Synthetic Dollar Funding

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Job Market Paper

June 2025

Abstract

What happens to dollar credit when global banks' access to wholesale funding dries up? Wholesale funding is vital for banks' dollar liquidity needs, but is subject to policy levers that can restrict access. This paper uses novel quantities data to show that foreign exchange (FX) swaps emerge as alternative ("synthetic") funding instruments when banks face constraints in accessing wholesale dollar funding. Using an instrumental variables strategy that exploits idiosyncratic variation in the availability of wholesale dollars, I show that an increase in banks' demand for swaps (i) causes deviations from covered interest parity (CIP)—a fundamental no-arbitrage asset pricing condition, and (ii) increases non-bank institutions' currency hedging costs, reflecting inelastic demand. I use my empirical estimates to calibrate a model in which global banks optimally substitute into synthetic dollars to offset funding shortfalls, generating CIP deviations in equilibrium. I show that a sharp decline in wholesale funding can disrupt global dollar credit, as the marginal cost of synthetic dollars quickly exceeds banks' asset returns. Conversely, relaxing funding constraints could halve CIP deviations with a modest increase in the default risk borne by wholesale investors. My findings highlight the externalities of domestic liquidity regulations on the pricing and availability of US dollar credit, as well as on the distribution of risks across the financial system.

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

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

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I am grateful to Tong Yao, Ishita Sen, Fotis Grigoris, Petra Sinagl, and the late David Bates for regular guidance and feedback. This paper benefited from helpful comments by Iñaki Aldasoro, Adolfo Barajas (discussant), Falk Bräuning, Ricardo Correa (discussant), Wenxin Du, Zhiyu Fu, Xavier Gabaix, Marco Graziano (discussant), Ingomar Krohn (discussant), Victoria Ivashina, Jetson Leder-Luis, Thomas A. Maurer (discussant), Ioana Neamțu, 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 conference/seminar participants at the American Finance Association (PhD poster), Bank for International Settlements - University of Basel, CFTC, 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: European FA, Northern FA, FMA.

"EU firms fear dollar liquidity becoming tariff bargaining chip."– Risk.net, April 2025

The recent escalation in cross-border trade tensions has reignited concerns about disruptions to US dollar liquidity in the international financial system. A large number of financial and non-financial firms worldwide heavily depend on US dollar credit, and constraints in dollar supply are known to destabilize asset markets and the real economy (Ivashina et al., 2015, Avdjiev et al., 2019), often necessitating central bank intervention (Bahaj and Reis, 2022).[1] At the heart of this system are large global banks that facilitate cross-border dollar flows. Strikingly, a majority of US dollar credit is provided by *non-US* banks that have limited access to stable funding sources such as insured deposits, making them particularly vulnerable to disruptions in dollar liquidity.

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 dollar 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 restrict access, particularly for non-US borrowers. For example, following a series of destabilizing runs during the 2008 financial crisis, regulations significantly restricted wholesale investors' exposure to risky bank debt (Kacperczyk and Schnabl, 2013, Schmidt, Timmermann, and Wermers, 2016, Anderson, Du, and Schlusche, 2021). While existing research shows that such restrictions can affect banks' access to dollar liquidity, it tends to examine wholesale markets in isolation, overlooking its interaction with and spillovers to other funding markets.

This paper examines the second major source of dollar funding - the off-balance sheet *synthetic funding* 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 spot risk. Synthetic funding relies on foreign currency deposits paired with derivatives, potentially allowing banks to sidestep restrictions on US wholesale investors. However, analyzing its role in banks' funding portfolio is challenging because quantities traded are not directly observable, leaving key questions unanswered: Do swaps help banks offset declines in wholesale dollar liquidity? If so, what are the implications for the pricing and availability of global dollar credit?

Using a comprehensive dataset linking large banks' FX swap transactions with their wholesale borrowing, this paper makes three contributions. First, I show that globally active dealer 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 spe-

[1] 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.

cialized intermediaries, i.e., swap arbitrageurs. This enables banks with access to multiple money markets to raise marginal dollars in response to the limited scalability of funding from US wholesale investors. Banks' substitution from wholesale to synthetic funding highlights one reason why FX swaps - with over $60 trillion in outstanding notional and $3.8 trillion in daily turnover - are among the most heavily traded financial instruments (Bank for International Settlements, 2022).[2]

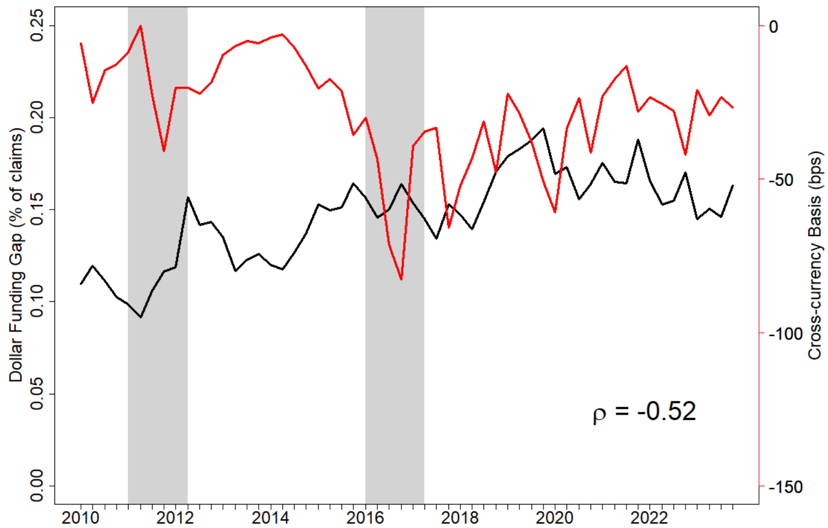
My second contribution is to show that banks' swap demand widens deviations from covered interest parity (CIP). CIP deviations, measured as cross-currency bases, reflect the breakdown of no-arbitrage asset pricing conditions. They imply a wedge between synthetic and wholesale dollar funding costs, with real economic consequences for credit allocation (Keller, 2024), capital flows (Kubitza et al., 2024), and investment (Ippolito et al., 2024). I show that banks' demand for synthetic dollars is a key driver of CIP deviations. As a "smoking gun", Figure 1 shows a strong negative correlation between non-US banks' dollar funding gap and cross-currency bases, consistent with banks using swaps to bridge funding shortfalls. I provide the first causal evidence of this link by instrumenting banks' swap demand with shocks to wholesale dollar availability, and show that the bases become more negative (i.e., synthetic dollars become costlier) as swap demand increases.

I argue that banks' swap demand affects bases because it interacts with an upward-sloping supply curve of swap arbitrageurs. Post-crisis regulations, such as Basel III leverage ratio requirements, have raised the balance sheet cost of risk-free arbitrage (Du et al., 2018, Rime et al., 2022). Thus, the price impact I document reflects the intersection of two regulatory forces that jointly explain CIP deviations — one that steepens the supply curve and the other that shifts banks' demand from wholesale to synthetic markets. To quantify the broader effects of these frictions, I estimate *non-bank* institutions' demand elasticities to CIP deviations and find that they largely absorb negative bases as higher hedging costs, potentially amounting to billions of dollars annually.

My third contribution is to quantitatively assess the limits of synthetic market in offsetting sharp dollar funding shortfalls. If US regulators were to further restrict non-US banks' access to wholesale markets, then 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 their dollar assets. My key innovation is to incorporate a constrained 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 banks' wholesale funding constraints tighten. As a result, a sharp reduction in wholesale funding can ultimately hamper US dollar credit in the economy because the marginal cost of swaps quickly exceeds the marginal revenue on bank assets.

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

Figure 1: Dollar Funding Gap of Non-US Banks and Cross-Currency Basis



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

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. The data span seven tenors and nine major currency pairs that together represent over 90% of swaps trading and cover 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 sector — including large dealer banks, non-bank financials, investment funds, and corporations — over an 11-year period from 2013 through 2023, capturing major policy events such as the 2016 US money market fund reform. 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 US money market funds (MMFs), e.g., Vanguard and Fidelity, 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-US 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 US MMF exposures to individual banks are available, that allow me to jointly analyze these two major short-term 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 associates 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.

To causally show that banks use swaps to compensate for wholesale funding decline, I exploit a major regulatory reform that triggered a sharp contraction in MMF assets. In October 2016, the Securities and Exchange Commission implemented structural changes to MMFs aimed to improve 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.

Synthetic markets compensate banks for a decline in wholesale funding but create two major externalities. First, I show that an increase in banks' demand for swaps turns cross-currency bases more negative across funding currencies and for maturities from 1 week to 3 months. 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 individual non-US banks.

The key idea of my identification strategy is to isolate *idiosyncratic shocks* to banks' wholesale funding from broad market shifts, which may be correlated with confounding factors such as macroeconomic volatility or swap arbitrageurs' constraints. These shocks arise from several sources: (i) fund-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 affected

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

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 meaningful macro-level fluctuations. I construct a 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 less negative cross-currency bases, confirming its relevance.

The key threat to my identification is that wholesale funding shocks faced by non-US banks might affect cross-currency bases independently of their swap demand—for instance, by simultaneously impacting US banks (swap arbitrageurs) or non-bank investors. I empirically confirm that my instrument is uncorrelated with any such confounding factor, with its validity supported by three institutional features. First, MMFs exhibit differential risk appetite by borrower type and specialize in their lending targets, limiting the spillover of idiosyncratic funding shocks across diverse institutions. Second, US banks and non-banks collectively receive only half the MMF investments compared to non-US banks, further decoupling them from the primary source of variation in my instrument. Third, by construction, the instrument strips out common factors, such as quarter-ends, regulatory shifts, and systemic constraints, that are known to impact swap arbitrageurs. With these features supporting the exclusion restriction, 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 global banks.

The second externality of banks' use of synthetic dollars is the increased hedging cost borne by non-bank users of FX swaps—investment funds, non-financial corporations, and non-bank financial intermediaries. Using my instrument, I estimate non-banks institutions' demand elasticity to wider CIP deviations, which they either absorb passively (if inelastic) or adjust volumes to limit total hedging cost (if elastic). I find that all non-bank institutions exhibit downward-sloping demand curves, but with an elasticity parameter under one. For example, a 10% decline in the basis leads funds to reduce swap positions by less than 2%. These estimates imply that foreign investors largely absorb price shocks in the form of higher hedging costs. A back-of-the-envelope calculation suggests that, for an estimated $2 trillion in outstanding FX hedges (Du and Huber, 2023), foreign investors pay an additional $2.6 billion in FX hedging costs per annum.

My results indicate that banks face additional costs when raising dollars synthetically, raising an important question in the current policy backdrop: can synthetic markets fully offset a decline in wholesale funding without hampering dollar credit availability? To address this question, I develop a model where global banks lend dollars using a combination of wholesale and synthetic funding. My framework builds on Ivashina, Scharfstein, and Stein (2015), with three key extensions. First, given that cross-currency bases have been persistently negative since 2008, banks in my model exhaust wholesale funding before turning to swaps to cover any shortfall. Second, I introduce a swap arbitrageur to makes cross-currency 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 quantitative counterfactual results.

I find that a reduction of more than 20% in wholesale funding beyond current limits can curtail 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 I allow swap arbitrageurs' balance sheet constraints to 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 the additional default risk for US wholesale investors well below financial crisis levels.

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, making it more difficult to implement macro-prudential policies such as central bank swap lines (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 US dollar in the global financial 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 US wholesale 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, potentially hampering dollar liquidity. Similar trade-offs arise in other markets. For example, central bank bond purchase programs 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 (Du et al., 2023, Khetan et al., 2023). These frictions call for a coordinated assessment of how multiple regulations interact across markets.

Related literature. This paper contributes to the literatures on financial intermediation, international asset pricing, and frictions in short-term funding markets.

Recent studies highlight the scarcity of intermediary banks' balance sheet space (Siriwardane, 2019, Fleckenstein and Longstaff, 2020). My unique contribution is to analyze the growth of off-balance sheet instruments that enable global banks to reduce dollar funding constraints. In doing so, my research also contributes to the literature on banks' short-term capital management under market frictions: Cetorelli and Goldberg (2012) show that global banks manage liquidity using cross-border funding that insulates them from local monetary policy shocks; Hilander (2014) reports that Swedish banks raise short-term funding in foreign currency; Iida, Kimura, and Sudo (2018) document increasing dependence of non-US banks on FX swaps; Correa, Du, and Liao (2020) find that large US banks drain reserves parked with the Federal Reserve to finance short-term lending; Du and Schreger (2022) argue that non-US banks face barriers in accessing dollar cash markets; and Siriwardane, Sunderam, and Wallen (2022) document segmentation in banks' internal funding sources. 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 arbitrage: Du, Tepper, and Verdelhan (2018) and Du, Hébert, and Li (2023) focus on post-financial crisis regulatory regime shifts, Rime, Schrimpf, and Syrstad (2022) on funding costs, and Barbiero, Bräuning, Joaquim, and Stein (2024) on risk limits. However, the role of *demand* as a factor has been understudied. Notable exceptions include Baba, Packer, and Nagano (2008) who correlate the demand for dollar funding and cross-currency basis during the financial crisis, Liao and Zhang (2020) who study FX hedging by non-US investors, and Ben Zeev and Nathan (2024) who study institutional investors' demand under limits to arbitrage. While each of these sources of demand is important, they abstract away from analyzing systematic variation in the supply of dollars to global banks. Focusing on the largest set of institutions that regularly bear on-balance sheet dollar funding gap, my paper provides a causal link between their swap demand and CIP deviations, and traces the source of this activity to frictions that lead banks to substitute cheaper wholesale funding with costlier synthetic funding.

