Arbitrage Capital of Global Banks*

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Abstract

We document an important business activity for global banks in the post-crisis environment: use wholesale funding to finance near risk-free arbitrage positions, in particular, the interest on excess reserves arbitrage and the covered interest rate parity arbitrage. Under this business model, we examine the effects of a large negative wholesale funding shock for global banks as a result of the US money market mutual fund reform implemented in 2016. 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. Furthermore, we examine the relationship between arbitrage capital and arbitrage profits.

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1 Introduction

In addition to taking deposits, banks turn to wholesale funding markets—the federal funds and euro-dollar markets, the markets for commercial paper and certificates of deposits, and the repo market—to finance their operations.[1] In contrast to deposits, wholesale funding is more "fragile" and subject to sudden dry-ups (for example, Pérignon et al. (2018)). In the past, large negative wholesale funding shocks often led to fire sales of assets, significant contractions in credit supply and elevated financial distress. In this paper, we document an important business activity for global banks after the global financial crisis: Banks use wholesale funding to finance near risk-free arbitrage positions. Under this business model, global banks are more resilient to negative wholesale funding shocks, as they can swiftly reduce their arbitrage positions in response to a wholesale funding dry-up, which are comprised of liquid assets.

U.S. money market mutual funds (MMFs) are an important supplier of wholesale dollar funding to global banks. In particular, we examine a $900 billion reduction in the wholesale funding supply from MMFs to global banks between October 2015 and October 2016, as a result of a major regulatory reform to the U.S. MMF industry introduced by the Securities and Exchange Commission (SEC). We find that the primary response of global banks to the negative wholesale funding shock was a reduction in their arbitrage positions funded by unsecured wholesale borrowing. In contrast to the traditional bank lending channel, banks did not reduce their loan provision.

We focus on two types of arbitrage funded by unsecured borrowing. The first type is interest on excess reserves (IOER) arbitrage, in which banks obtain short-term unsecured dollar funding and park the proceeds at the Federal Reserve, earning the spread between the IOER rate and their cost of short-term funding. The second type is covered interest rate parity (CIP) arbitrage, in which banks borrow unsecured term dollar funding from

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

the cash market and then lend out the dollars in the FX forward/swap markets. Both arbitrage strategies contain very little risk, but 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.

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. For each wholesale funding instrument, we observe the issuer, volume and the rate. Such detailed information on the wholesale funding market is rarely available in existing studies. Another key novelty of our datasets is that we observe banks' activities outside of quarter-end regulatory reporting dates, in contrast to the bulk of empirical banking research that uses quarter-end bank reports. This feature turns out to be essential for us to gauge the size and time variations of arbitrage activities. Since the Basel III leverage ratio is calculated based on quarter-end snapshots of bank balance sheets in many foreign jurisdictions, foreign banks have incentives to reduce their balance sheet size on quarter-ends to obtain a more favorable leverage ratio. As a result, low-yielding, balance sheet intensive, and easily scalable arbitrage activities are primary candidates to be scaled back on quarter-ends, and thus quarter-end reports can significantly understate these arbitrage activities.

We measure the potential arbitrage capital for the IOER and CIP arbitrages as the amount of short-term wholesale funding raised below the IOER rate and the implied dollar rates from the dollar-yen swap markets, respectively. We show that the overwhelming majority of unsecured wholesale dollar funding of our sample banks can be used for arbitrage, with about 95% of total funding raised at a rate below the swapped JPY rate and about a third of total funding raised at a rate below the IOER rate. The cumulative amount of the potential unsecured arbitrage capital for the IOER and CIP arbitrage stands at around \$1.5 trillion between 2015-2017. Foreign banks account for more 80% of total potential arbitrage capital.

In addition to measuring the potential arbitrage capital, we also construct proxies for actual arbitrage positions. Using data on daily reserve balances at the Federal Reserve, we construct a proxy for the IOER arbitrage positions as the minimum of the reserve balances and the amount of funding obtained at a rate below the IOER rate. For the CIP arbitrage, we do not directly observe the long position of the arbitrage because it is generally conducted by foreign affiliates of U.S.-based banks. Instead, we construct a coarse proxy for CIP arbitrage positions as the net lending to foreign affiliates using our data on the net-due-to and euro-dollar positions.

U.S. MMFs are a key provider of dollar arbitrage capital to global banks, but their role has significantly diminished since the SEC MMF reform. Over the year leading up to the MMF reform implementation deadline, the cumulative amount of potential arbitrage capital for the IOER and CIP arbitrages declined from \$1.6 trillion in October 2015 to about \$1.3 trillion in October 2016, and the share of the potential arbitrage capital coming from MMFs declined from about two thirds to about one quarter.

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 funds and changes in banks' outcome variables over the one year prior to the reform implementation deadline. To instrument for the loss of funding from MMFs, we construct a Bartik-style shift-share estimator that allows us to estimate the amount of funding lost from MMFs for a particular bank based on the inner product of the pre-reform shares of the bank in an individual MMF complex's assets under management (AUM) and the changes in the respective MMF complex's AUM.

We find that the MMF reform significantly reduced the availability of potential arbitrage capital for banks. For every dollar of funding from prime MMFs lost, potential arbitrage capital declines by \$0.6, on average, for both the IOER and CIP arbitrages. The decline in unsecured funding directly translated into declines in excess reserve balances. In addition to the decline in arbitrage capital, we show that the proxy for the IOER arbitrage position also declined by about \$0.6, and the proxy for the CIP arbitrage position declined by about \$0.3, on average, per dollar of funding lost. In contrast to the strong response of potential arbitrage capital and reserve positions, we do not find any significant evidence of a decline in banks' loan positions following this large negative funding supply shock.

In addition to showing the average effect across all sample banks, we also examine heterogeneous responses to the reform depending on banks' business models. We divide our sample banks into two groups based on their arbitrage activities. In particular, we sort on the correlation between daily changes in unsecured funding and daily changes in reserve balances. We label banks that exhibit above median correlation between unsecured funding and reserves as "IOER arbitrageurs" and banks that exhibit below median correlation as "non-IOER arbitrageurs". Overall, we find stronger responses to the reform by the IOER arbitrageurs. In response to a \$1 reduction in unsecured funding from prime funds, IOER arbitrageurs cut their potential arbitrage capital and arbitrage positions by between \$0.8 and \$1 and shrink their balance sheet size by about \$0.6. Non-IOER arbitrageurs, on the other hand, cut their potential arbitrage capital by only about \$0.5 and do not shrink their overall balance sheet size.

Besides balance sheet adjustments, we also show that the loss of funding as a result of the MMF reform also increases banks' funding costs. The effect on the funding costs is more pronounced for the non-IOER arbitrageurs than for the IOER arbitraguers. Our interpretation is that non-IOER arbitraugers have less elastic demand for dollar wholesale funding since they have to obtain sufficient costs in order to maintain their real business activities, whereas IOER arbitraguers have more elastic demand for dollar funding as arbitrage activities can be scaled down more easily.

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. Smaller differences in the potential arbitrage capital intra-quarters and on quarter-ends suggest reductions in 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 declined significantly after the reform. Instead, *secured* funding plays an increasingly important role in quarter-end dynamics. These findings support the view that MMF reform has reduced arbitrage activities funded by unsecured borrowing.

Finally, we find evidence that reductions in arbitrage capital are associated with increases in arbitrage profits over the reform implementation period. The negative correlation between arbitrage capital and arbitrage profits supports the hypothesis that there was a reduction in the supply of arbitrage capital over the reform implementation period. This negative relationship is stronger on quarter-ends when banks are more constrained by their balance sheet capacity. In addition, for the IOER arbitrage, we find an even stronger negative correlation between arbitrage capital and arbitrage profits after the MMF reform implementation deadline.

Our paper contributes to several strands of literature. First, we contribute to the literature on bank funding shocks due to MMFs. The MMF runs during the Global Financial Crisis after the Reserve Primary Fund "broke the buck" and the policy response from the Federal Reserve were carefully examined by Duygan-Bump et al. (2013) and Kacperczyk and Schnabl (2010, 2013). During the European Debt Crisis, MMFs again suffered heavy redemptions, which resulted in a large negative funding shock for banks (see, for example, Chernenko and Sunderam (2014)). Our paper is mostly closely related to Ivashina et al. (2015) and Correa et al. (2016), which use the negative funding supply shock from MMFs during the European Debt Crisis to study the effect on global banks' funding and lending behavior. The focus of their papers is on the traditional bank lending channel. Our results highlight the significant transformation of business models of global banks after the crisis: a large portion of unsecured wholesale funding was used to support risk-free arbitrage and, therefore, the primary response of banks to a large reduction in wholesale funding was a reduction in arbitrage positions rather than in real lending. Cipriani and Spada (2018) also study the 2014 MMF reform, with a different focus on estimating the premium for "money-like" assets.

