my counterfactual estimates to allowing for a strong correlation between swap arbitrageurs' balance sheet constraints and wholesale funding shocks.

Table 2: Descriptive Statistics for Daily Synthetic $ Borrowing by Global Banks

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

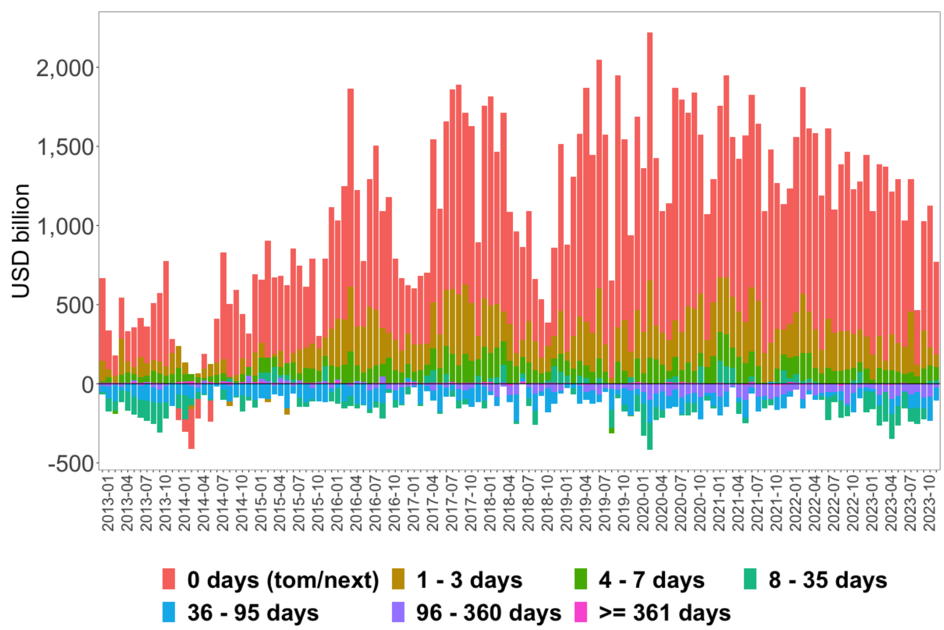
Notes: This table presents summary statistics of daily net synthetic dollars borrowed by global banks using FX swaps. USD is borrowed for settlement at the near leg of the swap and exchanged back at the far end. The near date for all tenors is the spot date, except for tenor "0 days (tom/next)" where 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 (N=2,853). 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.

2. Demand for Synthetic Dollar Funding

2.1. Stylized Facts

The market for synthetic dollar funding is large, and dominated by banks and institutional investors. Figure 2 plots the time series of monthly net USD borrowing by global banks (i.e., sell-side institutions in the CLS data) against all 9 currencies in my sample put together. Notably, global banks are net dollar borrowers in almost every month from January 2013 through December 2023, with the magnitude frequently exceeding \$1.5 trillion. Disaggregating by individual currencies, Figure A3 shows that banks borrow USD primarily against EUR and JPY. In terms of counterparties, Figure A4 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 (Figure A5). 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 2: 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.

Two notable events during my sample period highlight that the synthetic dollar market is sensitive to external supply shocks. First, panel (a) of Figure A6 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 during the COVID-19 pandemic disruption. Second, panel (b) of Figure A6 uses hourly data to show that on 10 March 2023, when Silicon Valley Bank in the U.S. was declared insolvent, global banks became net dollar *lenders* in the swap market because the stress in domestic banking sector hampered non-dealer banks' ability to supply synthetic dollars.

For my empirical analysis, I convert raw transaction volumes into monthly percentage changes in the stock of banks' synthetic dollars against each currency. I start with the daily stock of net swap volume outstanding on a given day, constructed using all the transactions executed up to that day, with new trades added to and maturing swaps deducted from it. Then, I average the daily stock to a monthly level and compute month-on-month percentage changes. Since the stock may be negative (indicating dollars lent), I approximate the percentage change as the difference in stock from month $t-1$ to t, divided by the average absolute stock in each month, resulting in a scaled variable bounded between -/+ 2 that mitigates the effect of outliers (Davis and Haltiwanger, 1992).

My measure, that I term "Δ Synthetic Dollars", addresses two limitations of raw transaction volumes. First, transaction volumes are non-stationary. Autocorrelation plots in Figure A7 show that transaction volumes are strongly persistent, while the change in stock is not. Second, aggregate transaction volumes mask the composition of maturities over which banks borrow or lend dollars (Figure 2). The change in stock measure captures this variation by accounting for swap tenors.

2.2. Constrained Wholesale Funding

This section tests whether global banks turn to synthetic dollar funding when faced with a reduced supply from U.S. money market funds. The null hypothesis posits that banks' use of swaps is unrelated to the frictions they encounter in wholesale markets. Using the joint time series of banks' wholesale and synthetic dollar borrowing, I construct a currency-month panel and estimate:

$$\Delta\text{Synthetic Dollars}_{c,t} = \beta\Delta\text{MMF Holdings}_{c,t} + \text{Controls} + \alpha_c + \alpha_T + \varepsilon_{c,t}. \tag{1}$$

The dependent variable, $\Delta\text{Synthetic Dollars}_{c,t}$, 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, $\Delta\text{MMF Holdings}_{c,t}$, is the change in money market fund holdings of debt issued by banks domiciled in currency (country) c in month t.

I control for other factors that may drive co-movement between wholesale and synthetic funding markets: (i) banks' dollar assets;[12] (ii) gross swap positions and intermediary sector's leverage ratio (ILRS) that affect swap arbitrageurs' capital constraints, (iii) difference between the balance sheet sizes of the Federal Reserve and foreign central banks scaled by GDP (CBBS/GDP), (iv) U.S. 1-month interest rates, (v) spot price, and (vi) overnight swap price. The sample period ranges from 2013 through 2023, and includes all the currencies facing USD except the NZD, as New Zealand banks do not borrow from U.S. MMFs in meaningful amounts. I include currency fixed effects to capture currency-specific features and year-quarter fixed effects for common time trends.[13] Table 3 reports the estimation results, with standard errors clustered by currency.[14]

A decline in U.S. MMF holdings significantly increases global banks' synthetic dollar borrowing. Panel A of Table 3 shows results using equal-weighted observations, and panel B weights them by the level of currency-specific MMF investments to account for the dominance of European and Japanese banks. Panel C repeats the estimation using the count of net buy trades as an alternate dependent variable. Across all panels, 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) adds year-quarter fixed effects. 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 is associated with a 22% increase in banks' synthetic dollar demand.

I report three additional robustness tests in Table A6. Panel A of Table A6 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. Panel B disaggregates MMF holdings into collateralized (e.g., repo) and uncollateralized (e.g., commercial paper) products. I find that the substitution result holds for both, but is economically 1.5 times as large for uncollateralized products that are subject to greater risk limits. Panel C confirms that my results are not driven by "smaller" currencies: using a panel constituted by the four largest currencies (EUR, JPY, GBP, CHF), I find the negative relationship to hold. The specification curve in Figure A8 summarizes the results from the baseline and robustness tests.

[12] Data on aggregate dollar assets by bank nationality are available from the BIS locational banking statistics, but do not separate short-term and long-term assets. For two countries - Norway and Australia - the currency denomination of assets is not available. I use aggregate bank assets for these countries.

[13] Time series variation is important to my analysis for two reasons. First, the cross section includes only eight currencies, with EUR and JPY significantly dominating the market. Second, banks can raise synthetic dollars against non-home currencies, which would induce cross-sectional correlation precisely due to the channel I emphasize. Consequently, I use year-quarter fixed effects to control for broader time trends.

[14] Due to the limited cross-section, clustering by currency may not always produce reliable standard errors. As robustness checks, Table A5 reports the statistical significance of Table 3 results using Driscoll-Kraay (Driscoll and Kraay, 1998), double clustered, and wild bootstrapped standard errors (Cameron et al., 2008).

Table 3: **Synthetic Dollar Funding and Money Market Fund Holdings**

	Δ Synthetic Dollars (by global banks)			
Panel A: Equal-weighted % change in stock	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.232**	-0.228***	-0.228***	-0.228***
	(0.073)	(0.058)	(0.058)	(0.061)
Δ Assets		0.014	0.022	0.089
		(0.058)	(0.053)	(0.063)
Δ Gross position		0.031	-0.156	-0.460*
		(0.030)	(0.095)	(0.234)
Δ ILRS (log)		0.040	0.049	0.122
		(0.221)	(0.223)	(0.225)
Δ CBBS/GDP		0.043	0.042	0.098
		(0.024)	(0.024)	(0.057)
Δ U.S. 1-month OIS		-0.086	-0.088	-0.087
		(0.183)	(0.184)	(0.338)
Δ Spot		-0.006	-0.001	-0.005
		(0.005)	(0.006)	(0.011)
Δ Swap (overnight)		-0.004	-0.004	-0.005
		(0.004)	(0.004)	(0.004)
Panel B: Investment-weighted % change in stock	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.185***	-0.210***	-0.213***	-0.198***
	(0.018)	(0.020)	(0.022)	(0.032)
Panel C: Count of net buy trades	(1)	(2)	(3)	(4)
Δ MMF holdings	-4.657**	-6.440***	-6.325**	-6.827**
	(1.957)	(1.518)	(1.820)	(2.082)
N	1,048	1,040	1,040	1,040
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 panels A and B is the % change in the stock of synthetic dollars held by global banks. Panel A weights observations equally while panel B weights them by the level of money market fund investments. The dependent variable in Panel C is the count of net buy trades. The regressor of interest is the change in money market fund holdings (Δ MMF holdings) in banks located in currency (country) i, expressed in \$ hundreds of 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. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

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 balance sheet line items for U.S. branches and agencies of non-U.S. banks.[15] 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, this dataset is not split by the domicile country of non-U.S. banks, and the time frequency is lower compared to CLS swaps data.

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 A9. 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 non-related foreign banks when MMF investments decline. However, the magnitude of impact is much smaller compared to the impact on swaps (Table 3). Other items such as funds with depository institutions show wide confidence intervals. Overall, relative to swaps, there is smaller adjustment to on-balance sheet items on account of wholesale funding declines.

This exercise echoes the findings of Correa et al. (2021), who show that U.S. branches of non-U.S. banks do not draw on cash buffers when wholesale funding tightens. In contrast to on-balance sheet items, FX swaps can be tapped quickly at the margin without triggering significant regulatory costs. Moreover, being effectively collateralized, swaps obviate the need to establish time-consuming relationships that characterize unsecured lending markets (Li et al., 2024).[16]

Regulatory shock. I strengthen the evidence linking banks' use of swaps to fill wholesale funding gaps using a natural experiment that led to a sharp, exogenous decline in MMF holdings of bank debt: the 2016 MMF reform. The key identifying assumption is that this reform impacted FX swaps through no channel other than a decline in the availability of wholesale funding to banks.

In October 2016, the Securities and Exchange Commission (SEC) implemented a major regulatory change that would primarily affect non-government U.S. money market prime funds. Provisions of this reform required prime MMFs to move away from "fixed net asset value (NAV)" to "floating NAV", making it difficult for investors to redeem their shares at par. The reform also allowed prime funds to introduce liquidity restrictions on investors, such as redemption gates and fees, while leaving government funds unaffected. This reform was intended to improve the resilience and stability of MMFs that came under severe liquidity pressure during the financial crisis.[17]

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

[16] I also examine Federal Home Loan Banks (FHLBs), a growing source of wholesale funding (Ashcraft et al., 2008, Gissler and Narajabad, 2017), but find no evidence that changes in their holdings affect FX swap quantities. This is likely because FHLBs primarily invest in U.S. banks and insurers, which rely less on synthetic dollar funding compared to non-U.S. banks.

[17] Hanson, Scharfstein, and Sunderam (2015) assess these reforms prior to the implementation, Cipriani and La Spada (2021) show that the reform triggered large outflows from prime to government funds, and Li et al. (2021) argue that the resulting liquidity restrictions exacerbated runs on prime funds during COVID-19.

Panel (a) of Figure 3 shows that this reform represented an economically significant negative wholesale funding shock to non-U.S. banks domiciled in various countries. In the six months after the reform implementation, the average monthly MMF investment in non-U.S. banks declined by about $250 billion, compared to the six months prior to October 2016. This change observed in my data aligns with Anderson, Du, and Schlusche (2021) who report that global banks lost hundreds of billions in MMF investment due to the regulatory reform.

I leverage this reform as a quasi-natural experiment to causally establish banks' use of swaps as alternative dollar funding instruments. I employ a difference-in-differences estimation technique, where my outcome variable is the quantity of synthetic dollars held by each sector s (banks, funds, corporations, and non-bank financial institutions) in currency c and month t. My specification examines the outcome in each of the 6 months before and after October 2016 when the reform was implemented, saturating the model with sector, currency, and time fixed effects:

$$\text{Net Synthetic Dollars}_{s,c,t} = \beta \text{Treated} \times \text{Post} + \text{Controls} + \alpha_{s\times c} + \alpha_{c\times t} + \varepsilon_{s,c,t}, \tag{2}$$

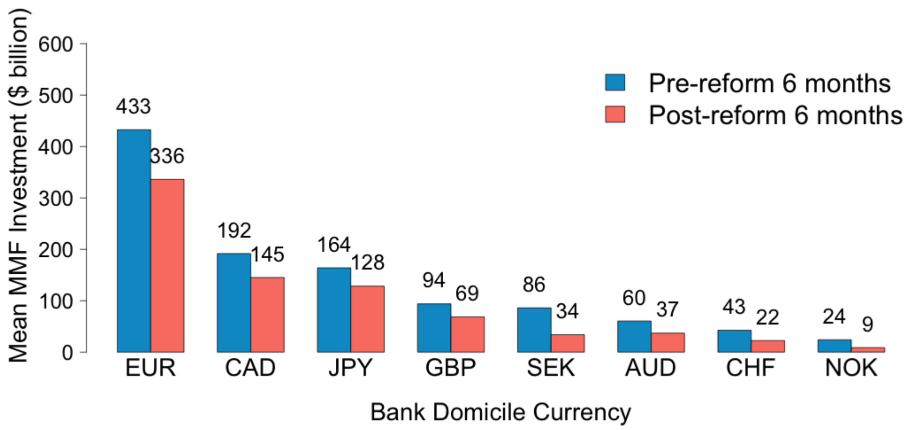
where the dependent variable is the stock of synthetic dollars held by sector s in currency c in month t. Since the reform affected prime funds that were mostly invested in *bank* debt, the variable "Treated" takes a value of 1 for banks and 0 for all other sectors. "Post" takes a value of 1 if the month is after October 2016, and 0 otherwise. The β coefficient identifies the average treatment for the six months following the reform, compared to six months prior. I add sector-currency $\alpha_{s\times c}$ and currency-month $\alpha_{c\times t}$ fixed effects, and controls consistent with Equation 1. I weight observations by the level of money market fund investments and cluster standard errors by sector-currency.

