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Interest on Reserves and Arbitrage in Post-Crisis Money Markets

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ABSTRACT

Currently, Eurodollars and fed funds markets combined trade about $220 billion in funds daily, the vast majority of which with overnight tenor. In this paper, we document several features of these wholesale unsecured dollar funding markets. Using daily confidential data on wholesale unsecured borrowing and reserve balances, we show that foreign banks, which make up most of the trading volumes in these markets, keep around 99% of each additional Eurodollar and 80% of each fed fund borrowed as reserve balances. With these risk-free trades, banks earn the spread between interest on reserves and the borrowing rate. Relative to foreign banks, large domestic institutions borrow less often, but when they do, they keep around 99% of each additional Eurodollar or fed fund raised as reserves. Small domestic banks do not display any correlation between net borrowing and their reserves accumulation. We also discuss how regulatory costs affect trading patterns and interest rate differentials in wholesale dollar funding markets.

JEL Classification: E43, E52, G21.

Keywords: Interest on reserves, Arbitrage, Monetary policy, Fed funds, Eurodollars.

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1. Introduction

The set of liquidity injections put in place by the Federal Reserve to fight the financial crisis created, as a by-product, a large amount of excess reserves. The abundance of excess reserves, in turn, pushed the effective fed funds rate below its target (Bech and Klee (2011)) and in order to set a floor for the effective fed funds rate, the Federal Reserve started to pay interest on reserves (IOR). Many cash lenders that participate in money markets are not banks, and therefore are not eligible to earn IOR; as a result, they are willing to lend overnight wholesale funds at rates below IOR. This segmentation creates an opportunity for banks to borrow overnight wholesale funds to keep as reserve balances, earning the positive spread between IOR and the overnight funding rate. As these trades involve no credit or interest rate risk for the borrowing bank, we call these trades "IOR arbitrage trades".[2]

In this paper, we use confidential, daily data to empirically document several salient features of IOR arbitrage trades. We show that such arbitrage trades are concentrated at institutions that are subject to lower regulatory costs; namely, most U.S. branches and agencies of foreign banks (henceforth "foreign banks") are exempt from paying FDIC fees and are subject to a less stringent implementation of the Basel III leverage ratio, relative to domestic banks. Both factors make IOR arbitrage trades less costly for foreign institutions relative to domestic ones.

We find that foreign banks make up most of the Eurodollars and fed funds borrowing by volume, and keep on average around 99% of each additional Eurodollar and 80% of each fed fund borrowed as reserve balances.[3] Compared to foreign banks, large domestic institutions borrow unsecured funds less often and in smaller quantities, but when they do, they keep around 99% of

[2] As we discuss later in the paper, several factors other than the payment of IOR affect each institution's demand for reserves.

[3] Throughout the paper we refer to the correlation between net borrowing and changes in reserve balances held as pass-throughs.

each additional Eurodollar or fed fund raised as reserves. Since domestic banks incur an additional regulatory cost when conducting such arbitrage, they are only willing to borrow at a lower interest rate than their foreign counterparts. Small domestic banks borrow unsecured funds too, but not for the purpose of conducting IOR arbitrage – their pass-through from unsecured borrowing to reserve balances is not significantly different from zero.[4]

We also find that several institutions borrow on a daily basis from both the fed funds and the Eurodollar markets; these cross-market linkages provide a rationale for the tight correlation between the fed funds and Eurodollar rates.[5] Indeed, most days the two effective rates are identical.

Finally, we discuss the impact of the Basel III leverage ratio on dynamics in unsecured funding markets (window dressing). In particular, some banks located in jurisdictions that compute the leverage ratio using month-end or quarter-end snapshots deleverage on such dates: they drop wholesale borrowing on the liability side and shed reserves on the asset side, resembling the unwinding of an IOR arbitrage trade. To this point, we show that the IOR arbitrage result is not just due to these large month-end deleveraging patterns, but rather, is on month-ends, but rather, it occurs consistently throughout the month.

Competitive bidding for unsecured funding should push up the effective federal funds rate to the level at which most banks are indifferent between further borrowing in the fed funds market to fund a reserve position and not borrowing. Consistent with this hypothesis– excluding month-

[4] We refer to some banks as small to differentiate them from the largest banks in the panel, which we define as the top 15 banks by reserve balances for each FDIC status. However, none of the banks in our sample are particularly small: only banks with more than $18 billion in assets, or banks with assets between $5 and $18 billion but with fed funds activity of more than $200 million in two or more days in the previous three months need to report.

