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ARBITRAGE CAPITAL OF GLOBAL BANKS

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ABSTRACT

We show that the role of unsecured, short-term wholesale funding for global banks has changed significantly in the post-financial-crisis regulatory environment. Global banks mainly use such funding to finance liquid, near risk-free arbitrage positions—in particular, the interest on excess reserves arbitrage and the covered interest rate parity arbitrage. In this environment, we examine the response of global banks to a large negative wholesale funding shock as a result of the U.S. money market mutual fund reform implemented in 2016. In contrast to past episodes of wholesale funding dry-ups, we find that the primary response of global banks to the reform was a cutback in arbitrage positions that relied on unsecured funding, rather than a reduction in loan provision.

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Abstract

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Keywords: Money Market Mutual Funds, Wholesale Funding, Arbitrage
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1 Introduction

In addition to deposits, banks rely on short-term wholesale funding markets, such as the markets for federal funds, Eurodollars, certificates of deposit, commercial paper, and repos to finance their operations.[1] In contrast to deposits, which are often insured, wholesale funding is more "fragile" and subject to sudden dry-ups (for example, Pérignon, Thesmar, and Vuillemey, 2018; Kacperczyk and Schnabl, 2013). Such large negative wholesale funding shocks have led to fire sales of assets, significant contractions in credit supply, and elevated financial distress (for example, Diamond and Rajan, 2009; Shin, 2009; Schnabl, 2012; Chernenko and Sunderam, 2014; Ivashina, Scharfstein, and Stein, 2015).

In this paper, we document an important transformation of the role of unsecured short-term wholesale funding for global banks in the post-financial-crisis regulatory environment. In particular, many large global banks have transitioned to a business model in which they mainly use unsecured wholesale funding to finance liquid assets as part of near risk-free arbitrage positions. In other words, short-term wholesale funding has become arbitrage capital for global banks. Through our analysis, we uncover about $1.5 trillion of potential arbitrage capital for global banks. As a result of this business model, global banks have become more resilient to negative wholesale funding shocks, as they can swiftly reduce their arbitrage positions in response to wholesale funding dry-ups. However, the use of wholesale funding as arbitrage capital also reduces the usefulness of short-term wholesale funding in spurring lending to the real economy.

The changing nature of unsecured wholesale funding occurs against the backdrop of significant regulatory reforms to the banking sector since the Global Financial Crisis (GFC). Importantly, to address global banks' vulnerability due to over-reliance on unsecured wholesale funding, Basel III introduced the Liquidity Coverage Ratio (LCR) re-

[1] When we refer to "banks", we mean the entire banking organization, not strictly the commercial banking arm.

quirement. The LCR requires banks to hold a stock of high-quality liquid assets (HQLA) at least equal to 100 percent of the expected net cash outflows during a 30-day stress scenario. Under the LCR, the use of unsecured wholesale funding for liquidity and maturity transformation is heavily penalized in the sense that most short-term unsecured wholesale funding borrowed from financial institutions has an assumed outflow rate equal to 100 percent under distress. In contrast, stable insured deposits have an assumed outflow rate of only 3 percent. Therefore, if a bank obtains one dollar of unsecured short-term funding from a financial institution, in order not to worsen its LCR, the bank's only choice is to invest the dollar in HQLA.

Why would the bank borrow if it cannot lend? Beyond maturity and liquidity transformation, persistent violations of the textbook no-arbitrage principle give rise to an important new role for unsecured wholesale funding. Unsecured wholesale funding can be used to finance arbitrage positions consisting of liquid assets, neutral to the LCR. We focus on two types of arbitrage positions funded by unsecured borrowing. The first type is interest on excess reserves (IOER) arbitrage, in which banks obtain unsecured, short-term dollar funding and hold the proceeds as reserves at the Federal Reserve, earning the spread between the IOER rate and their cost of short-term funding (Bech and Klee, 2011; Keating and Macchiavelli, 2017; Banegas and Tase, 2020). The second type is covered interest rate parity (CIP) arbitrage, in which banks borrow unsecured, short-term dollar funding from the cash market and then lend the dollars in the FX forward/swap markets (for example, Du, Tepper, and Verdelhan, 2018). Both arbitrage strategies contain very little risk and have persisted after the GFC. The ability of banks to engage in these types of arbitrage crucially depends on their ability to obtain wholesale dollar funding at attractive terms as well as the total leverage constraint banks face in scaling up the arbitrage activities.

Using granular daily bank-level supervisory data on various wholesale funding instruments and reserve balances, our paper provides the first systematic account of potential arbitrage capital and arbitrage positions for U.S. banks and foreign banking organizations (FBOs) in the United States.[2] For each wholesale funding instrument, we observe information on the issuers, volumes, and interest rates. Such detailed information on the U.S. dollar wholesale funding market is not available in existing studies. Another key novelty of our datasets is that, in contrast to the bulk of empirical banking research that uses quarter-end bank reports, we observe banks' activities outside of quarter-end regulatory reporting dates. This feature is essential to accurately gauge the size and time variations of banks' arbitrage activities, as banks window dress their quarter-end balance sheets in order to improve their reported regulatory capital ratios.

Our sample comprises 58 highly-rated global banks that frequently trade with U.S. prime money market funds (MMFs)—the primary lenders in unsecured wholesale funding markets.[3] We measure the potential arbitrage capital for the IOER and CIP arbitrages as the amount of unsecured, short-term wholesale funding raised below the IOER rate and the implied dollar rates from the dollar-yen swap markets, respectively. We find that the overwhelming majority of unsecured wholesale dollar funding of our sample banks can be used as arbitrage capital, with about 95% of the total funding raised at a rate below the implied dollar interest rate from the dollar-yen swap and about a third of the total funding raised at a rate below the IOER rate.

With this arbitrage capital perspective of unsecured wholesale funding in mind, we study the impact of a recent wholesale funding dry-up on global banks. As a result of a major regulatory reform of the U.S. MMF industry introduced by the Securities and Exchange Commission (SEC), prime MMFs reduced their supply of wholesale funding to global banks by more than $800 billion between October 2015 and October 2016. We find that the primary response of global banks to this negative wholesale funding shock was a

[2]Throughout the paper, we use the terms "foreign banking organizations," "foreign banks," and "U.S. branches and agencies of foreign banking organizations" interchangeably.

[3]These institutions are the global banks with the highest credit quality because U.S. MMFs are required to invest the bulk of their portfolios in top-quality issuers.

reduction in their arbitrage positions funded by their unsecured wholesale borrowing. In contrast to the traditional bank lending channel, banks did not reduce their loan provision.

To establish a causal relationship between funding supply from MMFs and banks' activities, our identification relies on the cross-sectional variations in reductions in unsecured funding from prime MMFs and changes in banks' outcome variables over the one-year period prior to the reform implementation deadline. To isolate the effect of the funding supply shock from any changes in banks' demand for funding, we construct a Bartik-style shift-share instrument for MMFs' cutback in funding supply to banks.[4] We closely follow the recommended diagnostic tests proposed by Goldsmith-Pinkham, Sorkin, and Swift (2020) to justify the validity of our instrumental variable approach.

We find that the MMF reform significantly reduced the availability of potential arbitrage capital for banks. For a 1% decline in unsecured funding from prime MMFs as a share of total assets, potential arbitrage capital as a share of total assets declines by 0.9% on average. In addition, using data on daily reserve balances held at the Federal Reserve, we construct a proxy for the IOER arbitrage position as the minimum of the excess reserve balances and the amount of funding obtained at a rate below the IOER rate. We show that this proxy for the IOER arbitrage position as a share of total assets also declines by about 0.8% in response to a 1% reduction in unsecured prime MMF funding.

In contrast to the strong response of potential arbitrage capital and reserve balances, this large negative funding supply shock had no significant impact on banks' loan provision. We first examine changes in the loan positions on the balance sheets of the U.S.-based bank entities of our sample banks using weekly bank-level balance sheet data. Second, we use Dealscan data on the U.S. dollar-denominated syndicated loan issuance of the entire banking organization. We find consistent evidence across the two data sources that the

[4]The Bartik instrument, first proposed by Bartik (1991), has been widely used in the applied microeconomics literature. Our setting is analogous to the "immigration enclave" setting in Card (2009). Applications of the Bartik instrument in finance are less common. A few recent examples are Greenstone, Mas, and Nguyen (2020) and Xu (2020).

negative wholesale funding shock triggered by the MMF reform did not translate into a significant reduction in loan supply. In contrast, using a similar methodology, we find that the sharp decline in global banks' unsecured funding from MMFs during the peak of the European debt crisis in 2011-2012 reduced banks' loan origination, consistent with the evidence presented in Ivashina, Scharfstein, and Stein (2015), as this shock occurred before the implementation of the Basel III liquidity regulations.

In addition to documenting the average effect across all sample banks, we also examine heterogeneous responses to the reform depending on differences in banks' business models. We show that banks that specialize in the IOER arbitrage, as indicated by a high correlation between daily changes in unsecured funding and daily changes in excess reserve balances, cut down significantly more IOER arbitrage. Beyond balance sheet adjustments, we show that the loss of funding due to the MMF reform also increases banks' wholesale funding costs. The effect on funding costs is less pronounced for IOER arbitrageurs than for non-IOER arbitrageurs, consistent with a more elastic demand for dollar funding among IOER arbitrageurs.

Furthermore, we show that the reform led to more muted quarter-end effects attributable to declines in unsecured funding around quarter-ends. Given that both the IOER and CIP arbitrages are balance sheet intensive, banks in foreign jurisdictions have incentives to scale down their arbitrage activities on quarter-end regulatory reporting dates. We observe smaller drops in potential arbitrage capital on quarter-ends after the MMF reform, suggesting that banks reduced their intra-quarter arbitrage activities. We find strong evidence that the quarter-end effects in total *unsecured* funding outstanding and *unsecured* funding borrowed from prime funds have both declined significantly after the reform. Instead, *secured* funding plays an increasingly important role in quarter-end dynamics. These findings support the view that the MMF reform has reduced arbitrage activities funded by unsecured borrowing.

Finally, we examine the relationship between arbitrage capital and arbitrage profits. In general, we find that reductions in arbitrage capital are associated with increases in arbitrage profits, which is evidence that supply shocks to arbitrage capital matter for the variation in equilibrium arbitrage profits. This negative relationship is stronger on quarter-ends when banks' balance sheet capacity is more constrained. In addition, for the IOER arbitrage, we find a stronger negative correlation between arbitrage capital and arbitrage profits after the MMF reform implementation.

The arbitrage capital perspective of wholesale funding has important implications for monetary policy. In an environment with abundant reserves, the IOER arbitrage profits earned by global banks anchor overnight unsecured funding rates, including the effective federal funds rate—the Federal Reserve's policy rate. The CIP arbitrage profits determine the offshore dollar funding costs, which directly affect the international transmission of U.S. monetary policy. As such, the dynamics of the IOER and CIP arbitrage activity by global banks is crucial for monetary policy implementation and transmission.

Our results also have important implications for financial regulations. Further reforms to the MMF industry are being actively discussed by regulators in light of another run on prime MMFs during the peak of the COVID-19-induced financial distress in March 2020. The resilience of large global banks to the pandemic-induced wholesale funding crunch is again consistent with the changing nature of unsecured wholesale funding. As large global banks improve their liquidity profiles under Basel III regulations, the likely migration of liquidity risks from large global banks to smaller banks and non-bank financial institutions is an important area of future research.

Our paper contributes to the literature by providing a new perspective on the role of short-term wholesale funding for global banks. Existing theoretical models, such as Calomiris and Kahn (1991) and Diamond and Rajan (2011), provide reasons for banks to have a maturity mismatch between assets and liabilities, as they borrow from wholesale lenders to support loan growth. However, a large strand of literature highlighted the fragility of wholesale funding. In particular, fragility during the GFC has been documented for many wholesale funding markets, including the market for federal funds (Afonso, Kovner, and Schoar, 2011), commercial paper (Kacperczyk and Schnabl, 2013; Duygan-Bump et al., 2013), and repo (Gorton and Metrick, 2012; Copeland, Martin, and Walker, 2014). This fragility affects providers of wholesale funding, such as MMFs, as shown by Kacperczyk and Schnabl (2010) during the GFC and by Chernenko and Sunderam (2014) during the European debt crisis. Ivashina, Scharfstein, and Stein (2015) and Correa, Sapriza, and Zlate (2016) find a significant contraction in dollar lending by global banks following the negative funding supply shock from MMFs during the European debt crisis. Our findings differ given the significant transformation of the role of wholesale funding after the implementation of post-GFC regulations. In an environment in which a large portion of wholesale funding is used to support liquid arbitrage positions, the primary response of banks to a funding shock is a reduction in arbitrage positions rather than loan provision.[5]

In addition, the arbitrage capital perspective of short-term wholesale funding connects our paper to the recent literature on no-arbitrage violations and the implications of post-GFC financial regulations on arbitrage activities. To our knowledge, we provide the first direct empirical measure of the *quantity* of dollar arbitrage capital for global banks across different wholesale funding markets. Keating and Macchiavelli (2017) and Banegas and Tase (2020) study the dynamics of the IOER arbitrage. Munyan (2017) and Anbil and Senyuz (2018) document regulatory-driven repo window dressing activities. Du, Tepper, and Verdelhan (2018) show persistent CIP violations and their quarter-end dynamics due to banks' window dressing activities on regulatory reporting dates. A growing literature

[5]A few other papers also examine the impact of the 2016 MMF reform from different perspectives. Cipriani and Spada (2021) focus on estimating the premium for "money-like" assets. Gissler and Narajabad (2017a,b,c) and Sundaresan and Xiao (2018) examine the growing role of the Federal Home Loan Banks (FHLBs) following the reform and other post-crisis liquidity regulations. Since foreign banks cannot borrow from FHLBs and U.S. banks source very little arbitrage capital to begin with, the growing role of the FHLBs does not directly affect the arbitrage capital of global banks.

has been examining the frictions in the global dollar intermediation that help explain the persistence of these CIP violations (for example, Borio, McCauley, McGuire, and Sushko, 2016; Avdjiev, Du, Koch, and Shin, 2019; Rime, Schrimpf, and Syrstad, 2017; Aldasoro, Ehlers, and Eren, 2019). Understanding these money market dynamics is also crucial to the implementation of monetary policy (Ihrig, Meade, and Weinbach, 2015; Duffie and Krishnamurthy, 2016; Anderson and Kandrac, 2017; Correa, Du, and Liao, 2020).

The paper is structured as follows. In Section 2, we discuss the various data sources used in the paper and provide some background on the MMF reform. In Section 3, we describe the IOER and CIP arbitrage strategies as well as our measures of arbitrage and present some stylized facts regarding global banks' arbitrage activities. In Section 4, we discuss our identification approach and present our main empirical results on the effects of the MMF reform as a negative wholesale funding shock for global banks. In Section 5, we document the relationship between arbitrage capital and arbitrage profits. Section 6 concludes.

2 Data and Background on the MMF Reform

2.1 Data and Sample

An important contribution of the paper is that we provide insights into the wholesale dollar funding profiles of domestic banks and FBOs in the United States at a daily frequency. To obtain funding profiles that are as comprehensive as possible, we compile our dataset from a host of confidential data on various wholesale funding instruments at the transaction level. Compared with datasets based on banks' quarter-end regulatory filings, our data offers much more granular information on various wholesale funding instruments and, importantly, it allows us to examine fluctuations in wholesale funding activities on days outside of quarter-ends. In addition to detailed wholesale funding information, we obtain daily data on banks' reserve balances held at the Federal Reserve as well as weekly balance sheet information on some broad categories of bank business operations. Finally, we observe security-level information on MMFs' holdings of bank securities at a monthly frequency, which is collected by the SEC and made publicly available.[6] We now briefly discuss each of these data sources and the construction of our sample.

First, we compile a transaction-level dataset for various wholesale funding instruments, including certificates of deposit (CD), commercial paper (CP), Eurodollars (ED), federal funds (FF), and tri-party repos (RP). Each data entry includes the instrument type (CD, CP, ED, FF, or RP), the borrower name, the trade date, the maturity of the instrument, the borrowing amount, and the borrowing rate. We obtain CP transactions from the Depository Trust and Clearing Corporation (DTCC)—the national clearinghouse for the settlement of securities trades and a custodian for securities.[7] For FF, ED, and CD, we use transaction-level data from the FR 2420 *Report of Selected Money Market Rates*, which, starting in April 2014, collects daily issuance data on FF, ED, and CD from U.S. banks and FBOs that meet certain size requirements.[8] For RP, we use position-level data from the tri-party repo market, which are reported to the Federal Reserve Bank of New York.[9] While we do not have detailed data on the bilateral repo market, the tri-party repo market captures virtually all repo lending from MMFs during our sample period.