Table 4 reports that the negative exogenous shock to MMF holdings resulted in significantly greater use of synthetic dollars by global banks. The coefficient attached to "Treated $\times$ Post" is positive and significant across all specifications, which reflects that banks switched to swaps to offset the sharp decline in wholesale funding. This increase is relative to both banks' own pre-reform swap quantities, and after controlling for trends exhibited by all other sectors that were not affected by this reform. Next, I estimate a dynamic version to validate the pre-trends assumption:

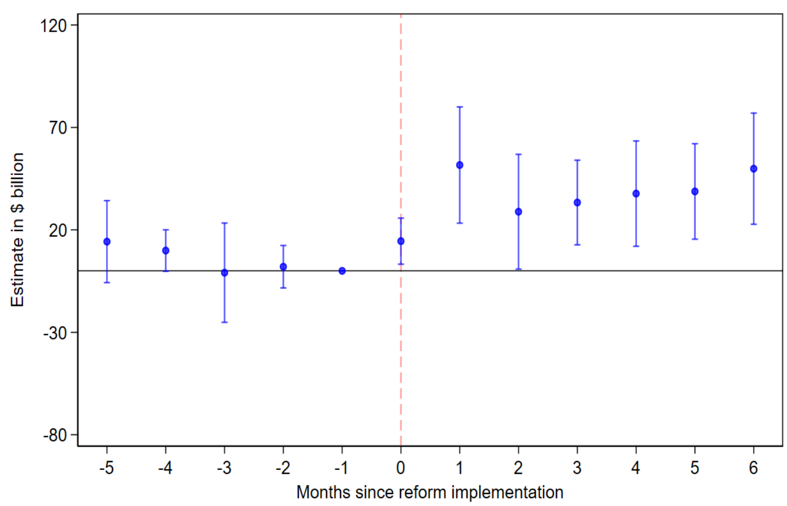
$$\text{Net Synthetic Dollars}_{s,c,t} = \sum_{\substack{\tau\in -5,6, \\ \tau\neq -1}} \beta_\tau \times \mathit{Reltime}_\tau + \alpha_{s\times c} + \alpha_{c\times t} + \varepsilon_{s,c,t}, \tag{3}$$

where "Reltime" is the relative number of months since October 2016. Panel (b) of Figure 3 plots the event study for β_τ coefficients. The increase in banks' holding of synthetic dollars was immediate and persistent after the reform was implemented. The figure also supports the pre-trends assumption in the months before the reform: synthetic dollar borrowing in months -5 through -2 was not statistically different from that in month -1.

Figure 3: Treatment Effects of 2016 Money Market Fund Reform



(a) Decline in MMF funding to banks



(b) Event study on net synthetic dollars borrowed by banks

Notes: Panel (a) shows that U.S. money market fund (MMF) holdings sharply declined in non-U.S. banks after the implementation of the 2016 regulatory reform. Panel (b) plots the treatment effects in $ billion for the months before and after the reform implementation in October 2016. The β_τ coefficients from Equation 3 and 95% confidence intervals are displayed in blue.

Table 4: Treatment Effect of 2016 MMF Reform on Synthetic Dollar Funding

	Net Synthetic Dollars ($ billion)			
	(1)	(2)	(3)	(4)
Treated × Post	26.857**	24.700**	26.857**	24.700**
	(12.939)	(12.106)	(12.227)	(11.239)
N	384	384	384	384
Controls	Y	Y	Y	Y
Fixed Effects	Sector, Currency, Month	Sector×Currency, Month	Sector, Currency×Month	Sector×Currency, Currency×Month

Notes: This table reports estimates of a fixed-effects model of the form in Equation 2. The dependent variable is the average daily stock of synthetic dollars held by sector s against currency c in month t. Banks are considered treated and non-banks are controls. Post equals 1 for six months following October 2016, and 0 for six months preceding. Observations are weighted by the level of money market fund investments. Standard errors clustered by sector-currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

My interpretation of funding substitution complements Anderson, Du, and Schlusche (2021), who find that certain banks scaled back their arbitrage positions in USDJPY following this regulatory reform. In contrast, I focus on banks that run persistent dollar funding gaps and borrow synthetically to bridge these gaps. The positive coefficients in Table 4 and Figure 3 underscore this demand-side mechanism: a rightward shift in the demand curve *increased* net swap quantities.

Additional tests. Appendix B provides two additional results to reinforce my finding that banks substitute into FX swaps when short-term wholesale funding declines. First, panel A of Table A7 shows that banks also increase forward purchase of the dollar in response to a decline in MMF holdings. Forwards provide another method by which banks can close dollar funding gaps but may be exposed to the spot price risk (unless combined with an opposite direction spot - effectively a swap). Figure A10 confirms that banks mostly borrow in short-term forwards, consistent with swaps. However, the magnitudes in both Figure A10 and Table A7 are small, reflecting that swaps are the dominant method of synthetic dollar funding for large global banks.

Second, I show that banks reduce reliance on swaps when interest rates increase because at higher interest rates, households shift their savings from checking accounts to money market funds (Aldasoro and Doerr, 2023). I calculate the fraction of the total short-term dollar borrowing attributable to swaps, and find that this ratio declines when interest rates rise (panel B of Table A7). Consistent with my hypothesis, the increased availability of wholesale funding from MMFs makes banks less reliant on costlier synthetic products to raise dollar funding.

3. Asset Pricing Implications

In this section, I show that banks' synthetic dollar funding demand contributes to wider deviations from 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 4. 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 interest rate for borrowing directly in U.S. money markets, $y_{t,t+n}$ represents the rate for foreign currency borrowing, and $\rho_{t,t+n}$ is the FX swap premium for converting the foreign currency into USD on the spot date and swapping it back into the foreign currency at the far date, thereby eliminating FX spot risk. I use the overnight indexed swap (OIS) rate as a measure of local currency borrowing cost (Augustin et al., 2024). I calculate the cross-currency basis over two tenors (n) that together cover the vast majority of trading in the FX derivatives market: 1 week and 1 month, as well as the first principal component of the basis up to the 3 month tenor. FX swap premium is the percentage premium over the prevailing spot rate at time t. I average the daily annualized bases to a monthly frequency.

Table A4 shows that the average EURUSD basis, $x_{t,t+n}$, is negative across the term structure, which indicates that it is costlier to borrow dollars synthetically compared to wholesale borrowing. Under perfectly integrated markets, the basis would equal zero because borrowers can choose the cheaper of the two options and optimize borrowing costs. Even if price distortions arise, they could be arbitraged away. However, recent studies show that swap arbitrageurs face balance sheet costs when lending dollars synthetically. In the below analysis, I test the demand channel: when banks use swaps for synthetic dollar funding, cross-currency basis turns more negative. I estimate the model:

$$\Delta x_{c,t,t+n} = \beta \Delta \text{Synthetic Dollars}_{c,t} + \text{Controls} + \alpha_c + \alpha_T + \varepsilon_{c,t,t+n}, \tag{5}$$

where the dependent variable is the change in cross-currency basis in currency c in month t for tenor n. I regress the 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 and year-quarter fixed effects, cluster standard errors by currency, and estimate Equation 5 in turn for maturities of 1 week and 1 month, as well as for the first principal component of tenors up to 3 months (PC1). Table 5 reports the estimation results, with observations weighted by the level of money market fund investments.

Table 5: 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)
Δ Synthetic Dollars	-3.831***	-3.930***	-2.953***	-2.446***
	(0.929)	(0.620)	(0.433)	(0.458)
Δ Assets	0.940	-2.515	-2.979*	-1.147
	(6.598)	(2.730)	(1.403)	(2.246)
Δ Gross position	-0.312	-12.337	-9.121	-6.029
	(0.917)	(8.963)	(5.099)	(5.439)
Δ ILRS (log)	-38.460***	-43.449***	-23.513***	-38.298***
	(10.747)	(6.992)	(4.594)	(6.068)
Δ CBBS/GDP	-4.583***	-0.036	0.179	1.699**
	(1.263)	(1.016)	(0.707)	(0.666)
Δ U.S. 1-month OIS	28.430**	51.401**	31.607**	30.192**
	(9.803)	(15.720)	(11.209)	(10.433)
Δ Spot price	1.019***	1.143***	0.875***	1.222***
	(0.259)	(0.235)	(0.201)	(0.173)
Δ Swap price (overnight)	0.599	0.361	0.238	0.258
	(0.919)	(0.671)	(0.390)	(0.520)
Cross-currency basis (t-1)	-0.558***	-0.834***	-0.946***	-0.908***
	(0.053)	(0.121)	(0.096)	(0.093)
N	1,036	1,036	1,038	1,040
Adj. R^2	0.41	0.60	0.61	0.62
Currency FE	N	Y	Y	Y
Time 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 of 1 week and 1 month, respectively. 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. Observations are weighted by the level of money market fund investments. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Synthetic dollar borrowing through FX swaps turns cross-currency basis significantly more negative. Table 5 shows that the coefficients on ΔSynthetic Dollars are negative and statistically significant across all tenors, as well as for their first principal component. As banks increase their reliance on swaps to obtain dollars, the cost of synthetic funding rises relative to direct wholesale dollar funding. Moreover, the high R^2 values across all specifications indicate that the specified model explains a substantial portion of the variation in cross-currency bases.

While these reduced-form results are consistent with a demand-based explanation for CIP deviations, they may not accurately identify the extent to which prices adjust to accommodate increased bank demand. This is due to two reasons. First, quantities and prices are simultaneously determined in equilibrium, potentially inducing estimation bias. Second, the price impact in Table 5 could partly reflect the tightening of supply-side constraints of swap arbitrageurs if there is co-movement between their own balance sheet constraints and wholesale funding available to non-U.S. banks. In the following sub-section, I sharpen the identification of my proposed channels using granular data on MMF investments in non-U.S. banks' short-term debt.

3.1. Granular Instrumental Variables (GIV)

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 U.S. MMFs are large global banks, headquartered in currency areas such as the euro (EUR), yen (JPY), and pound sterling (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.

I follow the GIV framework proposed in Gabaix and Koijen (2024) to extract idiosyncratic shocks to wholesale funding at a bank level, aggregate them to a currency level, and then use it as an instrument for banks' synthetic dollar funding demand. Relative to other studies using GIV in currency markets (Ben Zeev and Nathan, 2024, Kubitza et al., 2024), I introduce an additional layer of exogeneity, using shocks in a related but different market.

Identification strategy. I extract shocks to the availability of wholesale dollar funding from U.S. money market funds to individual non-U.S. banks, and aggregate them at a currency-level to instrument for swap quantities demanded by global banks. The key identifying assumption is that 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 MMF investment. 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 A11 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 A11 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 can be 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 A11 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.[18]

Instrument construction. Let there be N banks domiciled in a country with currency c, that source wholesale funding from U.S. MMFs. The monthly change in MMF funding to bank i is:

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

where $\Delta y_{i,t}$ is the change in MMF funding to bank i in month t, scaled by the moving average of the past 6 months. Price p_t is the relative cost of wholesale versus synthetic funding in currency c against the U.S. dollar, expressed as the cross-currency basis, and $\boldsymbol{\eta_t}$ is the vector of common shocks that all banks are exposed to. I extract the bank-level idiosyncratic shocks $u_{i,t}$ and aggregate them to a currency-level time series instrument in a three step procedure.

First, under the assumption that the cross-currency basis faced by all banks (p_t) and their elasticities (ϕ^d) are equal, I difference out the time fixed effects from Equation 6. The resulting variable, $\Delta y_{i,t} - \overline{\Delta y}_t$, removes the price-related component and the equal-weighted changes in

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

wholesale funding experienced by all banks in a country.

Second, I remove the variation in banks' wholesale funding that arises from heterogeneous exposures ($\boldsymbol{\lambda_i}$) to common factors ($\boldsymbol{\eta}$), such as macro-economic changes. Following Gabaix and Koijen (2021), I extract the first three principal components (PCs) of the monthly change in de-meaned MMF flows across all banks in a country.[19] Then, I regress each bank's de-meaned MMF flows on these three PCs to remove any variation explained by factors that are common to all banks (while allowing different banks to respond differently). The specification takes the form:

$$\Delta y_{i,t} - \overline{\Delta y}_t = \beta_{i1} PC_{1,t} + \beta_{i2} PC_{2,t} + \beta_{i3} PC_{3,t} + \boldsymbol{z_{i,t}} \tag{7}$$

I also adjust for heteroskedasticity in the residuals extracted above. Heteroskedasticity arises when, for example, the residuals $z_{i,t}$ correlate with bank size, thereby biasing the estimates. To address this possibility, I weight the observations by the inverse of bank-level variance of residuals.

In the third step, I aggregate bank-level shocks $z_{i,t}$ to the currency level using the size of individual banks. If each bank's share in MMF funding in month $t-1$ is $S_{i,t-1}$ (potentially time-varying), then the instrument is given by:

$$z_t = \sum_i S_{i,t-1} z_{i,t}. \tag{8}$$

I construct the instrument for each currency and denote it $z_{c,t}$ or "excess wholesale funding".

Relevance. 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 strongly explains variation in swap quantities. I find support for all three conditions.

First, panel (a) of Figure 4 shows a high level of concentration (excess Herfindahl > 0.2) across all the major currencies against which global banks borrow dollars synthetically. 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. For the euro and British pound in particular, the concentration increased after 2016 because some banks lost access to MMF funding as a result of the MMF regulatory reform.

Second, using EURUSD as an example, panel (b) of Figure 4 shows that idiosyncratic shocks (expressed in dollars) can be economically significant: there are large and frequent deviations in the size-weighted changes in MMF holdings from equal-weighted changes. These shocks can be

[19] Table A8 shows that the first three PCs explain over 90% of the common variation for Euro-area, Japanese, British, Swedish, Australian, and Canadian banks. I drop CHF and NOK from this analysis as the PCs explain 100% of variation in MMF flows to the (few) Swiss and Norwegian banks in my sample.

traced to some of sources mentioned earlier. For example, in 2017, several MMFs had 5% of their assets invested into BNP Paribas, which led to a sharp decline in its subsequent additional funding. Furthermore, large inflows experienced by certain MMFs in 2019 disproportionately benefited large Euro-area banks. In contrast, common shocks that affect all banks, such as the COVID-19 pandemic, do not reflect as major outliers.

Third, I confirm that the instrument is relevant to explaining variation in swap quantities. I estimate the below first stage model:

$$\Delta \text{Synthetic Dollars}_{c,t} = \beta z_{c,t} + \text{Controls} + \alpha_c + \alpha_T + \varepsilon_{c,t}. \tag{9}$$

Analogous to the OLS set up in Equation 1, the endogenous variable, ΔSynthetic Dollars$_{c,t}$, 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 my instrument, $z_{c,t}$ or excess wholesale funding. Table 6 presents the estimation results, with column (1) without fixed effects, and columns (2) and (3) with currency fixed effects. In order to account for common time trends that may not reflect idiosyncratic shocks, I drop the year around MMF reform as recommended in Gabaix and Koijen (2024), and add year-quarter fixed effects in column (3). I report first-stage instrument F-statistics under heretoskedastic as well as homoskedatic residuals, for robustness.