[5] Fed funds are unsecured loans in U.S. dollars from exempt entities (mainly U.S. banks and government-sponsored enterprises) to a U.S. office of a bank. Eurodollars are unsecured loans in U.S. dollars from insuredentities (mainly non-financial corporations and U.S. money market mutual funds) to banks' offices outside the United States. These offshore funds are then routinely transferred onshore. Since fed funds and Eurodollars are regulated similarly and are not subject to reserve requirements, U.S.-based banks consider them close substitutes. Under Regulation D, federal funds transaction are exempt from reserve requirements and since 1990 net Eurodollar deposits have been subject to a reserve requirement ratio of zero percent.

ends when foreign banks pare back their IOR arbitrage – the effective fed funds rate has recently traded around nine basis points below the IOR rate (see Figure 1), which is close to the average FDIC fee paid by domestic banks.[6] In other words, the effective fed funds rate seems to trend around the level that makes the average domestic bank indifferent between engaging in IOR arbitrage or not.

It is important to point out that the arbitrage trades we identify, namely raising additional overnight funding to hold as reserve balances, can also serve an additional purpose. In the post-crisis world, access to intraday credit from clearing banks has been limited, prompting banks active in repo markets to seek out other sources of intraday credit and to hold precautionary liquidity buffers.[7] One way for these entities to bootstrap intraday credit is to borrow funds in the wholesale market and hold the balances as reserves. These reserves can be used to substitute for intraday credit around, for example, repo settlement windows and then be held as reserve balances overnight to earn the IOR rate. Additionally, with the opportunity cost of holding reserves diminished, banks may want to hold additional reserves to avoid daylight overdrafts (Bech et al. (2012) and Lipscomb et al. (2017)).[8]

There are several papers that explain how the post-crisis monetary policy regime works through arbitrage, for example, (Beck, Klee (2011), Ihrig et al. (2015), Frost et al. (2015)). To the best of our knowledge, we are the first to empirically document these IOR arbitrage trades, and which groups of banks engage in them. In particular, for each group of banks (large vs. small,

6 In July 2016, the FDIC introduced a 4.5 bps surcharge for banks with more than $10 billion in assets; in addition, the March 2017 FDIC Quarterly Banking Profile shows the distribution of assessment base rates, averaging 4.1 bps, excluding the surcharge. Thus, large banks face an overall FDIC premium of about 8 to 9 bps.

7 See https://www.newyorkfed.org/medialibrary/media/banking/nyfrb_triparty_whitepaper.pdf

8 Note that funding reserves by borrowing overnight in the wholesale market does not generally improve a bank's liquidity coverage ratio (LCR): the increase in the LCR numerator due to holding reserves, a level 1 high quality liquid asset (HQLA), is counteracted by a higher LCR denominator due to increased unsecured overnight wholesale funding, which receives a 100 percent runoff rate. The US implementation of the LCR treats fed funds borrowing from non-financial entities (including FHLBs) more favorably, with just a 40% runoff rate.

FDIC-exempt vs. FDIC-insured) and each market (fed funds, Eurodollars, certificates of deposits) we estimate pass-throughs from net borrowing into changes in reserve holdings. For several groups of banks we estimate complete a pass-through, indicating that each extra dollar raised in the wholesale market is kept in the reserve account. We also provide evidence of window dressing in unsecured markets due to the foreign implementation of the Basel III leverage ratio, in line with Banegas and Tase (2016).

Few papers have explored the impact of recent regulatory changes on money market dynamics. Banegas and Tase (2016) document the effect of the FDIC fee on the distribution of reserves across banks, and the impact of the Basel III leverage ratio implementation on quarter-end window dressing. Anbil and Senyuz (2016) as well as Munyan (2016) document the impact of the leverage ratio on window dressing in the repo market.

2. Background on the Incentives to Borrow in Unsecured Markets

Prior to the financial crisis, the Federal Reserve implemented monetary policy primarily using open market operations (OMO), which directly adjusted the aggregate level of reserves in the system.[9] If the Fed wanted to increase short-term interest rates, it would do so by selling or repoing out Treasury securities to primary dealers, debiting reserves from the account of the primary dealer's bank that cleared the transaction as payment for the securities. This process would make reserve balances scarcer by draining reserves from the system (Ihrig et al. (2015), Kroeger et al. (2017)). As reserves became scarcer, the federal funds rate – the price at which banks borrow reserves in the interbank market – would rise.[10] Under Regulation D, banks are

[9] Repos and reverse repos were the primary tools used.