In addition to the detailed information on banks' wholesale funding instruments, we obtain weekly data on bank balance sheet items from the FR 2644 *Weekly Report of Selected Assets and Liabilities of Domestically Chartered Commercial Banks and U.S.*

[6]Throughout the paper, we use the term "securities" loosely to refer to any type of wholesale funding instruments.

[7]DTCC performs these functions for almost the entire domestic CP market.

[8]The FR 2420 report collects data from (1) domestically chartered commercial banks and thrifts with $18 billion or more in total assets, or $5 billion or more in assets and meeting certain unsecured borrowing activity thresholds, and (2) U.S. branches and agencies of foreign banks with total third-party assets of $2.5 billion or more (Federal Reserve Board, Instructions for Preparation of Report FR 2420). The ED transactions in the FR 2420 report include offshore borrowing by U.S. banks and FBOs through their offshore branches (mainly in the Caribbean) and domestic borrowing of offshore funding through international banking facilities (IBF). Before October 2015, the FR 2420 report only captures offshore borrowing by U.S. banks, but not by FBOs or by IBFs.

[9]These data include all activity on the tri-party platform, including collateral deposits and borrow pledges, so somewhat overstate strict tri-party repo activity.

Branches and Agencies of Foreign Banks. The FR 2644 report parallels the quarterly bank Call Reports, but, while available at a higher frequency, it is far less detailed. In addition, we obtain daily data on banks' reserve balances held at the Federal Reserve.

Finally, MMFs are among the most important suppliers of short-term wholesale funding to global banks. The two main types of MMFs in the United States are prime funds and government funds. Prime funds can hold short-term debt securities with maturities of up to one year across different types of issuers, whereas government funds can only hold government securities and repos backed by government securities. We use data on U.S. MMFs' month-end portfolio holdings from the N-MFP *Monthly Schedule of Portfolio Holdings of Money Market Funds* provided by the SEC. The N-MFP schedule discloses portfolio holdings of each MMF at the security level as well as the fund's AUM for every month-end since 2011.

From these datasets, we construct a sample of 58 global banks that frequently trade with U.S. MMFs.[10] These banks account for about 90% of the total prime fund holdings of bank securities. Since U.S. MMFs are required to invest the bulk of their portfolios in top-quality issuers, our sample only includes top-tier global banks in terms of credit risk. Table A1 provides a full list of our sample banks and the country of their headquarters.

2.2 Wholesale Funding Shock as a Result of the 2016 MMF reform

In 2014, the SEC introduced a package of reforms of the U.S. MMF industry to be implemented by October 14, 2016. The reform mainly targeted prime funds and left regulations regarding government funds largely unchanged. Prior to the reform, both prime and government funds used a constant net asset value (NAV) to value their assets, which allowed investors to redeem their MMF shares at par, on demand. The reform requires institutional prime MMFs to use a floating NAV to value their assets and allows

[10] We require a sample bank to have at least 100 transactions with all U.S. MMFs (including both secured and unsecured transactions) between 2014 and 2017 and to have total assets equal to at least $100 billion in 2014.

all prime funds to implement redemption gates and liquidity fees to limit outflows. In contrast, government funds can still use constant NAVs and are largely not subject to gates and fees. Overall, the reform made prime MMFs less "money-like" and triggered large flows of AUM from prime to government funds (Cipriani and Spada, 2021). As illustrated in Panel A of Figure 1, between the reform announcement date on July 23, 2014 and the implementation deadline on October 14, 2016, prime funds lost about $1 trillion in AUM, whereas government funds gained about $1 trillion in AUM. Most of the changes in AUM occurred in the year prior to the implementation deadline.[11]

The $1 trillion reduction in prime funds' AUM resulted in a large negative funding supply shock for global banks. As shown in Panel B of Figure 1, our sample banks experienced a loss of secured and unsecured funding from prime funds of more than $800 billion, far exceeding the losses of funding from prime MMFs' during the peaks of the European debt crisis (Chernenko and Sunderam, 2014) and the GFC after Lehman's bankruptcy (Duygan-Bump et al., 2013) of about $200 billion and $400 billion, respectively.

3 Arbitrage Capital: Measurements and Stylized Facts

We consider two types of risk-free arbitrage strategies based on unsecured funding: IOER arbitrage and CIP arbitrage. [12] The ability of banks to engage in these arbitrages crucially depends on their ability to borrow wholesale dollars at attractive terms. We first describe the two arbitrages and the measurement for arbitrage capital, and then present some new stylized facts.

[11]U.S. MMFs are only allowed to hold debt securities with remaining maturities less than one year. Therefore, the effect of the reform shows up one year before the implementation deadline. We refer to the period from October 2015 to October 2016 as the MMF reform implementation period.

[12]We focus on unsecured funding as arbitrage capital to better align with the textbook-version of arbitrage, which has zero initial costs. Secured funding can also be used for arbitrage, but the arbitrageur needs to finance the collateral first.

3.1 IOER Arbitrage

First, banks can engage in IOER arbitrage by raising unsecured dollar funding from the FF, ED, CD, and CP markets, and directly depositing the proceeds at the Federal Reserve, earning the spread between the IOER rate and the unsecured funding rate. Since a deposit at the Federal Reserve is the safest and most liquid asset, IOER arbitrage based on unsecured funding is a textbook version of risk-free arbitrage. Banks do not scale up this trade more and arbitrage away the profits because such arbitrage positions expand the size of a bank's balance sheet and make the Basel III leverage ratio requirement more binding. Separately, non-depository institutions either do not earn IOER on the balances they hold at the Federal Reserve or cannot hold balances at the Federal Reserve at all, and therefore cannot engage in this arbitrage (Bech and Klee, 2011). These features led to a consistently positive profit for IOER arbitrage in our sample period from 2015 to 2017.[13]

We measure the amount of potential arbitrage capital for bank i at time t, $Y_{i,t}^{IOER}$, as the total outstanding amount of unsecured wholesale funding borrowed at a rate below the IOER rate:

$$Y_{i,t}^{IOER} = \sum_{n,k} y_{i,n,k,t}[y_{i,n,k,t} | r_{i,n,k,t-n} < r_{t-n}^{IOER}], \tag{1}$$

where $y_{i,n,k,t}$ denotes the outstanding amount at time t for unsecured funding instrument k with a remaining maturity of n days issued by bank i, and $r_{i,n,k,t-n}$ denotes the issuing rate of the same instrument on the issuance date $t-n$, and r_{t-n}^{IOER} denotes the IOER rate on the issuance date.

In addition to measuring potential arbitrage capital, we can also calculate a proxy for IOER arbitrage positions. As IOER arbitrage is limited by both the amount of funding

[13]The spread between IOER and overnight funding rates remained positive until October 2018, and then became zero and later negative beginning in early 2019, amid falling reserve balances as a result of the Federal Reserve's balance sheet normalization. However, the spread once again turned positive following the large increase in reserve balances resulting from the Federal Reserve's response to the COVID-19 pandemic in March 2020.

obtained at a rate less than IOER and the amount actually earning IOER at the Federal Reserve, a proxy for IOER arbitrage positions can be computed by taking the minimum of excess reserves and potential IOER arbitrage capital for each sample bank:

$$Q_{i,t}^{IOER} = \min(ExcessReserves_{i,t}, Y_{i,t}^{IOER}),$$

where $ExcessReserves_{i,t}$ denotes the amount of reserve balances held in excess of required reserve balances at the Federal Reserve by bank i at time t.

3.2 CIP Arbitrage

Second, banks can engage in CIP arbitrage by raising unsecured dollar wholesale funding, and then lending these dollars in the FX forward/swap markets, thereby earning any deviation in CIP. As shown in Du, Tepper, and Verdelhan (2018), there are large and persistent CIP deviations for all G10 currencies vis-à-vis the U.S. dollar. For currencies with low nominal interest rates, such as the euro, Japanese yen, and Swiss franc, there are risk-free arbitrage profits when borrowing dollars in cash markets, investing in the foreign currency, and hedging the exchange rate risk using FX forwards and swaps.

We use the Japanese yen as a benchmark currency to gauge the potential capital for CIP arbitrage. The dollar-yen is one of the most liquid FX currency pairs, and banks and real-money investors (e.g., pension funds and life insurers) in Japan have a strong demand for dollar funding and hedging services, therefore becoming natural counterparties for global banks' CIP arbitrage positions. We use the Japanese overnight index swap (OIS) curve to measure the risk-free interest rates that global banks earn on their yen investments. We obtain very similar results if we instead use T-bill or repo rates, or the deposit rate at the Bank of Japan's deposit facility. One advantage of using the OIS curve is that it has a very granular maturity breakdown (overnight, 1-week, 2-week, 3-week, 1-

month, 2-month, ..., 12-month), which allows us to more precisely match the OIS tenor with the corresponding maturity of the dollar funding leg.

To calculate the potential arbitrage capital for the CIP arbitrage, we first calculate the swapped yen rate expressed in dollars, $r_{n,t}^{¥\to\$}$:

$$r_{n,t}^{¥\to\$} = r_{n,t}^{¥} - \rho_{n,t}^{¥-\$},$$

where $r_{n,t}^{¥}$ denotes the yen OIS interest rate with a tenor of n days, and $\rho_{n,t}^{¥\to\$}$ denotes the FX forward premium to swap yen into dollars. Analogous to equation (1), we can measure the amount of potential capital for the CIP arbitrage as the total outstanding amount of funding obtained at a rate below the swapped yen rate upon issuance:

$$Y_{i,t}^{CIP} = \sum_{n,k} y_{i,n,k,t}[y_{i,n,k,t}|r_{i,n,k,t-n} < r_{n,t-n}^{¥\to\$}]. \tag{2}$$

As we have balance sheet information only for U.S.-based entities, we are missing information on the investing leg of the CIP arbitrage, which would generally show up on the balance sheets of foreign affiliates. This makes calculating a proxy for CIP arbitrage positions difficult. However, in Section 4.6, we discuss how we use intra-office flows to shed light on some CIP arbitrage activities.[14]

3.3 Stylized Facts on Arbitrage Capital of Global Banks

We now provide some stylized facts on arbitrage capital and arbitrage activities of global banks. First, almost every dollar raised from unsecured wholesale funding markets by our sample banks can potentially be used for IOER or CIP arbitrage. The total amount of observed potential arbitrage capital averages about \$1.5 trillion ahead of the October 2016 implementation date. Panel A of Figure 2 plots unsecured wholesale funding outstanding

[14] Correa, Du, and Liao (2020) use excess reserve balances in foreign central banks and the net reverse repo lending in foreign currency as a proxy for dollar lending in the FX swap market.

by rates. The red area indicates funding issued at rates below the IOER rate, that is, potential arbitrage capital for IOER arbitrage. The yellow area indicates funding issued above the IOER rate, but below the swapped yen rate in dollars. The blue area indicates funding issued above the swapped yen rate in dollars, which can therefore not be employed for either arbitrage. We can see that more than 95% of our sample banks' short-term unsecured wholesale funding can be used for IOER or CIP arbitrage. These results confirm that IOER and CIP arbitrage opportunities are readily available for large global banks based on their actual wholesale borrowing costs.

Second, MMFs are an important supplier of potential arbitrage capital to banks, but their importance significantly declined after the MMF reform. As shown in Panel B of Figure 2, as of October 2015, the total potential arbitrage capital for the IOER and CIP arbitrages combined was around \$1.5 trillion, of which about \$1 trillion was borrowed from MMFs. After the MMF reform in October 2016, the total potential capital fell to about \$1.2 trillion, with funding from MMFs comprising only about \$300 billion of the total. That is, the share of total potential arbitrage capital coming from MMFs fell from about two-thirds to about one-quarter.

Third, the size of arbitrage capital is large for foreign banks and rather insignificant for U.S. banks. As shown in Table 1, foreign banks' average total potential arbitrage capital between October 2015 and June 2017 of \$1.2 trillion amounts to 46% of their total assets within the United States. Even though the arbitrage capital is relatively small as a share of foreign banks' global assets (2.5%), it accounts for 17% of their estimated global U.S. dollar-denominated assets.[15] In contrast, U.S. banks' average total arbitrage capital of \$0.2 trillion only accounts for 3% of U.S. banks' assets within the United States, 1.8% of U.S. banks' global assets, and 2.1% of U.S. banks' assets denominated in U.S. dollars.

[15] Based on the BIS Locational Banking Statistics for France, Japan, Netherlands, Switzerland, and the United Kingdom (where the currency composition of total bank balance sheets is available), we estimate that 15% of global assets of foreign banks are denominated in U.S. dollars.

The large difference between U.S. and foreign banks' dollar-denominated arbitrage capital can be attributed to a couple of key regulatory differences. First, foreign banks face a lower leverage ratio requirement compared to large U.S. banks. Both IOER and CIP arbitrage involve borrowing and lending, thereby increasing the size of the balance sheet and making the leverage ratio requirement more binding. A more stringent leverage ratio requirement can disincentivize these low-margin and balance sheet intensive arbitrage activities.[16] Second, while U.S. banks also face a deposit insurance fee on all of their wholesale funding after the Federal Deposit Insurance Corporation (FDIC) broadened the assessment base in 2011, foreign branches generally cannot raise FDIC-insured deposits and therefore are exempt from the fees (Kreicher, McCauley, and McGuire, 2014; Kandrac and Schlusche, forthcoming). The exact fee for a U.S. bank varies according to the size and complexity of the bank, but can be around 8 basis points for a large bank like JP Morgan (Whalen, 2011; Kreicher, McCauley, and McGuire, 2014). These fees erode the arbitrage profits for U.S. banks, leading to disproportionately large arbitrage activities by foreign banks.

Finally, the IOER arbitrage capital largely corresponds to the IOER arbitrage position. Figure 3 shows that our proxy for the IOER arbitrage position closely tracks IOER arbitrage capital for U.S. and foreign banks, respectively. Foreign banks account for about $300 billion of the IOER arbitrage, on average, in our sample, whereas the U.S. banks only account for about $50 billion on average.[17] Even though the IOER arbitrage is often known as the IOER-federal funds arbitrage, the total amount of the IOER arbitrage position is significantly larger than the total size of federal funds market ($60-80 billion

[16]Prior to Basel III, foreign banks did not face a non-risk-weighted total leverage ratio requirement, whereas U.S. banks had an existing 3% leverage ratio requirement. Under Basel III, foreign banks now face a 3% leverage ratio requirement, whereas U.S. banks' leverage ratio requirement increases to 5-6% under the supplementary leverage ratio rule.

[17]In calculating IOER arbitrage capital, we do not take into account the FDIC deposit insurance fee. If we do take into account the fee, foreign banks' potential arbitrage capital and position will largely be unaffected, and U.S. banks' IOER arbitrage capital and position would be even smaller.

outstanding), because banks also borrow IOER arbitrage capital from ED and short-term CP markets.

4 Effects of the 2016 MMF Reform on Global Banks

With this new perspective of unsecured wholesale funding being used as arbitrage capital in mind, we now examine the effects of a large negative unsecured wholesale funding shock as a result of the 2016 MMF reform. We first present some summary statistics on banks' balance sheet adjustments during the reform implementation period. We then discuss our empirical identification strategy and present the empirical results.

4.1 Summary Statistics on the Balance Sheet Adjustments

Before presenting our formal empirical methodology and regression results, we provide some summary statistics on global banks' wholesale funding, loan provision, and reserve balances over the reform implementation period. Panel A of Figure 4 plots the amount of unsecured wholesale funding by foreign and U.S. banks, respectively, along with prime funds' holdings of that funding. Overall, our sample banks lost about $700 billion in unsecured funding from prime funds, banks were only able to partially offset that funding loss by unsecured borrowing from other sources and, as a result, their total unsecured funding fell by about $300 billion. Foreign banks account for the majority of the decline in both unsecured funding outstanding and unsecured funding from prime funds. In contrast, U.S. banks have very little unsecured funding outstanding and rely very little on borrowing from prime MMFs. We explained the differences between U.S. and foreign banks' reliance on unsecured funding through the lens of arbitrage activities in Section 3.3.[18]

[18] Another important reason that U.S. banks rely less on unsecured wholesale dollar funding than foreign banks do is that U.S. banks have much broader access to the dollar deposit base.

It is possible that banks could have compensated for their loss of unsecured funding by sourcing secured funding in the form of repos. However, even though prime and government MMFs' holdings of repos issued by foreign banks increased somewhat, total repo funding of both foreign and U.S. banks remained quite flat (Panel B of Figure 4). Taken together, banks did not offset the decline in unsecured borrowing by increasing their secured funding.