All three columns of Table 6 confirm that the instrument is relevant for explaining variations in swap quantities in a manner consistent with the substitution hypothesis: greater excess wholesale funding to large non-U.S. banks associates with a reduction in swap quantities. Moreover, the negative coefficient on the instrument suggests that it does not capture capital constraints faced by swap arbitrageurs. If arbitrageurs get more MMF funding, swap quantities should *increase* due to a rightward shift in the supply curve. Instead, swap quantities decline when the instrument takes a positive value, indicating that it is picking up a leftward shift in the demand for synthetic dollars.

Note that the instrument remains strongly relevant in the expected direction despite potential forces that may attenuate its strength. For example, the instrument may be weakened if (i) it captures increased demand for dollar credit by banks' end-borrowers rather than MMF constraints, (ii) banks largely use non-swap products to offset wholesale funding declines (limiting the impact on the swap market), or (iii) banks immediately and frictionlessly replace lost investments from existing MMFs by switching to new MMFs.

Several features of the wholesale funding markets mitigate the above forces. First, as Figure A1 shows, the demand for dollar credit remains fairly steady at a high frequency, largely because it reflects banks' ongoing credit commitments to large corporations and financial institutions. Second, although non-U.S. banks can use non-swap products to offset wholesale funding declines, swaps are most readily expandable at the margin because they are highly liquid and do not require scarce dollar-denominated collateral.[20] Finally, the probability that banks would transition to entirely new MMFs on a monthly basis is low, given the stickiness of bank–MMF relationships and the time-intensive onboarding process.

Exclusion. My identification relies on the assumption that shocks to non-U.S. banks' wholesale funding affect cross-currency bases only through their FX swap demand. This assumption can be violated if their wholesale funding shocks correlate with other factors that independently move the bases. Below, I discuss the main threats to this exclusion restriction.

<u>Concern 1: Swap arbitrageurs.</u> If arbitrageurs primarily depend on U.S. MMFs to supply dollars in the swap market, then wholesale funding shocks would lead to more negative bases even if non-U.S. banks' swap demand remains unchanged, overestimating the price impact. Another channel that would lead to the same effect is an increase in inter-bank borrowing by non-U.S. banks, which could tighten arbitrageurs' capital constraints more generally and affect their swap pricing.

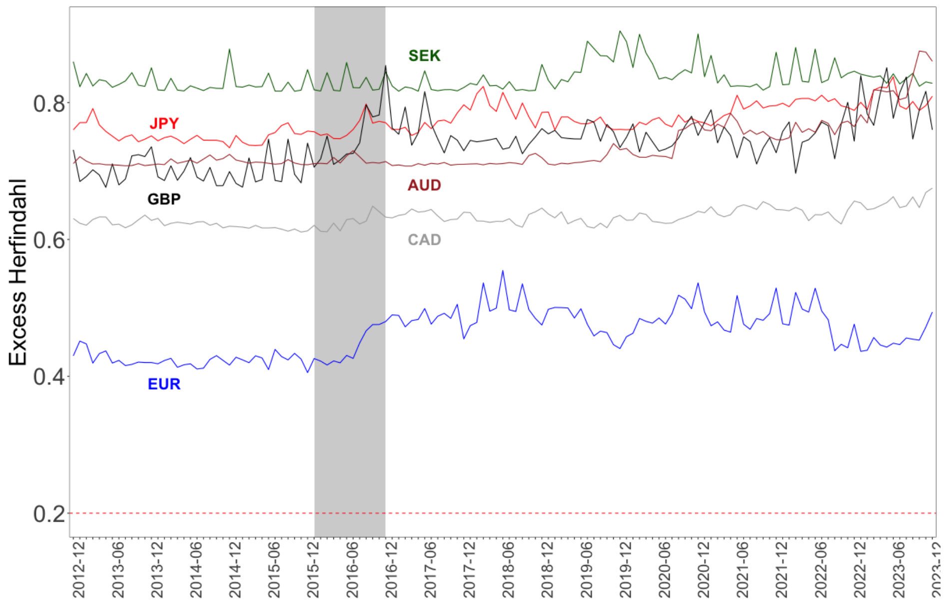
Table A9 shows that my instrument is uncorrelated with key indicators of arbitrageurs' capital constraints: changes in MMF holdings in U.S. banks, the intermediary sector's leverage ratio (He et al., 2017), and quarter-end dates when dealers' balance sheet constraints are known to tighten. This orthogonality is by construction: the instrument captures non-U.S. *bank-level* funding shocks, which do not spill over to swap arbitrageurs because MMFs specialize in lending by borrower type and exhibit differential risk appetite between U.S. and non-U.S. banks.

<u>Concern 2: Macroeconomic factors.</u> Changes in the macroeconomic environment — such as interest-rate hikes or tighter dollar liquidity — could confound the effect of demand shocks on cross-currency bases. To address this, I strip out the impact of common factors (η in Equation 6) by purging banks' exposure to the first three principal components that explain the vast majority of common variation in wholesale funding supply. Table A9 confirms that the resulting instrument no longer correlates with interest rate changes, non-MMF repo market borrowing, or its own lags.

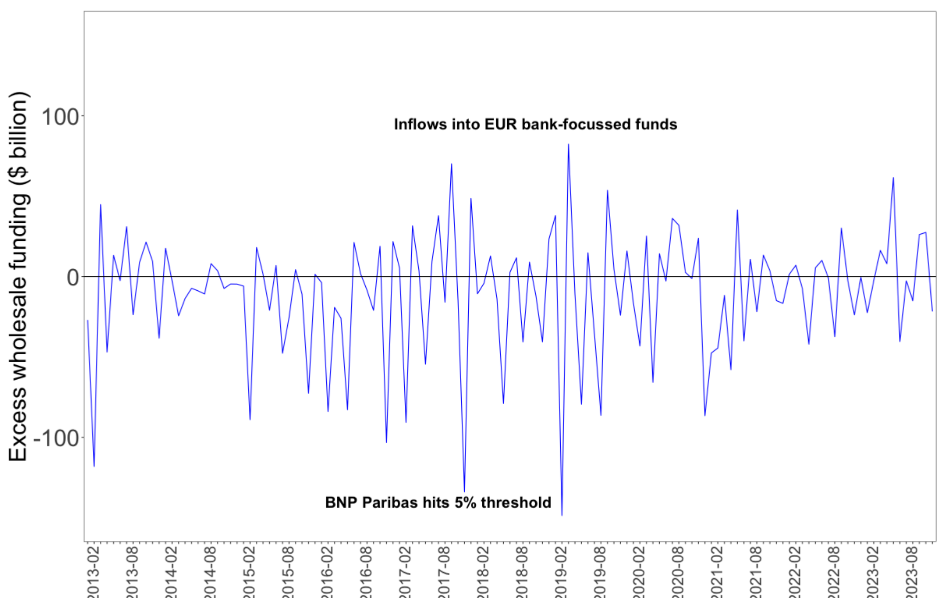
<u>Concern 3: Non-bank investors.</u> There are two channels through which non-bank investors' actions may violate the exclusion restriction. The first channel operates through the potential impact of wholesale funding constraints on non-bank investors' swap quantities. Figure A4 shows that several non-bank investors are active users of FX swaps. If their own swap demand increases in response to (banks') wholesale funding constraints, then the impact of banks' demand on prices may be overestimated. However, non-bank foreign investors borrow minimally from U.S. MMFs: under 1.5% of MMF assets are invested in non-U.S. corporations' and non-bank entities' debt.

[20] Consistent with this argument, Becker et al. (2023) find that banks replace FX-based dollar funding with cheaper wholesale funding several months after an increase in cross-border lending.

Figure 4: GIV Diagnostics – Concentration and Idiosyncratic Shocks



(a) High excess Herfindahl



(b) Large idiosyncratic shocks

Notes: This figure demonstrates the validity of granular instrumental variables (GIV) for extracting idiosyncratic shocks to global banks' wholesale funding from U.S. money market funds. Panel (a) plots the time series of excess Herfindahl index for banks that borrow from MMFs. Shaded area represents the transition period of the 2016 MMF reform in the U.S. 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.

Table 6: Instrumented Swap Quantities (First Stage)

	Δ Synthetic Dollars		
	(1)	(2)	(3)
Excess wholesale funding ($z_{c,t}$)	-0.800***	-0.794***	-0.912***
	(0.113)	(0.112)	(0.233)
Δ Assets	-0.007	-0.011	0.105
	(0.057)	(0.053)	(0.081)
Δ Gross position	0.003	0.082	-0.438
	(0.025)	(0.099)	(0.293)
Δ ILRS (log)	-0.135	-0.142	-0.593*
	(0.269)	(0.278)	(0.287)
Δ CBBS/GDP	-0.003	-0.002	-0.035
	(0.048)	(0.049)	(0.110)
Δ U.S. 1-month OIS	0.047	0.051	-0.105
	(0.238)	(0.234)	(0.520)
Δ Spot	-0.009**	-0.006	-0.010
	(0.003)	(0.003)	(0.017)
Δ Swap (overnight)	-0.006*	-0.006*	-0.003
	(0.002)	(0.002)	(0.004)
Cross-currency basis (PC1, t-1)	0.002***	0.002***	0.006***
	(0.000)	(0.000)	(0.001)
PC1	0.011***	0.010***	0.008***
	(0.001)	(0.001)	(0.002)
PC2	0.013***	0.012***	0.008**
	(0.001)	(0.001)	(0.002)
PC3	0.068***	0.069***	-0.047
	(0.002)	(0.003)	(0.034)
N	778	778	706
Instrument F-statistic	46.23	48.50	13.57
Instrument F-statistic (homoskedastic residuals)	52.63	55.74	14.11
Currency FE	N	Y	Y
Time FE	N	N	Y

Notes: This table reports the first-stage estimates from a two-stage least squares regression for a model of the form in Equation 9. The dependent variable is the change in the stock of synthetic dollars borrowed by global banks. The regressor of interest is the granular instrumental variable "Excess wholesale funding ($z_{c,t}$)". The table reports the instrument F-statistic with heteroskedasticity-adjusted residuals (baseline) as well as under the assumption of homoskedastic residuals, for robustness. Observations are weighted by the level of money market fund investments. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

As a result, non-bank investors' direct exposure to wholesale funding shocks is small, mitigating the concern about a simultaneous change in their swap demand.[21] To empirically confirm this, Table A9 reports a low correlation between my instrument and the synthetic funding demand of non-bank investor sectors - funds, non-financial corporations, and non-bank financial institutions.

The second channel through which non-bank investors may bias my estimates is through the reaction of their swap quantities to price changes, i.e., their demand elasticities. Consider a situation where non-bank investors reduce or increase their own swap demand when the cross-currency basis widens due to an increase in banks' demand for synthetic funding. In this case, a simultaneous change in their swap demand might have an opposite effect on the basis, leading to an underestimated price impact. To test if this is the case, I estimate non-bank investors' demand elasticity to (instrumented) cross-currency basis. I start with the below first stage model, regressing the changes in cross-currency basis on my instrument, excess wholesale funding ($z_{c,t}$):

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

The specification mirrors Equation 9 in terms of controls and fixed effects, and I estimate it in turn for bases calculated using the first PC 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 A10 shows that the instrument strongly co-moves with cross-currency bases. In all the columns of Table A10, there is a positive and statistically significant relation between the $z_{c,t}$ and the basis, which implies that when relatively larger banks receive excess wholesale funding, the basis for that currency becomes *less* negative. This relevance also confirms that the results in Table 6 are not attributable to a weak instrument.

Next, I estimate non-bank institutions' elasticity of FX hedging demand to instrumented bases:

$$\text{Hedging Demand}^S_{c,t} = \beta \widehat{\Delta\text{Cross-currency}} \text{ basis}_{c,t} + \text{Controls} + \alpha_c + \alpha_T + \varepsilon_{c,t}. \tag{11}$$

The dependent variable, Hedging Demand$^S_{c,t}$, captures the change in the stock of buy-sell USD swaps held by sector S in currency c in month t, with rest of the specification consistent with the first stage. The different non-bank sectors I estimate the model for are: funds, non-financial corporations ("corporate"), and non-bank financial institutions (NBFIs). Panel B of Table A10 reports the estimation results for parameter β for each of the three non-bank sectors.

All non-bank sectors react to changes in cross-currency basis in a direction that suggests downward-sloping demand curve. Taking funds as an example, for a 1 bps reduction in cross-currency basis (i.e., synthetic dollars are more expensive), funds reduce the stock of buy-sell USD swaps by 0.6%, with wide confidence intervals. Interpreting as elasticities, for a 10% reduction in

[21]The main non-bank beneficiary of MMF investments is the U.S. Treasury, which does not regularly participate in the FX swap market except through the Exchange Stabilization Fund.

the basis, funds reduce swap holdings by 1.6%. The elasticity estimates for funds, corporations, and NBFIs are all below 1, which suggests relatively inelastic demand.[22] Therefore, the bias arising out of any simultaneous change in non-bank investors' swap demand is likely negligible.

Causal impact of swap demand on CIP deviations. With its relevance confirmed, I now estimate the impact of instrumented swap quantities on cross-currency bases (second stage):

$$\Delta\text{Cross-currency basis}_{c,t,t+n} = \beta\Delta\widehat{\text{Synthetic Dollars}}_{c,t} + \text{Controls} + \alpha_c + \alpha_T + \varepsilon_{c,t,t+n}. \tag{12}$$

I estimate the impact on bases across tenors of 1 week and 1 month, as well as on the first principal component (PC) of bases across tenors up to 3 months. The controls and fixed effects in this specification are consistent with the first stage (Equation 9). Panel A of Table 7 reports the estimation results, where columns (1) through (3) consider the first PC of bases across tenors, column (4) considers the 1 week bases, and column (5) considers the 1 month bases.

All columns of Table 7 report a negative and statistically significant β coefficient on the instrumented synthetic dollar borrowing by banks. Further, the coefficient β is larger in magnitude than the OLS estimate in Table 5, suggesting the reduction of simultaneity bias. The economic magnitude of price impact is also large: if global banks increase net demand by 10%, then the 1 month bases turn more negative by about 7 bps, which is meaningful against a sample average of -26 bps for EURUSD. As a validation check, Euro-area banks lost an average of about \$100 billion in wholesale funding after the 2016 MMF reform, which increased their swap demand by about 22% (Table 3). At the same time, the EURUSD cross-currency basis turned more negative by 16 bps, which closely matches the price impact implied by Table 7. Overall, my GIV results provide a causal interpretation to the price impact of banks' swap demand reported in Table 5.