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

Closer to my setting, Abbassi and Bräuning (2021) document the use of FX forwards by German banks to close their dollar funding gap at quarter-ends, Syrstad and Viswanath-Natraj (2022) find that customer order flow affects swap prices during these periods, and Kloks, Mattille, and Ranaldo (2024) document that Euro-area banks substitute repo funding with FX swaps at quarter-ends. My paper focuses on persistent limits to wholesale dollar funding that are *not restricted to calendar dates* and are, therefore, generalizable across periods. This distinction is important because there are different dynamics at play at quarter-ends. First, regulations around leverage ratios make it particularly costly for dealers to price FX derivatives at quarter-ends, sharply affecting the supply curve (Cenedese, Della Corte, and Wang, 2021).[4] Second, Abbassi and Bräuning (2021) argue that foreign banks' end-of-quarter dollar demand reflects regulatory arbitrage, which is distinct from the ongoing wholesale funding frictions that I focus on. Third, Wallen (2020) shows that US banks exercise market power at quarter-ends which can explain a significant part of CIP deviations on these dates. Finally, non-bank end-users may also face end-of-period liquidity shocks, due to "dash for cash" for institutional investors (Etula et al., 2020) or "settlement breaks" for corporations (Khetan and Sinagl, 2023), which may not reflect funding market frictions.

I contribute to the literature that links funding frictions with credit provision, focusing on the large but often overlooked synthetic markets. While extensive work has examined deposit flightiness in the wake of SVB collapse (e.g., Blickle et al. (2024)), my work draws attention to banks that lack dollar deposits yet remain key dollar lenders. Closely related to my work is Keller (2024), who shows that banks change the currency composition of lending to arbitrage CIP deviations. Ivashina et al. (2015) provide an early theoretical framework under exogenous CIP deviations, extended by Iida et al. (2018) to include arbitrageurs, with empirical evidence from UK banks in Eguren-Martin et al. (2024). My paper is the first to calibrate key parameters of these models, enabling me to quantitatively link funding frictions with CIP deviations and dollar credit availability.

Finally, my paper joins the growing literature on the impact of market frictions on non-bank institutions' financial risk management. Several papers link the response of individual sectors to cross-currency bases: Liao (2020) jointly considers CIP and corporate bond spreads, Sialm and Zhu (2024) focus on fixed-income mutual funds, and Kubitza, Sigaux, and Vandeweyer (2024) study Euro-area institutional investors. Using *cross-sector* swap transactions data, my paper estimates the FX hedging demand elasticity of multiple non-bank sectors, and quantifies the spillover impact of banks' synthetic dollar funding on non-bank investors' hedging costs.

This paper proceeds as follows. Section 1 provides the institutional background and develops hypotheses. Section 2 discusses the data, and Section 3 analyzes the demand for synthetic dollar funding. Section 4 shows the causal impact on prices and spillover impact on non-banks. Section 5 calibrates the model to provide analytical and quantitative insights. Section 6 concludes.

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

1. Institutional Background and Hypotheses

With over 14 trillion in US dollar-denominated assets (panel (a) of Figure 2), non-US global banks play a pivotal role in supplying dollars to various segments of the world economy. Many of these assets consist of short-term working capital loans and credit lines extended to firms engaged in cross-border trade and capital flows.[5] Despite large asset holdings, foreign and US branches of non-US banks do not have direct access to FDIC-insured retail dollar deposits. As a result, a large portion of non-US banks' dollar assets is not matched by equivalent liabilities, creating a dollar funding gap on their balance sheets (Abbassi and Bräuning, 2021). In the absence of deposits, US money market funds (MMFs) such as Vanguard and Fidelity have traditionally remained among the largest investors in non-US banks' short-term debt (Aldasoro et al., 2022).

MMFs are tightly regulated pooled mutual funds that invest in short-term fixed income debt issued by governments, banks, and non-bank institutions, with capital preservation as their primary investment objective. Aldasoro and Doerr (2023) show that US MMFs held over $6 trillion in assets as of 2023, half of which was invested in banks' commercial papers and certificates of deposit. On the other hand, other funding sources such as eurodollar deposits have significantly shrunk since the financial crisis (New York Fed, 2024). Although vital for non-US banks, MMFs are increasingly subject to regulatory controls on liquidity and default 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. Further, the 2016 regulatory reform allowed prime MMFs to float their net asset values, increasing volatility in end-investor flows and reducing the stability of dollar funding for borrowers.

In contrast to wholesale markets, non-US banks typically have easier access to local currency deposits, especially when their home country central banks keep liquidity conditions loose. These deposits, paired with foreign exchange (FX) swaps, allow banks to raise dollars synthetically by exchanging the local currency for the US dollar at a near date (typically the spot date), with the transaction reversing at a later date. In addition to reducing reliance on constrained wholesale investors, swaps do not require scarce dollar collateral (unlike repo transactions), giving them additional flexibility in raising dollar funding.[6] This trade-off formulates my first hypothesis:

Hypothesis 1: *Banks increase reliance on synthetic dollar funding when wholesale funding from US money market funds declines.*

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

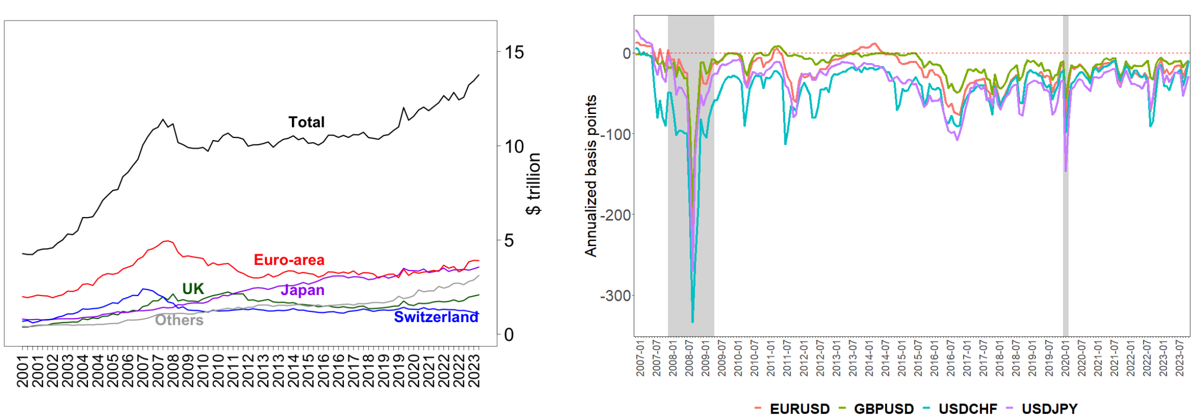
[6] Figure A1 depicts the balance sheet implications of wholesale dollar debt in panel (a) and synthetic debt in panel (b). Even though the cash flow profile of swaps resembles that of a collateralized term loan, accounting conventions imply that the resulting "dollar" debt is not reported as a balance sheet liability.

While the FX swap market enables banks to raise dollars synthetically, it is also characterized by persistent deviations from covered interest parity (CIP), the breakdown of a fundamental no-arbitrage pricing rule that pins down theoretical swap prices. The price of an FX swap should neutralize the cost differential between wholesale and synthetic dollar borrowing, i.e., the cross-currency basis should be zero. However, panel (b) of Figure 2 shows that, in practice, cross-currency bases deviate from zero across multiple currencies, and turn sharply negative during periods of economic contraction. Existing studies highlight that post-crisis regulations, such as Basel III leverage ratio requirements, have imposed additional costs on swap arbitrageurs, which reflects in non-zero cross-currency bases.

From a demand perspective, Figure 1 shows a strong negative correlation between non-US banks' dollar funding gap and the cross-currency basis. The gap has ranged between 15–20% of outstanding claims in recent years, which translates to \$1.2–\$2 trillion. A widening gap associates with more negative bases, indicating greater reliance on FX swaps to bridge the shortfall. The figure also shows that the funding gap widens when MMFs reduce investment in non-US bank debt, for example during the 2011 Euro debt crisis and the 2016 regulatory reform. I formally test this price impact in my second hypothesis:

Hypothesis 2: *A rightward shift in banks' demand for swaps interacts with upward sloping supply curve of swap arbitrageurs to turn cross-currency bases more negative.*

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



(a) US Dollar Assets

(b) CIP Deviations

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

2. Data

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

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

2.1. Swaps and Forwards

I source daily records of signed order flow across 9 currency pairs that include key economic details such as the sectors trading the instrument, buy and sell volumes and counts of trade, maturity buckets, and the currencies involved, separately for swaps and forwards.[8] Both the swaps and forwards data are structured similarly except that swaps are split by 7 tenor buckets, while forwards are split by 6 buckets (forwards exclude the overnight tenor). Further, swaps entail two sets of cash-

[7] Other studies that use CLS data include Hasbrouck and Levich (2021), Ranaldo and Somogyi (2021), Khetan and Sinagl (2023), Roussanov and Wang (2023) for FX spot, and Cespa, Gargano, Riddiough, and Sarno (2022), Ranaldo (2022), Bräuer and Hau (2022), Kloks, Mattille, and Ranaldo (2023), Kloks, McGuire, Ranaldo, and Sushko (2023), An and Huber (2025) for FX derivatives.

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

flows, with the near leg settling on the trade date or the spot date, while forwards entail a single set of cash-flows only at the far date. These two products comprise the bulk of FX derivatives volume and jointly provide me with a comprehensive picture of activity in this market. One limitation of this dataset is that I do not observe "inter-dealer" trading. Thus, my estimates of global dealer banks' net synthetic dollar funding could be understated to the extent that banks offset this demand among themselves.[9]

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

Table 1 shows that global banks borrow an average of over $43 billion on a given day from all other sectors put together. This demand is almost entirely supplied by non-dealer banks, while other end-users behave similar to global banks: funds borrow on average $14 billion per day, and corporate entities and non-bank financial institutions (NBFIs) each borrow about half a billion dollars. These facts 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 1 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 capital requirements from regulatory perspective. The activity in long-tenor swaps likely supports asset purchase, given that banks supply dollars in those tenors to the rest of the end-user sectors. Finally, panel C shows that most of the dollar borrowing is against Euro (EURUSD pair) at $25.8 billion per day, followed by the Japanese yen (USDJPY pair) at $12.2 billion, with the Swiss franc (USDCHF pair) and other currencies in single digits.

While dollar funding activity via FX swaps is concentrated between global banks and non-dealer banks, and for tenors up to one week, Table A2 shows that FX forwards are mainly traded by funds and corporations, with volumes more uniformly distributed up to the 3-month tenor.

[9] Correa et al. (2020) and Kloks et al. (2024) suggest that US Global Systemically Important Banks (GSIBs) lend US dollars via swaps to non-US GSIBs, particularly as quarter-ends.

Table 1: Descriptive Statistics for Daily Synthetic $ Borrowing by Global Banks

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

Notes: This table presents summary statistics of daily net 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. 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.

2.2. Money Market Fund Holdings

US money market funds report their holdings at a monthly frequency. I source these data from the N-MFP filings data set made available by the Securities and Exchange Commission (SEC), which covers both secured (repo and asset-backed commercial paper) and unsecured (commercial paper and certificate of deposit) instruments.[10] I focus on three reports to construct monthly bilateral flows between each MMF and the borrower's legal entity identifier (LEI): security-level holdings file, submission details file, and fund adviser file. I follow Chernenko and Sunderam (2014) and Cipriani and La Spada (2021) in the merging and cleaning of these data sets. Then, I match the borrower LEIs to their parent firms, their countries of domicile, and the "home" currencies. For example, all LEIs belonging to Deutsche Bank roll into the currency euro, with the idea that it is easiest for the bank to access its local currency money market for conducting synthetic dollar borrowing. Using these data, I construct the monthly time series of the total MMF investment in each bank LEI, mapped to the country and currency of its parent's domicile. Appendix A provides additional details on the data processing steps.

Panel A of Table 2 provides descriptive statistics on both the level and changes in monthly holdings of US MMFs. The average monthly holdings of MMFs in non-US bank securities during my sample period was \$963 billion, with a standard deviation of \$155.8 billion. Uncollateralized borrowing accounts for roughly half of total borrowing, reaching up to 70% in the early part of the sample period, and exhibits substantial variability. Euro-area banks were the largest foreign beneficiaries of MMF investment, at an average of \$345.5 billion per month, followed by Japanese banks at \$163.7 billion.

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

The N-MFP filings also report the collateral pledged by borrower banks to money market funds in secured dollar borrowing. The collateral includes not only marketable securities (e.g., US Treasuries), but also bank-held corporate debt, along with characteristics such as the value of the loan and the interest rate that banks earn on it. I use this granular data to capture non-US banks' dollar assets, and estimate their revenue function which anchors key parameters in my calibration.

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

2.3. Prices and Market Variables

The relevant measure of price in my context is cross-currency basis. I follow Du et al. (2018) to construct the basis for each currency pair across tenors ranging from one week to three months. I source daily FX spot and forward prices, and the overnight indexed swap (OIS) rates from Bloomberg. Then, I calculate the annualized difference between USD OIS rate and the corresponding synthetic borrowing rate (foreign currency OIS rate plus the swap premium) as the daily cross-currency basis, where a negative basis indicates that it is costlier to borrow dollars using swaps. Note that OIS rates for the Swiss franc (CHF) are unavailable prior to 2017. Hence, I use the CHF LIBOR series to construct USDCHF cross-currency basis.

Panel B of Table 2 shows that the average monthly EURUSD cross-currency bases are negative across the term structure. Between 2013 and 2023, the mean cross-currency basis was negative 19 bps for 1-week tenor, and negative 25 bps for 3-month tenor. Notably, the basis is negative even *outside of quarter-end* months. The EURUSD spot rate declined about 17 bps per month, indicating USD appreciation during the sample period. However, the change in overnight swap points was negligible, which suggests that swaps may be preferred over outright spot or forwards for borrowing dollars due to minimal price risk.

In addition to spot and swap prices, I source a number of variables that form control in my empirical analysis: (i) "Assets", the sum of country-level quarterly dollar assets, linearly interpolated to monthly;[11] (ii) "Gross position", the sum of buy and sell volume of swaps that could affect balance sheet costs (Bahaj et al., 2024); (iii) "ILRS (log)", log of the intermediary leverage ratio (squared) provided by He, Kelly, and Manela (2017); (iv) "CBBS/GDP", the difference between the European Central Bank and the Federal Reserve Bank's balance sheet size as a percentage of (linearly interpolated) GDP; and (v) "US 1-month OIS" for US interest rates.