On the asset side, as shown in Panel A of Figure 5, foreign banks did not decrease their loan provision despite the large declines in unsecured funding. Weekly loan positions for foreign banks remained quite stable over the reform implementation period. Meanwhile, as shown in Panel B of Figure 5, the decline in unsecured funding was correlated with a decline in excess reserve balances held by foreign banks. While the aggregate level of reserves is beyond the control of banks, they can determine the allocation of existing reserves. During our sample period, aggregate reserves were decreasing, in part due to a steady growth of currency in circulation and changes in Treasury's cash management practices, which led to a higher Treasury General Account balance. However, the aggregate decline in reserves was primarily borne by foreign banks rather than domestic banks since they could more easily accommodate the decline by scaling down their arbitrage positions, as discussed further in the next section.[19]

In summary, during the reform implementation period, foreign banks lost large amounts of unsecured funding from prime funds, and reduced their overall unsecured wholesale funding outstanding, but did not increase their repo outstanding. Interestingly, the large funding loss did not translate into declines in loan provision, but rather a large reduction in reserve balances at the Federal Reserve. These results motivate us to study the effect of unsecured wholesale funding shocks on banks' arbitrage activities.

[19]Furthermore, in Section 4.4.2, we establish parallel pre-trends across banks using reserves as the outcome variable for our empirical identification.

4.2 Methodology and Identification

We now formally examine the impact of the funding supply shock stemming from the MMF reform on banks' business activities. Our empirical strategy exploits the cross-bank variation in the size of the funding supply shocks and changes in bank-level outcomes. We start with the baseline OLS regressions of changes in bank i's outcome variable ($\Delta Y_{i,t}$) on changes in prime funds' holdings of bank i's unsecured debt securities ($\Delta hold_{i,t}^{Unsec}$):[20]

$$\Delta Y_{i,t}/Asset_{i,0} = \alpha + \beta \Delta hold_{i,t}^{Unsec}/Asset_{i,0} + \epsilon_{i,t}.$$

We normalize $\Delta Y_{i,t}$ and $\Delta hold_{i,t}^{Unsec}$ by total assets of the bank holding company in 2014 from SNL Financial, $Asset_{i,0}$, so that the changes are expressed as percentages of total pre-reform assets. We focus on changes between October 2015 and October 2016 to capture the effects over the reform implementation period. To increase the power of our regressions and, at the same time, avoid issues related to quarter-end window dressing, we use the four quarterly changes from October 2015 to January 2016, January 2016 to April 2016, April 2016 to July 2016, and July 2016 to October 2016.

However, one concern with this empirical approach is that changes in equilibrium quantities could be driven by both funding supply shocks from MMFs and funding demand shocks by banks. To isolate the effects of funding supply shocks from MMFs, we use a Bartik-style shift-share instrument for our independent variable, $\Delta hold_{i,t}^{Unsec}/Asset_{i,0}$:

$$\tilde{B}_{i,t} = \sum_j \text{Share}_{i,j,0} \times \text{Shift}_{j,t} = \sum_j (s_{i,j,0}/Asset_{i,0}) \times \Delta aum_{j,t}. \tag{3}$$

where $s_{i,j,0}$ denotes the lagged (pre-reform) share of bank i in fund complex j's portfolio, and $\Delta aum_{j,t}$ denotes the change in the AUM of all prime funds within fund complex

[20] We use the same methodology when analyzing other bank-level outcome variables beyond unsecured funding later in the paper. The arguments made here also apply to those later analyses.

j. We define the lagged bank share as of May 2014, just before the MMF reform was announced in July 2014.[21]

The "share" component, $\text{Share}_{i,j,0} = \frac{s_{i,j,0}}{Asset_{i,0}}$, captures the pre-reform exposure of bank i to prime funds in complex j.[22] The "shift" component, $\text{Shift}_{j,t} = \Delta aum_{j,t}$, captures changes in the AUM of prime funds in complex j, which are not attributable to the specific funding demand of bank i. The exclusion restriction of the Bartik instrument can either be justified by quasi-random "shares" (Goldsmith-Pinkham, Sorkin, and Swift, 2020) or quasi-random "shifts" (Adao, Kolesár, and Morales, 2019; Borusyak, Hull, and Jaravel, forthcoming). In our setting, we follow all the diagnostic tests proposed by Goldsmith-Pinkham, Sorkin, and Swift (2020) and show that the assumption of quasi-random "shares" holds up well.

Intuitively, the Bartik instrument in our application offers a pooled exposure design in which different banks have different pre-reform exposures to different fund complexes, and different prime funds experienced different AUM outflows over the reform implementation period, which resulted in different sizes of funding supply shocks for banks. These funding supply shocks would be independent of banks' funding demand shocks if the pre-reform exposures are quasi-randomly assigned (Goldsmith-Pinkham, Sorkin, and Swift, 2020).

Next, we present our main empirical results on arbitrage capital and arbitrage activities. We then discuss various diagnostic tests for the validity of the instrument in Subsection 4.4, followed by additional empirical results in Subsections 4.5 through 4.9.

[21] We chose to use the shares in May 2014, instead of June 2014, in order to avoid effects of quarter-end window dressing.

[22] Note that our setting maps almost exactly to the "immigration enclave" example in Card (2009), where i corresponds to location and j corresponds to the country of origin of the immigrants. As in Card (2009), these shares do not add up to 1 for a given bank. The sum of all shares equal to one is not required for the validity of the Bartik instrument.

4.3 Arbitrage Capital and Arbitrage Positions

Table 2 presents the baseline regression results for arbitrage capital and arbitrage positions. The OLS estimates are presented in the top panel and the IV estimates are presented in the bottom panel. Columns 1-3 show that a 1% reduction in unsecured funding from prime funds leads to a roughly 0.9% decline in arbitrage capital for IOER and CIP arbitrage, and to a roughly 0.8% decline in our proxy for the IOER arbitrage position over total bank assets. The OLS and IV coefficient estimates are very similar. These results suggest that the unsecured wholesale funding shock as a result of the MMF reform has a strongly significant effect on banks' arbitrage capital and arbitrage positions.

In addition to estimating the average effects across all sample banks, we also explore heterogeneous responses to the wholesale funding shock depending on banks' business models. To that end, we divide our sample banks into two groups based on the intensity of their arbitrage activities. Specifically, we sort banks based on the correlation between daily changes in their reserve balances and daily changes in their unsecured wholesale funding outstanding. We label banks in the top one-third of correlations as "IOER arbitrageurs" and banks in the bottom two-thirds of correlations as "non-IOER arbitrageurs" (for a similar concept, see Keating and Macchiavelli, 2017). Column 4 shows that the IOER arbitrage position of the "arbitrageurs" exhibits a much more significant response to the funding supply shock.

As we have seen in Figure 3, foreign banks account for the bulk of the total IOER arbitrage capital and arbitrage position. We therefore repeat the regression for the IOER arbitrage position using the sample of only foreign banks in Column 5, and find similar results compared to our full-sample estimate in Column 3. In the appendix, we offer several additional robustness checks for this set of benchmark results. We show that the regressions using annual changes instead of quarterly changes (Table A2), using dollar-amount changes instead of changes as a share of total assets (Table A3), and including additional bank-level controls, such as the short-term credit rating, return on assets, and Tier-1 common equity ratio (Table A4) produce qualitatively similar results.

4.4 Unpacking the Bartik Instrument

Having presented the benchmark results for arbitrage capital and arbitrage positions, we now discuss the validity of the Bartik instrument. We closely follow the diagnostic tests and visualizations outlined in Goldsmith-Pinkham, Sorkin, and Swift (2020).

First, Goldsmith-Pinkham, Sorkin, and Swift (2020) demonstrate that the Bartik IV estimator is numerically equivalent to a GMM estimator with all industry shares as instruments. In our application, the "industry" share corresponds to the exposure of individual bank i to fund complex j, $\text{Share}_{i,j,0} = \frac{s_{i,j,0}}{Asset_{i,0}}$. Our sample banks borrow from prime funds in 84 fund complexes, and thus the Bartik instrument is a weighted average of $J = 84$ individual instruments, one for each fund complex j. However, not all fund complexes are equally important. For the validity of the overall identification, it is important to justify the identifying assumptions of the most important individual instruments.

4.4.1 Rotemberg Weights

To formally rank the importance of the individual instruments, we can perform a Rotemberg decomposition of the Bartik IV estimator outlined in Goldsmith-Pinkham, Sorkin, and Swift (2020). If any particular instrument is misspecified, the Rotemberg weight tells us how sensitive the overall estimator is to the misspecification of the individual instrument. We illustrate the Rotemberg decomposition based on our benchmark result of the effect of changes in MMFs' funding supply on the IOER arbitrage position (Column 3 of Panel B in Table 2). Table 3 shows various summary statistics for the Rotemberg weights of the Bartik IV estimator. In Panel A, we first note that the Rotemberg weights are largely positive for all fund complexes. As seen in Panel B, these weights are -0.83 percent correlated with the AUM change at the fund complex level. In other words, the MMF complexes that experienced the largest AUM outflows are the most important funds for us to justify our identifying assumptions.[23] We identify the top five MMF complexes with the highest Rotemberg weights,[24] and report our benchmark estimate based on individual instruments constructed using banks' exposure to these top five fund complexes, respectively (Panel C). We can see that the point estimates based on individual instruments are broadly in line with the benchmark Bartik IV instrument presented in Column 3 of Panel B in Table 2. These top-five funds account for about 60 percent of the sum of all Rotemberg weights in the Bartik estimator.

Figure 6 visualizes the relationship among the Rotemberg weights associated with each prime fund complex j, the F-statistics for the first-stage regression of changes in the unsecured funding from prime funds on bank shares in individual complex j, and the IV estimate, β_j, of the baseline regression of changes in IOER arbitrage position on changes in unsecured funding from prime funds using the bank shares in individual fund complex j as an instrument. In terms of instrumental relevance, Panel A plots the first stage F-statistic against the Rotemberg weight for individual instruments. We can see that the F-statistic for instruments with higher Rotemberg weights is generally above 10, which passes the rule-of-thumb weak instrument test. Panel B plots the β_j estimate based on individual instruments against the F-statistic. The coefficient estimates are relatively close to the value of the overall coefficient reported in Column 3 of Panel B in Table 2 (as denoted by the horizontal dashed line), especially among fund complexes with high F-statistics.

[23]The ten fund complexes that experienced the largest prime AUM outflows, based on public N-MFP data, are: Fidelity (-\$247 billion), JP Morgan (-\$119 billion), BlackRock (-\$108 billion), State Street Global Advisors (-\$81 billion), Federated (-\$64 billion), Dreyfus (-\$52 billion), Legg Mason (-\$51 billion), Wells Fargo (-\$49 billion), Goldman Sachs (-\$49 billion), and Vanguard (-\$37 billion).

[24]Due to data agreements, we cannot disclose the top five fund complexes with the highest Rotemberg weights. Instead, we label these five fund complexes as Fund A, Fund B, Fund C, Fund D, and Fund E.

4.4.2 Instrumental Exogeneity

To assess the exclusion restriction that the "shares" are quasi-randomly assigned, we again follow Goldsmith-Pinkham, Sorkin, and Swift (2020) and perform three tasks: first, check the correlation between fund shares and bank-level characteristics; second, use alternative estimators and conduct over-identification tests; and third, test for parallel pre-trends.

Table 4 displays the regression results of the individual "shares" for the highest Rotemberg weight fund complexes and the Bartik instrument on bank-level characteristics. We see that these fund shares are largely uncorrelated with the overall size of the bank, the bank's classification as an "IOER-arbitrageur" or "Non-IOER arbitrageur", and its classification as a U.S. or foreign bank. However, there is some evidence that the fund complexes with the highest weight lend to more "sound" banks with better credit ratings, higher Tier-1 common equity ratios, and higher returns on assets.[25]

To address the concern that the correlation between the fund complex share and the soundness of banks may bias our results, we compare the coefficient estimates *without* any bank-level controls to the coefficients *with* controls (the credit rating, the Tier-1 common equity ratio, and the return on assets). Table 5 shows that the coefficients without (Column 1) and with (Column 2) controls are largely unchanged. The small difference in coefficients is not statistically significant for 4 out of 5 estimators (Column 3). In addition to the OLS and Bartik IV estimators, Table 5 also reports three alternative estimators applied to the case with many instruments. The two-stage least squares (2SLS) row uses the shares of each fund complex, j, separately as instruments. The modification of the bias-corrected two-stage least squares (MB2SLS) estimator follows Anatolyev (2013) and Kolesár et al. (2015). The heteroskedasticity robust version of the Fuller (1977) estimator (HFUL) is proposed by Hausman et al. (2012). The coefficient estimates are quite similar across these five estimators. Column 4 conducts the over-identification test based on the

[25]We assign numerical values to banks' short-term credit rating: 3–A1 (S&P) or P1 (Moody's), 2–A2 (S&P) or P2(Moody's), and 1–Unrated.

J-statistic for the 2SLS and the HFUL estimators, which cannot reject the null that all instruments are exogenous.

Our pooled exposure design based on the Bartik instrument resembles a difference-in-differences design. Banks' shares in MMF complexes measure their exposures to the negative funding shock from the MMF reform. Therefore, it is natural to also test for the pre-trends in our outcome variables to ensure that the banks' shares are not correlated with some unobserved confounders that would lead to similar changes in the outcome variables independent of the MMF funding supply shock. For our benchmark arbitrage regression on the IOER arbitrage position, we do not have a pre-period because the expanded collection of the ED data only began in October 2015. However, we have a long series of reserve balances held at the Federal Reserve, and therefore perform a pre-trend analysis for changes in reserves of U.S.-based entities prior to the 2016 MMF reform.

Figure 7 shows the coefficients from the reduced-form regression of running quarterly changes in reserves in 2014, 2015, and 2016 on the previously-constructed Bartik-instrument and on individual instruments for fund complexes with the largest Rotemberg weights. The coefficients for 2016 (the right-most observations in each panel) correspond to the reduced-form regression coefficients on changes in reserves on the bank shares as instruments during the MMF reform implementation period.[26] In contrast to the large and significant coefficient estimates in 2016, the coefficient estimates from the two pre-periods 2014 and 2015 (the left two observations) are both indistinguishable from zero in all panels.[27] In other words, changes in reserves before the funding shock in 2016 are

[26]Similar to our baseline estimation, we use 4 quarterly observations for each year that do not include quarter-ends: October of last year to January, January to April, and April to October.

[27]Note that the 2016 coefficient in the "Aggregate" panel has the opposite sign and is significantly smaller in magnitude than the coefficients in the panels for individual funds in Figure 7. This is because the aggregate panel reports reduced-form coefficients of quarterly changes in reserves on the standard Bartik instrument, where bank shares in different fund complexes are weighted by "negative" AUM flows at the fund complex level (measured in billions of USD) during the reform implementation period. In the other five panels, the instrument is the bank share in each of the top-five fund complexes with the highest Rotemberg weights, and no scaling of AUM loss at the fund complex level is applied.

uncorrelated with the instruments, which satisfies the parallel trend assumption for our identification.

4.5 Composition of Banks' Balance Sheets

In addition to studying the effects of the large funding shock due to the MMF reform on potential arbitrage capital and arbitrage positions, we examine the effects of the funding shock on the size and composition of banks' balance sheets. The traditional bank lending channel suggests that a large reduction in banks' funding supply would result in a reduction in banks' loan provision. Ivashina, Scharfstein, and Stein (2015) and Correa, Sapriza, and Zlate (2016) find supporting evidence for the traditional bank lending channel using the shock in funding from MMFs during the European debt crisis. Contrary to the traditional bank lending channel, we find that banks' loan provision and securities holdings were little changed in response to the MMF reform.

Using the Bartik instrument as discussed above, Table 6 presents IV estimates of the effects of the funding shock on key asset and liability items for U.S.-based entities—U.S. banks and FBOs based in the U.S.—from the FR 2644 data. Note that the FR 2644 data are voluntarily reported, and 50 of our 58 sample banks report these data. In the regressions, all changes in the balance sheet items are scaled by total assets of the bank holding company in 2014 from SNL Financial.

We find that a 1% reduction in unsecured funding from MMFs led to a 0.83% reduction in total assets (Column 1) and a 0.76% reduction in cash balances (Column 2) of U.S.-based entities. The reduction in cash balances, which mainly consist of reserve balances, accounts for the majority of the overall reduction in total assets. Columns 3-6 show that the funding supply shock had little effect on other asset items. The coefficients on loans, securities holdings, federal funds and reverse repo lending, and other assets are all close to zero and statistically insignificant.

On the liability side, we find that total liabilities of U.S.-based entities decline by 0.25% in response to a 1% reduction in unsecured funding from MMFs (Column 7), largely driven by a 0.32% reduction in deposits (including wholesale certificates of deposits). The difference between the 0.83% response for total assets and the 0.25% response for total liabilities is explained by a 0.57% change in the net-due-to position (Column 12).[28] The U.S.-based entities significantly contract their net internal borrowing from their foreign affiliates in response to the negative funding supply shock, which we explain in greater detail in the next subsection.