Panel B of Table 7 shows that the price impact holds when quarter-end months (March, June, September, December) are excluded from my sample. This is an important conditional analysis because quarter-ends are known to have special dynamics, when swap arbitrageurs' balance sheet constraints tighten due to regulatory reporting requirements (Du, Tepper, and Verdelhan, 2018, Favara, Ivanov, and Rezende, 2021, Cenedese, Della Corte, and Wang, 2021). The size of the β coefficient in panel B is generally smaller than in panel A because of flatter supply curves outside of quarter-ends, but highlights that the price impact is generalizable beyond quarter end dates.

SUTVA violation. In the panel IV setting, one concern is the violation of Stable Unit Treatment Value Assumption (SUTVA), which requires that treatment for one unit (instrumented swap quantities for a given currency) does not affect the outcome for another (cross-currency basis for

[22] My estimates align with Kubitza et al. (2024), who study how negative bases impact Euro-area investors.

another currency). Such spillovers could occur if dollar funding conditions in one currency influence another's basis via portfolio rebalancing. To assess this possibility, I perform a "leave-one-out" analysis (Angrist et al., 1999), re-estimating the second-stage IV regression six times, each time excluding one of the six currency pairs. If SUTVA were materially violated, excluding a currency would substantially change the estimated price impact. Table A11 shows that the price impact remains in a tight range across all specifications, from –3.3 to –4.1 bps, consistent with SUTVA.

Table 7: 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)	(5)
Δ $\widehat{\text{Synthetic Dollars}}_{c,t}$	-8.419***	-8.759***	-6.399***	-5.530***	-7.164***
	(0.778)	(0.917)	(1.197)	(0.624)	(0.753)
N	776	776	704	778	780
Controls	Y	Y	Y	Y	Y
Currency FE	N	Y	Y	Y	Y
Time FE	N	N	Y	N	N
Panel B: ex. quarter-end months	PC1 (1W, 1M, 3M)			1W	1M
	(1)	(2)	(3)	(4)	(5)
Δ $\widehat{\text{Synthetic Dollars}}_{c,t}$	-7.235***	-7.281***	-6.692***	-5.033***	-5.216***
	(0.576)	(0.507)	(1.036)	(0.313)	(0.428)
N	580	580	520	580	582
Controls	Y	Y	Y	Y	Y
Currency FE	N	Y	Y	Y	Y
Time FE	N	N	Y	N	N

Notes: This table reports the second-stage estimates from a two-stage least squares regression for a model of the form in Equation 12. 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), (2) and (3), the 1 week tenor in column (4), and 1 month tenor in column (5). 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 6). All control variables are consistent with the first stage table. Panel A uses the full sample period, while Panel B drops the months corresponding to quarter-ends: March, June, September, and December. Observations are weighted by the level of money market fund investments. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

4. Model and Counterfactuals

Building on my empirical findings, this section calibrates a model to assess how funding frictions affect global banks' dollar lending in the presence of synthetic markets. This exercise has two objectives. First, it quantifies the extent to which synthetic funding can offset sharp declines in wholesale funding, beyond which the global supply of U.S. dollar credit may be impaired. Such declines can arise from post-crisis regulations that limit wholesale investors' exposure to risky banks, or from geopolitical developments where dollar liquidity is used as a policy tool (Risk.net, 2025). Second, the model examines how much additional default risk wholesale investors would need to bear if regulators instead enable greater wholesale funding access to reduce swap mispricing. Evaluating these counterfactual scenarios requires quantifying the trade-off between default risk and cross-currency basis, and comparing the basis to banks' marginal revenue on dollar assets.

To this end, I present a tractable model that captures funding market dynamics and can be calibrated to my data. My model closely builds on Ivashina et al. (2015), where non-U.S. banks optimally choose synthetic dollar funding in the presence of limited scalability of wholesale funding. Relative to Ivashina et al. (2015), however, my model departs in three important ways. First, banks in my model face occasionally binding quantitative limits on their wholesale borrowing, which creates a demand shift in favor of FX swaps. Second, motivated by my empirical results, I add a swap arbitrageur to make CIP deviations an equilibrium object. Third, I calibrate the model to my data and empirical results to present counterfactual estimates.

4.1. Model Setup

The economy. Consider a two-country economy, the U.S. and Europe, with a global bank that has lending opportunities in USD and is able to borrow dollars both directly in U.S. 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 both U.S. and Europe equal r.[23]

The primary lenders to banks in the wholesale market are U.S. money market funds (MMFs). Their investable pool of funds ("corpus") scales linearly with interest rates, with sensitivity parameterized by η. MMFs also experience mean-zero flow shocks from end-investors, denoted by σ_X. To control default risk, MMFs lend only a fraction α of their assets to banks. This parameter captures two forces. Literally, α can be interpreted as the 5% regulatory concentration limit imposed on

[23] 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.

MMFs. More broadly, it reflects MMFs' aversion to risky bank lending. Since both, concentration limits and risk aversion, can be influenced by regulatory policies, I combine them into the single parameter α.[24] MMFs' total lendable corpus is therefore:

$$L^W = \alpha \bar{L}^W \left(1 + \eta(1+r) + \sigma_X\right), \tag{13}$$

where $\bar{L}^W$ is a steady state value. Next, MMFs incur a default risk on their lending to banks:

$$d = \beta(L^W)^2, \tag{14}$$

where d is the default risk, 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.

Lastly, MMFs earn a return of $r + pd$ on lending to banks, where p governs the compensation required, over and above the risk-free rate, for default risk. While I allow the interest rate charged by MMFs to vary with default risk in the model, in practice, the dispersion in MMF lending rates is limited. For example, in 2023 the mean interest rate charged by MMFs to banks was 5.2%, with a relatively small standard deviation of 19 bps. As a result, the additional compensation for default risk, pd, is typically lower than the extra cost of synthetic dollars (cross-currency basis). This limited variation reflects MMFs' primary objective of capital preservation, which often takes precedence over pursuing higher returns through riskier lending.[25]

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 U.S. dollars and earns the riskless rate r plus the (negative of) 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 from U.S. MMFs to European investors or depositors that provide euros to the bank for swapping against the dollar.

Note that the dollar borrowing banks and swap arbitrageurs do not always need to be two distinct agents. When flush with dollar liquidity, or when the arbitrage opportunity is profitable enough, banks may well act as swap arbitrageurs (e.g., Keller (2024)). While the model treats these as separate agents to delineate supply-side constraints from demand shifts, the equilibrium impact on prices and dollar credit are comparable even when the same institution switches from being a dollar borrower to a dollar lender in the swap market.

[24] For example, MMF risk aversion could be reduced through FDIC insurance on lending to risky banks.

[25] Industry report on an overview of money market fund objectives is available at: am.jpmorgan.com/content/dam/jpm-am-aem/global/en/liq/literature/brochure/introduction-to-mmfs.pdf

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 dollar loans from bank-dependent borrowers. I further assume that (i) the bank does not leave open currency 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.

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 U.S. 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).

4.1.1. Demand for Synthetic 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:

$$L^D = L^W + L^S. \tag{15}$$

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:

$$\max_{\{L^S\}} \left[g(L^W + L^S) - (r + pd)L^W - (r + S)L^S \right] \tag{16}$$

subject to the total lending and wholesale funding constraints:

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

$$L^W \leq \alpha \bar{L}^W \left(1 + \eta(1 + r) + \sigma_X\right)$$

The first order condition of Equation 16 with respect to L^S is given by

$$-(r + S) + g'(L^W + L^S) = 0, \tag{17}$$

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 $L^D \leq \alpha \bar{L}^W (1 + \eta(1+r) + \sigma_X)$. 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: $L^D > \alpha \bar{L}^W (1 + \eta(1+r) + \sigma_X)$. However, the marginal revenue on lending is still greater than the 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 core of the bank's decision problem. I now parametrize the concave revenue function, $g(L^D)$ as

$$g(L^D) = aL^D - b(L^D)^2 \tag{18}$$

Plugging Equation 18 into Equation 17, and recognizing that $L^S \leq N - L^W$, where $L^W = \alpha \bar{L}^W (1 + \eta(1+r) + \sigma_X)$, we arrive at the first proposition.

$$\underbrace{N - \alpha \bar{L}^W (1 + \eta(1+r) + \sigma_X)}_{\text{Swap quantity}(L^S)} \geq \underbrace{\frac{a - (r+S)}{2b}}_{\text{Marginal revenue over cost}} \tag{19}$$

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.*

$$\frac{\partial L^S}{\partial \alpha} > 0 \tag{20}$$

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, panel B). 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.

4.1.2. 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:

$$\max_{\{Z^S\}} \left[(r+S) \cdot Z^S - r \cdot Z^S - \frac{1}{2}\lambda (Z^S)^2 \right], \tag{21}$$

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. 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 a potential correlation in the calibration.

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.

$$L^S - Z^S = 0 \tag{22}$$

I take the first order condition of Equation 21 with respect to Z^S and plug the above market clearing condition to write the price impact as:

$$\text{S} = \lambda L^S \tag{23}$$

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).*

$$\frac{\partial S}{\partial L^S} > 0 \tag{24}$$

The equilibrium quantity of swaps is given by plugging Equation 23 into the RHS of Equation 19:

$$L^S = \frac{a - r}{2b + \lambda} \tag{25}$$

Next, I link MMF default risk with CIP deviations. To do so, re-write Equation 14 as $d = \beta(N - L^S)^2$, and then plug Equation 23 to get:

$$d = \beta \left[N - \frac{S}{\lambda} \right]^2 \tag{26}$$

Proposition 3. *An increase in wholesale investors' default risk is accompanied by narrower deviations from covered interest parity due to a reduction in reliance for synthetic dollars by banks.*

$$\frac{\partial S}{\partial d} < 0 \tag{27}$$

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

4.2. Calibration

I match the model to my empirical estimates and key moments in the data to (i) quantify the co-movement between equilibrium cross-currency bases and wholesale investors' default risk, and (ii) locate the threshold for α beyond which the marginal cost of synthetic dollars would exceed the revenue on bank assets. Table 8 summarizes the calibrated parameters for my sample period.

There are two state variables. First, interest rates r_t modulate the corpus of MMFs and overall demand for dollar credit. I set average r_t to 1.5% based on the mean observed during my sample period. Second, 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. A larger ψ indicates that swap arbitrageurs' balance sheet constraints simultaneously tighten when wholesale funding to non-U.S. banks declines.

The representative bank faces a credit demand of N dollars, which it seeks to meet using the available wholesale funding, L^W, and covers the remainder 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 parameters enter the bank's optimization problem, where it equates marginal revenue with marginal cost (Equation 19).

MMFs manage a pool of investable corpus, a fraction of which is allocated to risky bank securities (Equation 13). I set the average corpus at $\overline{L}^W = \$2,000$ billion based on the sample, excluding funds investing exclusively in U.S. Treasuries. The size of this corpus increases with interest rates, with sensitivity parameter $\eta = 0.15$, calibrated from a time series regression. In addition, MMFs face normally distributed, mean-zero flow shocks from end-investors, with a standard deviation of $\sigma_X = 200$, as observed in the data.

MMFs can lend only a fraction α to banks, which can be viewed as arising from three sources: (i) the regulatory 5% concentration limit, (ii) potential quantitative restrictions as a policy tool, and (iii) MMFs' own internal limit on unsecured investments, reflecting their risk aversion. I set $\alpha = 0.05 \times 10 = 0.5$, because a typical MMF lends to 10 non-U.S. 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., the U.S. Treasury) is willing to absorb the remaining 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.

Wholesale investors face default risk when lending to banks. I model this risk as increasing with the squared amount lent (Equation 14), reflecting the plausible scenario where defaults are correlated across issuers. The inclusion of the squared term captures the heightened risk associated with larger exposures to multiple banks. Following Collins and Gallagher (2014), I calculate the sensitivity parameter β as the value-weighted credit default swap (CDS) premium on bank debt. During my sample period, CDS premium averages 50 bps for a \$100 notional, so I set $\beta = 0.005$.[26]

MMFs charge an interest rate of $r + pd$ when lending to banks, where pd reflects additional compensation for bearing default risk. Using data on European banks' monthly 5-year CDS premia, I estimate that MMFs increase the interest rate charged to banks by 3.4 bps for every 10 bps rise in CDS premia. Accordingly, I set $p = 0.0344$.

The final agent in my model is the swap arbitrageur. Post-financial crisis regulations, such as leverage ratio requirements, impose costs on balance sheet expansion - even for risk-free arbitrage. These costs are captured by the parameter λ in Equation 21. I do not directly observe λ in my data. Instead, I observe the price impact of banks' synthetic dollar funding demand, detailed in Section 3. I apply an indirect inference approach to estimate λ such that I can match the empirically observed price impact from the GIV second stage. Specifically, Table 7 shows that a 10% increase in quantities demanded causes the cross-currency basis to decline by approximately 7 bps. Based on this estimate, I set $\lambda = 0.0006$, that accounts for potential convexity in this relationship.

[26] 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 ($0.005 \times (500)^2/100$).

Table 8: Calibration

Parameter	Definition	Source or Target
State variables		
$\overline{r} = 0.015$	Mean interest rate in the U.S.	Data
$\psi = 0$ (baseline)	Correlation between MMF flows and arbitrageur constraints	Assumption (sensitivity: $\psi = 0.5$)
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
$\alpha = 0.5$	Fraction of corpus lendable	Regulations and data
$\beta = 0.005$	Default risk sensitivity	CDS spreads (Collins and Gallagher, 2014)
$p = 0.0344$	Sensitivity to bank CDS spreads	Regression coefficient
Arbitrageurs		
$\lambda = 0.0006$	Balance sheet cost scaler	Indirect inference (Table 7)

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

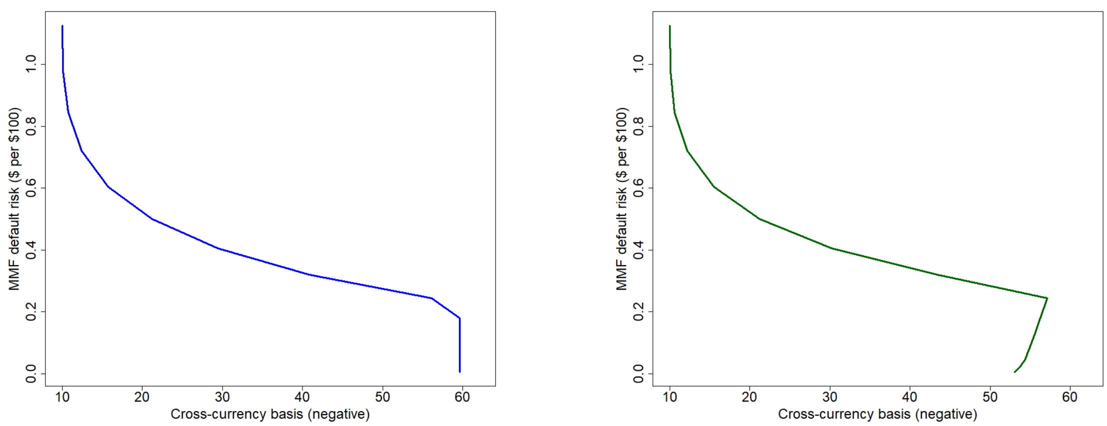
4.3. Default Risk vs. CIP Deviations

I apply my model to study the externalities of domestic money market regulations that seek to shield wholesale investors from default risk (Kacperczyk and Schnabl, 2013, Schmidt et al., 2016). As a first step, I quantify the trade-off between the default risk borne by MMFs and the cross-currency basis. To isolate this relationship, I hold all model parameters fixed at their calibrated values from Table 8 and vary only α, the fraction of MMF assets allocated to risky bank debt. Figure 5 illustrates this trade-off. Panel (a) considers a setting in which swap arbitrageurs' balance sheet constraints, λ, remain constant as wholesale funding to the borrower bank changes ($\psi = 0$). In contrast, panel (b) allows for a tightening of arbitrageur constraints when α falls ($\psi = 0.5$). The y-axis in both panels reports default risk scaled by the total MMF corpus, so it can be interpreted as expected dollar loss per $100 lent.