Our paper also builds on the recent literature on arbitrage and window-dressing activities in money markets and FX markets. Bech and Klee (2011), Banegas and Tase (2016), and Keating and Macchiavelli (2017) study the dynamics of the IOER arbitrage. Munyan (2017) and Anbil and Senyuz (2018) examine regulatory-driven repo window-dressing activities. Du et al. (2018) document persistent CIP violations and their quarter-end dynamics due to window dressing for capital regulations. The key contribution of our paper is to provide a systematic account of these arbitrage activities for banks and document a strong response of these activities to the MMF reform.

The paper is structured as follows. In section 2, we provide background on the US MMFs and discuss key features of the regulatory reform to the MMF industry introduced by the SEC in 2014. In section 3, we discuss various data sources used in the paper. In section 4, we describe the two arbitrage strategies and our measures of potential funding for arbitrage. In section 5, we present our main empirical results on the effects of the MMF reform. In section 6, we discuss the relationship between arbitrage capital and arbitrage profits. Section 7 concludes.

2 MMFs and the 2014 SEC Regulatory Reform

MMFs are an important player in the shadow banking system in the United States. Investors place cash with MMFs, which, in turn, use the cash to invest in liquid and short-dated debt securities issued by the government, as well as financial and non-financial companies. In particular, MMFs are an important source of short-term funding for foreign banking organizations (FBOs) in the United States. The two main types of MMFs in the United States are prime funds and government funds. Prime funds can hold short-term debt securities up to one year across different types of issuers, whereas government funds can only hold government securities and repos backed by government securities.

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 them to implement redemption gates and liquidity fees to limit outflows. 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.

As shown in 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 AUMs occurred within one year prior to the implementation deadline, reflecting the fact that MMFs cannot hold securities with remaining maturities longer than one year, so the new rules became relevant one year prior to the implementation deadline.

The $1 trillion reduction in prime funds' AUM affected primarily banks, especially FBOs. In particular, FBOs lost about $750 billion in unsecured funding from prime MMFs, while U.S. banks lost about $130 billion. The $750 billion loss in unsecured funding by FBOs represented about 30% of the total liabilities of all FBOs in the United States. In this paper, we narrow our sample to 62 global banks that frequently trade with MMFs. Our sample banks account for 90% of total prime fund holdings of bank securities. The total loss of unsecured funding from prime funds during the reform for our sample banks was about $700 billion, far exceeding the total loss of prime MMFs' funding of $200 billion during the peak of the European debt crisis and about $400 billion during the peak of the global financial crisis after the Lehman bankruptcy.

3 Data and Sample

3.1 Data Sources

One important contribution of the paper is that we provide a picture of dollar wholesale funding profiles for U.S. banks and FBOs in the United States at a daily frequency that is as comprehensive as possible, compiled from a host of supervisory data on various wholesale funding instruments at the transaction level. The advantage of our compiled dataset over banks' quarter-end regulatory filings is that it offers much more granular information on various wholesale funding instruments and that it allows us to examine fluctuations in wholesale funding activities on non-quarter-end days. In addition to detailed wholesale funding information, we also have daily data on reserve balances at the Federal Reserve and weekly balance sheet information on some broad categories of bank business operations. Finally, we have security-level information on MMFs' holdings of bank securities at a monthly frequency. We now briefly discuss each of these data sources and the construction of our sample.

First, we compile a dataset of various wholesale funding instruments at the transaction level, including certificates of deposit (CD), commercial paper (CP), euro-dollars (ED), federal funds (FF) and tri-party repos (RP). Each data entry includes information on the trade date, borrower name, maturity, borrowing amount, borrowing rate, and instrument type (CD, CP, ED, FF, or RP). We obtain CP transactions from the Depository Trust and Clearing Corporation (DTCC). DTCC is the national clearinghouse for the settlement of securities trades and a custodian for securities. DTCC performs these functions for almost the entire domestic CP market. For FF, CD, and ED, we use transaction-level data from the FR 2420 *Report of Selected Money Market Rates*, which collects, starting in April 2014, daily issuance data on FF, CD, and ED from U.S. banks and FBOs that meet certain size requirements.[2] For RP, we use position-level data from the tri-party repo market, which are reported to the Federal Reserve Bank of New York (FRBNY).[3] We do not have detailed data on the bilateral repo market. However, since MMFs mainly lend in repo via the tri-party market rather than via bilateral transactions, the MMF reform had a more direct effect on the tri-party market.

Therefore, we cover almost all funding in the FF, tri-party repo, and U.S.-based CP markets. In addition, we cover funding in CD and ED markets by U.S. banks and FBOs in the U.S. This collection represents the most significant segments of dollar cash funding markets for global banks. Furthermore, it nearly represents the universe of bank-issued

[2]The FR 2420 report collects data from (1) domestically chartered commercial banks and thrifts with \$18 billion or more 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 FR 2420 report captures U.S.-based ED transactions, which include offshore borrowing of U.S. banks, domestic borrowing of offshore funding through international banking facilities (IBF), borrowing done by offshore branches (mainly in the Caribbean) of U.S. banks and FBOs in the United States. Between April 2014 and October 2015, the FR 2420 report only captures offshore borrowing by U.S. banks, but not by FBOs or by IBFs. Starting in October 2015, ED transactions done by FBOs and by IBFs were added into the report, which account for the bulk of U.S-based ED activities.

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

instruments available to U.S. MMFs. However, we do not observe ED and CD borrowing by non-U.S.-based banks outside the United States.

In addition to detailed data on banks' wholesale funding instruments, we also have data on weekly bank balance sheet information from the FR 2644 *Weekly Report of Selected Assets and Liabilities of Domestically Chartered Commercial Banks and U.S. Branches and Agencies of Foreign Banks*. The FR 2644 report parallels the quarterly bank Call Reports, but it is, while available at a higher frequency, far less detailed than bank Call Reports. In addition, we have obtained data on daily bank-level reserve balances held at the Federal Reserve.

Finally, we use data on U.S. money market funds' month-end portfolio holdings from Form N-MFP *Monthly Schedule of Portfolio Holdings of Money Market Funds* from the SEC. The N-MFP schedule discloses portfolio holdings of each MMF at the CUSIP level, as well as the AUM of the fund every month-end since 2011.

3.2 Sample and Summary Statistics

Our sample contains 62 global banks that frequently trade with U.S. MMFs. These banks account for 90% of total prime fund holdings of bank securities. Our main sample period is from October 2015 to October 2016, the year prior to the MMF reform implementation deadline.[4]

We provide some summary statistics on our sample banks' wholesale funding profiles and business activities. Figure 2 shows total unsecured wholesale funding outstanding and prime funds' holdings of that unsecured debt issued by our sample banks. During the one year before the reform implementation deadline on October 14, 2016, our sample banks lost about $700 billion in unsecured funding from prime funds. Meanwhile, they only reduced their total unsecured funding outstanding by about $300 billion.

[4]Throughout the paper, we refer to this period as the reform implementation period.

U.S. and foreign banks differ significantly in terms of their reliance on unsecured whole funding, and, in particular, their reliance on unsecured funding from prime funds. Panel A of Figure 3 plots the unsecured wholesale funding outstanding and prime funds' unsecured holdings for foreign and U.S. banks, respectively. Foreign banks account for the bulk of total unsecured wholesale funding outstanding and the bulk of the reduction in unsecured funding from MMFs. On the other hand, U.S. banks relied very little on unsecured wholesale funding. Panel B shows that MMFs' holdings of repos issued by foreign banks increased somewhat, but total outstanding repos of both foreign and U.S. banks remained quite flat. Therefore, the decline in unsecured debt outstanding was not offset by an increase in secured debt outstanding.

On the assets side, as shown in Panel A of Figure 4, 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 4, the decline in unsecured funding was correlated with a decline in the excess reserve balances of foreign banks.

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 positions, but rather a large reduction in reserve balances at the Federal Reserve. This motivates us to study the effect of the reform on banks' arbitrage activities.

4 Arbitrage Strategies

We consider two types of risk-free arbitrage strategies based on unsecured funding: IOER arbitrage and CIP arbitrage. The ability of banks to engage in these arbitrages crucially depends on their ability to borrow wholesale dollars at attractive terms.

4.1 IOER Arbitrage

First, banks can engage in IOER arbitrage by raising unsecured dollar funding from the federal funds, 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 offers the best liquidity and safety, IOER arbitrage based on unsecured funding is a textbook version of risk-free arbitrage. The main reason banks do not scale up this trade to infinity and arbitrage away the profits is that such arbitrage positions expand the size of banks' balance sheets and make the Basel III leverage ratio requirement more binding. Additionally, non-depository institutions either do not earn IOER on their reserve balances or cannot hold reserve balances at the Federal Reserve, and therefore cannot engage in this arbitrage. These features led to a consistently positive profit for IOER arbitrage during our sample period.