Taken together, these results do not support the presence of the traditional bank lending channel during the MMF reform implementation period. The large negative shock on the liability side of banks' balance sheets had limited spillovers to the asset side, except for a significant reduction in cash positions due to the reduction in reserve balances, which is consistent with the previous finding of reduced arbitrage activity.

4.6 Intra-office Positions

Existing literature demonstrates that large global banks manage liquidity on a global scale (Cetorelli and Goldberg, 2012, 2011; Schnabl, 2012; Bräuning and Ivashina, 2020). When a subsidiary is hit by a negative funding shock, an active internal capital market within the bank provides liquidity support and insulates the subsidiary from local liquidity conditions. Therefore, it may at first appear puzzling that U.S.-based bank entities reduced their net borrowing from their non-U.S. affiliates (known as the net-due-to position of U.S.-based entities) after being directly hit by the negative funding supply shock due to the MMF reform. We show that the use of ED to fund the IOER arbitrage is the key to understanding the intra-office flows during the reform implementation period. The lower amount of the IOER arbitrage position in response to the MMF reform led to a lower

[28] A positive net-due-to position occurs when the U.S.-based entity is a net borrower from its foreign affiliates.

net-due-to position of U.S. entities, as a lower ED position is funded offshore and then transferred to the U.S.-based entities to be parked at the Fed.

Table 7 compares the regression results for the net-due-to and ED positions in response to the funding supply shock. As shown in Column 2, the ED position reacts more strongly than the net-due-to position and declines by 0.78% in response to a 1% reduction in unsecured prime funding. Furthermore, the strong responses of the net-due-to and ED positions are entirely driven by IOER arbitrageurs (Columns 4 and 5). These results suggest that the ED market is a key source from which global banks fund their IOER arbitrage position. The MMF reform-induced negative funding supply shock came in part through the ED market. As this funding was lost, the lower ED positions corresponded to a reduction in the net-due-to position.

Once we separate out the ED flows from the net-due-to positions, we find some evidence that U.S.-based entities actually increased their net borrowing from (or reduced their net lending to) their foreign affiliates in response to the negative funding supply shock (Columns 3 and 6). Even though we do not have any direct measure of the CIP arbitrage position, a reduction in net lending from the U.S. entities to their foreign affiliates is consistent with a reduction in the CIP arbitrage position since this arbitrage often entails the U.S. entity borrowing dollars and then transferring them to their foreign affiliates abroad to lend in the FX swap market.

4.7 Additional Evidence from Syndicated Loans

In addition to the loan positions in the FR 2644 data, we also examine new loan origination using the Dealscan data. In particular, we examine our sample banks' participation in dollar-denominated syndicated loans as lead arrangers.[29]

[29] Following Ivashina, Scharfstein, and Stein (2015), we identify the lead banks as those with the "Lead Arranger Credit" or the "Agent Credit" fields equal to "Yes" in Dealscan.

In Appendix Figure A1, we plot total new dollar loan origination by U.S. banks and foreign banks in our sample. We do not find any evidence that foreign banks reduced their dollar loans relative to U.S. banks during the reform implementation period. Using a similar Bartik instrument as before, Table 8 presents IV regression results of changes in dollar-denominated loan origination during the reform implementation period (relative to total loan origination during the previous 12 months) on changes in unsecured prime fund funding across banks. Column 1 shows regression results for changes measured in dollar amounts. Column 2 shows regression results for changes scaled by banks' total assets in 2014 from SNL Financial. The regression coefficient is very close to zero and statistically insignificant for both Columns 1 and 2, which suggests that there is no evidence that the negative funding supply shock reduced loan origination.

For comparison, we perform similar regressions for the European debt crisis period in Columns 3 and 4. For this period, we find evidence that banks reduced their dollar loan origination in response to the negative funding shock from the MMFs, consistent with the evidence shown in Ivashina, Scharfstein, and Stein (2015). More specifically, we regress the change in total dollar loan origination between June 2011 and May 2012 relative to total loan origination during the previous 12 months on the corresponding change in banks' unsecured borrowing from prime funds. Again, we instrument for the funding supply shock during the European debt crisis using a similar Bartik instrument as in equation (3), where $s_{i,j,0}$ measures the share of bank i in fund complex j's portfolio in April 2011. Column 3 shows the result based on the dollar amount change, and Column 4 shows the result scaled by banks' total assets in 2011. The regression coefficient is above 0.2 for both columns and statistically significant for the specification based on the dollar amount change. The contrast in results for dollar loan origination between the MMF reform sample in 2016 and the European debt crisis sample highlights the changing role of unsecured funding under the Basel III liquidity regulations.[30]

4.8 Bank Funding Costs

Beyond balance sheet adjustments, the loss of funding as a result of the MMF reform can also affect banks' funding costs. To test for differential responses in banks' funding costs to the MMF reform, we run cross-sectional regressions of changes in banks' funding rates for benchmark tenors on the change in unsecured prime funding from October 2015 to October 2016.[31] In order to ensure that our pricing data comprise only transactions at market rates, we discard transactions at rates below 5 basis points.[32]

Equilibrium funding costs are affected by both the supply of and demand for funding, so OLS regression estimates may suffer from simultaneity bias. As in previous analysis, to mitigate concerns about such bias, we provide IV estimates using the Bartik instrument specified in equation (3). Table 9 reports these IV regression results. In Column 1, we perform a pooled regression across all tenors, and find a negative, though statistically insignificant, coefficient on the change in the funding supply. In Column 2, we add an interaction between the change in funding supply and a long-dated tenor dummy that is equal to one if the tenor is at least six months. Here, we find that the coefficient on the interaction term is significantly negative, which implies a larger price effect on longer-dated tenors. In terms of economic magnitude, a 1% reduction in unsecured funding over

[30] The Basel LCR became a minimum requirement for Basel Committee Banking Regulations member countries on January 1, 2015, with a transition period between 2015 and 2017. The actual implementation deadline was postponed in some jurisdictions. However, it is reasonable to assume that the large global banks had not adjusted their business models in full accordance with the LCR requirement before the European debt crisis, but had already taken the LCR into account by the time of the MMF reform.

[31] The tenors included are overnight, 1-week, 1-month, 3-month, 6-month, 9-month, and 1-year. Including additional tenors available in the data produces very similar results.

[32] There are some very low-rate trades in the data that represent intra-bank trades or other non-market transactions. The rates on these trades do not respond to market conditions, including rate increases by the Federal Reserve. The 5-basis point cut-off was chosen because, as of October 2015, it was the offering rate at the Federal Reserve's overnight reverse repurchase agreement facility and therefore the minimum rate at which most market participants should be willing to lend funds. Alternative approaches to deal with outliers in the pricing data, such a winsorizing the data, yield very similar results.

total assets leads to an increase in unsecured term funding rates at 6 months and beyond of about 3.2 basis points. Columns 3 and 4 repeat the specification in Column 2 separately for IOER arbitrageurs and non-IOER arbitrageurs, as defined in Section 4.3. We find that the funding costs of longer tenors increase more among non-IOER arbitrageurs than among arbitrageurs, for a given funding supply shock. This suggests that non-IOER arbitrageurs have more inelastic demand for term funding, in part to support their non-arbitrage business activities, which is likely less scalable. Finally, to address the concern that the U.S. banks have better access to dollar funding markets in general, Column 5 shows that the negative relationship between funding costs and funding supply for longer tenors also holds within the sample consisting of only foreign banks.

4.9 Quarter-End Effects

In this section, we show that, during the reform implementation period as well as during the period after the reform implementation deadline, quarter-end effects associated with unsecured funding have become much more muted, which supports our main result that the MMF reform has reduced arbitrage funded by unsecured borrowing.

We first note that the magnitude of quarter-end effects is very informative about the amount of arbitrage positions outside of quarter-ends. Both the IOER and CIP arbitrage strategies contain very little risk, but expand banks' balance sheets, and therefore have a large effect on the leverage ratio under Basel III, which is defined as equity over total assets regardless of the risk characteristics of the assets. In many foreign jurisdictions, the leverage ratio is calculated using a quarter-end snapshot of bank balance sheets. As a result, banks have strong incentives to shed some arbitrage positions on quarter-end reporting days to improve their reported leverage ratio. A smaller quarter-end decline could suggest that banks have a smaller arbitrage position prior to quarter-ends, and therefore less need to window dress.

We observe MMF holdings at a monthly frequency and measure quarter-end effects by comparing the holdings on quarter-ends to the average holdings on adjacent non-quarter-end month-ends. Panel 1a of Figure 8 plots MMFs' total holdings of secured (repo) and unsecured instruments issued by our sample banks. The vertical yellow dashed lines indicate quarter-ends. We observe a significant drop in MMFs' secured and unsecured holdings on quarter-ends relative to the adjacent non-quarter-end month-ends. Panel 1b of Figure 8 displays the quarter-end effects for each quarter calculated as the difference between the quarter-end holdings and the average holdings on the two adjacent non-quarter-end month-ends for secured and unsecured instruments, respectively. In addition, the solid black line in Panel 1b shows the ratio of the unsecured quarter-end effects (red bars) to the total quarter-end effects (sum of the red and blue bars) over time. Overall, the total unsecured quarter-end effect in MMF holdings declined from about \$170 billion in 2015Q4 to only about \$30 billion in 2016Q4, and the share of unsecured quarter-end effects relative to total quarter-end effects declined from about 0.6 in 2015Q4 to about 0.1 in 2016Q4.

Panels 2a and 2b show the analogous results using banks total unsecured and secured wholesale funding, rather than just that held by MMFs. Since we are not limited to month-ends in this case, we calculate the quarter-end effect as the difference between the outstanding amount on the quarter-end date t, and the average outstanding amount two weeks before and after the quarter-end ($t - 14$ and $t + 14$). As we only have meaningful coverage for ED starting in October 2015, the quarter-end effects can be calculated only starting in 2015Q4. Despite the short time series, we still observe that the unsecured quarter-end effects measured using total debt outstanding also declined significantly, from \$200 billion in 2015Q4 to \$100 billion 2016Q4. Also, the share of unsecured quarter-end effects relative to total quarter-end effects trended down notably over the reform implementation period.

5 Arbitrage Capital and Arbitrage Profits

Finally, we examine the relationship between aggregate arbitrage capital and arbitrage profits for the IOER and CIP arbitrages. A negative association between the amount of potential arbitrage capital and arbitrage profits provides support for the notion that supply shocks to arbitrage capital matter for variation in equilibrium arbitrage profits. In addition to examining the relationship between prices and quantities over the reform implementation period, we also examine whether the relationship has changed in the post-MMF reform period, that is, after October 2016.

One important caveat to note is that the aggregate amount of arbitrage capital we capture in our data is only part of the total capital that is available globally for IOER and CIP arbitrages because we do not observe ED positions of non-U.S. affiliated branches and subsidiaries of foreign banks. In the case of CIP arbitrage, we also lack data on the amount of arbitrage capital from non-banks, such as real-money investors. Nevertheless, since global banks lie at the center of global capital markets and the U.S. market is the most important wholesale funding market for dollar funding, we capture a significant portion of global IOER and CIP arbitrage activities.

We calculate the volume-weighted IOER arbitrage profit as:

$$\pi_t^{IOER} = \sum_{i,n,k} (y_{i,n,k}/Y_{i,t}^{IOER})(r_{t-n}^{IOER} - r_{i,n,k,t-n}).$$

Panel A of Figure 9 plots the IOER profit along with the potential IOER arbitrage capital. We can see notable increases in the IOER arbitrage profits on all month-ends and notable declines in the potential arbitrage capital on quarter-ends.

To formally test the relationship between IOER arbitrage profits and arbitrage capital, we run regressions of daily changes in average arbitrage profits (in basis points) on daily changes in potential IOER arbitrage capital (in billions of dollars):

$$\Delta\pi_t^{IOER} = \alpha + \beta\Delta Y_t^{IOER} + \gamma Post_t + \delta Post_t \times \Delta Y_t^{IOER} + \epsilon_t. \tag{4}$$

We include a time dummy, $Post_t$, which equals one for observations after October 14, 2016 and zero otherwise, to denote the period after the MMF reform and an interaction between $Post_t$ and the potential arbitrage capital. We estimate the regression using data between October 2015 and June 2017. Therefore, the coefficient β measures the relationship between the price and quantity during the MMF implementation period and the coefficient δ indicates whether the relationship has changed in the post-MMF reform period. We estimate the regression separately for non-period-end dates and period-end-dates. In addition to quarter-ends, we also examine month-ends as the Basel III leverage ratio in some foreign jurisdictions is calculated as the average of the past three month-ends.

Panel A of Table 10 shows the regression results for the IOER arbitrage. Column 1 reports the results using daily changes that do not include a month-end. While we do not find a significant relationship between the IOER arbitrage profit and potential arbitrage capital over the reform implementation period, the coefficient on the interaction term between the potential arbitrage capital and the $Post_t$ dummy is negative and statistically significant, which suggests the negative relationship between arbitrage profits and potential arbitrage capital became more pronounced after the reform. As shown in Column 2, if the daily changes include a month-end, then a \$10 billion reduction in arbitrage capital translates into an increase in arbitrage profits of roughly 0.9 basis points. This elasticity is significantly more negative after the reform, with a \$10 billion reduction in arbitrage capital translating to an increase in arbitrage profits on month-ends of 2 basis points. As is evident in Columns 3 and 4, the price elasticity is particularly large in magnitude for non-quarter-end month-ends relative to quarter-ends. Specifically, over the reform implementation period, a $10 billion reduction in arbitrage capital is associated with an increase in arbitrage profits of 0.8 basis points on quarter-ends and 3 basis points on non-quarter-end month-ends. The estimates on both quarter-ends and non-quarter-end month-ends are also more negative after the reform implementation.

Similarly, we calculate the volume-weighted CIP arbitrage profit as:

$$\pi_{n,t}^{CIP} = \sum_{i,k} (y_{i,k}/Y_{i,t}^{CIP})(r_{t-n}^{¥\to\$} - r_{i,n,k,t-n}).$$

Due to the term-nature of the CIP arbitrage, we calculate the profit for different benchmark maturities: one-week, one-month, and three-month. After constructing these profit and quantity measures, we perform a regression similar to that specified in equation (4):

$$\Delta\pi_{n,t}^{CIP} = \alpha + \beta\Delta Y_t^{CIP} + \gamma Post_t + \delta Post_t \times \Delta Y_t^{CIP} + \epsilon_t. \tag{5}$$

Panel B of Table 10 presents the regression results. Columns 1 and 2 show the regression results for daily changes in the one-week CIP arbitrage profits that do not cross quarter-ends and that cross quarter-ends, respectively. A one-week contract starts crossing a quarter-end one week before the end of that quarter. Estimates for coefficients β and δ are both negative, but not statistically significant. Columns 3 and 4 show the regression results for daily changes in the one-month CIP arbitrage profits that do not cross quarter-ends and that do cross quarter-ends, respectively. Over the reform implementation period, the negative relationship between the arbitrage profit and potential arbitrage capital is present both outside quarter-ends and on quarter-ends, with a stronger relationship on quarter-ends. Finally, for three-month CIP arbitrage profits (Columns 5 and 6), a $10 billion reduction in arbitrage capital is associated with a 0.4 basis point increase in the arbitrage profit for contracts that do not cross the year-end and a 1.2 basis point increase in the arbitrage profit for contracts that do cross the year-end. Again, the coefficient on the interaction is not statistically significant.

In summary, we find a negative relationship between arbitrage profits and arbitrage capital over the reform implementation period. The relationship is stronger for contracts that cross regulatory reporting dates. For the IOER arbitrage, we also find that the negative relationship is strengthened in the post-reform period.

6 Conclusion

We document a significant transformation of the role of wholesale funding in global banks' business operations in the post-GFC regulatory environment. Consistent with the vision of the Basel III liquidity regulations, a significant portion of short-term wholesale funding is now used to finance liquid asset positions, which makes global banks more resilient to wholesale funding dry-ups. In this environment, in response to the large negative wholesale funding shock induced by the 2016 MMF reform, we find that global banks primarily scale down their arbitrage activities, without reducing their loan provision. While this new business model significantly reduces banks' liquidity risk, it also implies that the role of short-term wholesale funding in supporting banks' liquidity and maturity transformation and therefore their credit provision has become more limited.

More recently, the resilience of large global banks to the COVID-19-induced wholesale funding shock in March 2020 is again consistent with the changing nature of unsecured wholesale funding. Our findings have important implications for the implementation and transmission of U.S. monetary policy, and help inform the recent debates regarding further reforms to the MMF industry as well as banking regulations in general.