[10] When a bank borrows reserves from another bank in the fed funds market, the transaction is executed through the FedWire payment system.

subject to reserve requirements which oblige them to hold reserves equal to a portion of certain deposit categories, defined as net transaction accounts, in their reserve account over a two week period referred to as a "maintenance period". As such, within the pre-crisis framework for monetary policy implementation, reserve requirements created a stable, predictable demand for reserves against which the relative supply of reserves could be adjusted using OMOs.

In response to the financial crisis beginning in the summer of 2007, the Federal Reserve used a variety of conventional and unconventional tools designed to support the liquidity of financial institutions, put downward pressure on longer-term interest rates, and ease general financial conditions.[11] A byproduct of all of these measures to support the economy meant that the Federal Reserve added trillions of dollars in reserve balances into the banking system (Keister, McAndrews (2009)).

In the pre-crisis period, the aggregate level of reserve requirements closely matched the level of total reserves in the system, leaving very few reserves considered as "excess reserves". When the Federal Reserve's balance sheet expanded due to its response to the financial crisis, the total level of reserves in the system grew dramatically more than proportionally to the level of reserve requirements, leading to a large increase in the amount of excess reserves in the system. With such a large amount of excess reserves in the system, the demand for reserves stemming from reserve requirements fell far short of the supply of reserves, thus putting downward pressure on the effective fed funds rate. In order to provide a floor for the policy rate, the implementation of

[11] These tools included the provision of liquidity through the Discount Window and credit programs such as the Term Auction Facility (TAF), Primary Dealer Credit Facility (PDCF), Term Securities Lending Facility (TSLF), and the Term Asset-Backed Securities Loan Facility (TALF), among others. In addition to these steps, the Federal Reserve engaged in a series of large-scale asset purchases (LSAPs) by purchasing longer-term Treasury securities and agency mortgage-backed securities (MBS).

the payment of interest on reserves was accelerated from a planned introduction in October 2011 to October 2008.

If banks eligible to receive interest on reserves were the only participants in money markets, it is likely that interest on reserves would have created a floor for money market rates: no bank would have been willing to accept a remuneration lower than IOR for an overnight unsecured loan. However, the remuneration of reserves at the IOR rate proved insufficient to establish a firm floor for interest rates. The reason is that not all money market participants are eligible to receive IOR, among them money market funds (MMFs) and government-sponsored enterprises (GSEs). Thus, these investors were willing to make loans below the IOR rate, eroding the lower bound on money market rates that interest on reserves was supposed to create.[12]

In the absence of frictions, competition among banks borrowing below the IOR rate to fund IOR arbitrage would bid up money market rates closer to the IOR rate. However, there are balance sheet costs, such as the leverage ratio and FDIC fees, associated with a bank expanding its balance sheet to conduct such arbitrage (Frost et al. (2015)) which in practice created a wedge between the effective fed fund rate and IOR.

Due to differing regulatory requirements, not all institutions make the same profit when engaging in IOER arbitrage. In particular, domestic depository institutions are subject to FDIC assessment fees – which are used to fund federal deposit insurance – while foreign banking organizations (FBOs) are exempt from such fees.[13] For the marginal borrower, the return to engaging in IOR arbitrage is equal to the IOR rate minus the cost it faces; the differential regulatory

[12] In an effort to create a firmer floor on money market rates, in September 2013 the Federal Reserve began testing the Overnight Reverse Repurchase (ON RRP) facility, an OMO which provides overnight reverse repos to an expanded range of eligible counterparties relative to IOR. These counterparties can invest cash overnight at the Federal Reserve, and receive OMO-eligible assets as collateral. By providing access to MMFs and GSEs, the ON RRP facility has been largely successful in establishing a floor for overnight tri-party repo rates.

[13] There are a few foreign banks grandfathered into the FDIC insurance program, and thus subject to FDIC fees.

treatment of domestic and foreign institutions then leads to different IOR arbitrage profits between domestic and foreign banks.

In April 2011 the FDIC assessment base was widened from the level of total domestic deposits to total assets less tangible equity, thus including wholesale borrowing in the assessment base. This change discouraged the use of wholesale borrowing for FDIC-insured banks relative to the FDIC-exempt ones. This asymmetry led to lower costs of funding reserves through wholesale borrowing for foreign relative to domestic banks.