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 the k-th unsecured funding instrument 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 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 excess reserve balances held at the Federal Reserve by bank i at time t. IOER arbitrage is limited by both the amount of funding obtained at a rate less than IOER and the amount actually earning IOER.

4.2 CIP Arbitrage

Second, banks can engage in CIP arbitrage by raising unsecured dollar wholesale funding, and then lending dollars in the FX forward/swap markets, thereby earning any deviation in CIP. As shown in Du et al. (2018), there are large and persistent CIP deviations for all G10 currencies versus the U.S. dollar. For low-nominal-interest rate currencies (such as the euro, Japanese yen, and Swiss franc), there are risk-free arbitrage profits when borrowing dollars in cash markets, investing in foreign currencies, and hedging the foreign currency 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 reason is that the dollar-yen is one of the most liquid FX currency pairs, and banks and real-money investors (e.g., pension funds and life insurance companies) in Japan have 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:

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

Similarly to the IOER arbitrage, we can also create a proxy for CIP arbitrage positions. We only have balance sheet information for U.S.-based bank branches; however, the investing leg of the CIP arbitrage would generally show up on the balance sheets of foreign affiliates. Therefore, the most closely related information we have is the net positions that the U.S.-based branches have vis-a-vis their foreign affiliates. In other words, in order to do CIP arbitrage, a U.S.-based branch of a foreign bank needs to send dollars to their foreign affiliates abroad, resulting in a positive due-from position. From the FR 2644 report, we can observe firms' net-due-to positions. In addition, we can refine this measure by adjusting for ED positions. Since the bulk of the ED positions we observe from the FR 2420 report are funded offshore and transferred to the U.S. branches in order to park the cash at the Federal Reserve for IOER arbitrage, we adjust the net-due-to positions by the outstanding ED amounts to better proxy for dollar lending from U.S.-based branches to their foreign affiliates. Our proxy for CIP arbitrage positions is therefore:

$$Q_{i,t}^{CIP} = -(NetDueTo_{i,t} - Y_{i,t}^{ED}),$$

where $NetDueTo_{i,t}$ is the net borrowing from foreign affiliates and $Y_{i,t}^{ED}$ is the outstanding ED amount from the FR 2420 report for bank i at time t. We note that $Q_{i,t}^{CIP}$ is a very coarse measure for the actual CIP arbitrage positions, but it nevertheless contains information on global banks' dollar intermediation activities from U.S. to foreign offices.

5 Effects of the MMF Reform on Global Banks

5.1 Methodology

We run baseline OLS regressions of changes in bank i's unsecured funding activity ($\Delta Y_{i,t}$) on changes in prime funds' holdings of bank i's unsecured debt securities ($\Delta hold_{i,t}^{Unsec}$),

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

We focus on the changes between October 2015 and October 2016 to capture effects over the 1-year reform implementation period prior to the implementation deadline. To increase the power of our regressions and to 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 both by 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 $\Delta hold_{i,t}^{Unsec}$:

$$B_{i,t} = \sum_j s_{i,j,t-1} \Delta aum_{j,t}.$$

where $s_{i,j,t-1}$ 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 j.

We define the lagged bank share as of June 30, 2014, just before the MMF reform was announced in July. We construct the Bartik instrument at the fund complex level rather than the individual fund level to ensure the exogeneity of the instrument. It is less likely that bank demand is driving changes in the total AUM of all prime funds in a complex. Moreover, in order to not abstract from from intra-complex flows between prime and government funds as a result of the MMF reform, we consider only prime funds within a complex rather than all funds. Lastly, we refine the Bartik instrument by leaving out the changes of complex j's AUM held in securities issued by bank i ($\Delta aum_{i,j,t}$) to further ensure exogeneity:

$$\tilde{B}_{i,t} = \sum_j s_{i,j,t-1}(\Delta aum_{j,t} - \Delta aum_{i,j,t}). \tag{3}$$

Given that bank i's share in complex j's AUM is quite persistent, $\tilde{B}_{i,t}$ is a strong instrument. Figure 5 plots $\Delta hold_{i,t}^{Unsec}$ on the horizontal axis and, on the vertical axis, the fitted value from the first-stage regression:

$$\Delta hold_{i,t}^{Unsec} = \gamma + \delta \tilde{B}_{i,t} + \epsilon_{i,t}.$$

The correlation between the predicted loss of funding and actual loss of funding is 67%.[5] For $\tilde{B}$ to be an exogenous instrument, the key identifying assumption is that changes in the total prime funds' AUM of complex j are independent of funding demand shocks of individual bank i.

In addition to estimating the average effects using all sample banks, we also explore heterogeneous responses to the reform depending on banks' business models. We divide our sample banks into two groups based on 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 with above

[5]Our results are largely similar if we use annual changes from October 2015 to October 2016, instead of quarterly changes. With annual changes, the correlation in the first-stage increases to 86%.

median correlation as "IOER arbitrageurs" and banks with below median correlation as "non-IOER arbitrageurs". We report our results separately for these two types of banks.

5.2 Arbitrage Capital and Arbitrage Positions

In this section, we show that, even though banks were able to substitute some of their lost funding from MMFs with borrowing from other non-MMF counterparties, the MMF reform significantly reduced the amount of potential arbitrage capital and proxies for arbitrage positions for the IOER and CIP arbitrages.

Before presenting formal regression results, we first present some stylized facts on potential arbitrage capital. First, almost every unsecured dollar raised by our sample banks can potentially be used for either IOER or CIP arbitrage. Panel A of Figure 6 plots unsecured wholesale funding outstanding. The red area indicates funding issued at rates below the IOER rate; in other words, potential arbitrage capital for IOER arbitrage. Funding issued above the IOER rate, but below the swapped yen rate in dollars is shown as the yellow area. The sum of the red and the yellow areas indicates potential arbitrage capital for CIP arbitrage. The blue area indicates funding issued above the swapped yen rate in dollars, which is therefore not usable for either arbitrage. More than 95% of short-term unsecured wholesale funding outstanding from our sample banks can be used for IOER or CIP arbitrage. Similarly, Panel B of Figure 6 plots MMFs' unsecured holdings, broken down by rates. Virtually the entire supply of unsecured wholesale funding from MMFs can be used for either IOER or CIP arbitrage.

Second, MMFs are an important supplier of potential arbitrage capital to banks, but their importance significantly declined after the MMF reform. In October 2015, the total potential arbitrage capital for the IOER and CIP arbitrages combined was around $1.6 trillion, of which about $1 trillion was borrowed from MMFs. After the MMF reform in October 2016, the total potential capital fell to about $1.3 trillion, with funding from

MMFs only comprising 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 a quarter.

We now turn to our formal cross-sectional regressions. Panel A of Table 1 shows regression results for changes in both the potential arbitrage capital and proxies for arbitrage positions over the reform implementation period for all sample banks. The OLS estimates are presented at the top of the panel and the IV estimates are presented at the bottom. Column 1 shows that a \$1 billion loss in funding from MMFs led to a \$0.6 billion loss in potential arbitrage capital for IOER arbitrage. The estimates are quite similar for both the OLS and IV specifications. For the CIP arbitrage, in Column 2, a \$1 billion loss in funding from MMFs led to about a \$0.8 billion reduction in the potential arbitrage capital based on the OLS estimate and almost a \$0.7 billion reduction based on the IV estimate.

We also obtain significantly positive coefficients when using proxies of arbitrage positions. As shown in Column 3, a \$1 billion loss in funding from MMFs led to a decline in the IOER arbitrage position of about \$0.6 billion. In Column 4, we show that a \$1 billion loss in funding from MMFs led to a \$0.3-\$0.4 billion loss in our proxy for CIP arbitrage positions. In summary, we show that the MMF reform significantly reduced the amounts of arbitrage capital and proxies for arbitrage positions for our sample banks, on average.

Panels B and C show regression results for IOER arbitrageurs and non-IOER arbitrageurs, respectively. We generally find stronger results for IOER arbitrageurs than for non-IOER arbitrageurs. For IOER arbitrage, IOER arbitrageurs reduced their potential arbitrage capital (Column 1) and their arbitrage positions (Column 3) almost one-for-one in response to the loss of unsecured funding from prime funds, whereas non-IOER arbitrageurs only reduced their arbitrage capital and arbitrage positions by about \$0.4 in response to a \$1 loss of funding from prime funds. For the CIP arbitrage, the response of potential arbitrage capital (Column 2) is also slightly weaker for non-IOER arbitrageurs relative to IOER arbitrageurs. However, the magnitude of the response of the proxy for CIP arbitrage positions (Column 4) is similar across the two groups. It is plausible that some banks classified as non-IOER arbitrageurs actively engage in CIP arbitrage activities.