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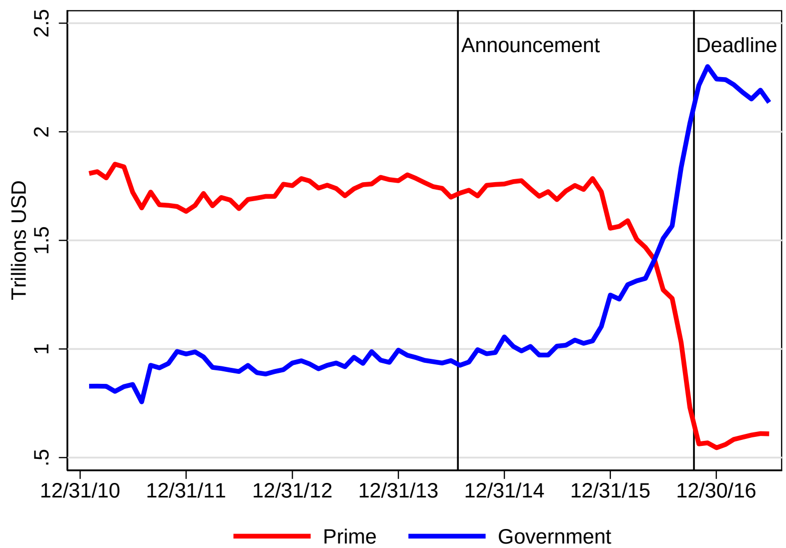
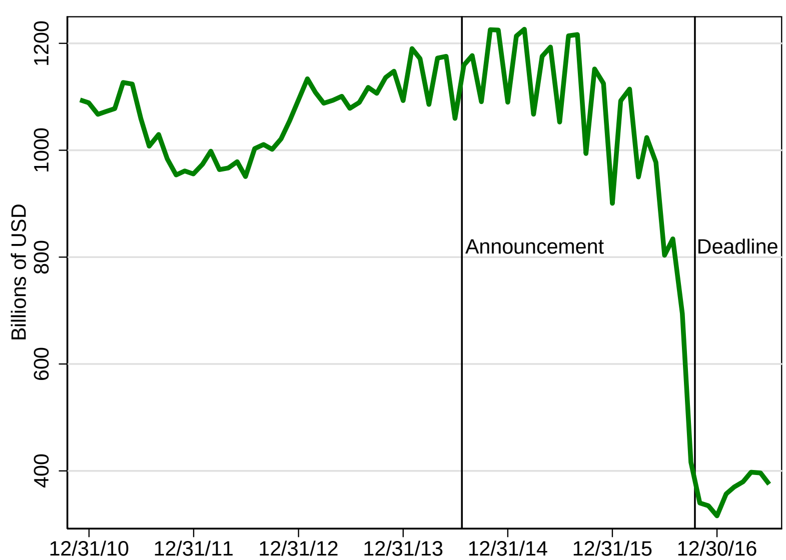
Figure 1: **MMF Assets Under Management**

(A) AUM by MMF Type



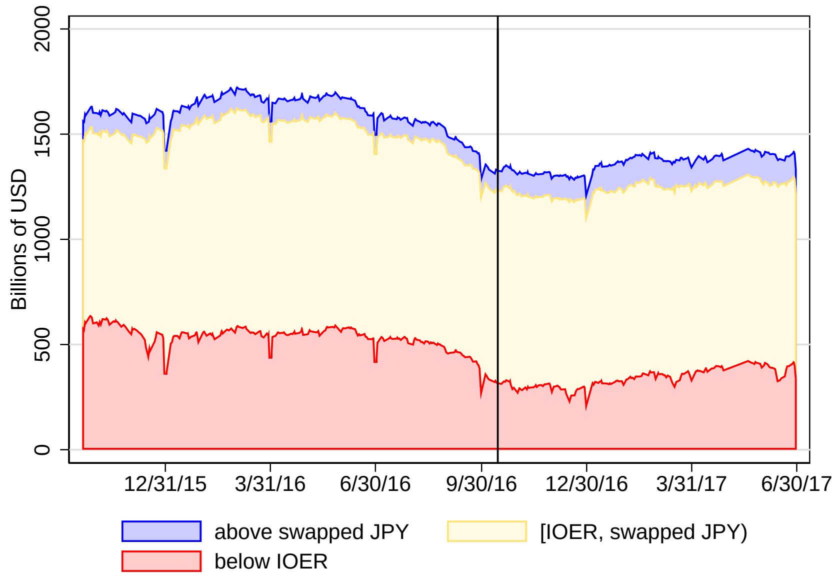
(B) Prime MMF Holdings of Bank Securities



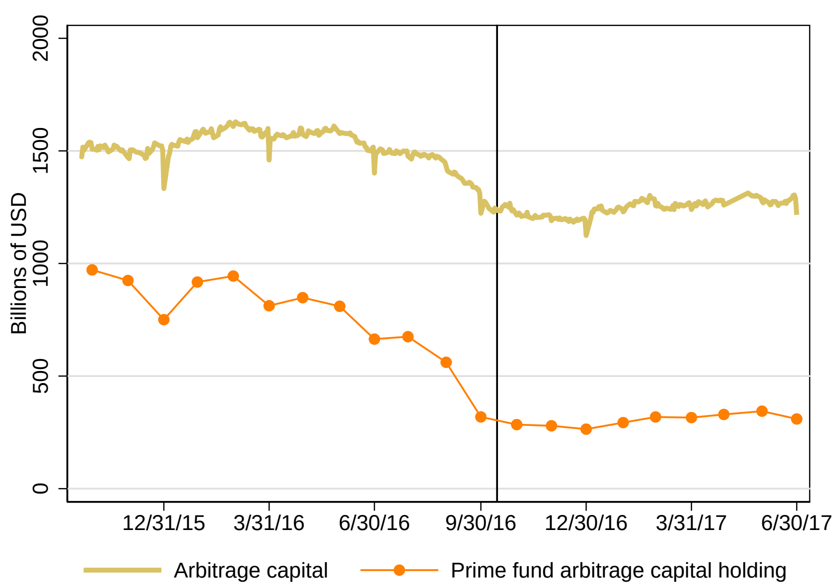
Notes: Panel (A) plots total assets under management (AUM) of prime (red) and government (blue) MMFs in the United States in trillions of dollars. Panel (B) plots prime funds' holdings of bank securities for our sample banks. The two vertical black lines denote the MMF reform announcement date on July 23, 2014 and the implementation deadline on October 14, 2016, respectively.
Source: N-MFP

Figure 2: **Unsecured Wholesale Funding Outstanding and MMF Holdings**

(A) Unsecured borrowing by rate

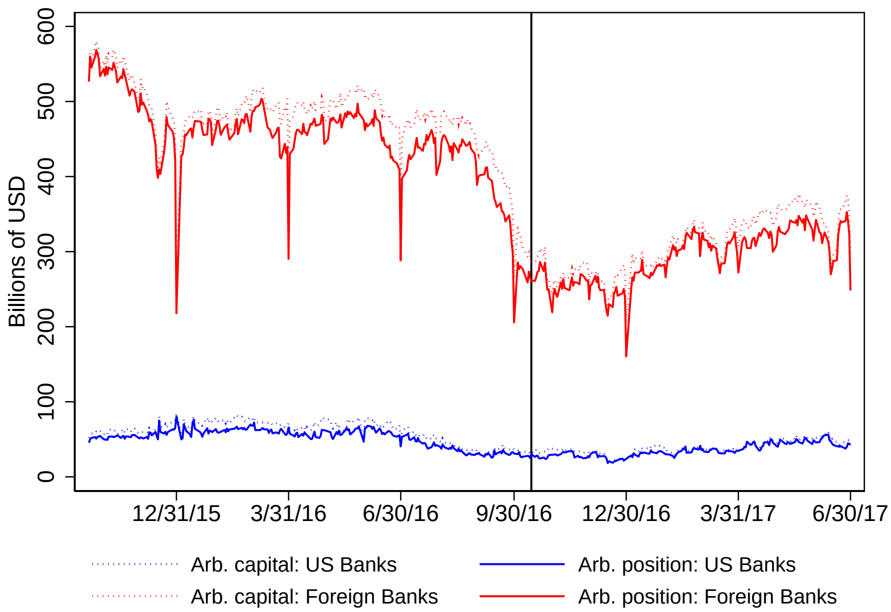


(B) Arbitrage capital and MMF holdings



Notes: Panel (A) plots unsecured wholesale funding outstanding broken down by rate. The red area denotes outstanding amounts with an issuance rate below the IOER rate. The yellow area denotes outstanding amounts with an issuance rate at or above the IOER rate and below the swapped yen rate in dollars. The blue area denotes outstanding amounts with an issuance rate at or above the swapped yen rate. Panel (B) plots total arbitrage capital (yellow) and the amount of arbitrage capital held by prime MMFs (orange) in billions of dollars. The vertical line indicates the MMF reform implementation deadline on October 14, 2016.
Sources: N-MFP; FR 2420; DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation.

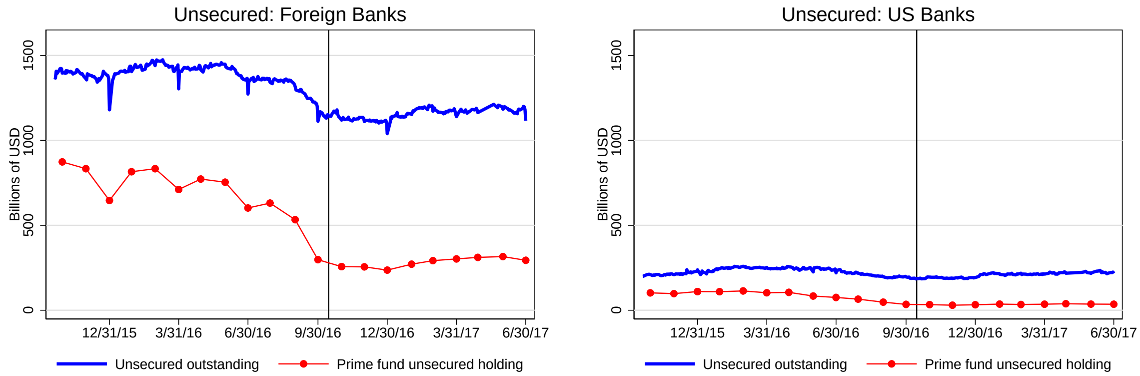
Figure 3: **IOER Arbitrage Capital and Arbitrage Position by Region**



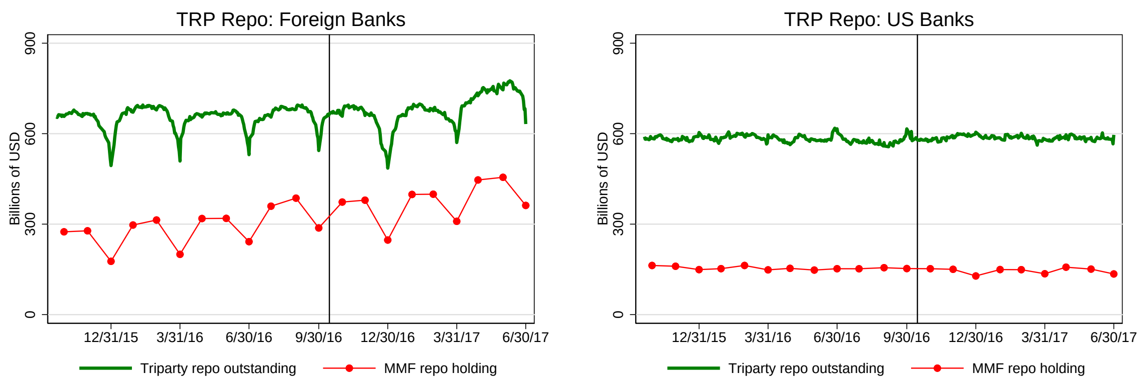
Notes: This figure plots potential IOER arbitrage capital—unsecured wholesale funding outstanding borrowed below the IOER rate—indicated by the dotted lines, and our proxy for the IOER arbitrage position—the minimum of excess reserves and potential IOER arbitrage capital—indicated by the solid lines. The arbitrage capital and arbitrage position are broken down by foreign (red) and U.S. (blue) banks. The vertical line indicates the MMF reform implementation deadline on October 14, 2016.
Sources: FR 2420; DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation

Figure 4: **Wholesale Funding Outstanding and MMF Holdings by Region**

(A) Unsecured funding



(B) Secured funding (repo)

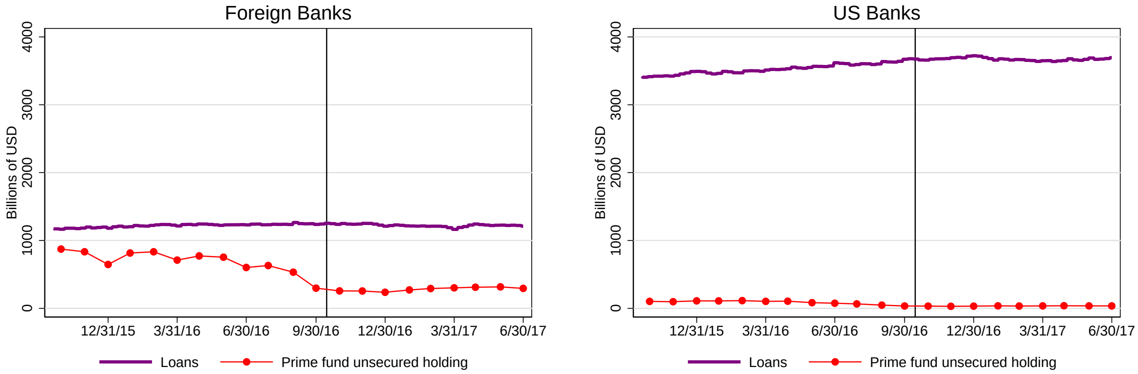


Notes: This exhibit plots total wholesale funding outstanding, along with MMF holdings, broken down by foreign (left column) and U.S. (right column) banks. Panel (A) plots total unsecured wholesale funding outstanding (blue) and prime MMFs' unsecured holdings (red). Panel (B) plots secured funding outstanding (green), specifically total tri-party repo, and repo holdings by prime and government MMFs (red). The vertical line indicates the MMF reform implementation deadline on October 14, 2016.

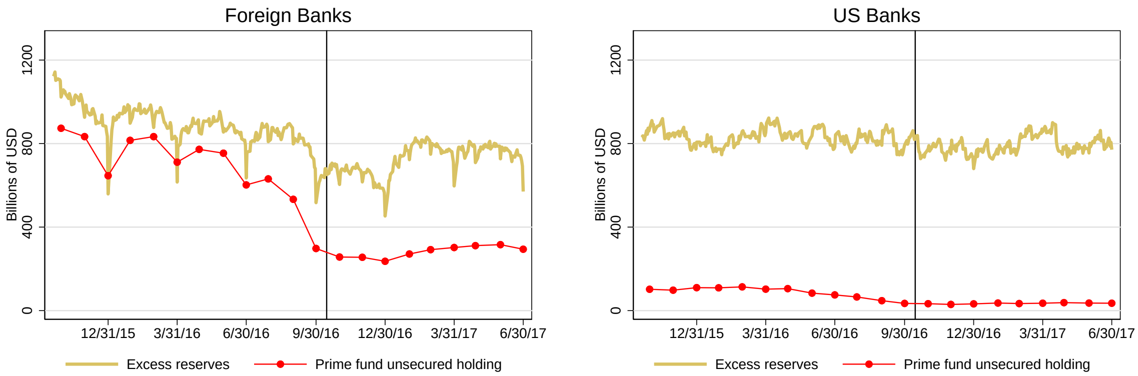
Sources: N-MFP; DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; FR 2420; FRBNY tri-party repo

Figure 5: **Assets and MMF holdings by region**

(A) Loans



(B) Reserve balances

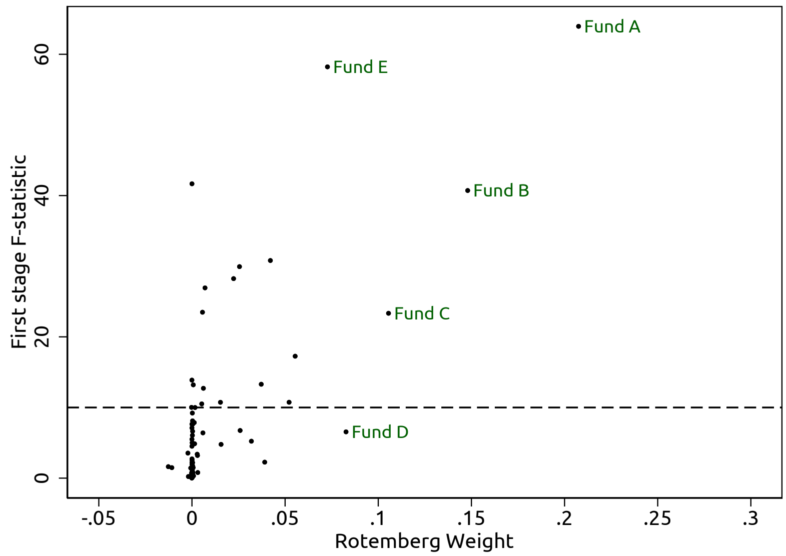


Notes: This exhibit plots bank assets, specifically total loans and reserve balances, along with MMF holdings, broken down by foreign (left column) and U.S. (right column) banks. Panel (A) plots total loans outstanding (purple) and prime MMFs' holdings of banks' unsecured funding (red). Panel (B) plots total excess reserve balances held at the Federal Reserve (yellow) and prime MMFs' unsecured holdings (red). The vertical line indicates the MMF reform implementation deadline on October 14, 2016.