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

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

Panel A: Money market fund holding	Mean	SD	p25	p50	p75	N
All non-US banks ($ billion)	963.9	155.7	867.4	979.8	1051.8	132
– of which, uncollateralized ($ billion)	495.8	181.7	351.7	422.6	679.3	132
Δ All non-US banks ($ billion)	-0.4	133.3	-85.6	2.5	76.7	131
EUR banks ($ billion)	346	80.1	290.1	340.8	408.7	132
Δ EUR banks ($ billion)	0.1	86.3	-52.5	4.0	48.4	132
JPY banks ($ billion)	163.7	30.3	139.8	154.1	187.4	132
Δ JPY banks ($ billion)	0.6	14.0	-7.0	-0.1	8.3	132
Panel B: EURUSD prices and controls	Mean	SD	p25	p50	p75	N
Cross-currency basis (1 week, bps)	-19.40	22.76	-24.46	-14.46	-7.05	132
Cross-currency basis (1 month, bps)	-26.08	27.65	-33.76	-20.71	-10.25	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	-34.18	-23.98	-11.58	132
Δ Spot price (bps)	-16.73	196.16	-139.52	-15.81	97.27	132
Δ Swap price (overnight, bps)	0.08	3.14	-0.87	-0.02	0.74	132
Assets ($ billion)	3,291.6	199.9	3,181.5	3,260.0	3,349.5	132
Gross position ($ billion)	138.78	18.62	123.68	136.33	151.88	132
ILRS (log)	5.57	0.30	5.35	5.59	5.76	132
CBBS/GDP	0.10	0.11	-0.00	0.13	0.19	132
US 1-month OIS	1.22	1.53	0.13	0.42	1.96	132

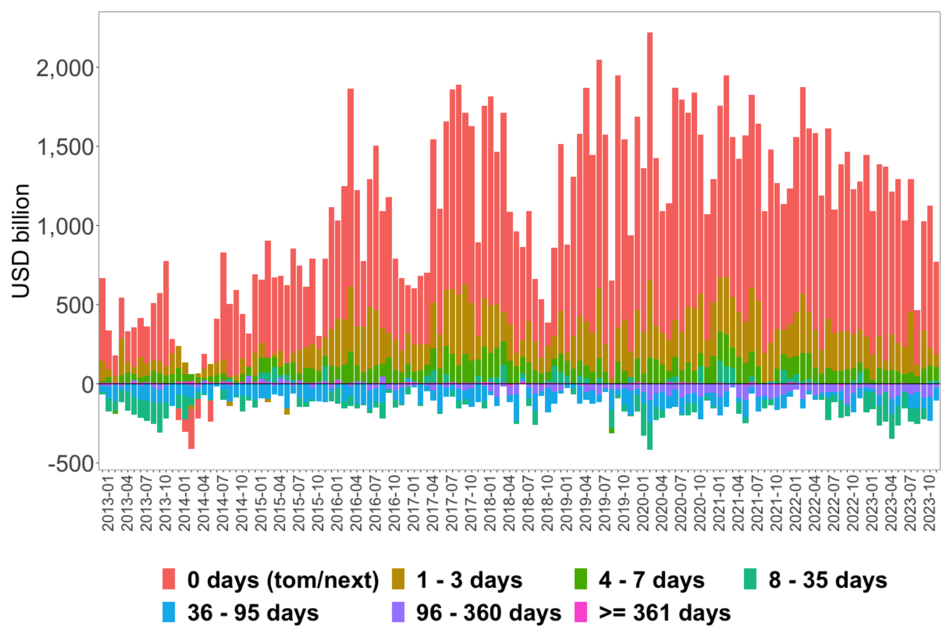
Notes: This table describes money market fund holdings in panel A, and price and market variables in panel B. Panel A shows US money market fund (MMF) holdings in non-US banks (in levels and changes) in $ billion. Holdings shown are aggregated across all non-US banks and separately for EUR and JPY banks. Panel B summarizes the EURUSD cross-currency bases across tenors from 1-week to 3-months, expressed in basis points. Panel B also describes the control variables. All variables are at a monthly frequency. MMF data are sourced from the SEC's N-MFP filings, and prices from Bloomberg.

3. Demand for Synthetic Dollar Funding

3.1. Stylized Facts

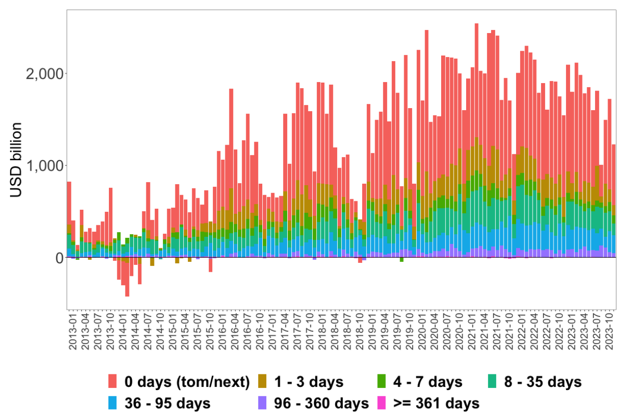
The market for synthetic dollar funding is large, and dominated by banks and institutional investors. Figure 3 plots the time series of monthly net USD borrowing by global banks (i.e., sell-side institutions in the CLS data) against all 9 currencies in my sample put together. Notably, global banks are net dollar borrowers in almost every month from January 2013 through December 2023, with the magnitude frequently exceeding $1.5 trillion. Dis-aggregating by individual currencies, Figure A2 shows that banks borrow USD primarily against EUR and JPY. In terms of counterparty sectors, panel (a) of Figure 4 shows that this demand is almost entirely supplied by non-dealer banks. In contrast, funds lend USD for short term and borrow over longer term, resembling carry trades. Corporations are consistently net borrowers, and non-bank financial institutions traded significant volumes in my sample only in the months following the onset of the COVID-19 pandemic.

Figure 3: Synthetic Dollars Borrowed by Global Banks

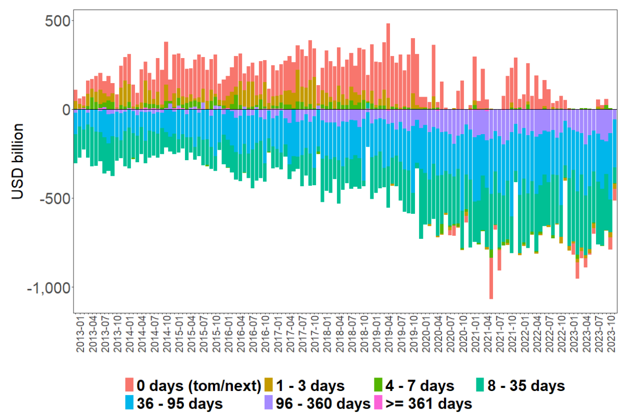


Notes: This figure plots the quantity of USD borrowed (positive y-axis) or lent (negative y-axis) by globally active dealer banks from/to all other counterparty sectors and against all 9 currencies put together. USD is borrowed for settlement at the near leg of the swap and exchanged back at the far end. Bar colors represent 7 maturity buckets, with "0 days (tom/next)" corresponding to overnight borrowing whose near leg settles one day after the trade date (T+1). The near date for all other tenors is the spot (T+2) date. The time series is at a monthly frequency from January 2013 through December 2023. This figure is constructed using daily signed FX swap order flow sourced from CLSMarketData and aggregated at a monthly level.

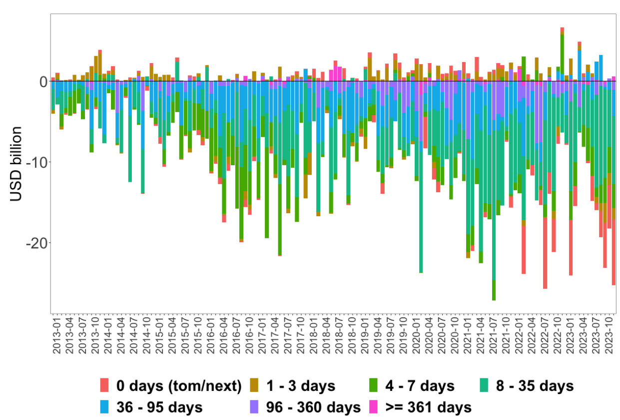
Figure 4: Sector-wise Synthetic Dollars Borrowed by Global Banks



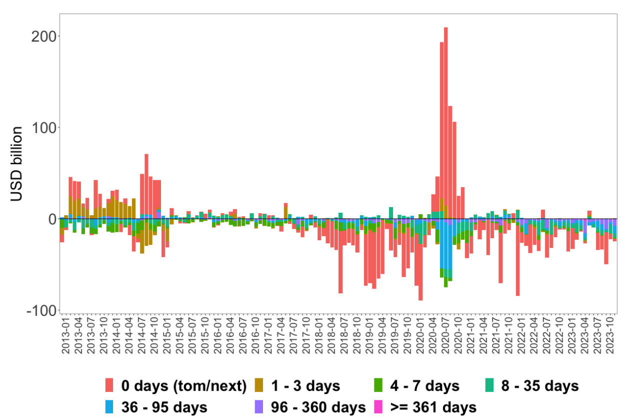
(a) From non-dealer banks



(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.

Two notable events during my sample period highlight that the synthetic dollar market is sensitive to external supply shocks. First, panel (a) of Figure A3 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 A3 uses hourly data to show that on 10 March 2023, when Silicon Valley Bank in the US was declared insolvent, global banks became net dollar *lenders* in the swap market because 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 A4 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 3). The change in stock measure captures this variation by accounting for swap tenors.

3.2. Constrained Wholesale Funding

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

$$\Delta\text{Synthetic Dollars}_{c,t} = \beta\Delta\text{MMF Holdings}_{c,t} + \text{Controls} + \alpha_c + \alpha_t + \varepsilon_{c,t}. \quad (1)$$

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 changes in other factors that may induce co-movement between wholesale and synthetic funding markets: (i) foreign banks' dollar assets; (ii) *gross* swap positions and intermediary sector's leverage ratio (ILRS) that affect swap arbitrageurs' capital constraints, (iii) the difference between the balance sheet size of the European Central Bank and the Federal Reserve Bank scaled by GDP (CBBS/GDP), (iv) US 1-month interest rates, (v) spot price, and (vi) overnight swap price. In terms of sample restrictions, I use the full sample period and include all currencies except the Canadian dollar, as Canadian banks hold substantial US dollar deposits which limits their use of swaps (Friedrich et al., 2025). I add currency fixed effects to capture currency-specific features, and year-quarter fixed effects to control for common time trends.[12] Table 3 reports estimation results for both the dependent variables, with standard errors clustered by currency.[13]

A decline in US MMF holdings significantly increases global banks' dollar borrowing through FX swaps. Panel A of Table 3 shows results using equal-weighted observations, and panel B weights them by the MMF investment in currency c and month t to account for the dominance of European and Japanese banks in these markets. Panel C repeats the estimation using the count of net buy trades as an alternate dependent variable. Across all three 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 in month t associates with a 23% increase in synthetic dollar borrowing by global banks.

Using investment-weighted observations, I report three additional robustness tests in Table A5. Panel A of Table A5 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 dis-aggregates MMF holdings into collateralized (e.g., repo) and uncollateralized (e.g., commercial paper) investments. It shows that the substitution result holds for both, but is economically twice as large for uncollateralized products where MMFs 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 between wholesale and synthetic markets to hold.

[12] Time series variation is important to my analysis for two reasons. First, the cross section includes only seven 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.

[13] Due to the limited cross-section, additional clustering by time renders standard errors in some of the analyses to be unreliable. As robustness checks, Table A4 confirms the statistical significance of Table 3 results using Driscoll-Kraay (Driscoll and Kraay, 1998) and double clustered standard errors.

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	-0.243**	-0.224**	-0.225**	-0.230**
	(0.083)	(0.062)	(0.062)	(0.065)
Δ Assets		-0.036	-0.021	0.031
		(0.054)	(0.051)	(0.071)
Δ Gross position		0.042	-0.186	-0.503
		(0.027)	(0.098)	(0.259)
Δ ILRS (log)		0.193	0.201	0.206
		(0.191)	(0.193)	(0.242)
Δ CBBS/GDP		0.049	0.049	0.111
		(0.027)	(0.026)	(0.065)
Δ US 1-month OIS		-0.117	-0.120	-0.084
		(0.209)	(0.210)	(0.390)
Δ Spot		-0.006	-0.001	-0.006
		(0.005)	(0.006)	(0.011)
Δ Swap (overnight)		-0.004	-0.004	-0.005
		(0.005)	(0.005)	(0.004)
Panel B: Investment-weighted % change in stock	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.189***	-0.197***	-0.200***	-0.197***
	(0.022)	(0.014)	(0.017)	(0.035)
Panel C: Count of net buy trades	(1)	(2)	(3)	(4)
Δ MMF holdings	-5.081**	-7.060***	-7.005***	-7.235***
	(1.593)	(1.016)	(1.321)	(1.632)
N	917	910	910	910
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 size of MMF investment in currency i and month t. 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 aggregated balance sheet line items for US branches and agencies of non-US banks.[14] 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-US 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 A5. On the assets side, I find that only non-treasury trading assets decline with MMF investments. On the liabilities side, there is a slight increase in funds borrowed from nonrelated foreign banks when MMF investments decline. However, the magnitude of impact is much smaller compared to Table 3. Other items such as funds with depository institutions show wide confidence intervals. Overall, relative to swaps, there is much smaller adjustment to on-balance sheet items on account of changes in dollar funding from money markets.

This exercise echoes the findings of Correa et al. (2021), who show that US branches of non-US banks do not draw on cash buffers when wholesale funding tightens. On the other hand, 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).[15]

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 US 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.[16]

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

[15] 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 US banks and insurers, which rely less on synthetic dollar funding compared to non-US banks.