5.3 Composition of Assets

In addition to studying the effect of the large funding shock due to the MMF reform on potential arbitrage capital and arbitrage positions, we also examine the effects on the size and composition of bank assets. The traditional bank lending channel suggests that a large reduction in the credit supply to banks would result in reductions in loan provision by banks. Ivashina et al. (2015) and Correa et al. (2016) find supporting evidence for the traditional bank lending channel using the funding shock from MMFs during the European Debt Crisis. However, contrary to the traditional bank lending channel, we find that banks' loan provision and securities holdings were little changed in response to the reform.

Table 2 presents results on total assets, loans, securities, and cash positions for all sample banks, IOER arbitrageurs, and non-IOER arbitrageurs, respectively. Panel A presents the results for all sample banks. Based on the IV estimates, the effect of the reform on banks' assets was quite limited. Only the cash position enters the regression significantly, which is unsurprising given that reserves are a large part of banks' cash positions.

Panel B of Table 2 shows that, for IOER arbitrageurs, the MMF reform led to a broad deleveraging. Based on the IV estimate, total assets fell by about \$0.6 billion in response to a \$1 billion loss in MMF funding. The reduction in cash explains most of the decline in total assets, while loan and securities positions were little changed.

In contrast, as shown in Panel C, non-IOER arbitrageurs did not exhibit a significant contraction in total assets as a result of the MMF reform. Cash positions declined by about \$0.3 billion in response to a \$1 billion loss in MMF funding. Loan and securities positions were not significantly affected by the reform.

Taken together, these results do not support 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.

5.4 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 funding obtained from MMFs from October 2015 to October 2016.[6] In order to ensure that our pricing data comprise only transactions at market rates, we discard transactions at rates below 5 basis points.[7]

As equilibrium funding costs are affected by both the supply of and demand for funding, OLS regression estimates may suffer from simultaneity bias. To mitigate concerns about such bias, we provide, as before, IV estimates in addition to OLS estimates, using the Bartik instrument specified in Equation (3).

As shown in Column (1) of Table 3, the loss of unsecured funding from MMFs led to an increase in banks' funding costs in the cross section. Specifically, a \$10 billion reduction in unsecured funding from MMFs is associated with a 2 basis point increase in a bank's funding rate relative to the funding rate of a bank without any funding loss. Although

[6] 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.

[7] There are some very low-rate trades in the data that represent intrabank 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 represented the offering rate on the overnight reverse repurchase agreement facility by the Federal Reserve and therefore the minimum rate at which 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.

this figure may seem small at first, it is economically meaningful given the extremely low level of rates during our sample period.

Columns (2) and (3) of Table 3 report the analogous results separately for IOER arbitrageurs and non-IOER arbitrageurs. We find that IOER arbitrageurs do not have a statistically significant relationship between changes in the funding they obtain from MMFs and their cost of borrowing. In contrast, for non-IOER arbitrageurs, both OLS and IV estimates are statistically significant. We find that non-IOER arbitrageurs' cost of funding increases by about 4 basis points for a $10 billion decline in unsecured funding. One interpretation for these results is that non-IOER arbitrageurs have a steeper demand curve for dollar wholesale funding than the IOER arbitrageurs. Given a large reduction in the supply of funding from MMFs, non-IOER arbitrageurs have to obtain sufficient funding at higher costs to maintain their business activities, while the IOER arbitrageurs can scale down their arbitrage activities more easily without incurring a large increase in funding costs.

5.5 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 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 the quarter-end, 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 7 plots MMFs' total holdings of secured (repo) and unsecured instruments issued by our sample banks. The yellow dashed lines indicates 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 7 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 line in Panel 1b shows the ratio of the unsecured quarter-end effects (red bar) to the total quarter-end effects (sum of the red and blue bars) over time. Overall, the 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 total unsecured and secured wholesale funding outstanding, rather than just that held by MMFs. Since we are not limited to just month-ends here, we calculate the quarter-end effect as the difference between the outstanding amount on the quarter-end date t, and the average outstanding amounts 2 weeks before and after the quarter-end ($t - 14$ and $t + 14$). Since we only have good coverage for euro-dollars starting in October 2015, the quarter-end effects can be calculated only starting in 2015Q4. Despite the short time series, we can still see 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.

6 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 that supply shocks to the 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 (after October 2016).

One important caveat to note is that the aggregate amount of arbitrage capital we capture in our data is part of the total arbitrage capital for these arbitrage strategies globally. This is because we do not observe euro-dollar positions done by 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 for non-banks, such as real-money investors. Nevertheless, since global banks still lie at the center of global capital markets and that the U.S. market is still the most important wholesale funding markets for dollar funding, we are capturing a significant part global arbitrage activities for the IOER and CIP arbitrage.

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 8 plots the IOER profit together 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.

We now run regressions of daily changes in the average arbitrage profits (in basis points) on the daily changes in the arbitrage capital (in billions of dollars) for IOER arbitrage:

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

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

Table 4 shows the regression results for IOER arbitrage. The results in Panel A are based on potential arbitrage capital, Y_t^{IOER}, as defined in equation (1). Column (1) reports 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 interactive term between the potential arbitrage capital is negative and statistically significant, which suggests the relationship between arbitrage profits and potential arbitrage capital became more negative 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 a roughly 0.8 basis point increase in arbitrage profits. This elasticity is significantly more negative after the reform, with a \$10 billion reduction in arbitrage capital translating into a 2 basis point increase in arbitrage profits on month-ends. Columns (3) and (4) show that the price elasticity is particularly large in magnitude for non-quarter-end month-ends relative to quarter-ends. In particular, over the reform implementation period, a \$10 billion reduction in arbitrage capital is associated with a 0.7 basis point increase in arbitrage profits on quarter-ends, but a 2.2 basis point increase in arbitrage profits on non-quarter-end month-ends. The estimates on both quarter-ends and non-quarter-end month-ends also became more negative after the reform implementation.

Banks may employ primarily overnight borrowing to fund their IOER arbitrage position, while using term funding for other purposes. In this case, running the IOER arbitrage regressions using a potential arbitrage capital measure, Y_t^{IOER}, that excludes any wholesale funding with a maturity other than overnight would produce stronger results than those presented in Panel A. If banks, however, use both overnight and term funding for IOER arbitrage, the results will be very similar to those presented above. The estimates in Panel B are slightly smaller than in Panel A, which is more consistent with the notion that both overnight and term borrowing is employed to fund IOER arbitrage positions.

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. We also calculate tenor-specific arbitrage capital by summing up all potential arbitrage capital with an issuance maturity less than or equal to the tenor of the arbitrage profit. After constructing these profit and quantity measures, we perform a similar regression as in equation (4):

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

Table 5 presents regression results for the CIP arbitrage profit. 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. The coefficient on the interaction term between the post reform dummy and arbitrage capital is not statistically significant, suggesting that the relationship does not get stronger after implementation. For the three-month CIP arbitrage profit, Columns 5 and 6 show that a \$100 billion reduction in arbitrage capital is associated with a 3 basis point increase in the arbitrage profit for contracts that do not cross the year-end, and a 9 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 profit and arbitrage capital over the reform implementation period. The relationship is stronger for contracts that cross regulatory reporting dates. For IOER arbitrage, we also find that the negative relationship is strengthened in the post-reform period.

7 Conclusion

We document a sizable new business activity for global banks after the global financial crisis: use short-term wholesale funding to finance risk-free arbitrage positions. Under this new business model, in response to the large negative funding cost induced by the SEC MMF reform in 2016, we find that global banks primarily scale down their arbitrage activities, without reducing their loan provision.

These results highlight a significant transformation of the role of wholesale funding in global banks' business operations post crisis. Consistent with the vision of the Basel III liquidity regulations, a large part of short-term wholesale funding has been used to finance liquid asset positions, which makes global banks more resilient to wholesale funding dry-ups.