Default risk and cross-currency basis exhibit a strong inverse relationship. Figure 5 shows that narrowing the EURUSD basis from –26 basis points to –13 basis points requires an increase in wholesale funding to banks, which raises the default risk borne by wholesale investors from 45 to 65 basis points. However, this additional risk remains modest compared to levels observed during the financial crisis, when the CDS premia on non-defaulting banks exceeded 200 basis points.

Interestingly, the curve becomes nearly vertical around a cross-currency basis of –60 basis points. This occurs because, in the model, banks cease borrowing additional dollars via swaps once the marginal cost of synthetic funding exceeds their marginal return on dollar assets. This feature reflects the joint determination of CIP deviations and bank profitability, which I explore further in the next sub-section. Panel (b), which allows swap arbitrageur's supply curve to steepen as MMF constraints tighten, displays a slightly more convex relationship compared to panel (a).

Figure 5: Money Market Fund Default Risk and Cross-Currency Basis



(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 cross-currency basis (x-axis) through the channel of banks' synthetic dollar funding demand. The basis is represented as the (negative) of the price impact resulting from banks' substitution from wholesale to synthetic funding to meet dollar credit demand. 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.

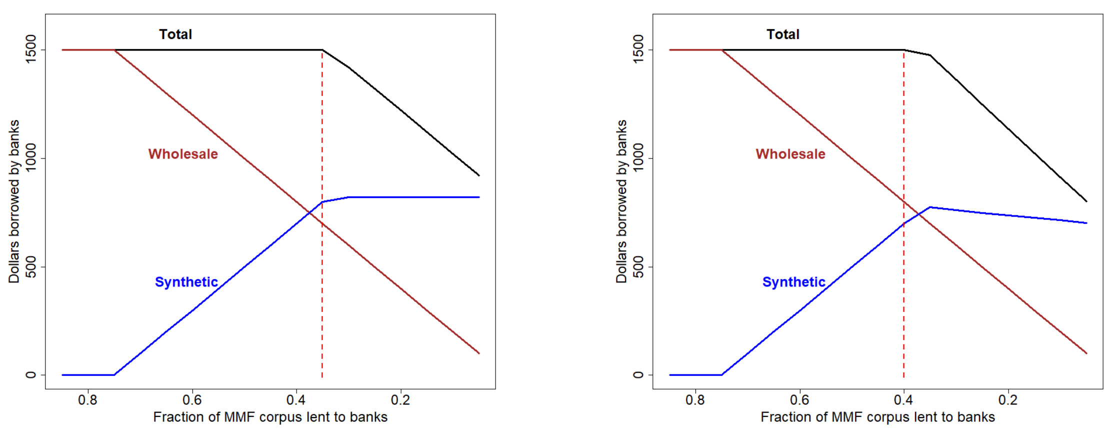
4.4. Counterfactual Decline in Lending

Next, I quantify the threshold at which tighter constraints on wholesale funding to banks begin to affect its capacity 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 6 illustrates this by plotting the dollars borrowed by banks through wholesale (L^W) and synthetic (L^S) markets on the y-axis, and the corresponding fraction of MMF corpus lent to banks (α) on the x-axis (going from looser to tighter constraints).

Panel (a) presents the baseline case ($\psi = 0$) and shows that total dollar borrowing by banks, holding end-user credit demand fixed, begins to decline once $\alpha < 0.35$. Below this threshold, wholesale funding continues to contract, but synthetic funding does not rise further, as CIP deviations become too costly for banks to absorb. The 2011 European sovereign debt crisis serves as an illustrative case, when U.S. MMFs reduced their lending to European banks, turning cross-currency basis sharply negative while also decreasing USD lending in the Euro-area (Ivashina et al., 2015). Alternatively, banks could pass the higher funding costs on to end users, raising the price of U.S. dollar credit in the affected countries. Either case could undermine the long-run dominance of the U.S. dollar in the international financial system.

Panel (b) allows arbitrageur constraints to tighten in response to falling α and shows that the critical threshold is reached earlier, at $\alpha = 0.4$. This corresponds to a slack of no more than 20% in wholesale funding, based on the average MMF allocation of \$1 trillion to non-U.S. banks (Table 1).

Figure 6: 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.

4.4.1. Which assets are most vulnerable?

Assets with the lowest risk-adjusted returns are likely to be the first affected when funding conditions tighten. Using data on collateral pledged to MMFs, Table 9 reports average returns (net of funding costs) on four major categories of European banks' U.S. dollar assets, excluding U.S. Treasury holdings, which may carry a convenience yield and thus be less sensitive to funding pressures. The table disaggregates returns by maturity: ≤1 month, 1–6 months, and >6 months.

Table 9 shows that short-term corporate debt and asset-backed securities are particularly vulnerable to sharp wholesale funding declines, as the marginal cross-currency basis can exceed their returns (Figure 5). While the analysis is suggestive — due to the exclusion of unsecured assets and lack of detailed loan-level data — it underscores the potential for funding market stress to spill over into the real economy via reduced availability or increased cost of U.S. dollar credit.

Table 9: Bank Asset Profitability

Asset category	≤ 1 month	1 - 6 months	> 6 months
Corporate Debt Securities	0.53%	0.79%	0.74%
Asset-Backed Securities	N/A	0.49%	0.66%
Agency Debentures and Agency Strips	0.71%	0.73%	0.71%
Agency Mortgage-Backed Securities	0.77%	0.80%	0.91%

Notes: This table reports the mean returns, in excess of wholesale funding costs, on four major categories of European banks' U.S. dollar assets (excluding U.S. Treasuries). Returns are further disaggregated by asset maturity buckets. Data source: collateral reports on secured lending from the SEC N-MFP filings.

5. Conclusion

The U.S. 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 dollar create demand for synthetic funding, which affects the pricing and availability of dollar credit, as well as the distribution of risks in the international financial system. My empirical strategy identifies a causal link between wholesale funding shocks and negative cross-currency bases, through the channel of global banks' demand for foreign exchange swaps. My quantitative framework identifies the thresholds of wholesale funding constraints at which the higher cost of synthetic dollar funding begins to limit banks' ability to provide dollar credit. More broadly, my paper highlights the mechanism through which intersecting regulations — such as those on liquidity, capital, or balance sheet use — jointly affect risk allocation and financial market outcomes.

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Supplemental Appendix
"Synthetic Dollar Funding"

Umang Khetan

August 2025

A. DATA APPENDIX

A.1. Money Market Fund Data

U.S. 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 the following four sets of files from this database for the full sample period.

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 field 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 two 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 with the issuer-month-level dataset using the "Accession Number". I do not expand 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.
4. Collateral information for dollar assets (form "NMFP_COLLATERALISSUERS"): This form reports details of the collateral that are provided by issuers to MMFs when borrowing using

secured instruments, such as repurchase agreements. The collateral provided by issuers represents the closest measure of their dollar assets. I extract several fields from this dataset, such as the value of the collateral, the coupon or yield on the collateral, the issuer identification, and the collateral type (e.g, U.S. Treasury securities, agency securities, corporate debt). I use the collateral value and the coupon or yield to calibrate banks' marginal revenue function, and also analyze the assets most vulnerable to funding shortfalls.

A.2. 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.[27] 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.

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 BIS (e.g., report the volume in

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

terms of the base currency, and report only one leg of the trade to avoid double counting).

The FX forward and swap flow datasets that this paper uses contain executed buy and sell contracts in terms of number of trades (trade count) and total value in the base currency of the respective currency pair. However, as part of CLS' client confidentiality policy, there must be a minimum of 2 trades in the currency-maturity bucket over the day for CLS to publish the data. The final CLS dataset includes all matched trades in the eligible currencies between CLS (direct or indirect) members, with at least two trades over the reporting period.[28]

A.3. 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. 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 relates to intra-group trading across dealer desks and double-counts prime-brokered trades.

I make a few 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 the 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.4. Variable Construction

I measure synthetic dollar funding using the daily CLS flow data by sector, tenor, and currency.

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

Sectors. Sector-level data are constructed in two (potentially overlapping) cuts. In the first cut, trades are reported between sell-side and buy-side parties. Most of these sell-side banks are in the globally systemically important banks (GSIBs) category that are able to access multiple money markets, that I term "global banks". For the currencies in my sample, the majority of sell-side banks are tier-one international investment and custodian banks, that are headquartered in the U.S., 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. Note that CLS data exclude trades that settle on the trade date (“cash” trades).

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 this conversion.

A.5. Variance Decomposition for Net Synthetic Dollars

This appendix performs a variance decomposition exercise to address a potential concern that the aggregated CLS sector-level data may largely reflect factors other than non-U.S. banks’ synthetic dollar funding demand. To do so, I regress the aggregate quantities of net synthetic dollars from the perspective of sell-side institutions on the net synthetic dollars borrowed *only* by non-U.S. banks for a sample of EURUSD overnight swaps. The available sample for this analysis spans daily data in 2023 (N=259). I estimate the model:

$$\text{Net Synthetic Dollars (sell-side)}_t = \beta \text{Net Synthetic Dollars (Non-U.S. Banks)}_t + \varepsilon_t, \tag{28}$$

where the dependent variable is the aggregate net synthetic dollars borrowed (or lent) by global banks. The regressor is constructed by carving out the demand of *U.S.* banks, thus capturing only non-U.S. banks in the independent variable. I find that $\beta = 0.8$, with adj. $R^2 = 0.74$, which highlights that a vast majority of variation in the aggregate data is driven by non-U.S. banks’ demand.

B. Demand for Synthetic Dollar Funding - Additional Results

I present two additional results in support of my finding that banks use synthetic dollars when short-term wholesale dollar funding declines.

The use of FX forwards. I show that banks also increase their use of short-tenor FX forwards to raise dollars synthetically. Forwards, combined with FX spot, achieve the same cash flows as swaps. Hence, these two products can be substitutes for raising dollars synthetically. However, a combination of spot and forwards entails executing two trades, which leads to slippage across multiple bid-offers. As a result, forwards are less efficient means of dollar funding than swaps.

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, to test the impact of reduction in MMF holdings on banks' use of FX forwards:

$$\Delta \text{Synthetic Dollars}_{c,t} = \beta \Delta \text{MMF Holdings}_{c,t} + \text{Controls} + \alpha_c + \alpha_t + \varepsilon_{c,t}. \tag{29}$$

Panel A of Table A7 collects the estimation results. I find that changes in MMF holdings negatively correlate with banks' use of FX forwards, across all combinations of controls and fixed effects. However, the economic magnitude of impact is about half that on swaps, as shown in Table 3. The extra cost incurred as a result of slippage could potentially explain why swaps are preferred by banks over forwards. Nonetheless, this test provides additional validation that synthetic dollar funding helps banks compensate for declines in wholesale dollars.

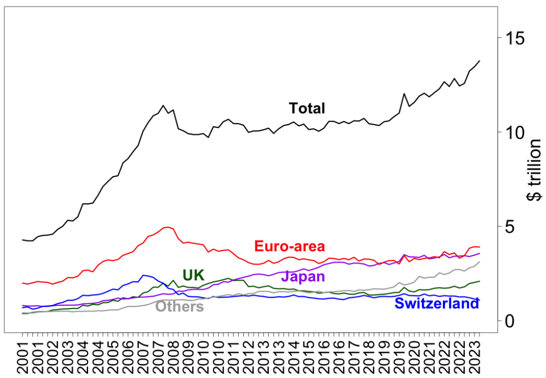
Interest rates. I show that the interest rate environment partly governs banks' substitution from wholesale to synthetic dollar funding markets. The intuition is that at higher interest rates, households shift their savings from lower-yielding bank deposits to money market funds (Aldasoro and Doerr, 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 2 shows a decline in net dollar borrowing via swaps during the 2022-23 tightening cycle.

I construct a variable, *Fraction Synthetic*, defined as the stock of net synthetic dollars borrowed by global banks (aggregated across tenors) in each currency, scaled by the dollar assets of non-U.S. 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:

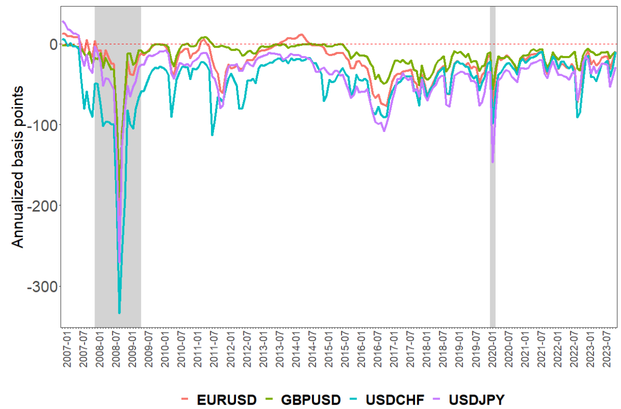
$$\Delta \text{Fraction Synthetic}_{c,t} = \beta \Delta \text{U.S. 1-month OIS}_t + \text{Controls} + \alpha_c + \alpha_t + \varepsilon_{c,t}, \tag{30}$$

where I regress changes in *Fraction Synthetic* on changes in U.S. 1-month OIS rate, with other controls and fixed effects as before. Panel B of 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.

Figure A1: Non-U.S. Banks' Dollar Assets and Cross-Section of CIP Deviations



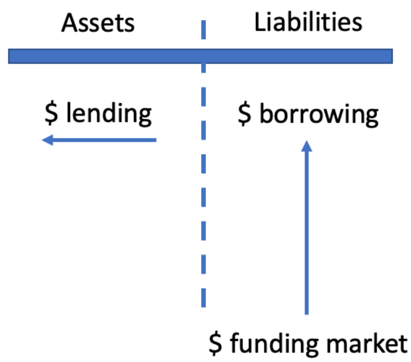
(a) U.S. Dollar Assets



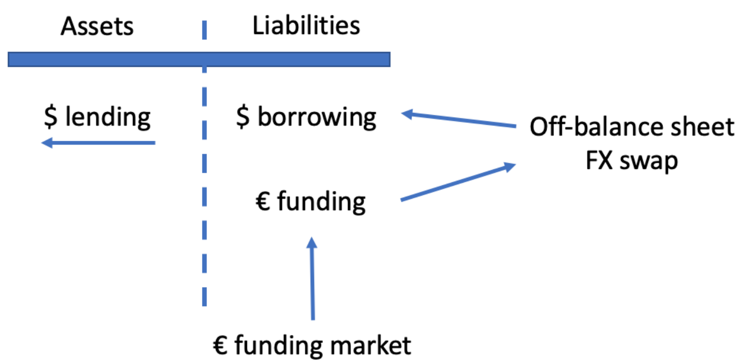
(b) CIP Deviations

Notes: Panel (a) plots the time series of aggregate U.S. 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 U.S. dollar. Shaded region indicates NBER-dated recessions.