Another advantage of foreign banks relative to domestic ones on most trading days is associated with the implementation of the Basel III leverage ratio. Most foreign countries calculate leverage ratios either using month-end or quarter-end snapshots of banks' balance sheet, whereas the U.S. implementation relies on daily averages. Therefore, other than at month-ends, foreign banks are not constrained by their leverage ratios and therefore leverage up by borrowing wholesale funds to finance reserve balances. At month-end, when they face the leverage constraint, they deleverage by pulling back borrowing from fed funds and Eurodollar markets. This window dressing phenomenon is also present in the repo market (Anbil and Senyuz (2017)).

3. Data

The dataset consists of two separate pieces of confidential Federal Reserve daily data: individual reserve balance holdings and transaction-level wholesale borrowing (FR2420 report).

The first is Federal Reserve data that contains reserve balances and calculates reserve requirements and interest payments are used to construct a daily series of individual reserve balances and excess balances. As discussed earlier, reserve requirements are the amount of funds that a depository institution (DI) must hold in reserve against specified deposit liabilities. Reserve

requirements must be satisfied by holding vault cash or, if vault cash is insufficient, by holding reserve balances in a master account at a Reserve Bank over a 14-day maintenance period. The amount an institution must hold at a Reserve Bank to satisfy its reserve requirement is called its reserve balance requirement. For our analysis, we construct a daily panel of total balances and excess balances held in each DI account. Excess balances are calculated as the daily level of reserve balances held in the DI's master account minus the DI's average reserve balance requirement for the relevant maintenance period.[14]

The second is the FR2420, which collects daily transaction-level wholesale borrowing in fed funds, Eurodollars and certificates of deposits (CDs), from domestically chartered commercial banks, and U.S. branches and agencies of foreign banks.[15] Borrowing bank, amount borrowed, interest rate paid, settlement and maturity dates, and lender type classification are reported for each transaction. This data collection began in April of 2014, but did not capture Eurodollar borrowings from foreign banks until mid-October 2015, which we use as the starting point of our empirical analysis.[1] While the vast majority of fed fund and Eurodollar trades are overnight, we use both overnight and term trades in the empirical analysis – unless otherwise noted. An important component of the unsecured wholesale dollar funding market not covered by the FR2420 report is financial commercial paper.

In our empirical analysis we aggregate branches/subsidiaries-level reserves and borrowing data up to the U.S. head-office level. Throughout the analysis, we refer to individual U.S. head-

[14] In practice, banks have some flexibility in meeting their reserve balance requirement: a bank may hold a level of reserve balances, on average over the 14-day maintenance period, anywhere within the penalty-free band, which is a range around the bank's reserve balance requirement equal to plus or minus the greater of 10% of the bank's reserve balance requirement or $50,000.

[15] Domestic banks with less than $18 billion in assets, and US branches of foreign banks with less than $2.5 billion in assets do not report. See https://www.federalreserve.gov/reportforms/forms/FR_242020160115_i.pdf.

offices as banks.[16] The final dataset combines reserves data and FR2420 borrowing data and consists of banks that hold a master reserve account at the Federal Reserve and borrow in at least one of the CD, Eurodollar or fed fund wholesale funding markets.

As shown in the summary statistics (Table 1), we have 81 FDIC-exempt banks and 105 FDIC-insured banks in our sample. All the FDIC-exempt banks are U.S. subsidiaries of foreign banks, while the vast majority of the FDIC-insured banks are domestic; in our sample there are just seven foreign banks with grandfathered FDIC insurance. For both domestic and foreign banks, most of the reserve balances in our time horizon consist of excess reserves.

CDs have the largest number of transactions in our panel, followed by Eurodollars and then fed funds. However, the average transaction size is largest for Eurodollars, followed by fed funds and CDs. Finally, most of the Eurodollar borrowing is undertaken by foreign (FDIC-exempt) banks, while the majority of fed funds transactions involve U.S chartered borrowers.

Figure 2 shows the distribution of reserves and amounts borrowed divided by FDIC status: while reserves are similarly split between FDIC-insured (domestic) and FDIC-exempt (foreign) banks, unsecured borrowing is almost entirely accounted for by foreign banks.[17] This suggests that a non-negligible portion of foreign banks' reserves are financed by unsecured overnight borrowing, while domestic banks finance reserves with other liabilities, such as deposits.