[16] 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 5 shows that this reform represented an economically significant negative wholesale funding shock to non-US banks domiciled across countries. In the six months after the reform implementation, the average monthly MMF investment in non-US 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 using a two-way fixed-effects model. My outcome variable is the quantity of synthetic dollars held by each sector (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 currency and time fixed effects:

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

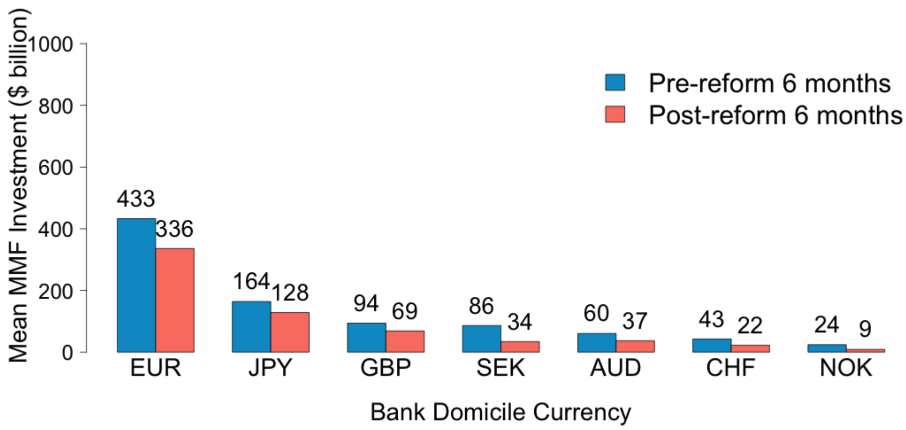
where the dependent variable is the stock of synthetic dollars held by sector s in currency c in month t. Since the reform affected prime funds that were mostly invested in *bank* debt, the variable "Treated" takes a value of 1 for banks and 0 for all other sectors. "Post" takes a value of 1 if the month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

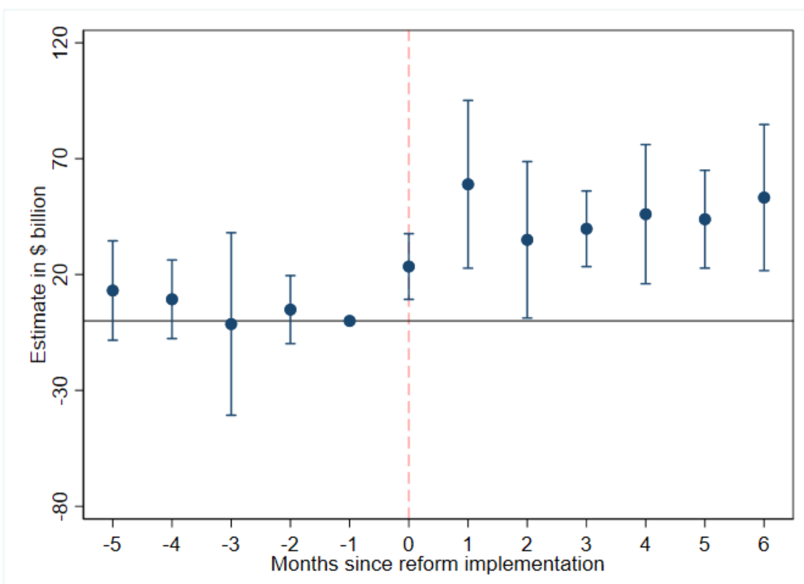
$$\text{Net Synthetic Dollars}_{s,c,t} = \sum_{\substack{\tau \in -5,6, \\ \tau \neq -1}} \beta_\tau \times \textit{Reltime}_\tau + \alpha_c + \alpha_t + \varepsilon_{s,c,t}, \tag{3}$$

where "Reltime" is the relative number of months since October 2016. Panel (b) of Figure 5 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 5: 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 US money market fund (MMF) holdings sharply declined in non-US 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	63.194**	68.806**	71.654**	74.701**
	(23.815)	(24.487)	(24.366)	(26.318)
N	336	336	336	336
Controls	N	Y	Y	Y
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Notes: This table reports estimates for a two-way fixed-effects model of the form in Equation 2. The dependent variable is the average daily stock of synthetic dollars held by sector s in currency c in month t. Banks are considered treated and non-bank sectors are controls. Post takes a value of 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 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 5 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 A6 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 A6 confirms that banks mostly borrow in short-term forwards, consistent with swaps. However, the magnitudes in both Figure A6 and Table A6 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 A6). Consistent with my hypothesis, the increased availability of wholesale funding from MMFs makes banks less reliant on costlier synthetic products to raise dollar funding.

4. Asset Pricing and Spillover Impact

In this section, I show that synthetic dollar demand contributes to increased deviations from the covered interest parity (CIP). In addition to being of independent interest as a major asset pricing phenomenon, a causal impact on prices forms an important input to my model setup in Section 5. Following Du et al. (2018), I calculate daily currency-specific cross-currency basis as:

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

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

Table 2 shows that the average EURUSD basis, $x_{t,t+n}$, is negative across the term structure, 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 the existence of limits to arbitrage. In the below analysis, I test the demand channel: when global banks are compelled to use FX swaps for dollar funding, 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	-3.581**	-4.124***	-3.046***	-2.651***
	(1.075)	(0.636)	(0.478)	(0.430)
Δ Assets	5.241	-0.990	-1.961	-1.356
	(3.360)	(3.971)	(2.005)	(3.236)
Δ Gross position	-1.861***	-22.905***	-14.992**	-11.984**
	(0.478)	(4.552)	(4.912)	(3.735)
Δ ILRS (log)	-47.192***	-48.545***	-27.045***	-43.003***
	(7.832)	(3.824)	(2.228)	(4.057)
Δ CBBS/GDP	-5.449***	0.595	0.754	2.161**
	(0.924)	(1.371)	(0.734)	(0.745)
Δ US 1-month OIS	33.068**	58.471**	37.458**	34.250**
	(12.015)	(19.381)	(13.466)	(13.192)
Δ Spot price	0.965**	1.047***	0.760***	1.149***
	(0.283)	(0.170)	(0.143)	(0.136)
Δ Swap price (overnight)	0.508	0.287	0.191	0.200
	(0.918)	(0.619)	(0.365)	(0.488)
Cross-currency basis (t-1)	-0.583***	-0.892***	-0.991***	-0.950***
	(0.046)	(0.132)	(0.101)	(0.097)
N	906	906	908	910
Adj. R^2	0.43	0.63	0.64	0.64
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 reports negative and statistically significant coefficients attached to the regressor Δ Synthetic Dollars across all tenors and their first principal component, which highlights that as banks increase their demand for dollars via swaps, the price of such funding increases above that of wholesale dollars. Further, the R^2 across all specifications highlight that the specified model captures a large share of variation in cross-currency bases.[17]

While these reduced-form results are consistent with a demand-based explanation of 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 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-US banks. In the following sub-section, I sharpen the identification of my proposed channels using granular data on MMF investments in non-US banks' short-term debt. My identification strategy serves two goals: First, I confirm a causal impact of banks' swap demand on CIP deviations. Second, I estimate non-bank investors' demand elasticity to instrumented CIP deviations and examine the spillover effects of banks' synthetic dollar funding demand.

4.1. Granular Instrumental Variables (GIV)

A GIV extracts idiosyncratic shocks to a few but large players in the market, whose actions can significantly impact economic aggregates. It confers three advantages in my setting: (i) addresses simultaneity between swap quantities and cross-currency basis, as well as endogeneity from omitted variables by netting out banks' exposure to common shocks such as macro-economic factors; (ii) rules out the impact of US-banks' actions (e.g., through changes in arbitrage capital) that could confound the link between global banks' synthetic dollar borrowing and the basis; and (iii) allows me to directly shock the basis to estimate the demand elasticities of non-bank investors.

In related studies, Ben Zeev and Nathan (2024) use GIV to study the impact of institutional investors' demand on USDILS CIP deviations, and Becker et al. (2023) construct granular instruments from the syndicated loan market to study the impact of bank lending on exchange rates. My setting leverages institutional features of short-term funding markets to introduce an additional layer of exogeneity, using shocks in a related but different market to instrument for swap quantities.

[17] While the vast majority of swap borrowing is in the short tenor (≤1 month), we see CIP deviations impacted for tenors up to three months. A likely explanation for this price transmission is long-short carry trades, similar to the framework in Vayanos and Vila (2021). Figure A7 shows that investment "funds" supply USD in tenors up to 1 week and simultaneously borrow USD in tenors between 1 and 3 months.

Identification strategy. I extract shocks to the availability of wholesale dollar funding from US money market funds to individual non-US banks, and aggregate them at a currency-level to instrument for 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.

Gabaix and Koijen (2024) argue that in economies dominated by a few but large agents, idiosyncratic shocks to agents can lead to nontrivial aggregate shocks. In my context, borrowers from US MMFs are large global banks, headquartered in currency areas such as the euro (EUR), Japanese yen (JPY), Swiss franc (CHF), and the British pound (GBP). On one hand, aggregate MMF borrowing by the banking sector may co-move with swap demand for reasons other than MMF supply frictions (e.g., interest rate changes). On the other hand, when a subset of banks obtains differential investment compared to the overall sector, it could affect their FX swaps activity and thereby the cross-currency basis. Below reasons motivate the presence of idiosyncratic shocks.

1. MMF-specific inflows/outflows: MMFs frequently face large but heterogeneous inflows or outflows from their end investors due to their differential product features and expense ratios (Schmidt, Timmermann, and Wermers, 2016). These flows differentially impact the banks that MMFs specialize in lending to because MMF-to-bank lending does not resemble a perfect competition market. For example, panels (a) and (b) of Figure A8 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 A8 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 A8 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]

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

Instrument construction. Let there be N banks domiciled in a country with currency c, that source wholesale funding from US 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 US 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 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".

[19] Table A7 shows that the first three principal components explain over 90% of the common variation for Euro-area, Japanese, British, Swedish, and Australian banks. Using principal components instead of observable factors also helps to attenuate omitted variable bias.

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 6 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, British pound, and Swiss franc 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 6 shows that idiosyncratic shocks (expressed in dollars) can be economically significant: there are large and frequent deviations in the size-weighted changes in MMF holdings from equal-weighted changes. Most of these shocks can be traced to one of three sources mentioned earlier. For example, (i) In 2017, several MMFs had 5% of their assets invested into BNP Paribas, which led to a sharp decline in its subsequent additional funding; (ii) In 2014, Deutsche Bank's credit downgrade contracted its MMF funding compared to other Euro-area banks; (iii) Large inflows experienced by Charles Schwab in 2016 disproportionately benefited 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, $\Delta\text{Synthetic Dollars}_{c,t}$, 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. The table reports first-stage instrument F-statistics both under heretoskedastic and 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-US 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 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 2 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-US 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.

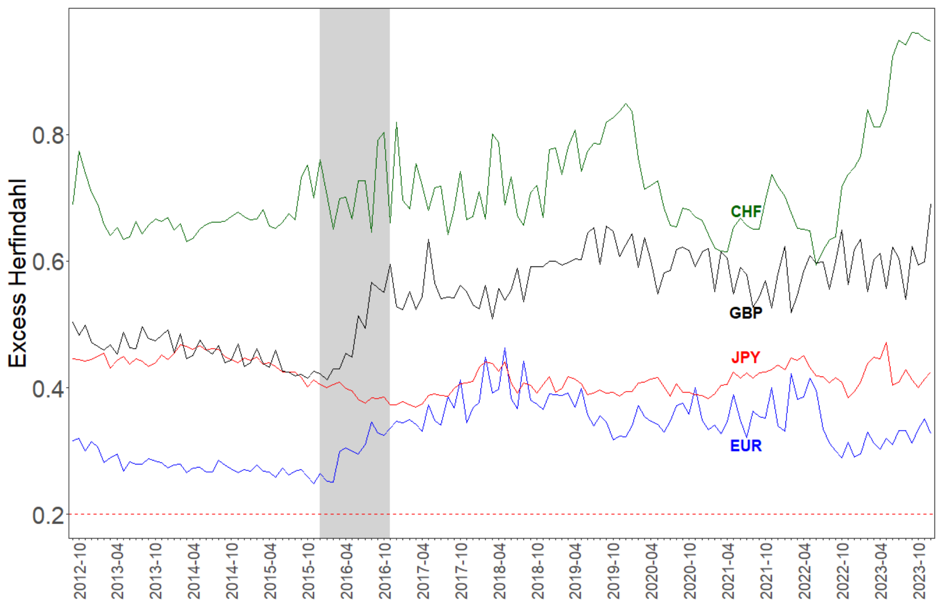
Exclusion. My identification relies on the assumption that shocks to non-US banks' wholesale funding affect cross-currency bases only through their FX swap demand. This assumption can be violated if their wholesale funding shocks correlate with other factors that independently move the bases. Below,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

Concern 1: Swap arbitrageurs. If arbitrageurs primarily depend on US MMFs to supply dollars in the swap market, then wholesale funding shocks would lead to more negative bases even if non-US 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-US banks, which could tighten arbitrageurs' capital constraints more generally and affect their swap pricing.