Figure A2: Bank Balance Sheets under Wholesale and Synthetic Dollar Funding



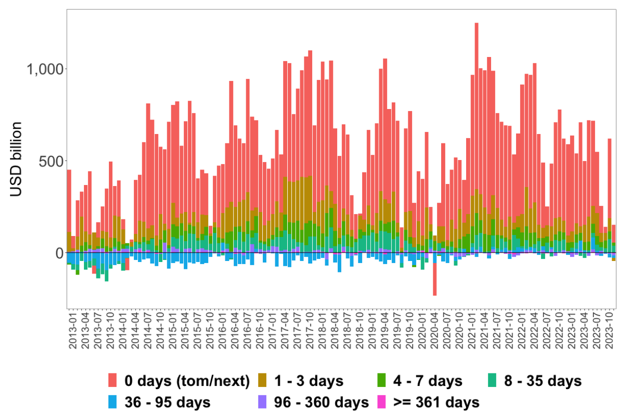
(a) Wholesale dollar funding



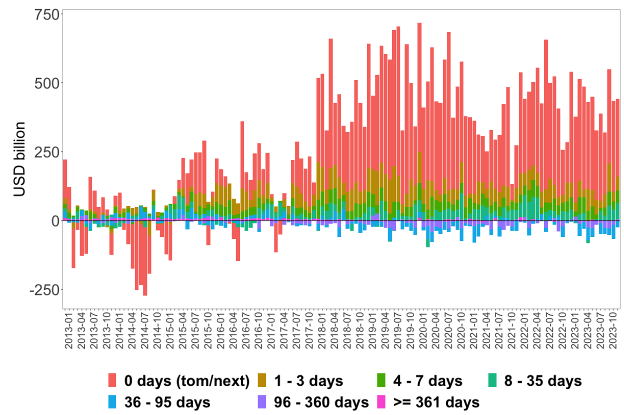
(b) Synthetic dollar funding

Notes: This figure shows the balance sheet flows associated with wholesale dollar funding in panel (a) and synthetic dollar funding in panel (b). Wholesale 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.

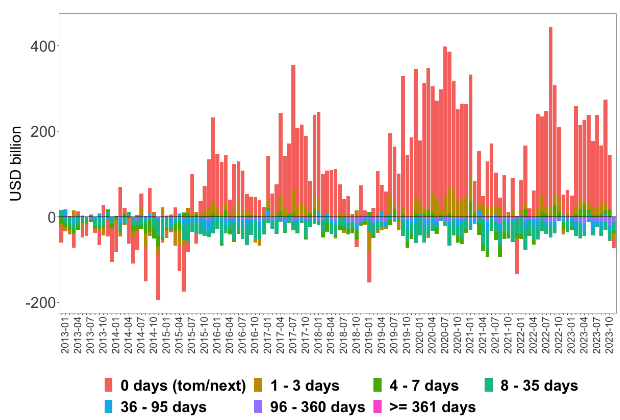
Figure A3: Currency-wise Synthetic Dollars Borrowed by Global Banks



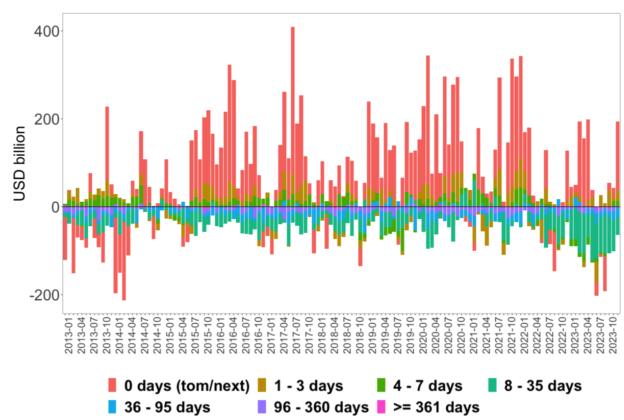
(a) Against EUR



(b) Against JPY



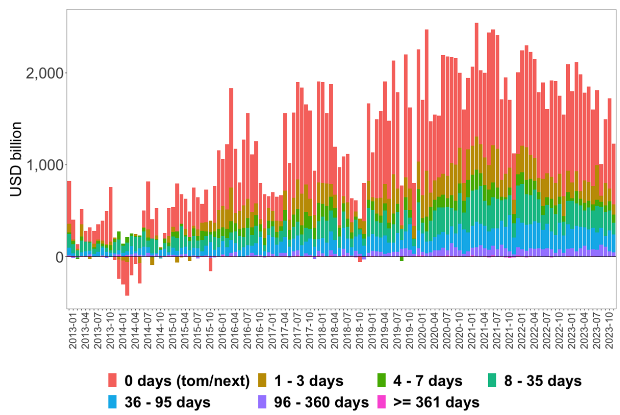
(c) Against CHF



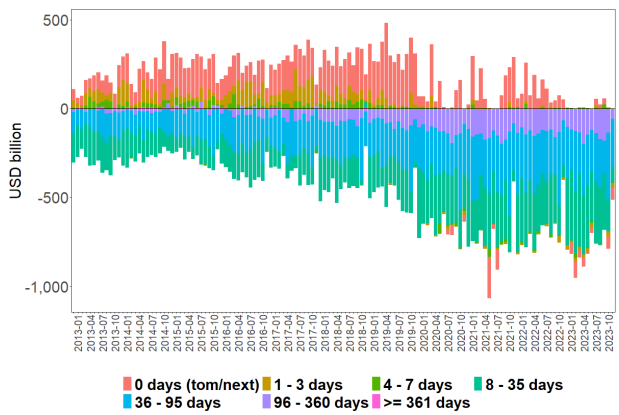
(d) Against GBP

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.

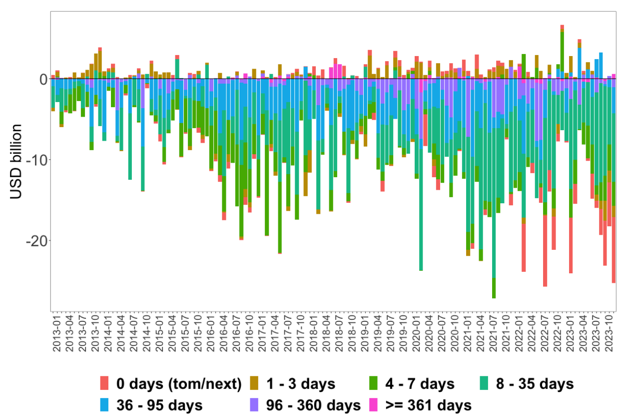
Figure A4: Sector-wise Synthetic Dollars Borrowed by Global Banks



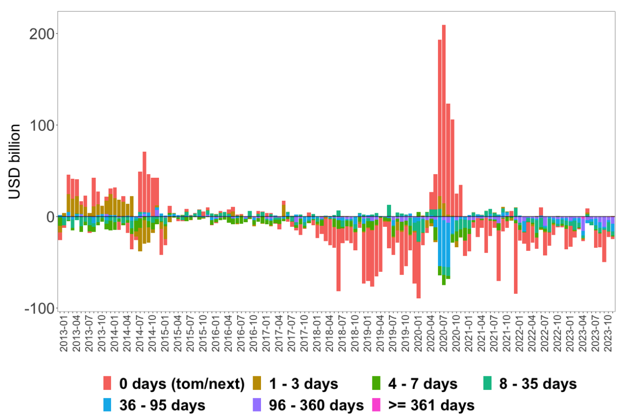
(a) From non-dealer banks



(b) From funds



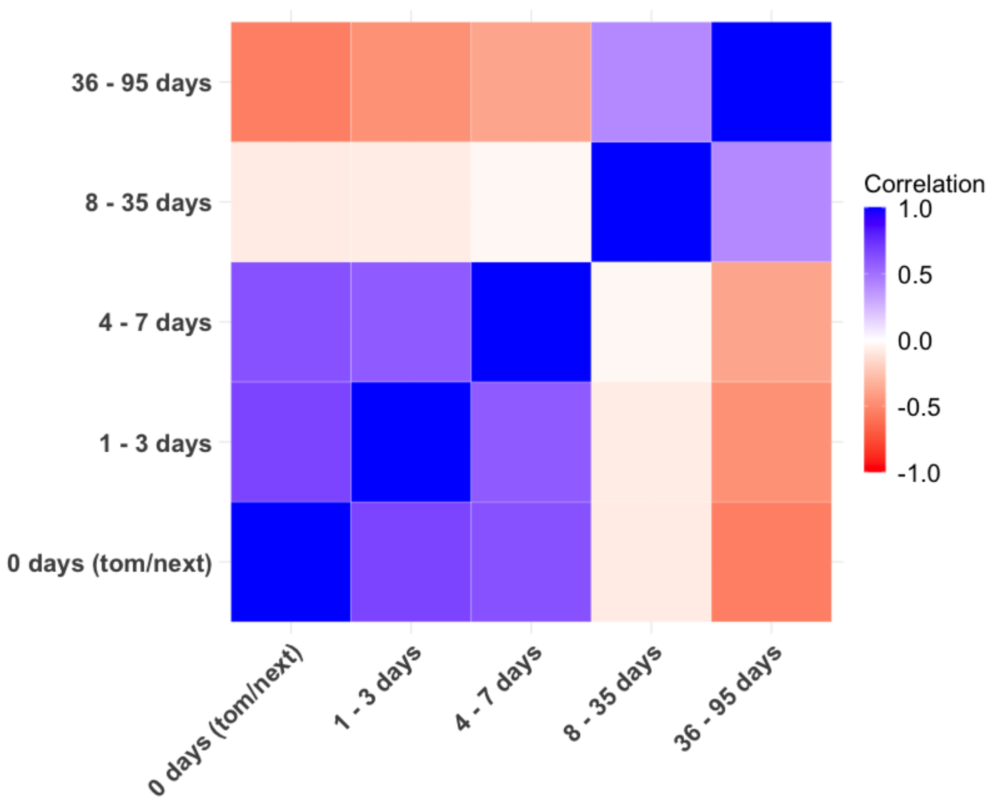
(c) From non-financial corporations



(d) From non-bank financial institutions

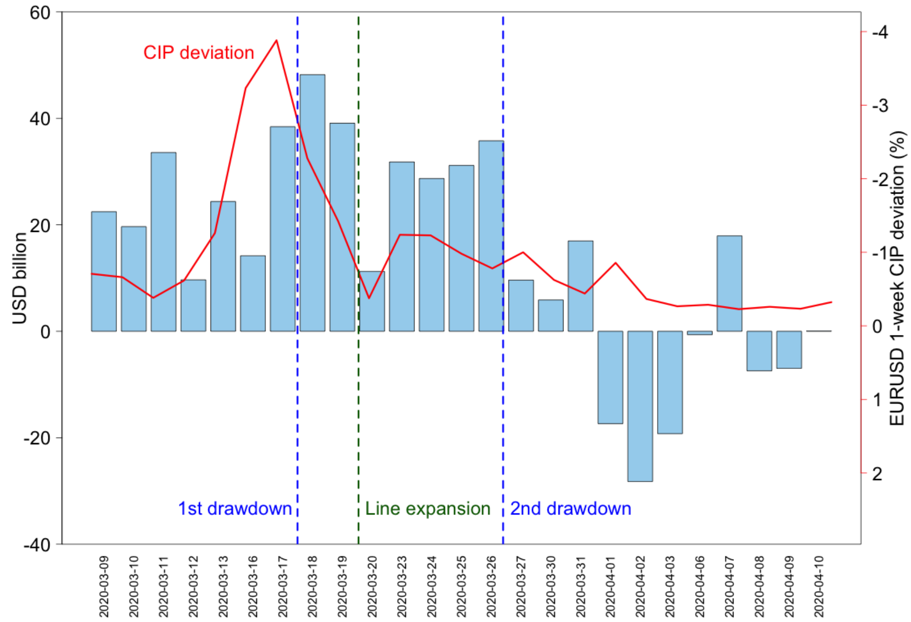
Notes: This figure plots the quantity of USD borrowed (positive y-axis) or lent (negative y-axis) by globally active dealer banks from/to non-dealer banks in panel (a), funds in panel (b), non-financial corporations in panel (c), and non-bank financial institutions in panel (d). USD is borrowed against 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.

Figure A5: Fund Carry Trades

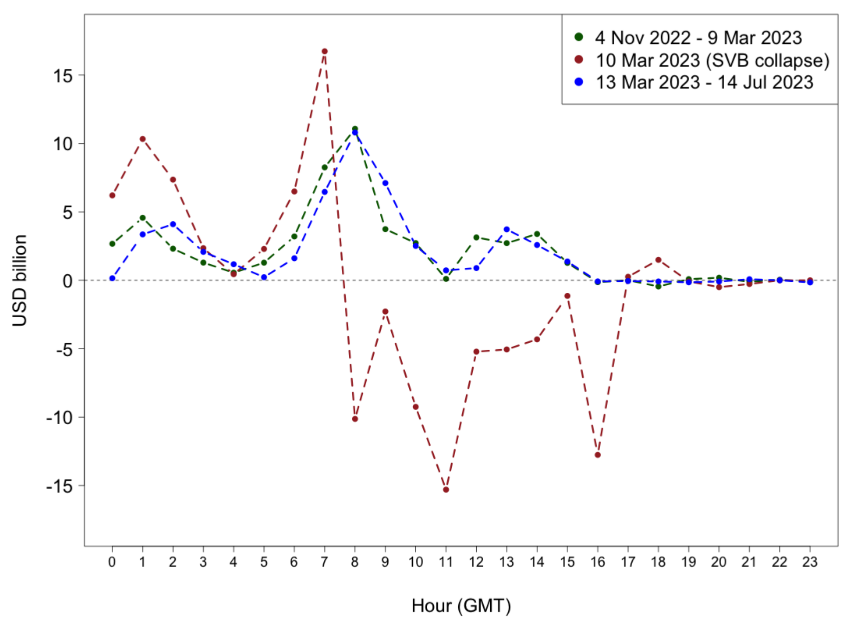


Notes: This figure correlates monthly net volume of dollars borrowed or lent by investment funds in each tenor against all other currencies put together. Funds lend dollars in the overnight ("0 days (tom/next)") to 1 week tenors, and simultaneously borrow dollars in longer tenors up to 3 months, resembling carry trades. This figure is constructed using daily signed FX swap order flow sourced from CLSMarketData and aggregated at a monthly level.