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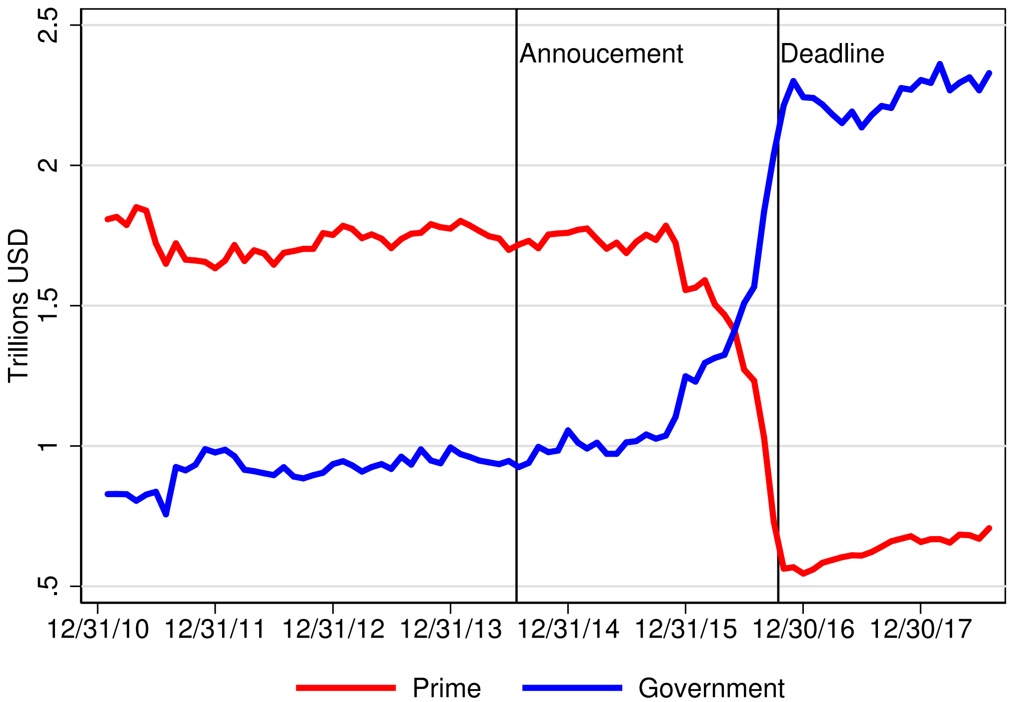
Appendix

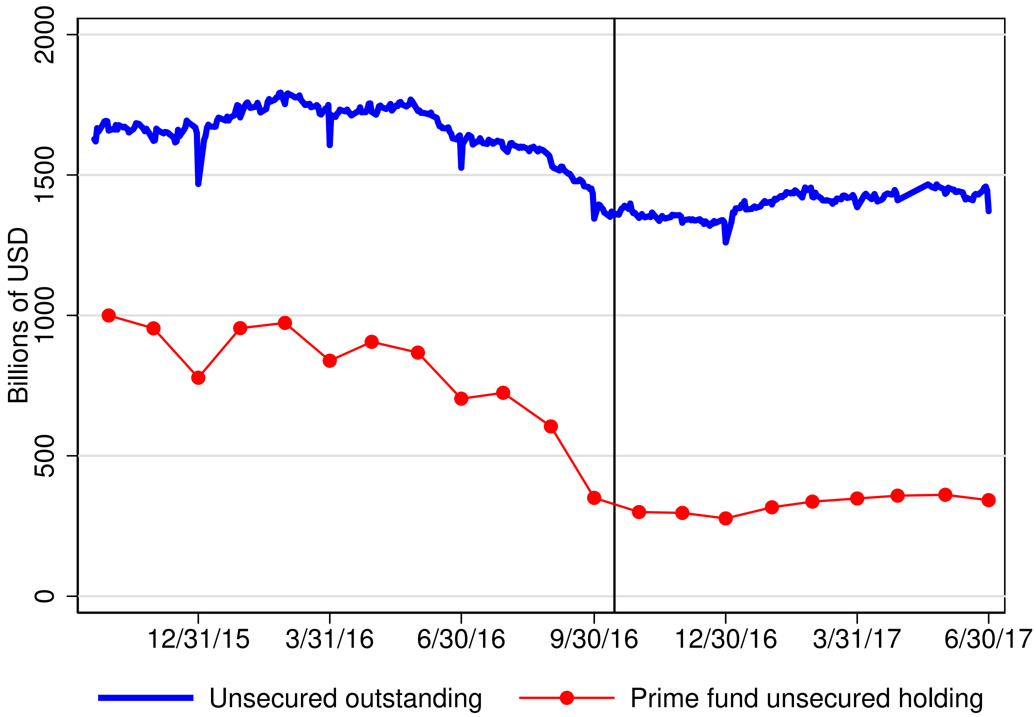
Appendix A Bartik-Style Shift-Share Instrument

Figure 1: Assets under management by MMF type



This figure plots total assets under management of prime (red) and government (blue) MMFs in the United States in trillions of dollars. The two vertical black lines denote the MMF reform announcement date on July 23, 2014 and the implementation deadline on October 14, 2016, respectively.
Sources: N-MFP (public)

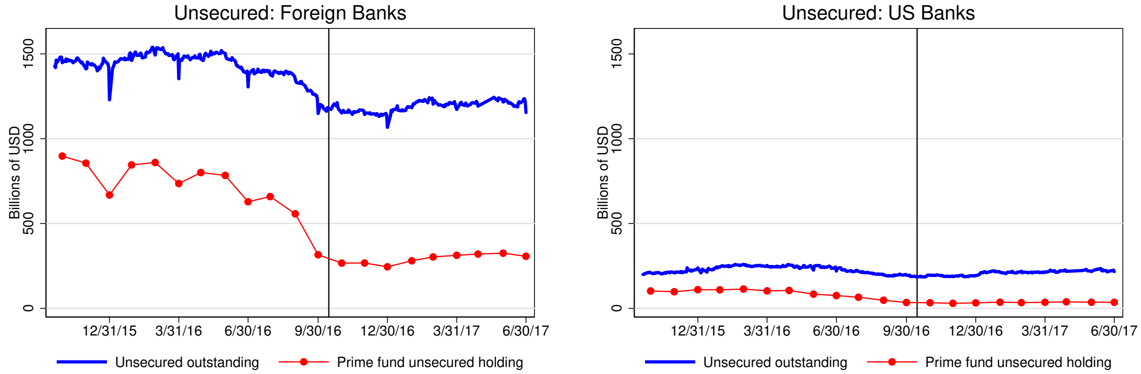
Figure 2: Unsecured wholesale funding outstanding and MMF holdings



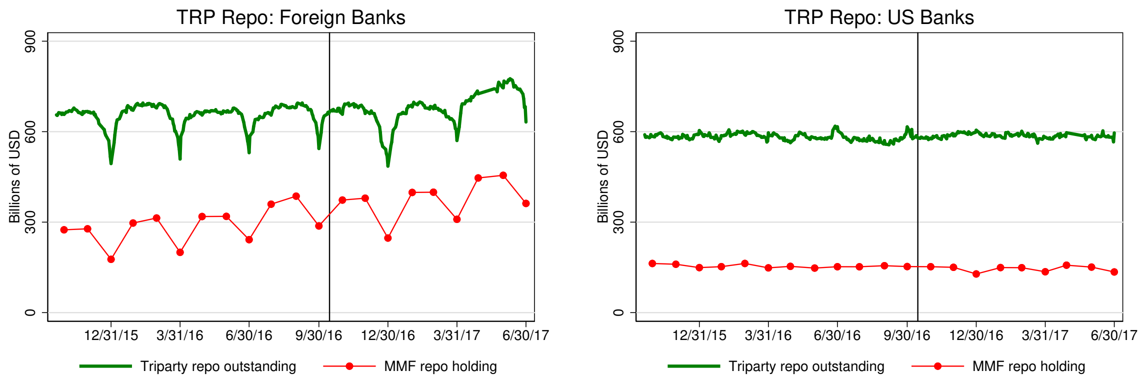
This figure plots total unsecured wholesale funding outstanding (blue) and the amount held by prime MMFs (red) in billions of dollars. The vertical line denotes the MMF reform implementation deadline on October 14, 2016.
Sources: N-MFP (public), FR 2420, DTCC CP

Figure 3: Wholesale funding outstanding and MMF holdings by region

(A) Unsecured funding



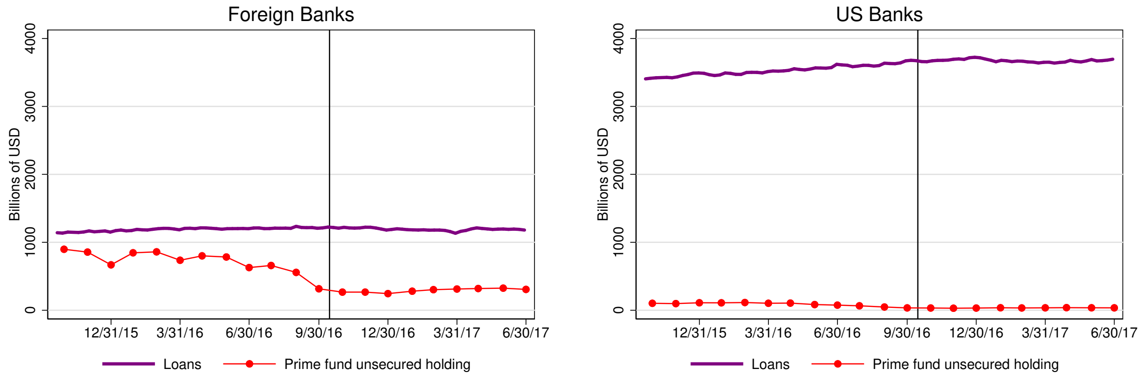
(B) Secured funding (repo)