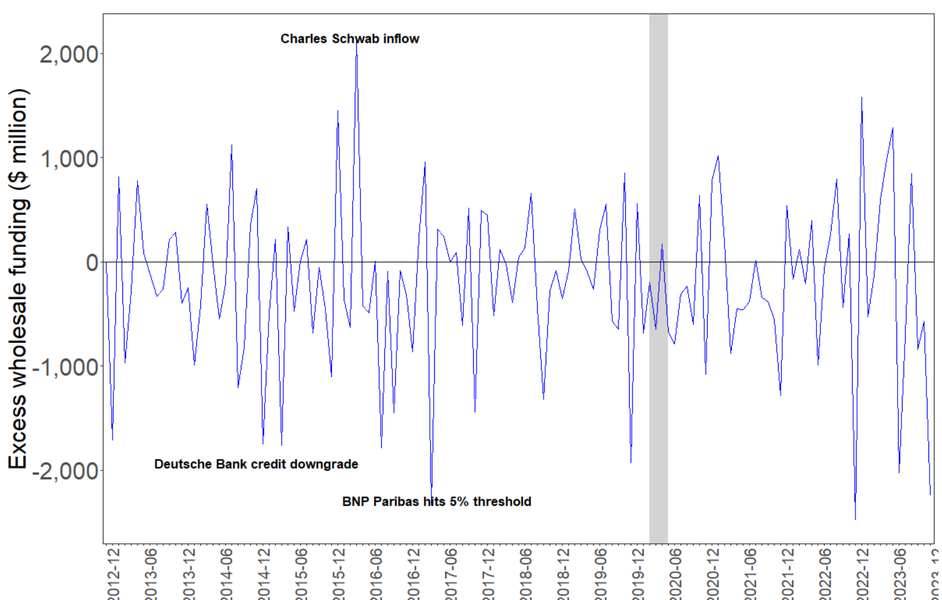
Table A8 shows that my instrument is uncorrelated with key indicators of arbitrageurs' capital constraints: changes in MMF holdings in US-banks, the intermediary sector's leverage ratio (He et al., 2017), and quarter-end dates when dealers' balance sheet constraints are known to tighten. This orthogonality is by construction: the instrument captures non-US *bank-level* funding shocks, which do not spill over to swap arbitrageurs because MMFs exhibit differential risk appetite and specialization in lending by borrower type.

[20] Consistent with this argument, Becker et al. (2023) find that banks replace FX-based dollar funding with cheaper wholesale funding several months after they are hit with cross-border demand shocks.

Figure 6: GIV Diagnostics – Concentration and Idiosyncratic Shocks



(a) High excess Herfindahl



(b) Large idiosyncratic shocks

Notes: This figure demonstrates the validity of granular instrumental variables (GIV) for extracting idiosyncratic shocks to global banks' wholesale funding from US money market funds. Panel (a) plots the time series of excess Herfindahl index for banks headquartered in four currency areas. Shaded area represents the transition period of the 2016 MMF reform in the US. Panel (b) plots the time series of the (unscaled) instrument for EURUSD and shows the presence of large shocks that can be traced to idiosyncratic economic factors. Shaded area represents the COVID-19 pandemic in 2020.

Table 6: Instrumented Swap Quantities (First Stage)

	Δ Synthetic Dollars		
	(1)	(2)	(3)
Excess wholesale funding ($z_{c,t}$)	-0.773***	-0.773***	-0.906***
	(0.114)	(0.110)	(0.241)
Δ Assets	-0.068*	-0.066*	-0.019
	(0.031)	(0.031)	(0.117)
Δ Gross position	0.039	0.027	-0.597
	(0.023)	(0.083)	(0.364)
Δ ILRS (log)	0.143	0.144	-0.566
	(0.122)	(0.131)	(0.389)
Δ CBBS/GDP	-0.000	0.000	-0.036
	(0.063)	(0.063)	(0.150)
Δ US 1-month OIS	-0.006	-0.005	-0.141
	(0.312)	(0.308)	(0.696)
Δ Spot	-0.007	-0.005	-0.003
	(0.004)	(0.004)	(0.020)
Δ Swap (overnight)	-0.005	-0.005	-0.003
	(0.003)	(0.003)	(0.005)
Cross-currency basis (PC1, t-1)	0.002***	0.002**	0.005**
	(0.000)	(0.000)	(0.002)
PC1	0.011***	0.011***	0.010***
	(0.000)	(0.001)	(0.001)
PC2	0.012***	0.012***	0.010***
	(0.002)	(0.001)	(0.001)
PC3	0.067***	0.067***	-0.056
	(0.003)	(0.003)	(0.042)
N	648	648	588
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. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Concern 2: Macroeconomic factors. 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 A8 confirms that the resulting instrument no longer correlates with interest rate changes, non-MMF repo market borrowing, or its own lags.

Concern 3: Non-bank investors. Figure 4 shows that several non-bank investors are active users of FX swaps. If their swap demand increases in response to wholesale funding frictions, then the impact of banks' swap demand on the bases may be overestimated. However, non-bank investors borrow minimally from US MMFs — under 1.5% of MMF assets are in corporate and non-bank financial debt. Hence, non-bank exposure to funding shocks is negligible, mitigating this concern.[21]

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):

$$\Delta\text{Cross-currency basis}_{c,t,t+n} = \beta\Delta\widehat{\text{Synthetic Dollars}}_{c,t} + \text{Controls} + \alpha_c + \alpha_t + \varepsilon_{c,t,t+n}. \qquad (10)$$

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

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

constraints tighten due to regulatory reporting requirements (Du, Tepper, and Verdelhan, 2018, Favara, Ivanov, and Rezende, 2021, Cenedese, Della Corte, and Wang, 2021). Both the size and the statistical significance of the β coefficient in panel B are smaller than in panel A because of a smaller sample and flatter supply curves outside of quarter-ends.

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	646	646	586	648	650
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	483	483	433	483	485
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 10. 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. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

4.2. Spillover to Non-banks Investors' Hedging Cost

In addition to banks, investors such as funds, corporations, and non-bank financial institutions (NBFIs) are major users of FX derivatives that enable cross-border investments while hedging the currency risk. Figure 4 shows that funds trade large quantities of FX swaps, both as borrowers and suppliers of dollars across the term structure, while corporations predominantly borrow dollars using swaps. In this section, I investigate the impact of global banks' synthetic dollar funding on the FX hedging activity of non-bank investors.

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

$$\Delta \text{Cross-currency basis}_{c,t} = \beta z_{c,t} + \text{Controls} + \alpha_c + \alpha_t + \varepsilon_{c,t}. \tag{11}$$

The specification mirrors Equation 11 in terms of controls and fixed effects, and I estimate it in turn for cross-currency bases calculated using the first principal component of 1-week, 1-month, and 3-month tenors, as well as for the 1-week and 1-month tenors separately. Panel A of Table 8 reports the estimation results.

Cross-currency bases across all tenors strongly correlate with my instrument. In all the columns of Table 8 panel A, there is a positive and statistically significant relation between the $z_{c,t}$ and cross-currency basis, which implies that when relatively larger banks receive excess wholesale funding, the cross-currency basis for that currency becomes *less* negative. The strong link between the instrument and cross-currency basis also confirms that the results in Table 7 are not attributable to a problem of weak instrument.

I use the instrumented cross-currency bases to estimate non-bank sectors' elasticity of FX hedging demand to CIP deviations. This analysis helps to understand the spillover effects of dollar supply frictions on FX risk management (whether quantities adjust or the cost changes). If non-bank users of FX derivatives adjust their hedging quantities in response to changes in cross-currency bases, then the frictions in dollar funding markets affect the *variance* in investors' asset portfolios. On the other hand, if demand is inelastic, then investors pay a higher hedging cost and realize lower *returns* on such assets.[22] I estimate the below second stage model to test which effect dominates:

$$\text{Hedging Demand}^{S}_{c,t} = \beta \Delta \widehat{\text{Cross-currency}} \text{ basis}_{c,t} + \text{Controls} + \alpha_c + \alpha_t + \varepsilon_{c,t}. \tag{12}$$

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. The regressor of interest is the instrumented change

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

in cross-currency basis 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-bank financial institutions (NBFIs), and non-financial corporations. Panel B of Table 8 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 cross-currency basis, funds reduce swap holdings by 1.6%. The elasticity estimates are all below 1, which suggests relatively inelastic demand. Corporations and non-bank financial institutions also exhibit inelastic demand. These estimates are also comparable to Kubitza, Sigaux, and Vandeweyer (2024) who study the impact of changes in cross-currency basis on foreign investors' FX derivative and USD bond holdings. Note that the elasticity measures are at a monthly frequency and abstract away from longer-term impact of negative bases on hedging activity, as well as on the underlying asset holdings of non-bank investors. However, they are informative about how banks' demand for synthetic dollars affect other investors active in the FX derivatives market.

A more negative cross-currency basis makes it *costlier* to sell USD forward or conduct a buy-sell USD swap, because the investor pays the synthetic cost of holding dollars for the time period. This means that foreign investors who hedge the FX risk on their USD-denominated investments face higher hedging costs as a result of increased synthetic dollar borrowing by global banks. Contrarily, US-based investors with non-USD denominated assets face lower FX hedging costs, because they supply USD in the near-term and buy it back on a later date (i.e., buy USD forward or conduct a sell-buy USD swap). In my sample, funds, on net, conduct buy-sell USD swaps (Table 1). This suggests that the sample represents a net of foreign investors who invest in USD-denominated assets. This is also true in the broader population; the US runs a negative net external assets position with more foreign investments into the US than the other way round.

A back-of-the-envelope calculation suggests that the economic magnitude of the cost absorbed by inelastic investors is large. Du and Huber (2023) report that non-US insurance, pension funds, and mutual funds held about \$8 trillion of US assets in 2020, of which an estimated \$2 trillion were currency hedged. Assuming a 50% cost pass-through of more negative CIP deviations, and given the average cross-currency basis of negative 26 basis points across major currencies, these investors pay an estimated additional \$2.6 billion in FX hedging costs per annum (\$2 trillion $\times$ 0.0026/2).

Table 8: Elasticity of Non-Bank Investors' Hedging Demand

Panel A: First stage	ΔCross-currency basis		
	PC1 (1W, 1M, 3M)	1W	1M
	(1)	(2)	(3)
Excess wholesale funding ($z_{c,t}$)	7.292***	4.486***	6.293***
	(1.010)	(0.462)	(0.709)
N	651	653	655
Instrument F-statistic	51.19	94.20	78.75
Controls	Y	Y	Y
Currency FE	Y	Y	Y
Time FE	Y	Y	Y

Panel B: Second stage	Hedging Demand^S		
	Fund	Corporate	NBFI
$\Delta\text{Cross-cu}\widehat{\text{rrency}}\ \text{basis}_{c,t}$	0.006	0.005	0.005
	(0.010)	(0.050)	(0.042)
N	646	645	645
Controls	Y	Y	Y
Currency FE	Y	Y	Y
Time FE	Y	Y	Y

Notes: This table reports estimates of a two-stage least squares regression for models of the form in Equation 11 (first stage) and Equation 12 (second stage). In Panel A, the dependent variable is monthly change in cross-currency basis, with the first principal component of 1-week, 1-month, and 3-month tenors in column (1), 1-week tenor in column (2), and 1-month tenor in column (3). The regressor of interest is the granular instrumental variable, "Excess wholesale funding ($z_{C,t}$)". All specifications include controls consistent with Table 6. Panel B reports the second-stage results where the dependent variable is the monthly change in the stock of net USD buy-sell swaps for each end-user sector, aggregated across all tenors. The regressor of interest is the instrumented change in the first principal component of cross-currency basis (column (1) in panel A). All columns include currency and 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. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

5. Model and Counterfactuals

This section quantifies the extent to which synthetic markets could compensate banks for sharp declines in wholesale dollar funding, beyond which the global availability of US dollar credit could suffer. Several situations motivate such declines. For example, post-financial crisis regulations have sought to mitigate default risk in US money market funds (MMFs) by limiting their exposure to risky banks (Kacperczyk and Schnabl, 2013). More recently, the escalation of trade tensions has raised the prospect of dollar liquidity restrictions being used as a policy lever (Risk.net, 2025). Evaluating these scenarios requires quantifying the trade-off between MMF default risk and cross-currency basis, and then 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-US 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 how much they can borrow from MMFs, which creates a demand *shift* in favor of FX swaps. Second, motivated by my empirical results, I add a swap arbitrageur to make CIP deviations an equilibrium object. Third, I calibrate the model to my data and indirect inference from my empirical results to present counterfactual estimates.

5.1. Model Setup

The economy. Consider a two-country economy, the US and Europe, with a global bank that has lending opportunities in USD and is able to borrow dollars both directly in US wholesale markets and synthetically in the FX swap market. The bank funds its synthetic borrowing via European money markets or euro deposits. If it lends an amount L^D in dollars at time 0, it earns an expected gross return of $g(L^D)$ at time 1, where $g(.)$ is a concave function. As in Ivashina et al. (2015), I assume that the riskless rates in both US and Europe equal r.[23] US MMFs are the primary wholesale market investors. Their corpus scales linearly with interest rates, with the sensitivity parameter η. Further, MMFs are subject to mean-zero flow shocks from end-investors, σ_X. To mitigate default risk, funds lend only a fraction, α, to banks. A literal interpretation of the parameter α is the 5% regulatory concentration limit that MMFs are subject to. More generally, α could reflect MMFs' aversion to unsecured investment, or other policy levers. Thus, MMFs' total lendable corpus is given by:

$$L^W = \alpha[\overline{L^W}(1 + \eta(1 + r) + \sigma_X)], \tag{13}$$

[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.

where $\overline{L^W}$ is a steady state value. MMFs earn a constant return of r on funds lent to banks.[24] Finally, funds incur a default risk on their lending to banks:

$$\text{Default Risk} = \beta (L^W)^2, \tag{14}$$

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

The third agent in the economy is a swap arbitrageur who is subject to leverage ratio constraints on its balance sheet. In the FX swap market, the arbitrageur lends US dollar and earns the riskless rate r plus the (negative 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 US money market funds to European investors that provide euros to the bank for swapping against the dollar. Note that the dollar borrowing banks and swap arbitrageurs do not always have to be two distinct agents. When flush with dollar liquidity, or when the arbitrage opportunity is profitable enough, non-US banks may well act as swap arbitrageurs (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 equal even when the same institution switches from borrower to lender in the swap market.

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 (Lee, 2024).

Unlike in the wholesale market, the bank faces no direct constraint on raising dollars synthetically because it can frictionlessly expand its euro borrowing, especially when European monetary conditions are loose. Even if the bank cannot immediately expand its retail deposit base beyond some baseline level, it can always resort to local money markets and drain European Central Bank reserves when the dollar investment opportunity is profitable enough. I make this assumption to keep the focus on constraints in the US 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).