Figure A6: Synthetic Dollar Funding during Macroeconomic Disruptions



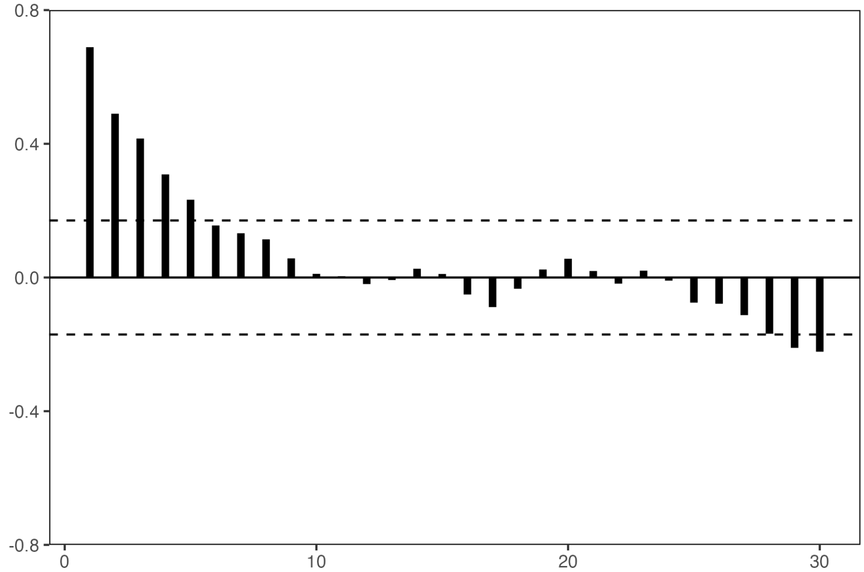
(a) March 2020 COVID-19 pandemic and central bank swap lines



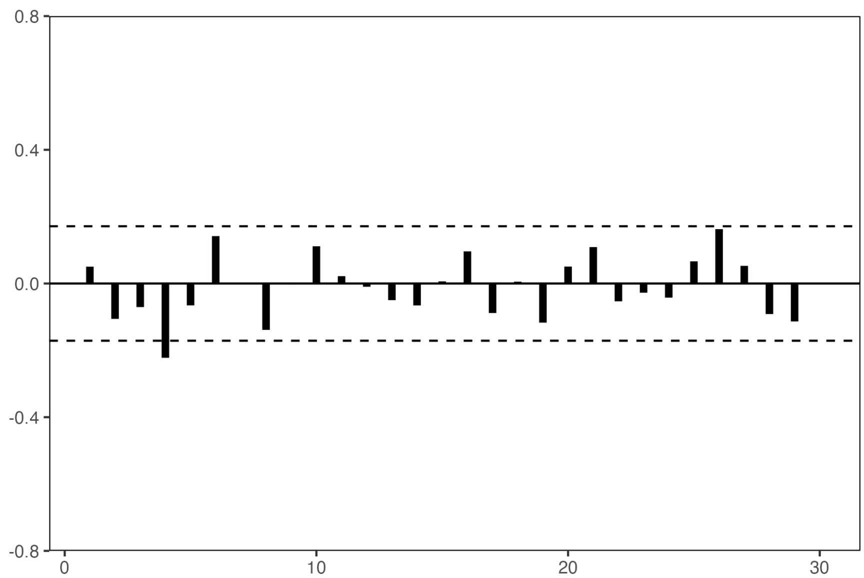
(b) Intra-day pattern during Silicon Valley Bank collapse

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 net dollars borrowed 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 A7: Autocorrelation Functions



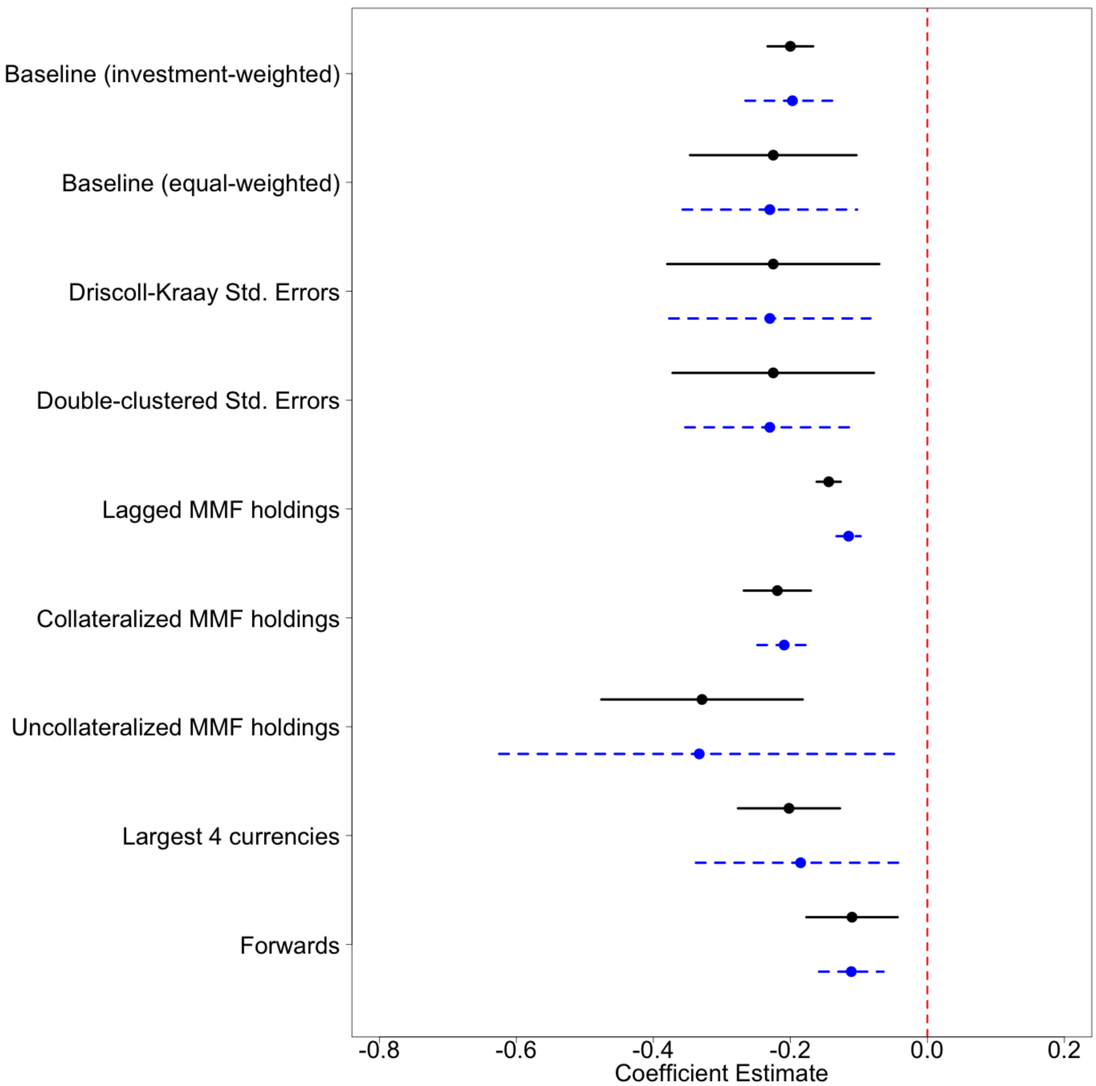
(a) Transaction amount



(b) % change in stock

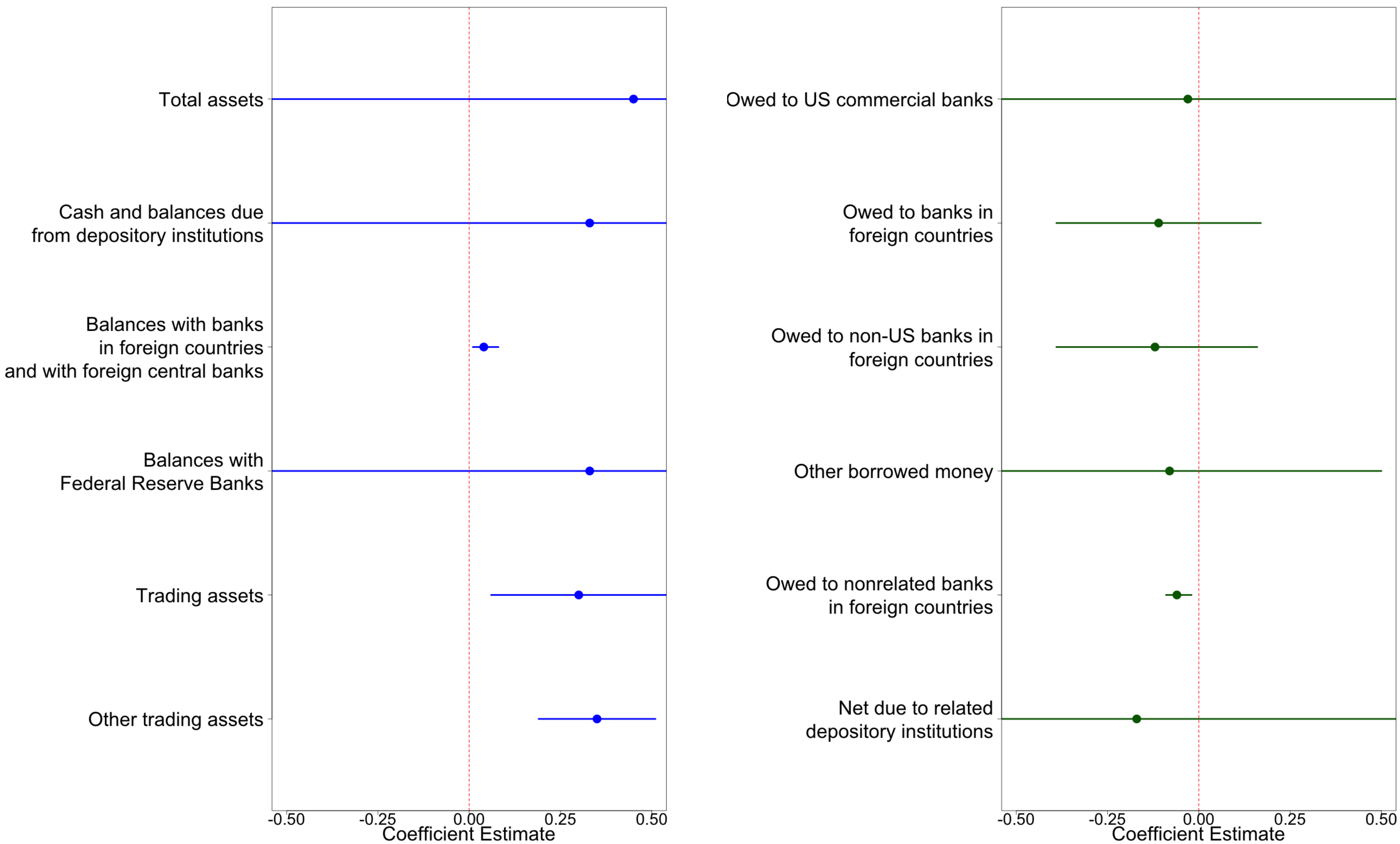
Notes: This figure plots the autocorrelation functions for monthly net synthetic dollars borrowed by global banks. Panel (a) considers the net transaction amount, calculated as the dollar value of buy minus sell trades aggregated across all maturity buckets, counterparty sectors and days in a month. Panel (b) considers the monthly percentage change in the stock of dollars borrowed. The x-axes reflect the number of lags, and the dashed lines represent 95% confidence interval.

Figure A8: Synthetic Dollar Funding and MMF Holdings - Specification Curve



Notes: This figure summarizes the OLS estimation results for banks' use of synthetic dollar funding regressed on changes in money market fund (MMF) holdings, across different specification choices. Dots on the plot indicate point estimates and horizontal lines show 95% confidence intervals. For each specification labelled on the y-axis, the figure plots two results: the black solid line considers models with currency fixed effects and the blue dashed line adds time (year-quarter) fixed effects. All specification choices include controls consistent with Equation 1. The corresponding full results are reported in (a) Table 3 for baseline, (b) Table A5 for standard errors, (c) Table A6 for lagged MMF flows, collateralization, and the largest 4 currencies, and (d) Table A7 for forwards.

Figure A9: On-Balance Sheet Items of Foreign Banks' U.S. Branches and MMF Holdings

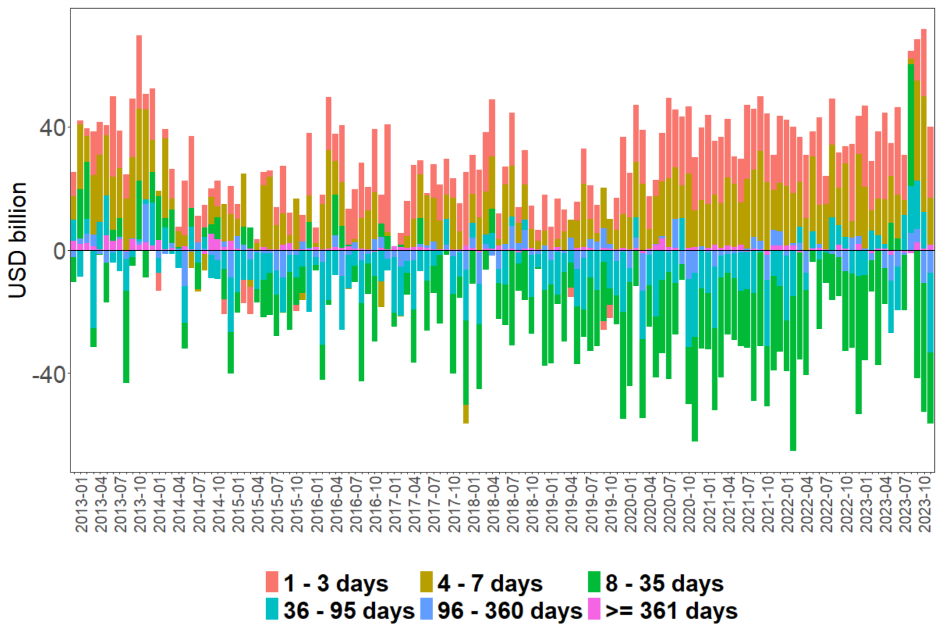


(a) On-balance sheet assets

(b) On-balance sheet liabilities

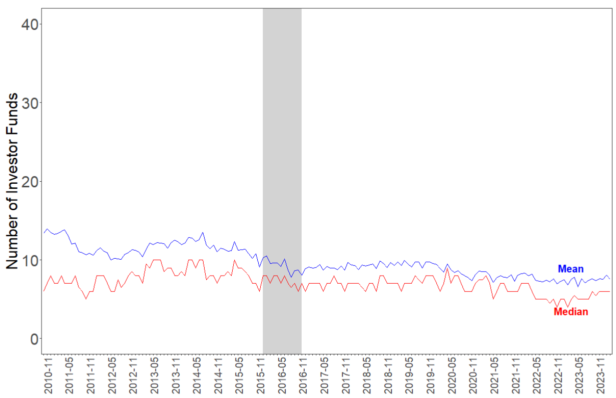
Notes: This figure plots estimates of Equation 1, where the dependent variables are each of the major line items on the balance sheets of U.S. branches and agencies of non-U.S. banks. For each dependent variable, I estimate Equation 1 at a quarterly frequency with changes in MMF holdings as the regressor. Dots indicate point estimates and horizontal lines show 95% confidence intervals. Panel (a) considers assetss while panel (b) considers liabilities. X-axes, representing percentage changes, are censored at -0.5/+0.5 for expositional clarity.