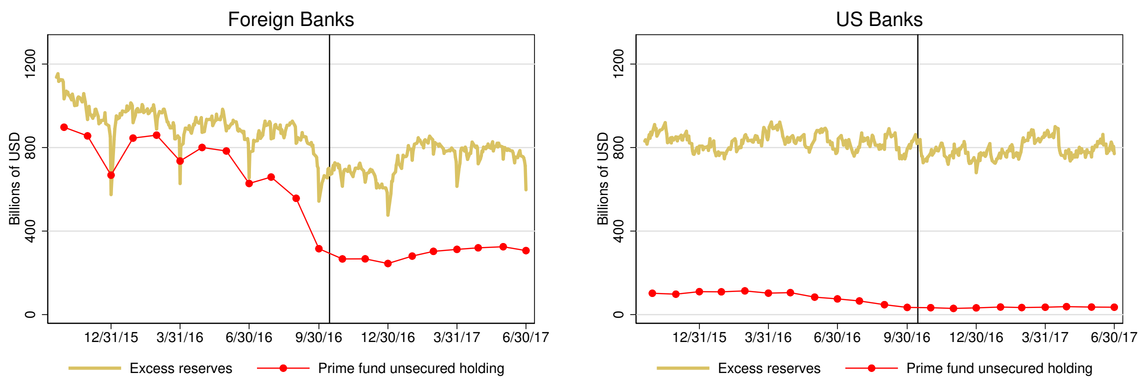
This exhibit plots total wholesale funding outstanding, together with MMF holdings, broken down by foreign (left column) and U.S. (right column) banks. Panel A plots total unsecured wholesale funding outstanding (blue) and prime MMFs' unsecured holdings (red). Panel B plots secured funding outstanding (green), specifically total tri-party repo, and prime MMFs' repo holdings (red). The vertical line in all figures denotes the MMF reform implementation deadline on October 14, 2016.
Sources: N-MFP (public), DTCC CP, FR 2420, FRBNY tri-party repo

Figure 4: Assets and MMF holdings by region

(A) Loans

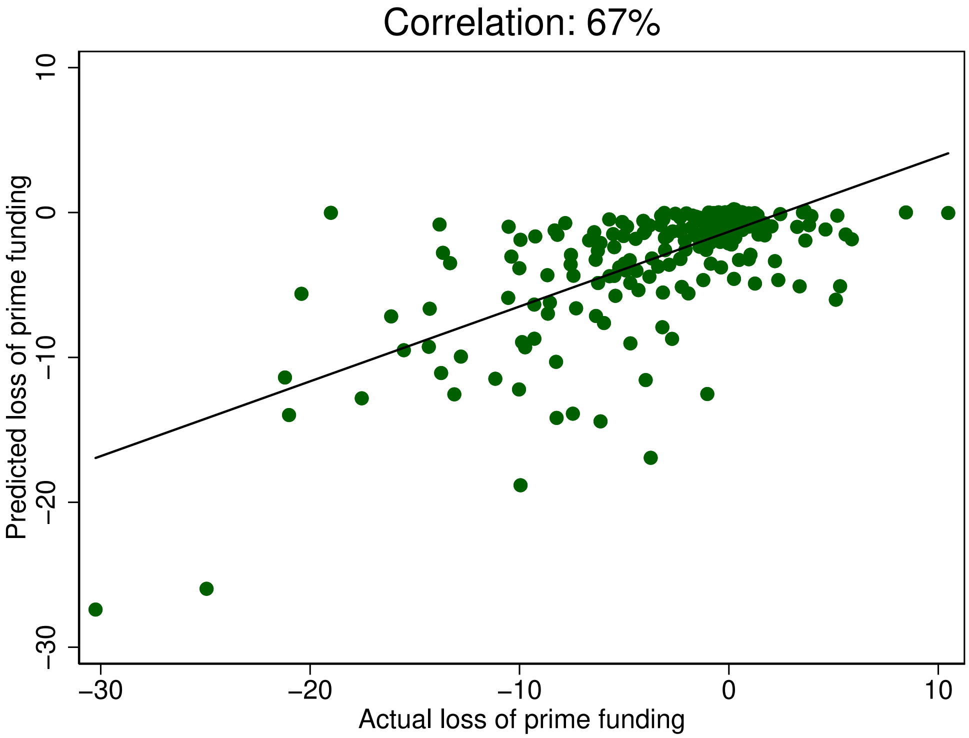


(B) Reserve balances



This exhibit plots bank assets, specifically total loans and reserve balances, together 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' unsecured holdings (red). Panel B plots total excess reserve balances held at the Federal Reserve (yellow) and prime MMFs' unsecured holdings (red). The vertical line in all figures denotes the MMF reform implementation deadline on October 14, 2016.
Sources: N-MFP (public), FR 2644, FRB reserves data

Figure 5: First-stage of the IV regression



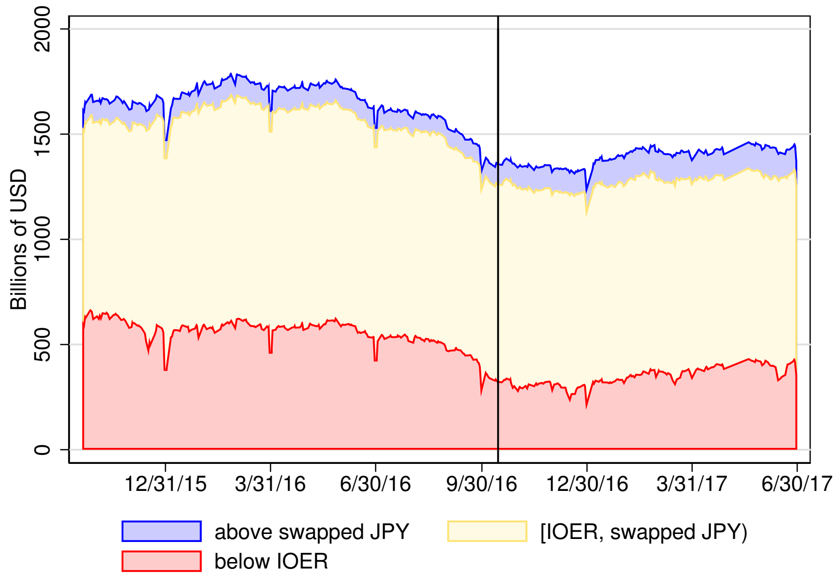
This figure plots the change in prime MMF funding on the horizontal axis and the predicted value of the change in prime MMF funding from the first-stage regression:

$$\Delta hold_{i,t}^{Unsec} = \gamma + \delta \tilde{B}_{i,t} + \epsilon_{i,t}$$

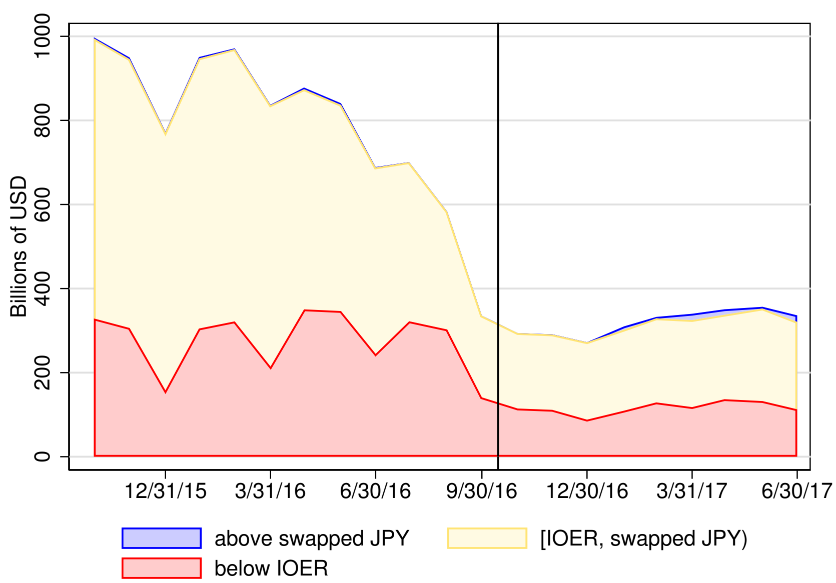
on the vertical axis. The correlation between the predicted loss of funding and actual loss of funding is 67%. All changes are quarterly at the bank level, and the sample period is October 2015 to October 2016.
Sources: N-MFP (public)