[24] In practice, the interest rate charged by MMFs can increase with the default risk of banks. However, in the data I find the dispersion of MMF rates to be small, such that r is almost always lower than the extra cost imposed by cross-currency bases. Hence, I assume it to be constant for simplicity.

5.1.1. *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:

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

subject to the total lending and wholesale funding constraints:

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

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

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 $L^D \le \alpha[\overline{L}^W (1 + \eta(1 + r) + \sigma_X)]$. The bank will not borrow at all using FX swaps: $L^S = 0$.
2. The overall dollar demand is higher than what MMFs can meet: $L^D > \alpha[\overline{L}^W (1 + \eta(1 + r) + \sigma_X)]$. However, the marginal revenue on lending is still greater than 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 $L^W = \alpha[\overline{L^W}(1 + \eta(1 + r) + \sigma_X)]$, we arrive at the first proposition.

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

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 A6, 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.

5.1.2. 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:

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

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 Default Risk $= \beta(N - L^S)^2$, and then plug Equation 23 to get:

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

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

$$\frac{\partial S}{\partial \text{Default Risk}} < 0 \tag{27}$$

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.

5.2. Calibration

I match the model to my empirical estimates and key moments in the data to (i) quantify the co-movement between CIP deviations and money market funds' default risk, and (ii) locate the regulatory threshold on MMF investments beyond which bank assets could decline. Table 9 summarizes the model calibration using the average values during 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.

The representative bank faces a credit demand of N dollars, which it tries to meet by raising as much wholesale funding is available L^W and the rest through FX swaps L^S. The bank earns a marginal revenue on lending which is a concave function. I leverage the collateral data available in the N-MFP filings to calculate the profits on short-term assets as a function of loan size, and calibrate the parameters attached to the linear term $a = 2.18$ and the squared term $b = -1.96e-04$. These two parameters enter the optimization function of banks as they try to equalize marginal cost with marginal revenue (Equation 19).

Money market funds manage a corpus of investments, a fraction of which is invested in risky bank securities (Equation 13). I set the sample average $\overline{L^W} = \$2,000$ billion as observed in the data (this figure excludes funds that invest exclusively in US Treasuries). The corpus increases with interest rates; I set the sensitivity parameter $\eta = 0.15$ based on a time-series regression coefficient. MMFs are also exposed to normally distributed mean-zero flow shocks, whose standard deviation is $\sigma_X = 200$ in the data.

MMFs can lend only a fraction α to (risky) banks, which can be viewed as resulting from three sources: (i) existing regulatorily-imposed 5% concentration limit, (ii) potential quantitative restrictions as a tariff policy tool, and (iii) funds' own internal limit on unsecured investments, reflecting their risk aversion. I set $\alpha = 0.05 \times 8 = 0.4$, because a typical MMF on average lends to 8 foreign banks. I vary this parameter in the counterfactual exercises to estimate the impact on prices and quantities borrowed via swaps. I assume that an outside borrower (e.g., US government) is willing to absorb the leftover MMF corpus, but do not model it explicitly to keep the focus on MMF-bank flows. I place a non-negativity constraint on MMF corpus as well as on bank lending.

Money market funds face default risk on their lending to banks. I model the default risk as increasing in the squared term of the amount lent (Equation 14). The squared term in default risk is meant to capture the plausible scenario where defaults are correlated across issuers. Following Collins and Gallagher (2014), I calculate the sensitivity parameter β as the value-weighted credit default swap (CDS) premium on dollars lent to risky banks. During my sample period, CDS premium averages 50 bps for a \$100 notional. Hence, I set $\beta = 0.005$.[25]

The last agent in my model is the swap arbitrageur. Post-financial crisis regulations penalize the expansion of balance sheet size, for example through leverage ratio requirements, even for risk-free arbitrage. This cost is 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 4. I apply an indirect inference approach to estimate λ such that I can match empirically observed price impact from the GIV second stage. Table 7 shows that for a 10% increase in quantities demanded, cross-currency basis turns negative by about 7 bps. This allows me to set $\lambda = 0.0006$.

Table 9: Calibration

Parameter	Definition	Source or Target
State variables		
$\overline{r} = 0.015$	Mean interest rate in the US	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
$\alpha = 0.4$	Fraction of corpus lendable	Regulations and data
$\beta = 0.005$	Default risk sensitivity	CDS spreads (Collins and Gallagher, 2014)
Arbitrageurs		
$\lambda = 0.0006$	Balance sheet cost scaler	Indirect inference from Table 7

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

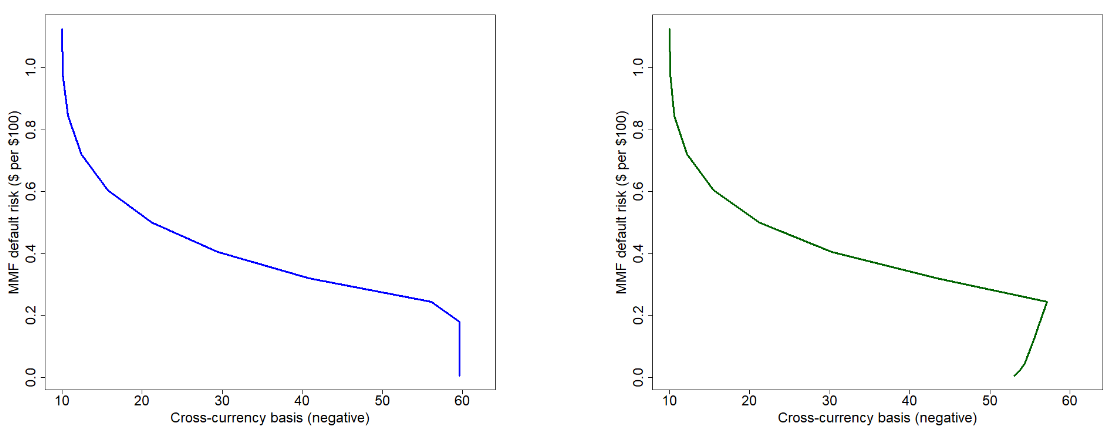
[25] Say MMFs lend \$100. The default risk on this lending is \$0.5 $(0.005 \times (100)^2/100)$. However, if they lend \$500, the default risk rises in a convex manner to \$12.5 $(0.005 \times (500)^2/100)$.

5.3. Default Risk vs. CIP Deviations

I apply my model to study the externalities of domestic money market regulations that seek to shield MMFs from default risk (Schmidt, Timmermann, and Wermers, 2016). As a first step, I quantify the trade-off between reducing default risk in MMFs and increasing CIP deviations. To do this, I fix all the model parameters to the values shown in Table 9, and vary only α, the fraction of corpus that MMFs invest in risky bank debt. Figure 7 plots the trade-off, where panel (a) assumes that swap arbitrageur constraints λ do not vary with MMF funding ($\psi = 0$), while panel (b) allows for a simultaneous tightening of arbitrageur constraints at lower α ($\psi = -0.5$).

Default risk and CIP deviations exhibit a strong inverse relationship. For example, reducing CIP deviations from -26 bps to -13 bps would require additional wholesale funding to banks, increasing the default risk from 45 to 65 bps. Note that the default risk shown on the y-axis is scaled by the total corpus so it can be interpreted as expected dollar loss for a \$100 lending. Interestingly, at around -60 bps cross-currency basis, the curve turns vertical. This is because, as per the model, banks stop borrowing more via swaps when the marginal cost exceeds their marginal returns. This reflects the joint dynamics of CIP deviations and dollar asset profitability, which I detail in the next sub-section. Panel (b), which allows for steepening of arbitrageurs' supply curve with tighter MMF constraints, shows a slightly more convex relationship than panel (a).

Figure 7: Money Market Fund Default Risk and CIP Deviations



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

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

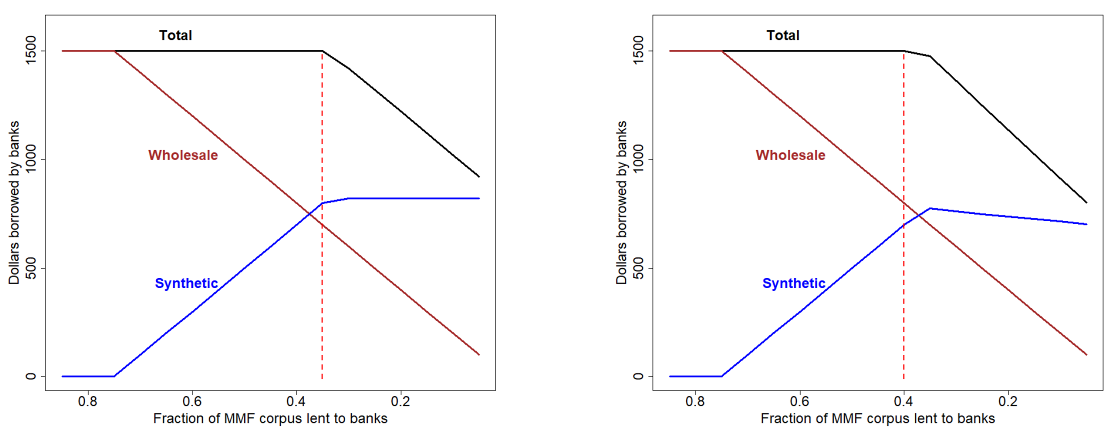
Notes: This figure compares the counterfactual limits on money market fund lending to banks (i.e., parameter α on y-axis) and the resulting CIP deviations (x-axis) through the channel of banks' synthetic dollar funding demand. CIP deviations are represented as the (negative) of the price impact resulting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

5.4. Counterfactual Decline in Lending

I quantify the thresholds at which tighter constraints on MMFs' wholesale lending to banks ultimately reduces banks' ability to supply global dollar credit. The key intuition in this counterfactual exercise is that banks endogenize the expected price impact of marginal synthetic dollars and do not borrow in excess of their marginal returns. Figure 8 plots the dollars borrowed by banks through wholesale (L^W) and synthetic (L^S) routes on the y-axis, and the corresponding fraction of MMF corpus that can be lent to banks (α) on the x-axis (going from looser to tighter constraints).

Panel (a) considers the baseline ($\psi = 0$) and shows that the total dollar borrowing by banks, holding fixed end-user demand, begins to shrink once $\alpha < 0.35$. After this point, while wholesale funding continues to decline, synthetic funding no longer increases as CIP deviations become prohibitively expensive for banks. The 2011 European sovereign debt crisis serves as an illustrative case, when US MMFs declined their lending to European banks, turning cross-currency basis sharply negative while also decreasing USD lending in the Euro-area (Ivashina et al., 2015). Panel (b), which allows arbitrageur constraints to co-vary with α, shows that the threshold at which bank lending declines arrives sooner, at $\alpha = 0.4$, corresponding to a slack of no more than 20% of wholesale funding based on the average MMF allocation of \$1 trillion to non-US banks (Table 2).

Figure 8: 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.

6. Conclusion

The US dollar underpins the global monetary system, and global banks play a particularly important role in its intermediation. This paper shows that frictions in the wholesale supply of the 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 offers a perspective on how intersecting regulations — such as those on liquidity, capital, or balance sheet use — jointly affect risk allocation and financial market outcomes.

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Appendix
"Synthetic Dollar Funding"

Umang Khetan

June 2025

A. DATA APPENDIX

A.1. CLS Data Collection

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

Similar to a clearing house for over-the-counter derivatives, CLS has direct members that comprise of large banks, and indirect members who settle through CLS with the help of member banks. This model is followed by other clearing houses such as the LCH Ltd. (formerly London Clearing House) and the Chicago Mercantile Exchange (CME). At the time of writing, 76 financial institutions were direct members of CLS, primarily FX market-making banks.[26] 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

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

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 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.[27]

A.2. CLS Data Coverage

I estimate that CLS swaps data cover between a quarter to a third of global dealer-to-client swaps turnover for major sectors, based on the April 2022 BIS benchmark (Bank for International Settlements, 2022). Further, the data are representative of the market both in terms of the tenors and currencies across which trading takes place. Table A1 reports the estimated coverage of average daily volume observed in CLS data in April 2022. For external comparison, Hasbrouck and Levich (2017) estimate that CLS data cover about 37.2% of global spot FX turnover, 14.4% of forwards, and 35.1% of FX swaps, and provide corroborating evidence of representation by currency. 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.

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

A.3. Variable Construction

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

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

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

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

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

Tenors. There are 7 tenor buckets (6 for forwards), ranging from overnight to over one year. Within both forwards and swaps datasets, tenor is defined as the difference between the settlement date of the far leg, and the spot settlement day. For the overnight tenor swaps (called "0 days (tom/next)"), the far leg is the tomorrow next day for all currencies except USDCAD for which it is the overnight next day. All volumes in the raw data are reported as on the far leg of a swap. For calculating the near-leg dollar borrowing, I assume that an equivalent amount of opposite-side cash flow occurs. 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.4. Money Market Fund Data

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

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:

$$\Delta \text{Synthetic Dollars}_{c,t} = \beta \Delta \text{MMF Holdings}_{c,t} + \text{Controls} + \alpha_c + \alpha_t + \varepsilon_{c,t}. \tag{28}$$

Panel A of Table A6 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.

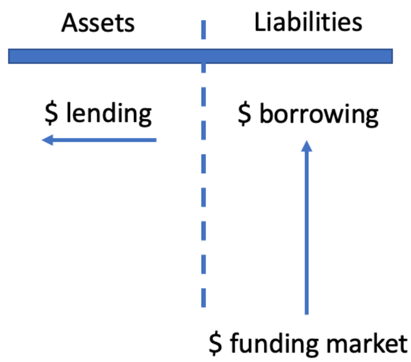
Interest rates. I show that the interest rate environment partly governs banks' substitution from wholesale to synthetic dollar funding markets. The intuition is that at higher interest rates, households shift their savings from lower-yielding bank deposits to money market funds (Aldasoro and Doerr, 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 3 shows a decline in net dollar borrowing via swaps during the 2022-23 tightening cycle.