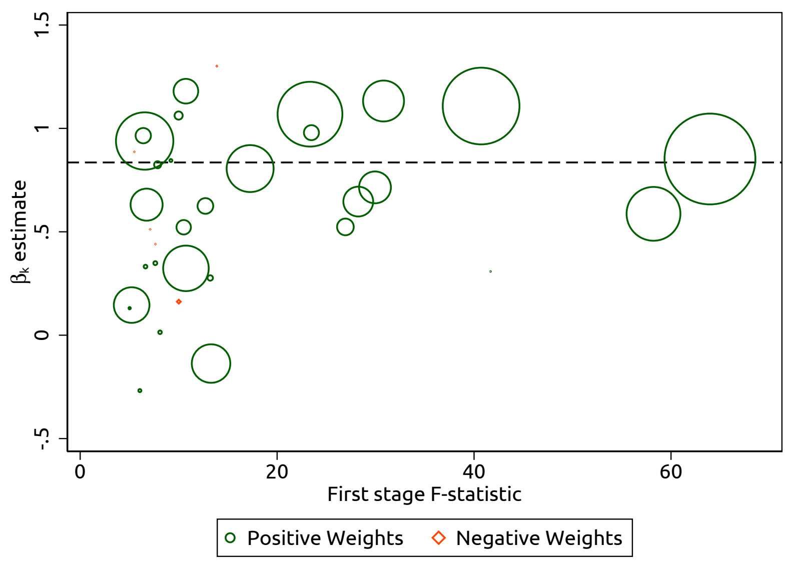
Sources: N-MFP; FR 2644; Federal Reserve Board reserves

Figure 6: **Rotemberg Weights, F-statistic and β_k**

(A) F-statistic vs. Rotemberg weights



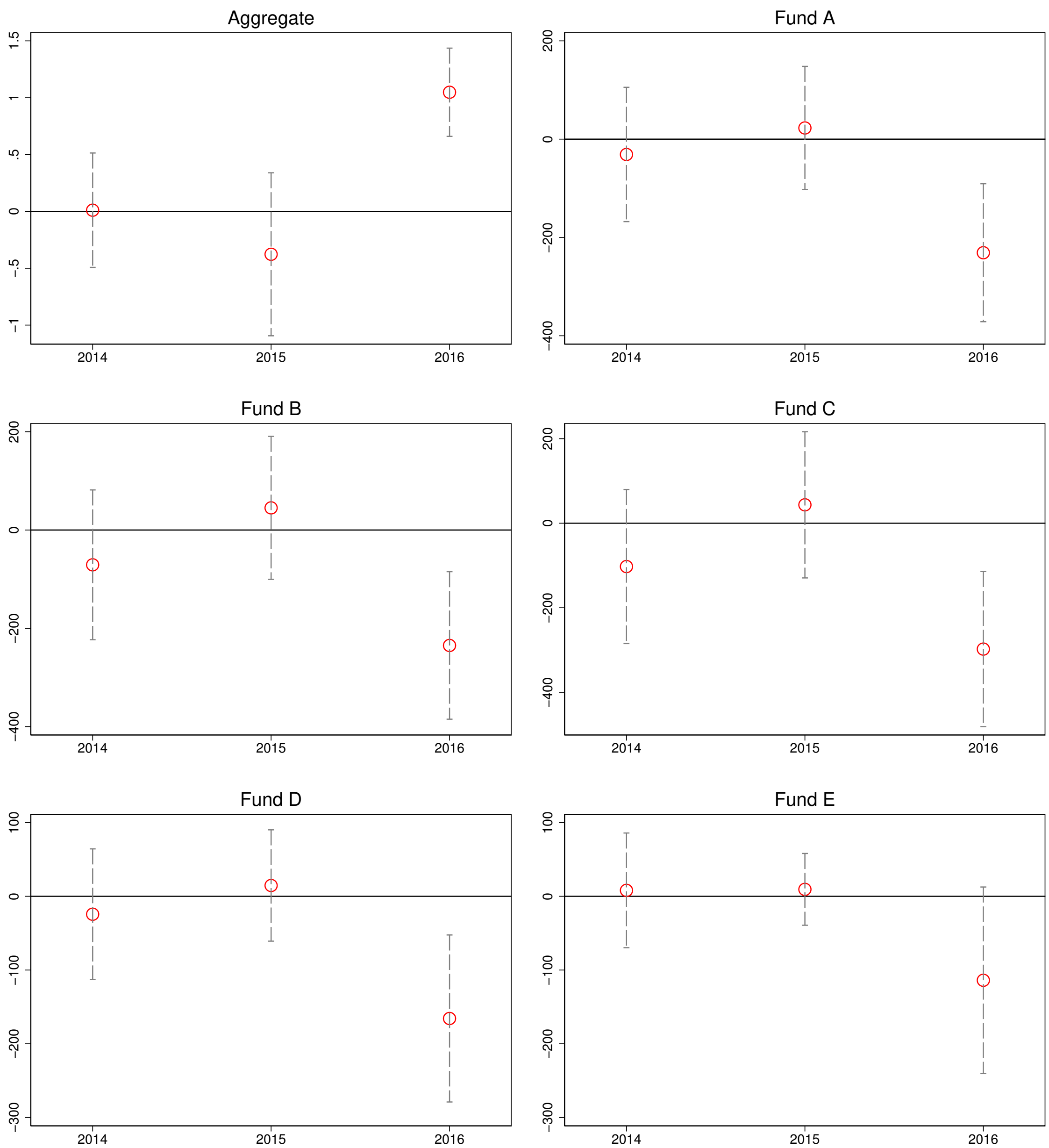
(B) β_k Estimates vs. F-statistic



Notes: This figure visualizes the relationship between Rotemberg weights, first-stage F-statistics, and individual β_k estimates by treating each individual fund complex share as an instrument for the benchmark regression in the Column 3 of Panel B in Table 2. Panel (A) plots the first-stage F-statistic for using each fund complex share as an instrument on the y-axis, against the Rotemberg weight of the instrument on the x-axis. The horizontal dashed line indicates a value of 10. Panel (B) plots the individual β_k estimate for each instrument on the y-axis against the F-statistic on the x-axis. The size of the bubbles represents the magnitude of the Rotemberg weights. The horizontal dashed line indicates the value for the overall $\hat{\beta}$ reported in Column 3 of Panel B in Table 2.

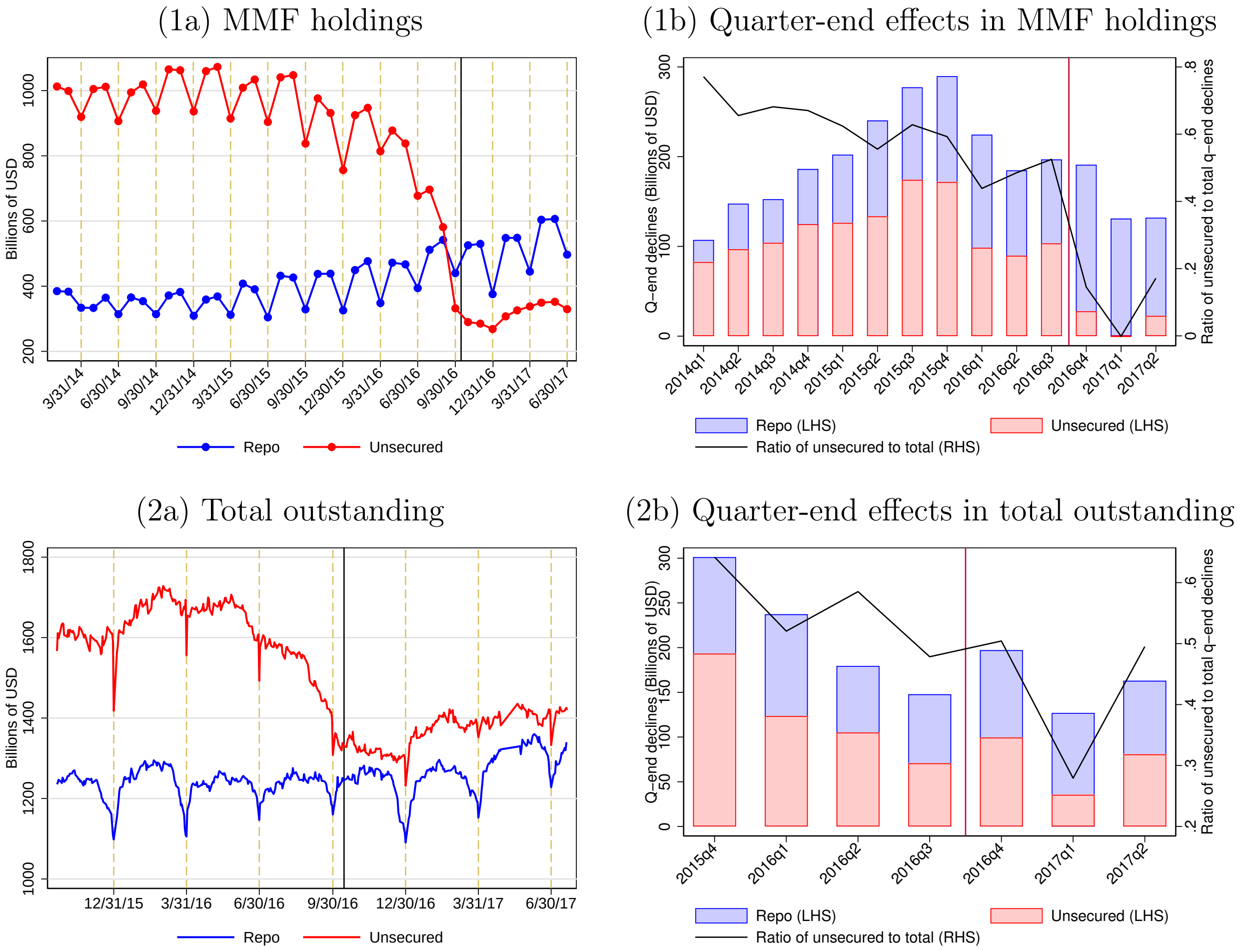
Source: N-MFP

Figure 7: **Pre-trends for Reserves held by U.S. Entities**



Notes: This figure shows the pre-trend for reserves in U.S. entities (Column 1 of Table 6). The coefficients are reduced-form estimates of quarterly changes in reserves on the Bartik instrument or individual instruments based on fund shares for the top Rotemberg weight fund complexes. The two pre-periods used for estimation are October 2013 to October 2014 ("2014") and October 2014 to October 2015 ("2015"). The actual period for the MMF reform is October 2015 to October 2016 ("2016").
Source: N-MFP; Federal Reserve Board reserves

Figure 8: **Quarter-End Effects in Secured and Unsecured Funding**

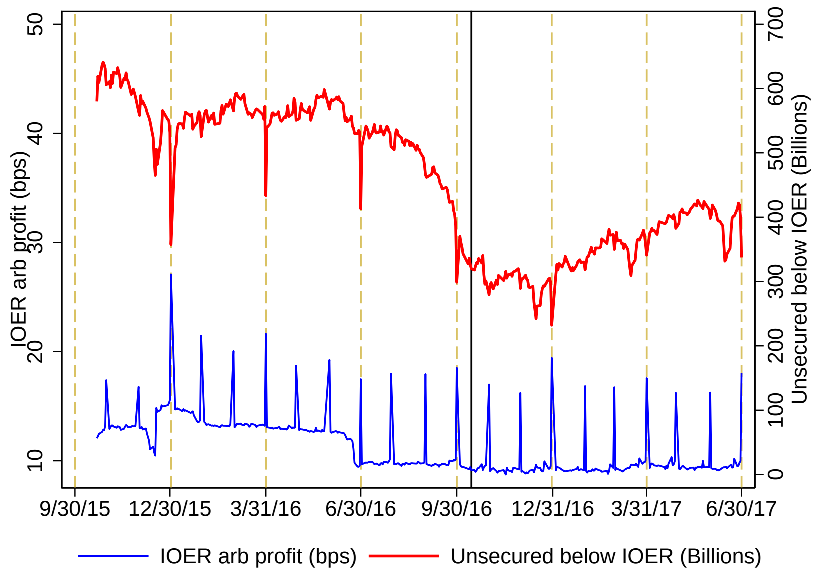


Notes: This figure illustrates the quarter-end effects in MMF holdings and total debt outstanding for both secured (repo) and unsecured wholesale funding instruments. Panel (1a) plots total MMF holdings of repo securities (blue) and unsecured securities (red) issued by our sample banks. Panel (1b) plots the quarter-end effects for MMFs' holdings of secured (blue) and unsecured (red) securities for each quarter, and the ratio of the unsecured quarter-end effect to the total (unsecured plus secured) quarter-end effect (black line). Panel (2a) plots total tri-party repo outstanding (blue) and total unsecured wholesale funding outstanding (red) for our sample banks. Panel (2b) plots the quarter-end effects for total secured (blue) and unsecured (red) funding outstanding, as well as the ratio of the unsecured quarter-end effect to the total quarter-end effect (black line). See Section 4.9 for details on how the quarter-end effects are constructed.

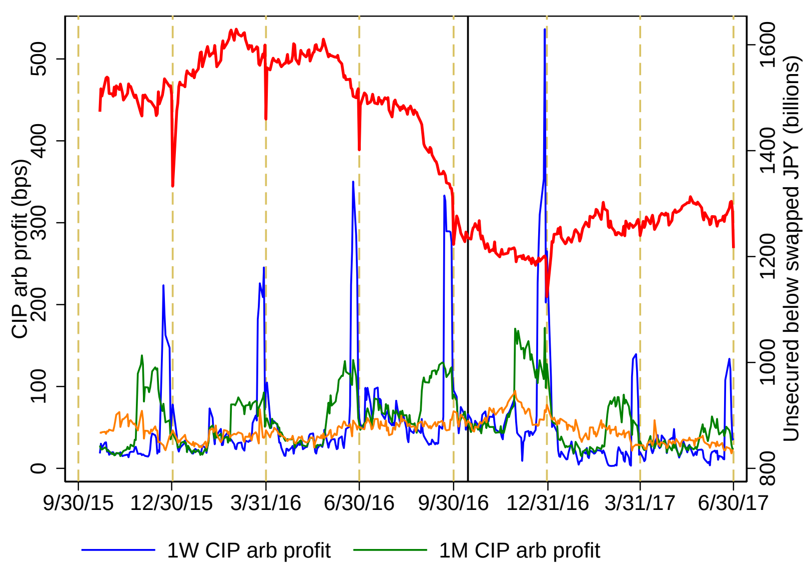
Sources: N-MFP; FR 2420; DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; FRBNY tri-party repo

Figure 9: **Volume-Weighed Average Arbitrage Profits**

(A) IOER arbitrage profit



(B) CIP arbitrage profit



Notes: This figure shows the profit of different arbitrage strategies. Panel (A) plots the volume-weighted average IOER arbitrage profit (blue) and total potential arbitrage capital for the IOER arbitrage (red). Only unsecured securities with one-week maturity or less are used in calculating the profits. Panel (B) plots the volume-weighted average CIP arbitrage profit for the CIP arbitrage at one-week (blue), one-month (green), and three-month (orange) maturities, as well as the potential arbitrage capital for the CIP arbitrage (red).
Sources: FR 2420; DTCC Solutions LLC, an affiliate of The Depository Trust & Clearing Corporation; Bloomberg

Table 1: **Amount of Potential Arbitrage Capital by U.S. and Foreign Banks**

	(1) Potential Arbitrage Capital	(2) Assets in U.S. Entities	(3) Total Global Assets	(4) Estimated Global USD Assets
Foreign Banks				
Amounts in $Tril.	1.2	2.6	47.7	7.2
(Share of potential arb. capital)		(45.8%)	(2.5%)	(16.7%)
U.S. Banks				
Amounts in $Tril.	0.2	6.9	11.4	9.1
(Share of potential arb. capital)		(3.0%)	(1.8%)	(2.1%)

Notes: This table reports daily averages related to potential arbitrage capital for foreign and U.S. banks in our sample between October 2015 and June 2017. In Column 1, we report the time-series average of total potential arbitrage capital for the IOER and CIP arbitrage. In Column 2, we report the time-series average of total assets in U.S-based entities from the FR 2644 report, and the share of potential arbitrage capital compared to the total assets in U.S.-based entities in parentheses. In Column 3, we report the time-series average of total global assets from SNL Financial, and the share of potential arbitrage capital compared to their total global assets in parentheses. In Column 4, we estimate total USD-denominated assets for foreign and U.S. banks. The share of USD-denominated assets in total assets is estimated based on the BIS Locational Banking Statistics for foreign banks and based on FR 2052a for U.S. banks. We also report the share of unsecured wholesale funding in total USD-denominated assets in parentheses.