Figure 6: Potential arbitrage capital

(A) Unsecured borrowing by rate



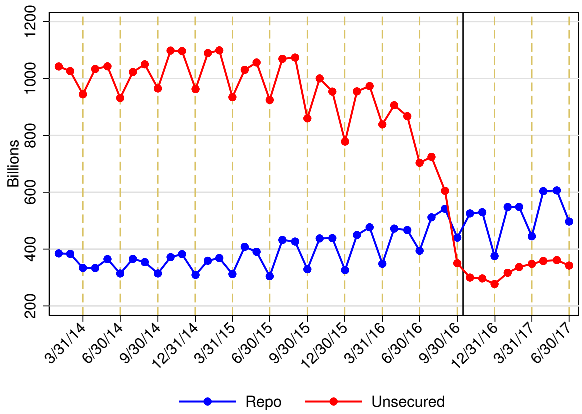
(B) MMF unsecured holdings by rate



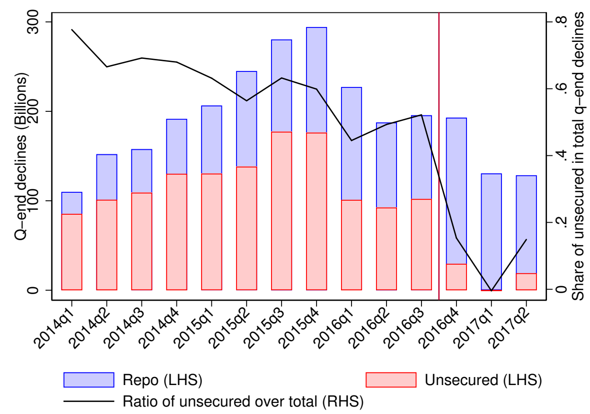
This figure shows the potential arbitrage capital, both in aggregate and held by MMFs. Panel A plots unsecured wholesale funding outstanding broken down by rate. Panel B plots prime MMFs' unsecured holdings broken down by rate. The red area denotes outstanding amounts with an issuance rate below the 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.
Sources: N-MFP (public), FR 2420, DTCC CP, Bloomberg

Figure 7: Quarter-end effects in secured and unsecured funding

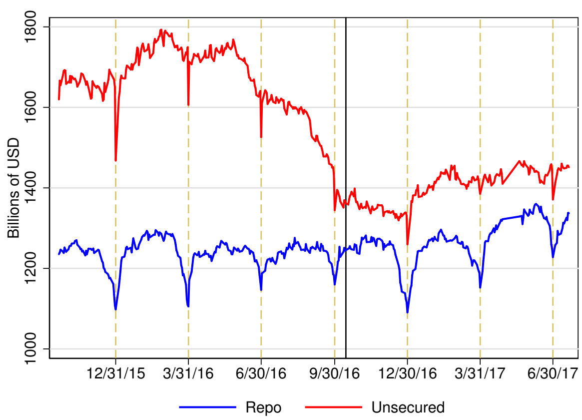
(1a) MMF holdings



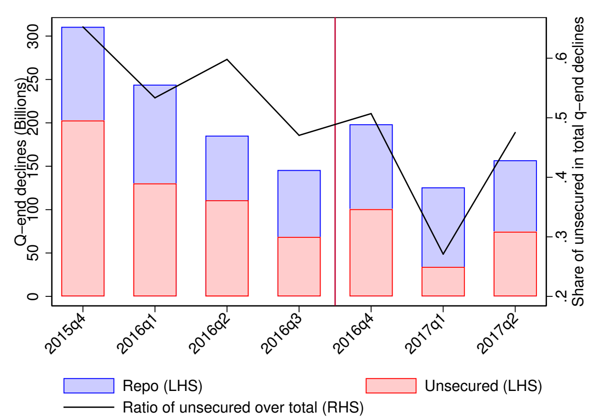
(1b) Quarter-end effects in MMF holdings



(2a) Total outstanding



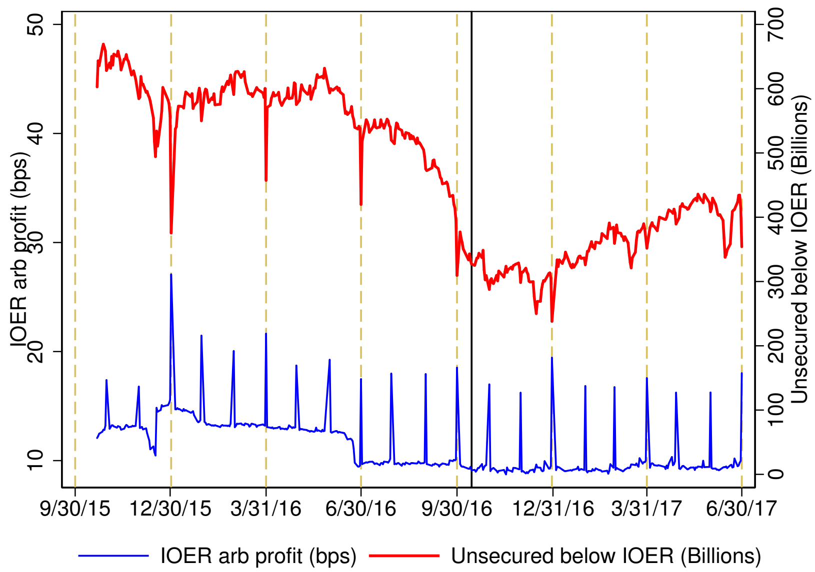
(2b) Quarter-end effects in total outstanding



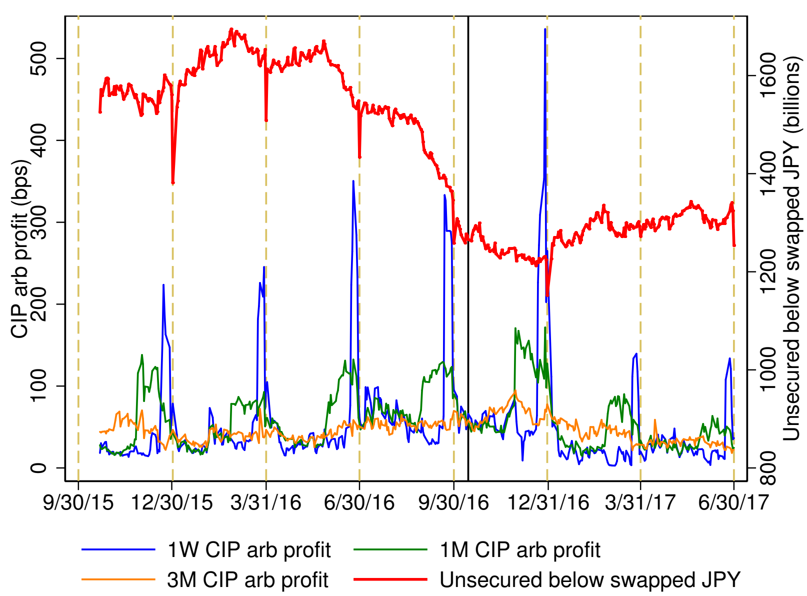
This figure illustrates the quarter-end effects in MMF holdings and total debt outstanding for both secured (repo) and unsecured wholesale funding instruments. Panel 1a plots total MMF holdings of repo securities (blue) and unsecured securities (red) issued by our sample banks. Panel 1b plots the quarter-end 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) debt outstanding, as well as the ratio of the unsecured quarter-end effect to the total quarter-end effect (black line). See Section 5.5 for details on how the quarter-end effects are constructed.
Sources: N-MFP (public), FR 2420, DTCC CP, FRBNY tri-party repo data

Figure 8: Volume-weighed average arbitrage profits

(A) IOER arbitrage profit



(B) CIP arbitrage profit



The 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 CP, and Bloomberg

Table 1: Regression results 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) $\Delta Q_{i,t}^{CIP}$
(A) All banks				
OLS estimates				
$\Delta hold_{i,t}^{Unsec}$	0.629***	0.845***	0.595***	0.449***
	(0.114)	(0.087)	(0.112)	(0.097)
IV estimates				
$\Delta hold_{i,t}^{Unsec}$	0.616***	0.665***	0.561***	0.359***
	(0.111)	(0.098)	(0.095)	(0.139)
Obs.	247	247	247	195
(B) IOER arbitrageurs				
OLS estimates				
$\Delta hold_{i,t}^{Unsec}$	0.869***	0.971***	0.849***	0.326**
	(0.146)	(0.130)	(0.139)	(0.119)
IV estimates				
$\Delta hold_{i,t}^{Unsec}$	1.034***	0.879***	0.875***	0.315
	(0.265)	(0.268)	(0.227)	(0.338)
Obs.	131	131	131	95
(C) Non-IOER arbitrageurs				
OLS estimates				
$\Delta hold_{i,t}^{Unsec}$	0.340***	0.732***	0.311***	0.561***
	(0.093)	(0.066)	(0.083)	(0.135)
IV estimates				
$\Delta hold_{i,t}^{Unsec}$	0.477***	0.581***	0.460***	0.353**
	(0.087)	(0.066)	(0.073)	(0.139)
Obs.	116	116	116	100