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

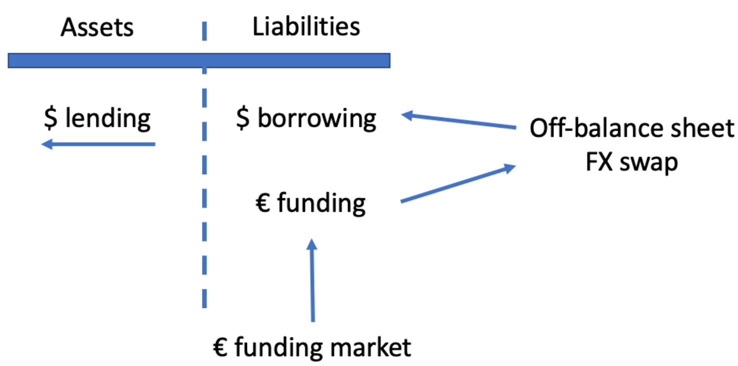
$$\Delta \text{Fraction Synthetic}_{c,t} = \beta \Delta \text{US 1-month OIS}_t + \text{Controls} + \alpha_c + \alpha_t + \varepsilon_{c,t}, \quad (29)$$

where I regress changes in *Fraction Synthetic* on changes in US 1-month OIS rate, with other controls and fixed effects as before. Panel B of Table A6 reports that banks reduce their dependence on FX swaps when interest rates rise, supporting the argument that at least a part of synthetic dollar funding demand reflects quantitative limits on the availability of wholesale dollars. Note that demand for credit typically declines at higher rates. Hence, the negative β coefficient in Table A6 cannot be attributed to a decline in the denominator.

Figure A1: Bank Balance Sheets under Wholesale and Synthetic Dollar Funding



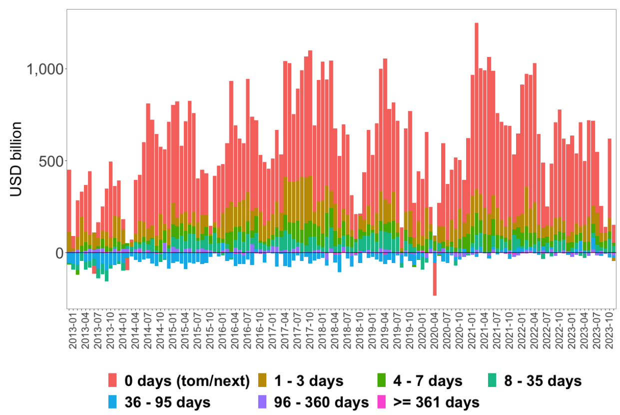
(a) Wholesale dollar funding



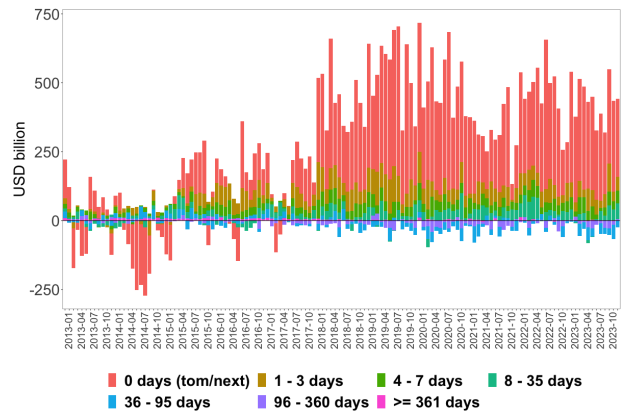
(b) Synthetic dollar funding

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.

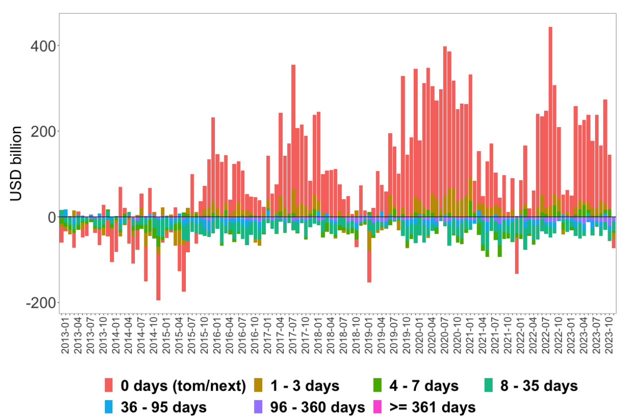
Figure A2: Currency-wise Synthetic Dollars Borrowed by Global Banks



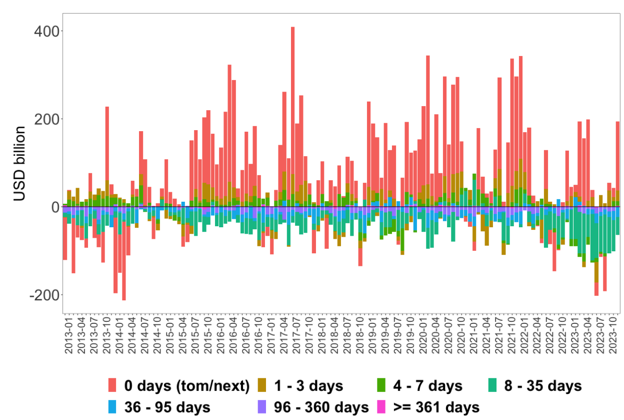
(a) Against EUR



(b) Against JPY



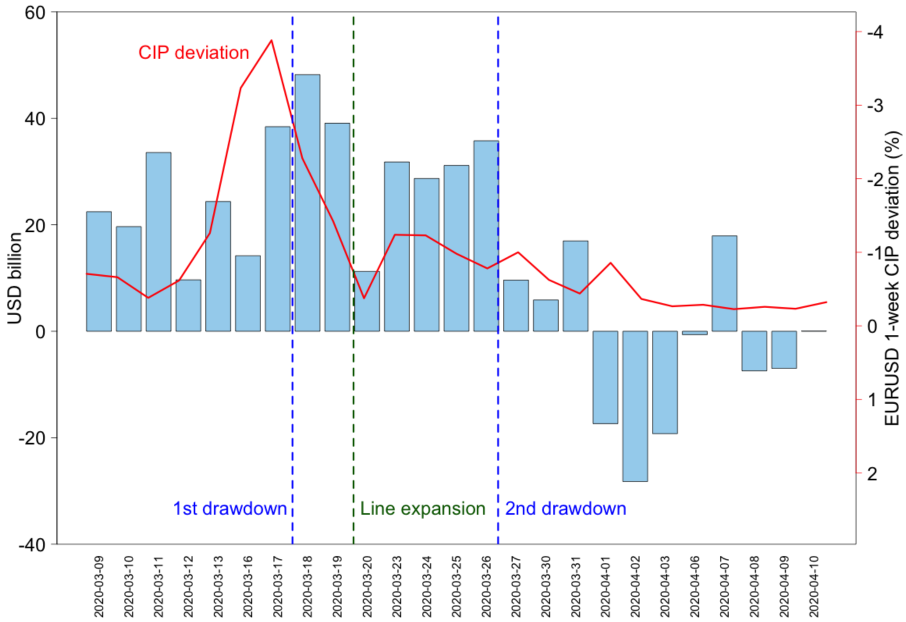
(c) Against CHF



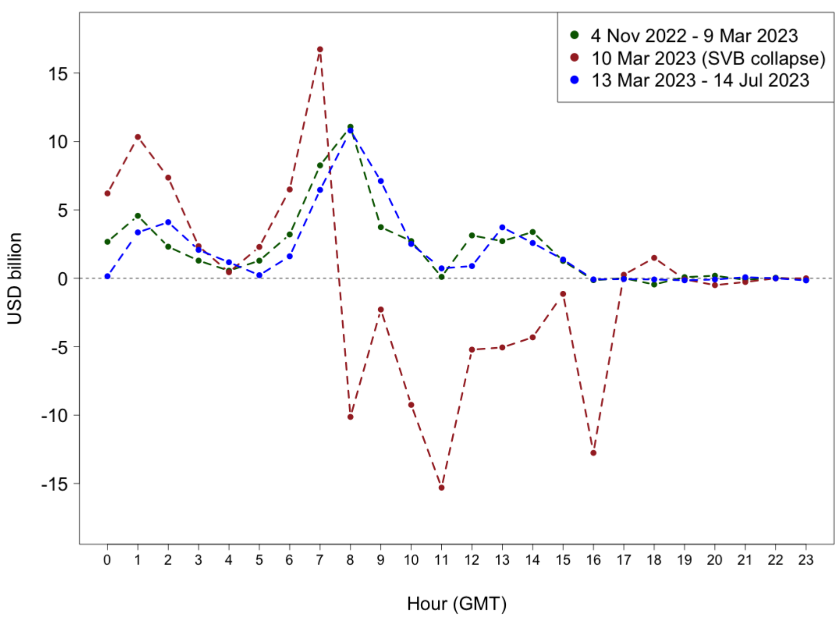
(d) Against GBP

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 A3: Synthetic Dollar Funding during Macroeconomic Disruptions



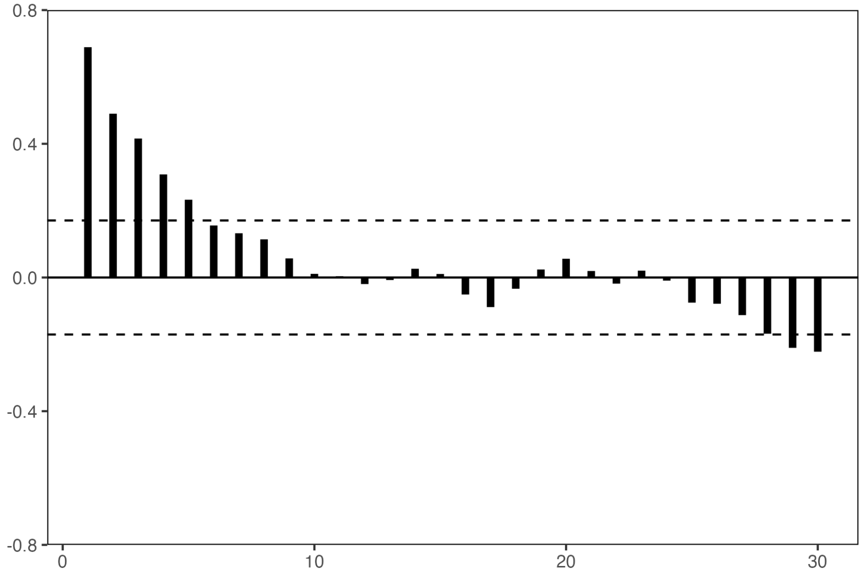
(a) March 2020 COVID-19 pandemic and central bank swap lines



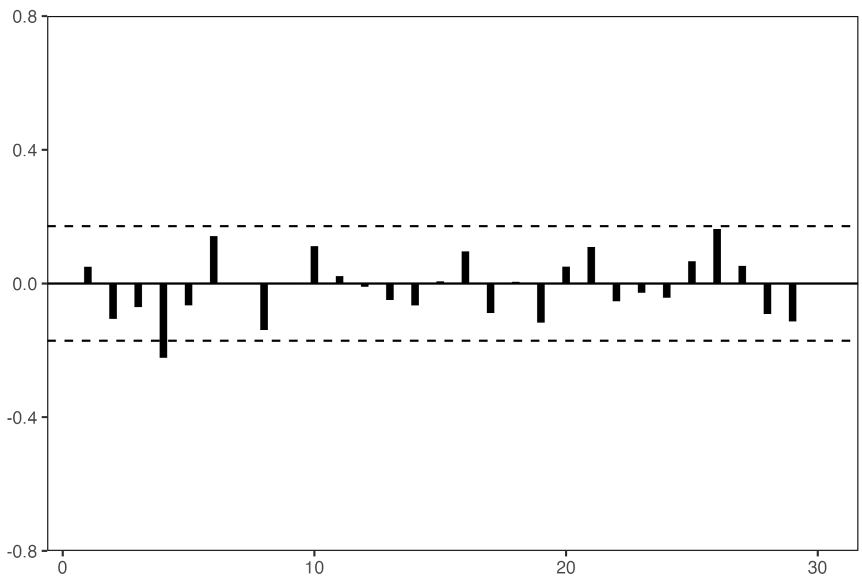
(b) Intra-day pattern during Silicon Valley Bank collapse

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 A4: Autocorrelation Functions