Table 2: **Benchmark Regressions for Arbitrage Capital and Arbitrage Positions**

	(1) $\Delta Y_{i,t}^{IOER}$	(2) $\Delta Y_{i,t}^{CIP}$	(3) $\Delta Q_{i,t}^{IOER}$	(4) $\Delta Q_{i,t}^{IOER}$	(5) $\Delta Q_{i,t}^{IOER}$
			Panel (A) OLS Estimates		
$\Delta hold_{i,t}^{Unsec}$	0.88***	0.97***	0.80***	0.16**	0.76***
	(0.18)	(0.20)	(0.18)	(0.07)	(0.21)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				0.98***	
				(0.10)	
Arb_i				0.00	
				(0.00)	
Sample	All	All	All	All	FBOs
N	232	232	232	232	192
R^2	0.52	0.58	0.54	0.76	0.50
			Panel (B) IV Estimates		
$\Delta hold_{i,t}^{Unsec}$	0.90***	0.91***	0.84***	0.25*	0.85***
	(0.28)	(0.28)	(0.25)	(0.14)	(0.25)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				0.85***	
				(0.17)	
Arb_i				0.00	
				(0.00)	
Sample	All	All	All	All	FBOs
N	232	232	232	232	192
R^2	0.52	0.58	0.54	0.76	0.49

Notes: This table shows regression results of changes in potential arbitrage capital and the IOER arbitrage position on changes in MMF holdings of unsecured bank securities. Panel (A) shows the OLS estimates and Panel B shows the IV estimates using the Bartik instrument defined by equation (3). The dependent variables are defined as follows: $\Delta Y_{i,t}^{IOER}$ is the change in the potential IOER arbitrage capital, $\Delta Y_{i,t}^{CIP}$ is the change in the potential CIP arbitrage capital, and $\Delta Q_{i,t}^{IOER}$ is the change in the proxy for the IOER arbitrage position. $\Delta hold_{i,t}^{Unsec}$ is the change in MMF holdings of unsecured debt issued by bank i. All changes above are quarterly, calculated from October 2015 to October 2016, and scaled by 2014 total assets from SNL Financial. Arb_i is a dummy variable equal to 1 if a bank's correlation between daily changes in unsecured funding and daily changes in reserve balances is in the top third of all banks. All specifications include time fixed effects, with standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table 3: **Summary Statistics of the Rotemberg Weights**

Panel (A): Negative and positive weights

	Sum	Mean	Share
Negative	-0.029	-0.001	0.027
Positive	1.029	0.018	0.973

Panel (B): Correlations of fund complex-level characteristics

	α_j	g_j	β_j	F_j	Var(z_j)
α_j	1				
g_j	-0.828	1			
β_j	0.004	0.051	1		
F_j	0.724	-0.507	-0.052	1	
Var(z_j)	0.263	-0.246	0.041	0.207	1

Panel (C): Top-five Rotemberg weight fund complexes

	$\hat{\alpha}_j$	g_j	$\hat{\beta}_j$	95 % CI
Fund A	0.208	-57.381	0.852	(0.40,1.30)
Fund B	0.148	-63.101	1.108	(0.90,1.30)
Fund C	0.106	-60.033	1.069	(0.70,1.40)
Fund D	0.083	-54.209	0.939	(-0.30,2.10)
Fund E	0.073	-34.376	0.587	(-0.20,1.20)

Notes: This table exactly follows Goldsmith-Pinkham, Sorkin, and Swift (2020) and reports summary statistics for the Rotemberg weights. Panel (A) reports the sum, the mean, and the share of positive and negative weights. Panel (B) reports correlations between the Rotemberg weights (α_j), the AUM growth of the MMF complex (g_j), the just-identified coefficient estimates (β_j), the first-stage F-statistic (F_j), and the variation of fund shares across banks (Var(z_j)). Panel (C) reports the top-five MMF fund complexes according to the Rotemberg weights. The 95% confidence interval is the weak instrument robust confidence interval using the method from Chernozhukov and Hansen (2008).
Source: N-MFP

Table 4: **Relationship between Fund Shares and Bank Characteristics**

	(1) Fund A	(2) Fund B	(3) Fund C	(4) Fund D	(5) Fund E	(6) Bartik
$\log(Asset_i)$	-0.042	-0.009	0.008	-0.096**	0.000	28.040
	(0.033)	(0.031)	(0.028)	(0.045)	(0.037)	(22.168)
$Rating_i$	0.046	0.115*	0.060	0.144	0.158*	-78.002
	(0.072)	(0.067)	(0.061)	(0.098)	(0.081)	(48.581)
$CET1_i$	0.069***	0.036***	0.033***	0.052***	0.053***	-31.577***
	(0.014)	(0.013)	(0.012)	(0.019)	(0.016)	(9.521)
ROA_i	0.201**	0.136*	0.070	0.266**	0.048	-115.543**
	(0.077)	(0.072)	(0.065)	(0.104)	(0.087)	(51.720)
Arb_i	0.068	0.168***	0.069	0.149	-0.003	-62.461
	(0.065)	(0.061)	(0.055)	(0.089)	(0.074)	(44.123)
US	-0.074	-0.047	0.022	0.125	-0.003	12.608
	(0.090)	(0.084)	(0.076)	(0.123)	(0.102)	(60.722)
Weighted by						
R^2	0.46	0.39	0.20	0.36	0.28	0.37
N	58	58	58	58	58	58

Notes: Each column reports regression results of the pre-reform fund share on bank characteristics for the top-five MMF complexes according to the Rotemberg weights. $Rating_i$ is a categorical variable for the short-term credit rating of bank i in 2014. ROA_i is the average return on assets in 2014. $CET1_i$ is the Tier-1 common equity ratio in 2014. Arb_i is a dummy variable equal to 1 if the bank's correlation between daily changes in unsecured funding and daily changes in reserve balances is in the top third of all banks. US is a dummy variable denoting U.S. banks. All independent variables are scaled by 10,000. Robust standard errors are reported in the parentheses. Statistical significance: *** $p \leq .01$, ** $p \leq .05$, * $p \leq .10$.

Source: N-MFP

Table 5: **Alternative Estimators and Over-Identification Tests**

	(1) No Controls	(2) Controls	(3) Coeff. equl	(4) Over ID test
OLS	0.80	0.77	[0.28]	
	(0.18)	(0.17)		
2SLS (Bartik)	0.84	0.79	[0.33]	
	(0.26)	(0.27)		
2SLS	0.80	0.77	[0.04]	204.77
	(0.20)	(0.20)		[0.73]
MB2SLS	0.80	0.74	[0.33]	
	(0.20)	(0.20)		
HFUL	0.52	0.52	[1.00]	250.41
	(8.61)	(7.57)		[0.07]

Notes: We follow the tests proposed in Goldsmith-Pinkham, Sorkin, and Swift (2020) and report a variety of estimates for the impact of MMF unsecured funding supply on the IOER arbitrage position (Column 3 of Table 2). Column 1 reports regression results without controls. Column 2 reports regression results controlling for banks' credit rating, return on assets, and the Tier 1 common equity ratio (as in Appendix Table A4. Column 3 reports the p-value for the test whether the coefficient in Columns 1 and 2 are equal. Column 4 reports the test statistic and the p-value for the over-identification test, if applicable. The 2SLS row uses each fund share (times time period) separately as instruments. The MB2SLS row uses the estimator of Anatolyev (2013) and Kolesár et al. (2015). The HFUL row uses the estimator of Hausman et al. (2012).

Table 6: **Balance Sheet Adjustments of U.S.-based Entities**

	(1) $\Delta Asset_{i,t}$	(2) $\Delta Cash_{i,t}$	(3) $\Delta Loan_{i,t}$	(4) $\Delta Sec_{i,t}$	(5) $\Delta FFRepo_{i,t}$	(6) $\Delta OtherA_{i,t}$
$\Delta hold_{i,t}^{Unsec}$	0.83***	0.76***	0.03	0.03	0.03	-0.00
	(0.14)	(0.14)	(0.03)	(0.02)	(0.02)	(0.02)
N	200	200	200	200	200	200
R^2	0.37	0.38	0.03	0.02	0.00	0.01
	(7) $\Delta Liab_{i,t}$	(8) $\Delta Borrow_{i,t}$	(9) $\Delta Deposit_{i,t}$	(10) $\Delta Trading_{i,t}$	(11) $\Delta OtherL_{i,t}$	(12) $\Delta NDT_{i,t}$
$\Delta hold_{i,t}^{Unsec}$	0.25**	-0.06	0.32***	-0.02	0.01	0.57***
	(0.11)	(0.05)	(0.12)	(0.01)	(0.01)	(0.22)
N	200	200	200	200	200	200
R^2	0.18	0.00	0.16	0.04	0.02	0.15

Notes: This table shows IV regression results of changes in the composition of banks' balance sheets on changes in MMF holdings of unsecured bank securities. The Bartik instrument is defined by equation (3). All balance sheet items are from the FR 2644 report, which is voluntarily reported by U.S.-based entities for U.S. and foreign banks. The dependent variables in Columns 1-6 are the change in banks' total assets ($\Delta Asset_{i,t}$), cash ($\Delta Cash_{i,t}$), loans ($\Delta Loan_{i,t}$), securities ($\Delta Sec_{i,t}$), federal funds and repo ($\Delta FFRepo_{i,t}$), and other assets ($\Delta OtherA_{i,t}$). In Columns 7-12, the dependent variables are the change in banks' total liabilities ($\Delta Liab_{i,t}$), borrowing ($\Delta Borrow_{i,t}$), deposits ($\Delta Deposit_{i,t}$), trading liabilities ($\Delta Trading_{i,t}$), other liabilities ($\Delta OtherL_{i,t}$), and net-due-to positions ($\Delta NDT_{i,t}$). The independent variable, $\Delta hold_{i,t}^{Unsec}$, is the change in MMF holdings of unsecured debt issued by bank i. All variables are scaled by 2014 total assets from SNL Financial. All changes are quarterly and the sample period is October 2015 to October 2016. All specifications include time fixed effects, with standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table 7: **Regression Results for Intra-Office Positions**

	(1) $\Delta NDT_{i,t}$	(2) $\Delta ED_{i,t}$	(3) $\Delta Q_{i,t}^{NDT-ED}$	(4) $\Delta NDT_{i,t}$	(5) $\Delta ED_{i,t}$	(6) $\Delta Q_{i,t}^{NDT-ED}$
$\Delta hold_{i,t}^{Unsec}$	0.57***	0.78***	-0.21	0.03	0.06	-0.03
	(0.22)	(0.26)	(0.15)	(0.09)	(0.04)	(0.09)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				0.75***	1.08***	-0.33
				(0.15)	(0.21)	(0.24)
Arb_i				-0.00	0.00***	0.00
				(0.00)	(0.00)	(0.00)
N	200	200	200	200	200	200
R^2	0.16	0.52	0.13	0.32	0.76	0.14

Notes: This table shows IV regression results of changes in net-due-to, Eurodollar (ED), and the difference between the ED and the net-due-to position on changes in MMF holdings of unsecured bank securities. The Bartik instrument is defined by equation (3). The dependent variables are defined as follows: $\Delta NDT_{i,t}$ is the change in the net-due-to position, $\Delta ED_{i,t}$ is the change in the ED position, and $\Delta Q_{i,t}^{NDT-ED}$ is the difference between $\Delta NDT_{i,t}$ and $\Delta ED_{i,t}$. $\Delta hold_{i,t}^{Unsec}$ is the change in MMF holdings of unsecured debt issued by bank i. Arb_i is a dummy variable equal to 1 if the bank's correlation between daily changes in unsecured funding and daily changes in reserve balances is in the top third of all banks. All continuous variables are scaled by 2014 total assets from SNL Financial. All changes are quarterly and the sample period is October 2015 to October 2016. All specifications include time fixed effects, with standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table 8: **Regression Results for Syndicated Loans**

	(1)	(2)	(3)	(4)
	MMF Reform		European Debt Crisis	
	Dollar Amount	Scaled by Assets	Dollar Amount	Scaled by Assets
$\Delta hold_{i,t}^{Unsec}$	0.0685	-0.0206	0.225**	0.242
	(0.0621)	(0.0472)	(0.109)	(0.234)
N	58	58	57	57
R^2	0.01	0.00	0.15	0.05

Notes: This table shows the results of IV regressions for changes in the new origination of syndicated loans on changes in the supply of unsecured funding from MMFs. Columns 1 and 2 report results for the MMF reform period, and Columns 3 and 4 report results for the European debt crisis period. The changes in dependent and independent variables are measured in dollar amounts in Columns 1 and 3, and are scaled by total assets in Columns 2 and 4. Standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table 9: **Regression Results for Funding Costs**

	(1) $\Delta r_{i,n,t}$	(2) $\Delta r_{i,n,t}$	(3) $\Delta r_{i,n,t}$	(4) $\Delta r_{i,n,t}$	(5) $\Delta r_{i,n,t}$
$\Delta hold_{i,t}^{Unsec}$	-0.77	0.011	-0.01	-0.12	0.50**
	(0.61)	(0.34)	(0.58)	(0.62)	(0.22)
$Tenor_{>6M} \times \Delta hold_{i,t}^{Unsec}$		-3.18**	-2.85	-4.21*	-3.06**
		(1.57)	(1.77)	(2.52)	(1.52)
Sample	All	All	Arb	Non-Arb	FBOs
N	256	256	82	174	215
R^2	0.38	0.40	0.59	0.37	0.49

Notes: This table shows the results of IV regressions for changes in banks' funding costs from October 2015 to October 2016 on changes in MMF holdings of unsecured bank debt. The Bartik instrument is defined in equation (3). The dependent variable, $\Delta r_{i,n,t}$, is the change in bank i's funding rate (measured in basis points) for tenor n, which is calculated as the volume-weighted monthly average. Transactions at rates below 5 basis points are dropped from the sample to ensure that our sample comprises only transactions at market rates. The independent variable, $\Delta hold_{i,t}^{Unsec}$, is the change in MMF holdings of unsecured debt issued by bank i, as a share of total assets in 2014 (measured in percentage points). $Tenor_{>6mos}$ is a dummy variable indicating observations for which tenor n is six months or longer. All specifications include tenor fixed effects, with standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table 10: **Arbitrage Profits and Arbitrage Capital**

Panel (A) IOER Arbitrage

	(1) $\Delta\pi_t^{IOER}$ Non-MEs	(2) $\Delta\pi_t^{IOER}$ ME	(3) $\Delta\pi_t^{IOER}$ QE	(4) $\Delta\pi_t^{IOER}$ Non-QE ME
ΔY_t^{IOER}	0.008	-0.086***	-0.076***	-0.300***
	(0.006)	(0.006)	(0.003)	(0.044)
$\Delta Y_t^{IOER} \times Post_t$	-0.015**	-0.107***	-0.072***	-0.159***
	(0.006)	(0.031)	(0.013)	(0.052)
$Post_t$	0.024	0.737	1.547	0.989
	(0.031)	(1.436)	(1.344)	(1.191)
Constant	0.003	-0.948	-1.062**	-2.605**
	(0.023)	(0.915)	(0.487)	(1.060)
N	372	40	13	27
R^2	0.073	0.673	0.951	0.806