Figure A10: Synthetic Dollar Funding using FX Forwards

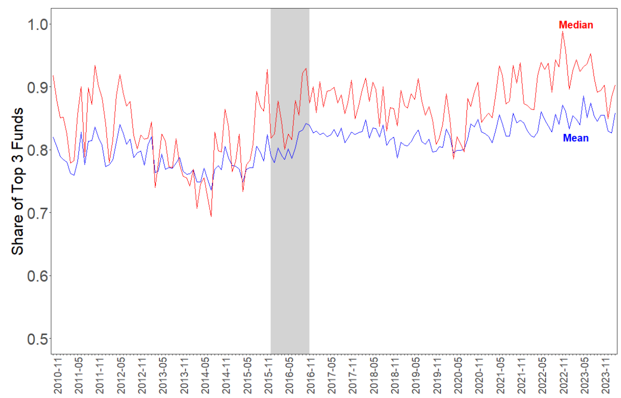


Notes: This figure plots the quantity of USD bought (positive y-axis) or sold (negative y-axis) against all 9 currencies in my sample put together by globally active dealer banks, facing all other counterparties. The time series is at a monthly frequency from January 2013 through December 2023. Bar colors represent 6 maturity buckets. The near date for all tenors is the spot date but no cash flow takes place on the near date. This figure is constructed using daily signed FX forward order flow sourced from CLSMarketData and aggregated at a monthly level.

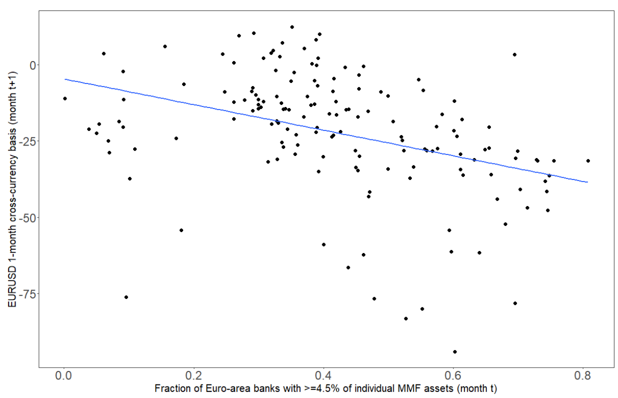
Figure A11: Drivers of Idiosyncratic Shocks to Money Market Fund Investments



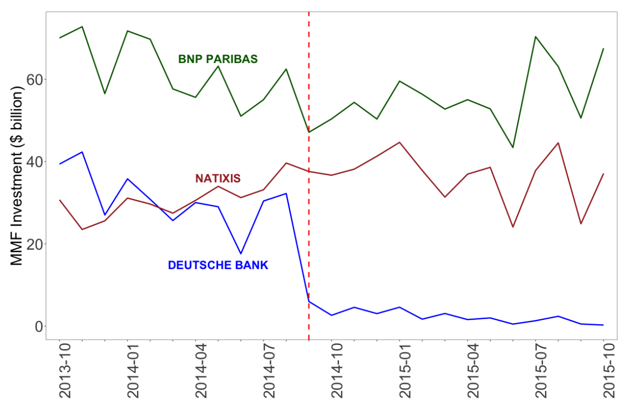
(a) Number of MMF investors in foreign banks



(b) Share of top 3 MMFs in foreign banks



(c) Concentration limit vs. CIP deviations



(d) Credit downgrade and MMF investment

Notes: This figure shows that money market funds (MMFs) represent a concentrated set of investors in bank securities, regulatory concentration limits on MMFs can occasionally bind for banks, and 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. In both the panels, 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 U.S. 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.

Table A1: Data Coverage and Representativeness

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

Notes: This table reports the estimated coverage and representativeness of FX swap transactions observed in CLS data against the April 2022 Bank for International Settlements (BIS) over-the-counter FX turnover survey. Panel A reports the gross volume of transactions between reporting dealers and various end-users as reported by the BIS, and the approximate share of this volume covered by the CLS data. (The CLS-equivalent sector names are in parentheses.) Panel B compares the share of each maturity bucket in the FX swaps turnover as reported by the BIS and observed in CLS data. Panel C compares the share of each currency in the FX swaps turnover as reported by the BIS and observed in CLS data. 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
All non-dealers	-0.29	3.89	-2.19	-0.28	1.43
NBFI	0.01	0.76	-0.16	-0.03	0.12
Fund	1.56	4.19	-0.30	1.08	2.83
Corporate	-0.68	1.81	-0.71	-0.21	0.00
Non-dealer Banks	-1.18	3.25	-2.81	-1.02	0.53
Panel B: By tenor	Mean	SD	p25	p50	p75
1 - 3 days	-0.60	1.60	-1.10	-0.30	0.20
4 - 7 days	-0.60	1.30	-1.00	-0.30	0.10
8 - 35 days	0.50	3.40	-0.90	0.20	1.40
36 - 95 days	0.30	1.70	-0.50	0.30	1.10
96 - 360 days	0.00	0.70	-0.30	0.00	0.30
>= 361 days	-0.00	0.20	-0.10	-0.00	0.00
Panel C: By currency pair	Mean	SD	p25	p50	p75
AUDUSD	0.10	0.80	-0.20	0.10	0.40
EURUSD	-0.40	2.40	-1.40	-0.40	0.70
GBPUSD	-0.10	1.70	-0.80	-0.20	0.40
NZDUSD	0.00	0.40	-0.10	0.00	0.10
USDCAD	-0.10	0.80	-0.40	-0.00	0.30
USDCHF	0.10	0.60	-0.10	0.10	0.30
USDJPY	0.10	1.30	-0.40	0.00	0.50
USDNOK	-0.00	0.20	-0.10	-0.00	0.10
USDSEK	-0.00	0.30	-0.10	-0.00	0.10

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 (N=2,853). 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 Largest Banks Borrowing from Money Market Funds

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

Notes: This table lists the 30 largest bank borrowers from U.S. money market funds and reports their average monthly borrowing in $ billion during my sample period (2013-23). The table also compares their classification in the CLS database and the parent's domicile country. CLS settlement members are large market-making financial institutions in the foreign exchange market.

Table A4: Descriptive Statistics for Prices and Control Variables

Panel A: EURUSD prices	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
– non-quarter-end months (1 month, bps)	-19.24	15.91	-30.29	-17.34	-9.80	88
Cross-currency basis (3 months, bps)	-25.30	20.42	-34.40	-23.98	-11.43	132
Panel B: Control variables	Mean	SD	p25	p50	p75	N
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
U.S. 1-month OIS	1.22	1.53	0.13	0.42	1.96	132

Notes: This table describes prices (cross-currency bases) and other control variables. Panel A summarizes EURUSD cross-currency bases across tenors from 1-week to 3-months, expressed in basis points. Panel A also shows that (1 month) bases are negative outside of quarter-end months. Panel B describes the control variables used throughout the analyses. All variables are at a monthly frequency. Data sources: Bloomberg and FRED.

Table A5: Synthetic Dollar Funding and MMF Holdings (Standard Errors)

	ΔSynthetic Dollars (by global banks)			
Panel A: Driscoll-Kraay	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.232***	-0.228***	-0.228***	-0.228***
	(0.072)	(0.077)	(0.078)	(0.074)
Panel B: Clustered by currency and time	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.232**	-0.228**	-0.228**	-0.228**
	(0.084)	(0.073)	(0.071)	(0.067)
Panel C: Wild bootstrap	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.232**	-0.228*	-0.228*	-0.228*
	[p=0.016]	[p=0.092]	[p=0.094]	[p=0.086]
N	1,048	1,040	1,040	1,040
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 is the % change in the stock of synthetic dollars held by global banks. Panel A uses Driscoll-Kraay (Driscoll and Kraay, 1998) standard errors while panel B clusters them by both currency and time. Panel C reports the p-values using wild bootstrap standard errors (256 replications). The regressor of interest is the change in money market fund holdings (Δ MMF holdings) in banks located in currency (country) i, expressed in \$ hundreds of billion. Columns (3) and (4) include currency fixed effects, and column (4) includes time (year-quarter) fixed effects. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A6: Synthetic Dollar Funding and MMF Holdings (Robustness I)

Panel A: Lagged MMF flows	ΔSynthetic Dollars (by global banks)			
	(1)	(2)	(3)	(4)
Δ MMF holdings (t-1)	-0.126***	-0.127***	-0.127***	-0.104***
	(0.019)	(0.026)	(0.026)	(0.014)
N	1,048	1,040	1,040	1,040
Controls	N	Y	Y	Y
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Panel B: Collateralization	ΔSynthetic Dollars (by global banks)			
	(1)	(2)	(3)	(4)
Δ MMF holdings (collateralized)	-0.228***	-0.204***		
	(0.024)	(0.025)		
Δ MMF holdings (uncollateralized)			-0.365***	-0.356**
			(0.088)	(0.146)
N	1,040	1,040	1,040	1,040
Controls	Y	Y	Y	Y
Currency FE	Y	Y	Y	Y
Time FE	N	Y	N	Y

Panel C: Largest 4 currencies	% change in stock		count of net buy trades	
	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.202**	-0.185*	-6.279**	-8.219***
	(0.038)	(0.078)	(1.645)	(1.351)
N	520	520	524	524
Controls	Y	Y	Y	Y
Currency FE	Y	Y	Y	Y
Time FE	N	Y	N	Y

Notes: This table reports three robustness checks for the baseline results of Table 3. Panel A re-estimates Equation 1 using *lagged* changes in MMF holdings. Panel B disaggregates MMF holdings by collateralized (e.g., repo) and uncollateralized instruments. Panel C repeats the estimation only for the four largest currency pairs: EURUSD, USDJPY, GBPUSD, USDCHF. Controls, fixed effects, and observation weights are consistent with Table 3. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A7: Synthetic Dollar Funding and MMF Holdings (Robustness II)

Panel A: Forwards	Δ Synthetic Dollars (short-term forwards)			
	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.075**	-0.086*	-0.083	-0.103***
	(0.026)	(0.048)	(0.049)	(0.026)
N	1,048	1,040	1,040	1,040
Controls	N	Y	Y	Y
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Panel B: Interest Rates	Δ Fraction Synthetic			
	(1)	(2)	(3)	(4)
Δ U.S. 1-month OIS	-0.304*	-0.437*	-0.439*	-0.806
	(0.175)	(0.215)	(0.212)	(0.580)
N	1,048	1,048	1,048	1,048
Controls	N	Y	Y	Y
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Notes: Panel A reports estimates of Equation 29 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. Panel B reports estimates of Equation 30, where 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 U.S. 1-month OIS rate in month t. In both the panels, columns (2) through (4) include controls, columns (3) and (4) include currency fixed effects, and column (4) includes time (year-quarter) fixed effects. Observations are weighted by the level of money market fund investments. Standard errors clustered by currency are reported in parentheses. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A8: Common Variation in Bank-level Money Market Fund Flows

	% of variation explained					
	EUR	JPY	GBP	SEK	AUD	CAD
PC1	55	62	54	64	41	91
PC2	27	27	22	34	36	4
PC3	11	9	16	1	21	2
Cumulative	93	98	92	99	98	97

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 banks that had outstanding investments from U.S. money market funds in a given month.

Table A9: Instrument Correlations with Confounding Variables

Correlation of "excess wholesale funding" with	Average across currencies	Pooled
Δ Money market fund holdings of U.S. banks	0.092	0.038
Δ Intermediary leverage ratio (squared)	-0.016	-0.030
Quarter-end indicator (1/0)	-0.031	-0.059
Δ U.S. 1-month OIS	0.017	0.006
Δ Repo market borrowing (non-MMF)	-0.033	-0.033
Serial correlation	-0.183	-0.102
Δ Synthetic Dollars (Funds)	0.104	0.086
Δ Synthetic Dollars (Corporate)	0.071	0.021
Δ Synthetic Dollars (Non-bank financial institutions)	-0.008	-0.015

Notes: This table reports the correlations between the granular instrumental variable, "excess wholesale funding", and other potentially confounding variables. The table shows the average correlation across each of the five currency pairs as well as the pooled correlation.

Table A10: Elasticity of Non-Bank Investors' Hedging Demand

Panel A: First stage	ΔCross-currency basis		
	PC1 (1W, 1M, 3M)	1W	1M
Excess wholesale funding ($z_{c,t}$)	7.292***	4.486***	6.293***
	(1.010)	(0.462)	(0.709)
Instrument F-statistic	51.19	94.20	78.75
Panel B: Second stage	Hedging Demand^S		
	Fund	Corporate	NBFI
$\Delta\widehat{\text{Cross-currency}}$ basis$_{c,t}$	0.006	0.005	0.005
	(0.010)	(0.050)	(0.042)
N	782	784	786
Controls	Y	Y	Y
Currency, Time FE	Y	Y	Y

Notes: This table reports the two-stage least squares estimates for Equation 10 (first stage) and Equation 11 (second stage). In Panel A, the dependent variable is monthly change in cross-currency basis, regressed on the instrumental variable, "Excess wholesale funding ($z_{c,t}$)". Panel B reports the second stage results where the dependent variable is the change in the stock of net USD buy-sell swaps held by different non-bank sectors. Standard errors clustered by currency are reported in parentheses. $^*p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A11: Causal Impact on CIP Deviations (Leave One Currency Out)

	ΔCross-currency basis$_{c,t}$ (1 week)					
	(1)	(2)	(3)	(4)	(5)	(6)
Δ $\widehat{\text{Synthetic Dollars}}_{c,t}$	-3.293*	-3.905***	-3.380***	-4.106**	-3.868***	-3.915***
	(1.770)	(0.913)	(0.558)	(1.688)	(0.794)	(0.765)
N	625	625	625	625	625	625
Controls	Y	Y	Y	Y	Y	Y
Currency, Time FE	Y	Y	Y	Y	Y	Y

Notes: This table uses the leave-one-out method to test the SUTVA assumption underlying the estimates of Equation 12. The specification mirrors Table 7, with EURUSD excluded in column (1), GBPUSD in column (2), USDJPY in column (3), USDSEK in column (4), AUDUSD in column (5), and USDCAD in column (6). Standard errors clustered by currency are reported in parentheses. $^*p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.