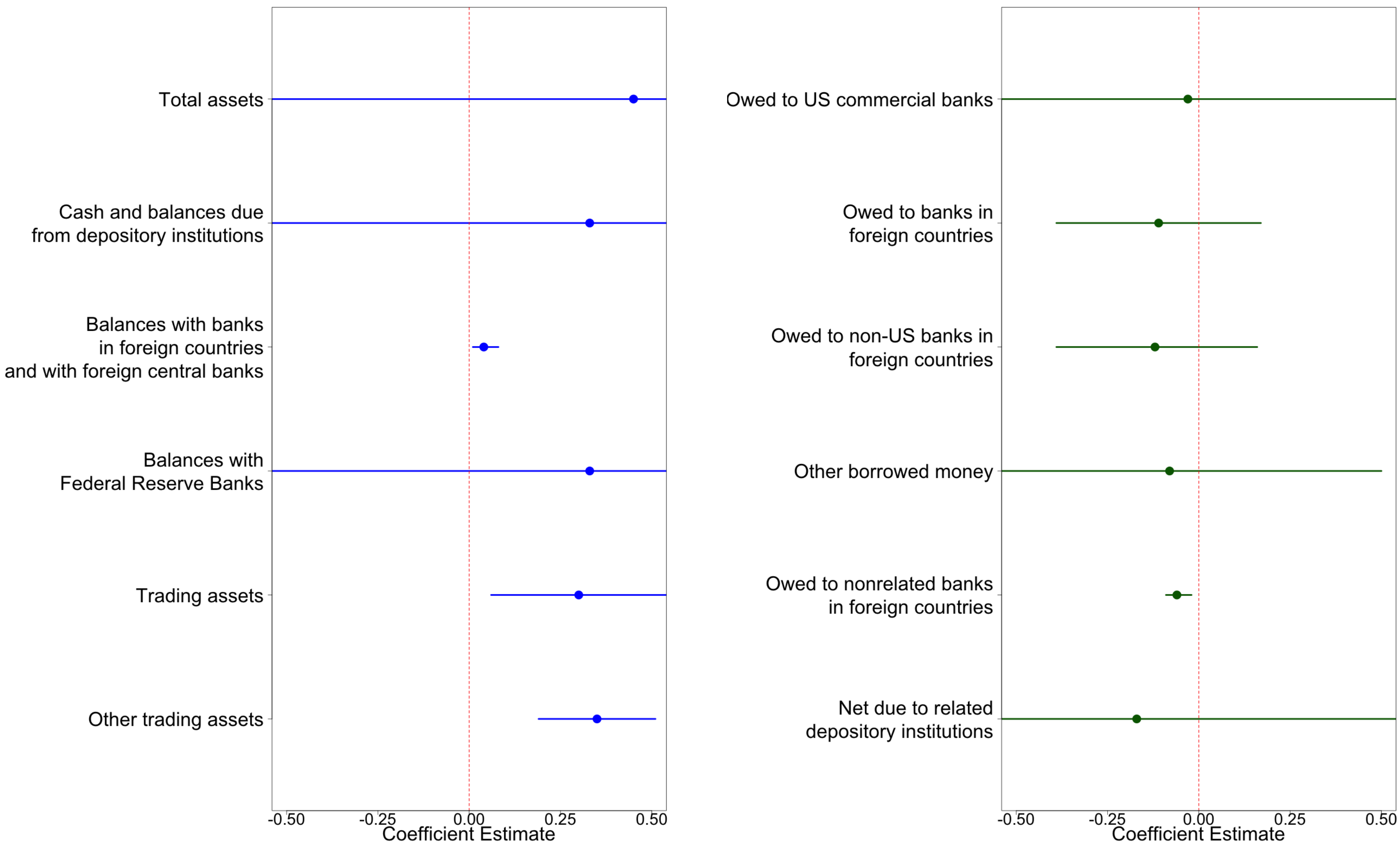
(a) Transaction amount



(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 A5: On-Balance Sheet Items of Foreign Banks' US Branches and MMF Holdings

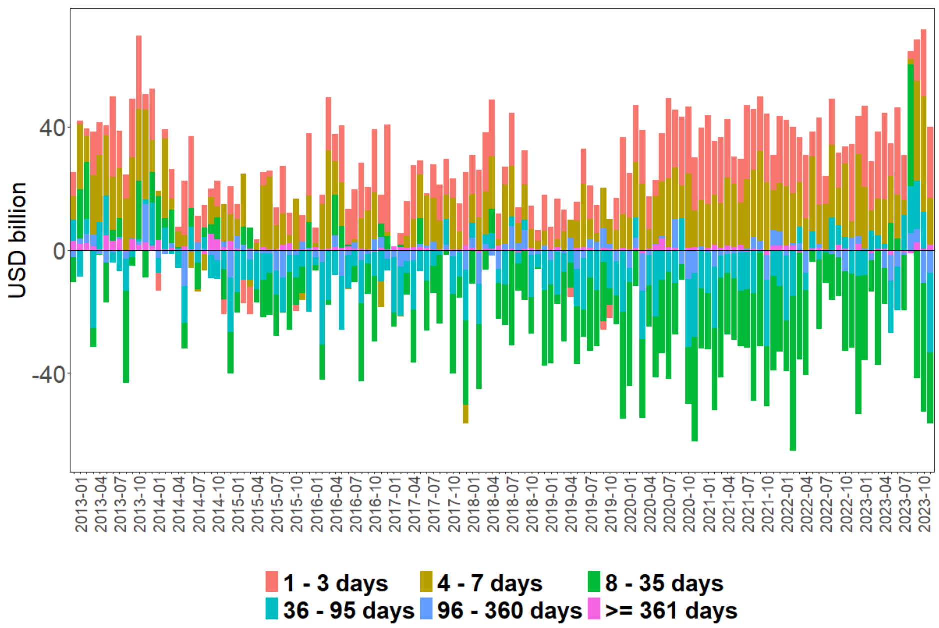


(a) On-balance sheet assets

(b) On-balance sheet liabilities

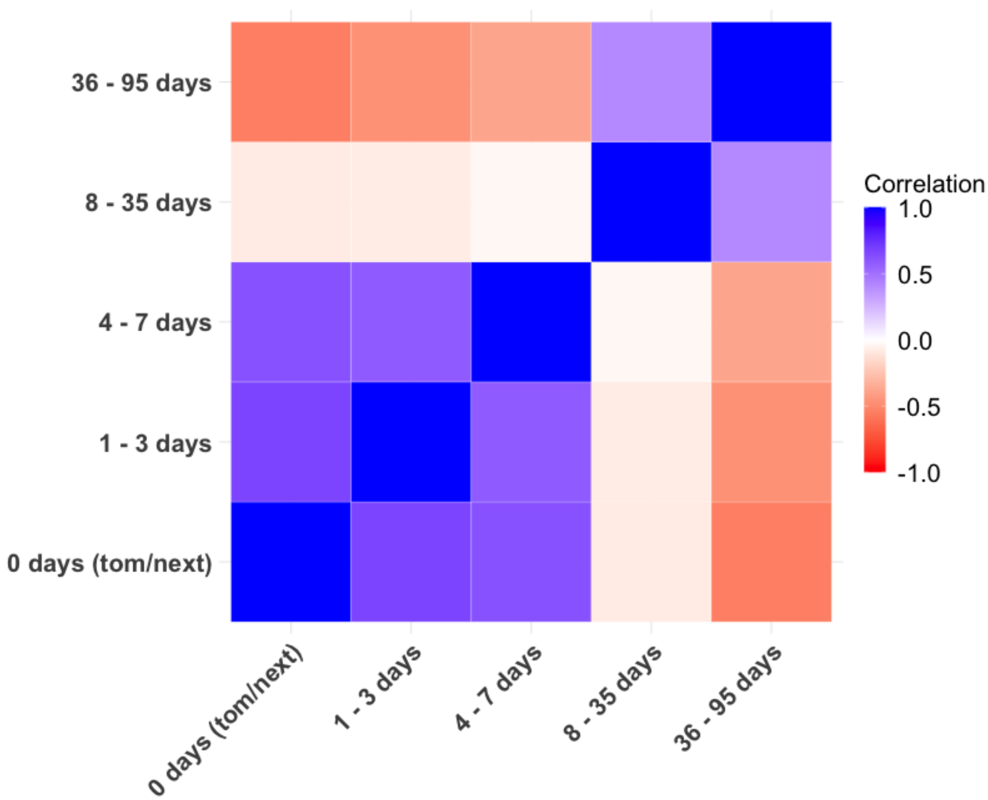
Notes: This figure plots estimates of Equation 1, where the dependent variables are each of the major line items on the balance sheets of US branches and agencies of non-US banks. For each dependent variable, I estimate Equation 1 at a quarterly frequency with changes in MMF holdings as the regressor. 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 A6: Synthetic Dollar Funding using FX Forwards



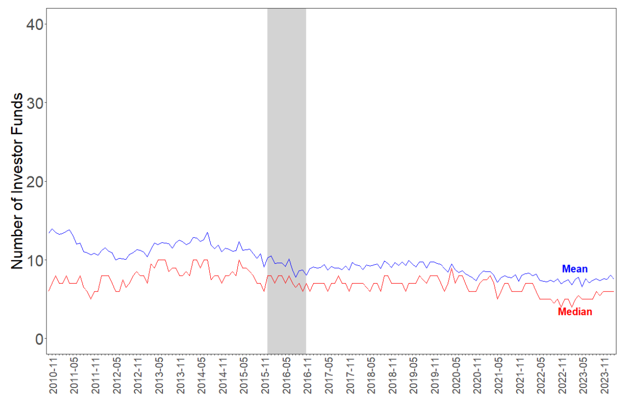
Notes: This figure plots the quantity of USD bought (positive y-axis) or sold (negative y-axis) against all 9 currencies in my sample put together by globally active dealer banks, facing all other counterparties. The time series is at a monthly frequency from January 2013 through December 2023. Bar colors 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 A7: Fund Carry Trades

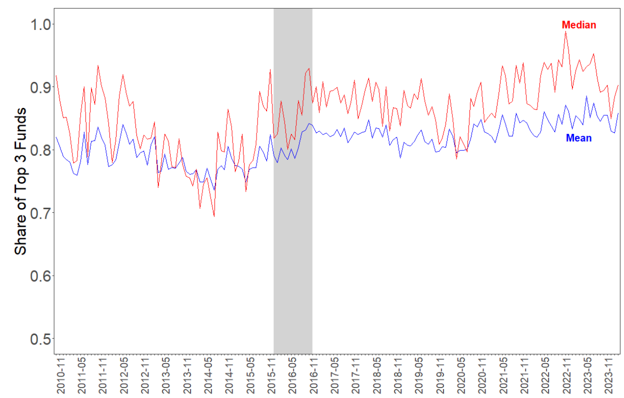


Notes: This figure correlates monthly net volume of dollars borrowed or lent by investment funds in each tenor against all other currencies put together. Funds lend dollars in the overnight ("0 days (tom/next)") to 1 week tenors, and simultaneously borrow dollars in longer tenors up to 3 months, resembling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

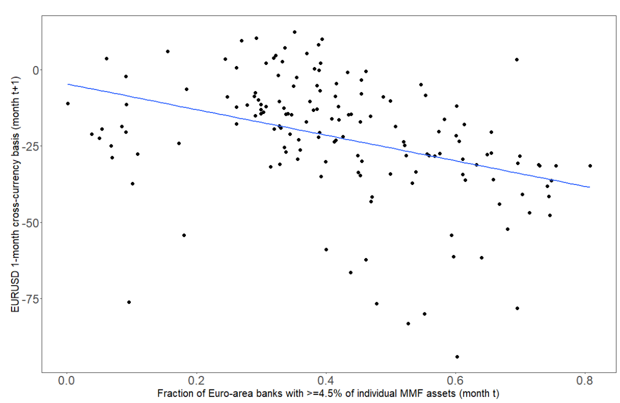
Figure A8: Drivers of Idiosyncratic Shocks to Money Market Fund Investments



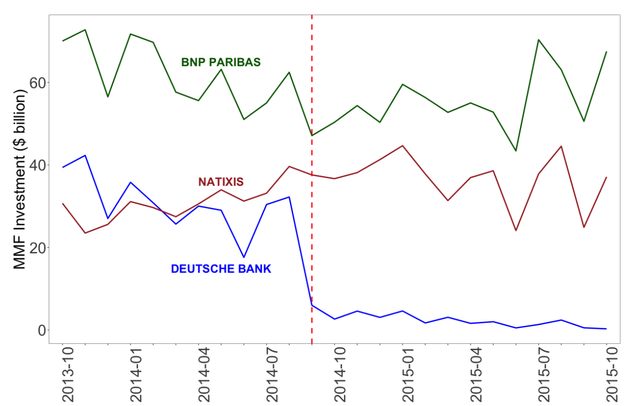
(a) Number of MMF investors in foreign banks



(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 US MMFs' unsecured lending to individual borrowers is 5% of total assets.) Panel (d) shows a drop in MMF investments in Deutsche Bank in 2014 due to multiple credit rating downgrades, with no impact on other Euro-area banks.

Table A1: Data Coverage and Representativeness

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

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

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

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

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

Table A3: Classification of Largest Banks Borrowing from Money Market Funds

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

Notes: This table lists the 30 largest bank borrowers from US 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: Synthetic Dollar Funding and MMF Holdings (Standard Errors)

	ΔSynthetic Dollars (by global banks)			
Panel A: Driscoll-Kraay	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.243***	-0.224***	-0.225***	-0.230***
	(0.074)	(0.079)	(0.079)	(0.075)
Panel B: Clustered by currency and time	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.243**	-0.224**	-0.225**	-0.230**
	(0.094)	(0.076)	(0.075)	(0.063)
N	917	910	910	910
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. 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. Observations are weighted by the level of money market fund investments. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table A5: 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)	-0.136***	-0.143***	-0.144***	-0.115***
	(0.007)	(0.008)	(0.008)	(0.007)
N	917	910	910	910
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)	-0.219***	-0.209***		
	(0.025)	(0.020)		
Δ MMF holdings (uncollateralized)			-0.329***	-0.333*
			(0.075)	(0.149)
N	910	910	910	910
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 A6: Synthetic Dollar Funding and MMF Holdings (Robustness II)

Panel A: Forwards	Δ Synthetic Dollars (short-term forward purchase)			
	(1)	(2)	(3)	(4)
Δ MMF holdings	-0.085***	-0.113**	-0.110**	-0.111***
	(0.016)	(0.034)	(0.034)	(0.024)
N	917	910	910	910
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 US 1-month OIS	-0.388*	-0.572***	-0.578***	-1.181*
	(0.194)	(0.150)	(0.150)	(0.484)
N	917	910	910	910
Controls	N	Y	Y	Y
Currency FE	N	N	Y	Y
Time FE	N	N	N	Y

Notes: Panel A reports estimates of Equation 28 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 29, 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 US 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 A7: Common Variation in Bank-level Money Market Fund Flows

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

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 US money market funds in a given month.

Table A8: Instrument Correlations with Confounding Variables

Correlation of "excess wholesale funding" with	Average across currencies	Pooled
Δ Money market fund holdings of US banks	0.092	0.038
Δ Intermediary leverage ratio (squared)	-0.016	-0.035
Quarter-end indicator (1/0)	-0.031	-0.064
Δ US 1-month OIS	0.017	0.001
Δ Repo market borrowing (non-MMF)	-0.033	-0.033
Serial correlation	-0.212	-0.103

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.