This table shows regression results of changes in potential arbitrage capital and proxies for arbitrage positions on changes in MMF holdings of unsecured bank securities. The first row of each panel shows the OLS estimates and the second row shows the IV estimates using the Bartik instrument defined by equation (3). The sample includes all banks in Panel A, IOER arbitrageurs in Panel B, and non-IOER arbitrageurs in Panel C. IOER (non-IOER) arbitrageurs are defined as banks with above (below) median correlations between daily changes in unsecured funding and daily changes in reserve balances. The dependent variables are: $\Delta Y_{i,t}^{IOER}$ is the change in the potential IOER arbitrage capital, $\Delta Y_{i,t}^{CIP}$ is the change in the potential CIP arbitrage capital, $\Delta Q_{i,t}^{IOER}$ is the change in the proxy for the IOER arbitrage position, and $\Delta Q_{i,t}^{CIP}$ is the change in the proxy for the CIP arbitrage position. The independent variable, $\Delta hold_{i,t}^{Unsec}$, is the change in MMF holdings of unsecured debt issued by bank i. 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 2: Regression results for the composition of assets

	(1) $\Delta Assets_{i,t}$	(2) $\Delta Loan_{i,t}$	(3) $\Delta Securities_{i,t}$	(4) $\Delta Cash_{i,t}$
		(A) All banks		
		OLS estimates		
$\Delta hold_{i,t}^{Unsec}$	0.483***	-0.053	-0.080	0.565***
	(0.171)	(0.072)	(0.071)	(0.132)
		IV estimates		
$\Delta hold_{i,t}^{Unsec}$	-0.131	-0.242	-0.209	0.359*
	(0.371)	(0.194)	(0.165)	(0.191)
Obs.	195	195	195	195
		(B) IOER arbitrageurs		
		OLS estimates		
$\Delta hold_{i,t}^{Unsec}$	0.860***	0.0227	-0.0179	0.869***
	(0.145)	(0.0268)	(0.0240)	(0.160)
		IV estimates		
$\Delta hold_{i,t}^{Unsec}$	0.607***	0.005	-0.014	0.647***
	(0.236)	(0.078)	(0.036)	(0.244)
Obs.	95	95	95	95
		(C) Non-IOER arbitrageurs		
		OLS estimates		
$\Delta hold_{i,t}^{Unsec}$	0.166	-0.0951	-0.151	0.315**
	(0.241)	(0.139)	(0.168)	(0.134)
		IV estimates		
$\Delta hold_{i,t}^{Unsec}$	-0.138	-0.225	-0.191	0.324*
	(0.418)	(0.219)	(0.184)	(0.191)
Obs.	100	100	100	100

This table shows regression results of changes in the composition of banks' assets on changes in MMF holdings of unsecured bank securities. The first row of each panel shows the OLS estimates and the second row shows the IV estimates using the Bartik instrument defined by equation (3). The sample includes all banks in Panel A, IOER arbitrageurs in Panel B, and non-IOER arbitrageurs in Panel C. IOER (non-IOER) arbitrageurs are defined as banks with above (below) median correlations between daily changes in unsecured funding and daily changes in reserve balances. The dependent variables are banks' total assets, loans, securities, and cash based on FR 2644 data. The independent variable, $\Delta hold_{i,t}^{Unsec}$, is the change in MMF holdings of unsecured debt issued by bank i. 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 3: Regression results for funding costs

	(1) All banks	(2) IOER arbitrageurs	(3) Non-IOER arbitrageurs
	OLS estimates		
$\Delta hold_i^{Unsec}$	-0.215*	0.052	-0.393**
	(0.126)	(0.139)	(0.185)
	IV estimates		
$\Delta hold_i^{Unsec}$	-0.277**	-0.025	-0.402**
	(0.122)	(0.154)	(0.175)
Tenor FE	Yes	Yes	Yes
Obs.	268	135	133

This table shows cross-sectional regression results of changes in bank i's funding rates on changes in MMF holdings of unsecured bank securities. The first row shows the OLS estimates and the second row shows the IV estimates using the Bartik instrument defined by equation (3). The sample includes all banks in Column (1), IOER arbitrageurs in Column (2), and non-IOER arbitrageurs in Column (3). IOER (non-IOER) arbitrageurs are defined as banks with above (below) median correlations between daily changes in unsecured funding and daily changes in reserve balances. The dependent variable, $\Delta r_{i,m}$, is the change in bank i's funding rate for tenor m, which is obtained 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, $\Delta hold_i^{Unsec}$, is the change in MMF holdings of unsecured debt issued by bank i. All specifications include tenor fixed effects. Standard errors clustered at the bank level. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table 4: Regression results for IOER arbitrage profits

	(1) $\Delta\pi_t^{IOER}$ Non-ME	(2) $\Delta\pi_t^{IOER}$ ME	(3) $\Delta\pi_t^{IOER}$ QE	(4) $\Delta\pi_t^{IOER}$ Non-QE ME
Panel A: Total IOER arbitrage capital				
ΔY_t^{IOER}	0.007	-0.083***	-0.073***	-0.219***
	(0.005)	(0.006)	(0.003)	(0.027)
$\Delta Y_t^{IOER} \times Post_t$	-0.014**	-0.116***	-0.081***	-0.220***
	(0.006)	(0.031)	(0.013)	(0.040)
$Post_t$	0.0223	0.469	1.201	0.0461
	(0.032)	(1.379)	(1.374)	(1.141)
Obs.	371	40	13	27
R^2	0.063	0.702	0.946	0.799
Panel B: Only overnight IOER arbitrage capital				
ΔY_t^{IOER}	0.002	-0.061***	-0.055***	-0.176***
	(0.002)	(0.008)	(0.006)	(0.024)
$\Delta Y_t^{IOER} \times Post_t$	-0.010***	-0.047**	-0.036***	-0.276***
	(0.003)	(0.021)	(0.011)	(0.067)
$Post_t$	0.026	1.016	2.169	-0.187
	(0.031)	(1.740)	(2.200)	(1.618)
Obs.	358	40	13	27
R^2	0.028	0.530	0.815	0.627

This table shows regression results of daily changes in the average IOER arbitrage profit on daily changes in the potential arbitrage capital. In Panel A, ΔY_t^{IOER} is the change in the aggregate potential arbitrage capital for the IOER arbitrage; in Panel B, ΔY_t^{IOER} is the change in the aggregate potential *overnight* arbitrage capital, where potential arbitrage capital with tenors other than "overnight" is excluded in the computation of Y_t^{IOER}. $Post_t$ is equal to one after October 14, 2016 and zero otherwise. $\Delta\pi_t^{IOER}$ is the IOER arbitrage profit. 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). The sample period is from October 2015 to June 2017. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.

Table 5: Regression results for CIP arbitrage profits

	(1) $\Delta\pi^{CIP}_{1W,t}$ Non-QE	(2) $\Delta\pi^{CIP}_{1W,t}$ QE	(3) $\Delta\pi^{CIP}_{1M,t}$ Non-QE	(4) $\Delta\pi^{CIP}_{1M,t}$ QE	(5) $\Delta\pi^{CIP}_{3M,t}$ Non-YE	(6) $\Delta\pi^{CIP}_{3M,t}$ YE
$\Delta Y^{CIP}_{n,t}$	-0.057	-0.701	-0.030*	-0.305**	-0.034***	-0.094***
	(0.047)	(1.023)	(0.016)	(0.127)	(0.011)	(0.034)
$\Delta Y^{CIP}_{n,t} \times Post_t$	-0.342	-2.181	-0.178	0.315	-0.050	0.066
	(0.334)	(2.754)	(0.129)	(0.203)	(0.042)	(0.093)
$Post_t$	-1.469	11.300	-0.545	0.187	-0.558	0.443
	(2.996)	(24.770)	(1.304)	(2.744)	(0.747)	(1.175)
Obs.	375	36	259	152	305	106
R^2	0.022	0.033	0.049	0.031	0.030	0.057

This table shows regression results of daily changes in the average CIP arbitrage profit on daily changes in the potential arbitrage capital. $\Delta Y^{CIP}_{n,t}$ is the change in the aggregate potential arbitrage capital for the CIP arbitrage. $Post_t$ is equal to one after October 14, 2016 and zero otherwise. The dependent variables are as follows: $\Delta\pi^{CIP}_{1W,t}$ is the 1-week CIP arbitrage profit, $\Delta\pi^{CIP}_{1M,t}$ is the 1-month CIP arbitrage profit, and $\Delta\pi^{CIP}_{3M,t}$ is the 3-month CIP arbitrage profit. 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. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10.