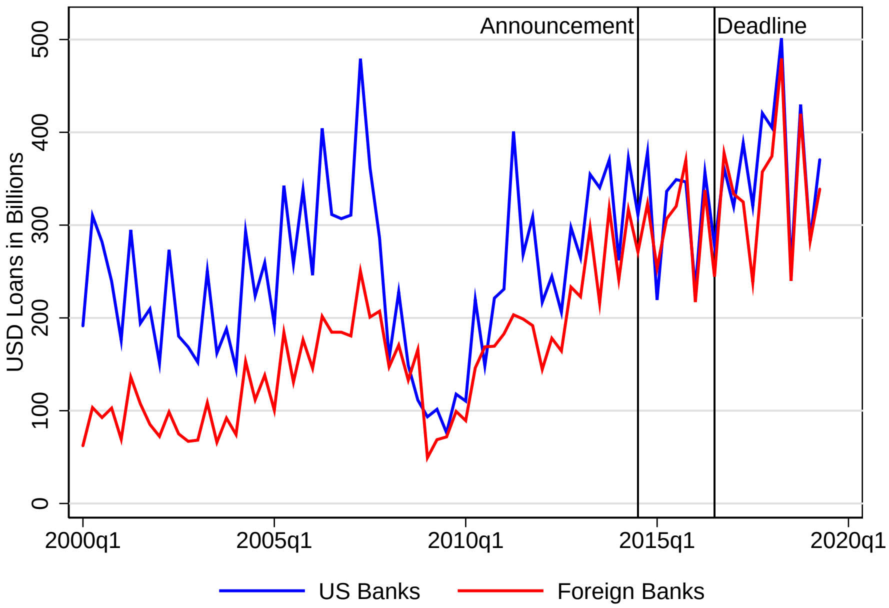
Panel (B) CIP Arbitrage

	(1) $\Delta\pi_{1W,t}^{CIP}$ 1W non-QE	(2) $\Delta\pi_{1W,t}^{CIP}$ 1W QE	(3) $\Delta\pi_{1M,t}^{CIP}$ 1M non-QE	(4) $\Delta\pi_{1M,t}^{CIP}$ 1M QE	(5) $\Delta\pi_{1M,t}^{CIP}$ 3M non-YE	(6) $\Delta\pi_{1M,t}^{CIP}$ 3M YE
$\Delta Y_{n,t}^{CIP}$	-0.086	-0.534	-0.040**	-0.386***	-0.036***	-0.117***
	(0.055)	(1.130)	(0.018)	(0.133)	(0.013)	(0.040)
$\Delta Y_{n,t}^{CIP} \times Post_t$	-0.348	-1.545	-0.172	0.404**	-0.056	0.093
	(0.305)	(2.525)	(0.118)	(0.198)	(0.042)	(0.082)
$Post_t$	-1.685	16.928	-0.551	0.629	-0.549	0.431
	(3.010)	(28.364)	(1.287)	(2.695)	(0.745)	(1.155)
Constant	-2.886*	31.498*	-0.992	1.089	0.067	-0.185
	(1.484)	(17.550)	(0.653)	(1.475)	(0.455)	(0.940)
N	376	36	260	152	305	107
R^2	0.028	0.018	0.060	0.041	0.034	0.077

Notes: This table shows regression results of daily changes in the average arbitrage profit on daily changes in the total arbitrage capital for our sample banks. Panel (A) shows results for the IOER arbitrage and Panel (B) shows results for the CIP arbitrage. In Panel (A), the dependent variable is the daily change in the average IOER arbitrage profit $\Delta\pi_t^{IOER}$. ΔY_t^{IOER} is the change in the aggregate potential arbitrage capital for the IOER arbitrage. $Post_t$ is equal to one after October 14, 2016 and zero otherwise. The sample in specification (1) is non-month-ends (non-ME), in specification (2) is month-ends (ME), in specification (3) is quarter-ends (QE), and in specification (4) is non-quarter-end month-ends (non-QE ME). In Panel (B), the dependent variables are as follows: $\Delta\pi_{1W,t}^{CIP}$ is change in the 1-week CIP arbitrage profit (Columns 1-2), $\Delta\pi_{1M,t}^{CIP}$ is the change in the 1-month CIP arbitrage profit (Columns 3-4), and $\Delta\pi_{3M,t}^{CIP}$ is the change in the 3-month CIP arbitrage profit (Columns 5-6). $\Delta Y_{n,t}^{CIP}$ is the change in the aggregate potential arbitrage capital for the CIP arbitrage. The sample in specifications (1) and (3) is non-quarter-ends (non-QE), in specifications (2) and (4) is quarter-ends (QE), in specification (5) is non-year-ends (non-YE), and in specification (6) is year-ends (YE). The sample period is from October 2015 to June 2017. Robust standard errors are shown in parentheses. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Appendix

Figure A1: **Dollar Syndicated Loan Origination**



Notes: This figure plots total dollar syndicated loan origination by U.S. (blue) and foreign banks (red) in our sample as lead arrangers.
Source: Dealscan

Table A1: **List of Sample Banks**

Bank Name	Country	Bank Name	Country
Australia and New Zealand Banking Group	Australia	Bank Of Tokyo-Mitsubishi UFJ	Japan
Commonwealth Bank Of Australia	Australia	Chiba Bank	Japan
National Australia Bank Limited	Australia	Mizuho Corporate Bank	Japan
Westpac Banking Corp	Australia	Norinchukin Bank	Japan
KBC Groep NV	Belgium	Shizuoka Bank	Japan
Bank Of Montreal	Canada	Sumitomo Group	Japan
Bank Of Nova Scotia	Canada	Korea Development Bank	South Korea
Canadian Imperial Bank Of Commerce	Canada	Rabobank Nederland Nv	Netherlands
National Bank Of Canada	Canada	DNB Nor Bank Asa	Norway
Royal Bank Of Canada	Canada	DBS Bank Ltd	Singapore
Toronto Dominion Bank	Canada	Oversea Chinese Banking	Singapore
Agricultural Bank Of China	China	United Overseas Bank	Singapore
Bank Of China	China	Banco Bilbao Vizcaya Argentaria	Spain
China Construction Bank Corp	China	Banco Santander	Spain
Industrial & Commercial Bank Of China	China	Skandinaviska Enskilda Banken	Sweden
Barclays Plc	United Kingdom	Svenska Handelsbanken	Sweden
HSBC Bank	United Kingdom	Swedbank	Sweden
Lloyds Banking Group Plc	United Kingdom	Credit Suisse	Switzerland
Standard Chartered Bank	United Kingdom	UBS Ag	Switzerland
Banque Federative	France	Bank Of America Corporation	United States
BNP Paribas	France	Bank Of New York Mellon	United States
Credit Agricole	France	BB&T	United States
Dexia	France	Citigroup	United States
Groupe BPCE	France	Goldman Sachs Group	United States
Societe Generale	France	JP Morgan Chase	United States
Bayerische Landesbank	Germany	Morgan Stanley	United States
DZ Bank Ag	Germany	State Street Corporation	United States
Landesbank Baden-Wuerttemberg	Germany	US Bank	United States
Landesbank Hessen-Thueringen	Germany	Wells Fargo	United States

Notes: This table provides the full list of the 58 banks in our sample and the country of the bank headquarters.

Table A2: **Annual Regressions for Arbitrage Capital and Arbitrage Positions**

	(1) $\Delta Y_{i,t}^{IOER}$	(2) $\Delta Y_{i,t}^{CIP}$	(3) $\Delta Q_{i,t}^{IOER}$	(4) $\Delta Q_{i,t}^{IOER}$	(5) $\Delta Q_{i,t}^{IOER}$
Panel (A) OLS Estimates					
$\Delta hold_{i,t}^{Unsec}$	0.77***	0.86***	0.84***	0.11	0.85***
	(0.21)	(0.20)	(0.24)	(0.08)	(0.25)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				1.11***	
				(0.17)	
Arb_i				0.01*	
				(0.00)	
Sample	All	All	All	All	FBOs
N	58	58	58	58	48
R^2	0.58	0.64	0.60	0.88	0.63
Panel (B) IV Estimates					
$\Delta hold_{i,t}^{Unsec}$	0.77***	0.86***	0.84***	0.30**	0.85***
	(0.21)	(0.20)	(0.24)	(0.12)	(0.25)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				0.75***	
				(0.26)	
Arb_i				0.00	
				(0.01)	
Sample	All	All	All	All	FBOs
N	58	58	58	58	48
R^2	0.58	0.64	0.60	0.85	0.63

Notes: This table shows regression results of changes in potential arbitrage capital and the IOER arbitrage position on changes in MMF holdings of unsecured bank securities. Panel (A) shows the OLS estimates and Panel (B) shows the IV estimates using the Bartik instrument defined by equation (3). The dependent variables are defined as follows: $\Delta Y_{i,t}^{IOER}$ is the change in the potential IOER arbitrage capital, $\Delta Y_{i,t}^{CIP}$ is the change in the potential CIP arbitrage capital, and $\Delta Q_{i,t}^{IOER}$ is the change in the proxy for the IOER arbitrage position. $\Delta hold_{i,t}^{Unsec}$ is the change in MMF holdings of unsecured debt issued by bank i. All changes are annual, calculated from October 2015 to October 2016, and scaled by 2014 total assets from the SNL Financial. Arb_i is a dummy variable equal to 1 if a bank's correlation between daily changes in unsecured funding and daily changes in reserve balances is in the top third of all banks. Robust standard errors are shown in parentheses. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table A3: **Quarterly Regressions for Arbitrage Capital and Arbitrage Positions (Dollar Amounts)**

	(1) $\Delta Y_{i,t}^{IOER}$	(2) $\Delta Y_{i,t}^{CIP}$	(3) $\Delta Q_{i,t}^{IOER}$	(4) $\Delta Q_{i,t}^{IOER}$	(5) $\Delta Q_{i,t}^{IOER}$
			Panel (A) OLS Estimates		
$\Delta hold_{i,t}^{Unsec}$	0.65***	0.88***	0.62***	0.31***	0.58***
	(0.12)	(0.08)	(0.11)	(0.07)	(0.12)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				0.69***	
				(0.13)	
Arb_i				0.51	
				(0.37)	
Sample	All	All	All	All	FBOs
N	232	232	232	232	192
R^2	0.44	0.57	0.44	0.61	0.41
			Panel (B) IV Estimates		
$\Delta hold_{i,t}^{Unsec}$	0.66***	0.71***	0.62***	0.47***	0.64***
	(0.09)	(0.08)	(0.09)	(0.07)	(0.10)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				0.43***	
				(0.13)	
Arb_i				-0.25	
				(0.40)	
Sample	All	All	All	All	FBOs
N	232	232	232	232	192
R^2	0.44	0.55	0.44	0.59	0.40

Notes: This table shows regression results of changes in potential arbitrage capital and the IOER arbitrage position on changes in MMF holdings of unsecured bank securities. Panel (A) shows the OLS estimates and Panel (B) shows the IV estimates using the Bartik instrument defined by equation (3). The dependent variables are defined as follows: $\Delta Y_{i,t}^{IOER}$ is the change in the potential IOER arbitrage capital, $\Delta Y_{i,t}^{CIP}$ is the change in the potential CIP arbitrage capital, and $\Delta Q_{i,t}^{IOER}$ is the change in the proxy for the IOER arbitrage position. $\Delta hold_{i,t}^{Unsec}$ is the change in MMF holdings of unsecured debt issued by bank i. Unlike in the benchmark regressions in Table 2, all continuous variables are measured in dollars, instead of as percentages of total assets. Arb_i is a dummy variable equal to 1 if the bank's correlation between daily changes in unsecured funding and daily changes in reserve balances is in the top third of all banks. All changes are quarterly and the sample period is October 2015 to October 2016. All specifications include time fixed effects, with standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table A4: **Quarterly Regressions for Arbitrage Capital and Arbitrage Positions with Controls**

	(1) $\Delta Y_{i,t}^{IOER}$	(2) $\Delta Y_{i,t}^{CIP}$	(3) $\Delta Q_{i,t}^{IOER}$	(4) $\Delta Q_{i,t}^{IOER}$	(5) $\Delta Q_{i,t}^{IOER}$
Panel (A) OLS Estimates					
$\Delta hold_{i,t}^{Unsec}$	0.87***	0.96***	0.77***	0.15**	0.71***
	(0.18)	(0.20)	(0.17)	(0.07)	(0.19)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				0.97***	
				(0.10)	
Arb_i				0.00*	
				(0.00)	
$Rating_i$	1.44***	1.40**	1.17**	0.75*	0.54
	(0.52)	(0.60)	(0.56)	(0.40)	(0.72)
ROA_i	0.03	-0.09	-0.49	-0.66	-0.27
	(0.72)	(0.63)	(0.89)	(0.59)	(0.80)
$CET1_i$	-0.38	-0.29	-0.59*	-0.35*	-0.84***
	(0.24)	(0.19)	(0.31)	(0.21)	(0.30)
Sample	All	All	All	All	FBOs
N	232	232	232	232	192
R^2	0.53	0.58	0.56	0.77	0.52
Panel (B) IV Estimates					
$\Delta hold_{i,t}^{Unsec}$	0.88***	0.88***	0.79***	0.24	0.78***
	(0.30)	(0.30)	(0.25)	(0.16)	(0.24)
$Arb_i \times \Delta hold_{i,t}^{Unsec}$				0.82***	
				(0.18)	
Arb_i				0.00	
				(0.00)	
$Rating_i$	1.47*	1.14	1.22	0.89*	0.78
	(0.82)	(0.87)	(0.80)	(0.48)	(0.78)
ROA_i	0.07	-0.38	-0.44	-0.73	0.02
	(0.76)	(0.66)	(0.80)	(0.62)	(0.92)
$CET1_i$	-0.37*	-0.40**	-0.57**	-0.38**	-0.73**
	(0.21)	(0.18)	(0.28)	(0.18)	(0.32)
Sample	All	All	All	All	FBOs
N	232	232	232	232	192
R^2	0.53	0.58	0.56	0.76	0.52

Notes: This table shows regression results of changes in potential arbitrage capital and the IOER arbitrage position on changes in MMF holdings of unsecured bank securities with additional bank-level controls. Panel (A) shows the OLS estimates and Panel (B) shows the IV estimates using the Bartik instrument defined by equation (3). The dependent variables are defined as follows: $\Delta Y_{i,t}^{IOER}$ is the change in the potential IOER arbitrage capital, $\Delta Y_{i,t}^{CIP}$ is the change in the potential CIP arbitrage capital, and $\Delta Q_{i,t}^{IOER}$ is the change in the proxy for the IOER arbitrage position. $\Delta hold_{i,t}^{Unsec}$ is the change in MMF holdings of unsecured debt issued by bank i. All changes are quarterly, calculated from October 2015 to October 2016, and scaled by 2014 total assets from the SNL Financial. Arb_i is a dummy variable equal to 1 if a bank's correlation between daily changes in unsecured funding and daily changes in reserve balances is in the top third of all banks. $Rating_i$ is a categorical variable for the short-term credit rating of bank i in 2014. ROA_i is the average return on assets in 2014. $CET1_i$ is the Tier-1 common equity ratio in 2014. All specifications include time fixed effects, with standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table A5: **Balance Sheet Adjustments of FBOs in the US**

	(1) $\Delta Asset_{i,t}$	(2) $\Delta Cash_{i,t}$	(3) $\Delta Loan_{i,t}$	(4) $\Delta Sec_{i,t}$	(5) $\Delta FFRepo_{i,t}$	(6) $\Delta OtherA_{i,t}$
$\Delta hold_{i,t}^{Unsec}$	0.87***	0.88***	-0.01	0.00	0.03	-0.01
	(0.12)	(0.12)	(0.01)	(0.01)	(0.02)	(0.01)
N	160	160	160	160	160	160
R^2	0.35	0.38	0.06	0.01	0.02	0.04
	(7) $\Delta Liab_{i,t}$	(8) $\Delta Borrow_{i,t}$	(9) $\Delta Deposit_{i,t}$	(10) $\Delta Trading_{i,t}$	(11) $\Delta OtherL_{i,t}$	(12) $\Delta NDT_{i,t}$
$\Delta hold_{i,t}^{Unsec}$	0.25**	-0.01	0.27***	-0.02	-0.00	0.62***
	(0.10)	(0.04)	(0.10)	(0.01)	(0.00)	(0.22)
N	160	160	160	160	160	160
R^2	0.16	0.02	0.20	0.05	0.02	0.12

Notes: This table shows IV regression results of changes in the composition of banks' balance sheets for foreign banking organizations (FBOs) in the United States on changes in MMF holdings of unsecured bank securities. The Bartik instrument is defined by equation (3). All balance sheet items are from the FR 2644 report. The dependent variables in Columns 1-6 are the change in banks' total assets ($\Delta Assets_{i,t}$), cash ($\Delta Cash_{i,t}$), loans ($\Delta Loan_{i,t}$), securities ($\Delta Sec_{i,t}$), federal funds and repo ($\Delta FFRepo_{i,t}$), and other assets. In Columns 7-12, the dependent variables are change in banks' total liabilities ($\Delta Liab_{i,t}$), borrowing ($\Delta Borrow_{i,t}$), deposits ($\Delta Deposits_{i,t}$), trading liabilities ($\Delta Trading_{i,t}$), other liabilities ($\Delta Other_{i,t}$), and net-due-to positions ($\Delta NDT_{i,t}$). The independent variable, $\Delta hold_{i,t}^{Unsec}$, is the change in MMF holdings of unsecured debt issued by bank i. All variables are scaled by 2014 total assets from SNL Financial. All changes are quarterly and the sample period is October 2015 to October 2016. All specifications include time fixed effects, with standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.