4. Empirical Strategy and Results

[16] In our sample, there are about a dozen cases in which two separate head-offices belong to the same Bank Holding Company (BHC). In unreported tables we aggregate individual branches up to the BHC level instead of the head-office level; results are virtually unchanged.

[17] Fed funds and Eurodollars volumes in Figure 2 include both overnight and term loans, while the publicly available data published by FRBNY include only overnight fed funds and Eurodollars. Since both term fed funds and term Eurodollars represent about 2% of their respective total volumes, the series shown in Figure 2 do not substantially differ from the publicly available data.

With our dataset we are able to ask a few questions about trading patterns in money markets. We break these questions into three broad areas. First, we document IOR arbitrage trades across money market instruments and groups of banks (FDIC-exempt vs FDIC-insured, small vs large). Second, we analyze trading linkages and pricing patterns in the overnight markets (fed funds and Eurodollars). Lastly, we study how window dressing by foreign banks affects trading patterns in unsecured money markets.

4.1 IOR Arbitrage Trades

The main purpose of the empirical analysis is to estimate how much of the daily unsecured borrowing is used for the purpose of accumulating reserve balances at the Federal Reserve, hence earning the spread between the IOR and the rate paid on the unsecured borrowing. We therefore run the following panel regression:

$$\Delta. Reserves_{it} = \beta_1 Net\ CD_{it} + \beta_2 Net\ ED_{it} + \beta_3 Net\ FF_{it} + \gamma_t + \varepsilon_{it}$$

where $\Delta. Reserves$ is the daily change in reserve balances (in $ billion), Net CD is the daily net issuance of certificates of deposits, Net ED is the daily net issuance of Eurodollar, and Net FF is the daily net issuance of fed funds. Net issuance (in $ billion) is the difference between the amount issued and the amount maturing that day; net issuance thus measures the additional amount raised on the day. As a result, the $(\beta_1, \beta_2, \beta_3)$ coefficients capture how much of the additional amount raised is on average held in reserves to earn IOR. Finally, γ_t is a set of daily dummy variables.

Under the hypothesis that all the funds borrowed in unsecured markets are kept as reserve balances (earning IOR), we should observe that an additional dollar borrowed results in a daily increase in reserve balances by one dollar; namely, under the hypothesis of IOR arbitrage, β_m=1, where m indexes a specific funding market, ED, FF or CD. This is what we call "complete pass-

through." We also ask whether FDIC-exempt banks display larger pass-throughs from borrowing to reserve balances than FDIC-insured banks: we do so by fully interacting the above specification with an FDIC-exempt dummy. Lastly, we add another possible layer of heterogeneity by asking whether IOR arbitrage is more prevalent among *large* banks. Within each FDIC status, the top 15 banks by reserve balances each day are called *large*, while the remainder are referred to as *small*.

Table 2 displays the main results: in the columns with odd numbers, the dependent variable is the daily change in *total* reserves, while in the columns with even numbers, it is the daily change in *excess* reserves. With required reserves being such a small fraction of the total amount of reserves for most banks in the sample, results are virtually identical whether we use total or excess reserves.

From the first two columns, we see that on average over 99 cents for each dollar borrowed in the Eurodollar market is held as reserves, earning IOR overnight. This evidence suggests that banks use Eurodollar borrowing for IOR arbitrage. Net borrowing in fed funds and CDs are also strongly associated with increases in reserve balances, but by less than one-for-one.[18]

Next, Table 3 differentiates between FDIC-exempt and FDIC-insured banks. FDIC-exempt banks display the largest pass-throughs from net borrowing into reserve balances across the different funding markets. Insured banks display high pass-throughs in Eurodollar and fed funds markets too, but less pronounced than those of FDIC-exempt banks.

In the pre-crisis reserve-scarce world with no remuneration of reserve balances, the main purpose of borrowing fed funds was to meet reserve requirements (Kroeger et al. (2017)). Banks, therefore, held very few excess reserves. The banks in our sample, especially those displaying

[18] The incomplete pass-through in fed funds is mainly attributable to small domestic banks, as shown in Table 4; these banks may borrow in the overnight market because they find themselves short of reserves for operational purposes.

large pass-throughs, have high levels of excess reserves, and therefore are not borrowing in overnight unsecured markets to meet reserve requirements. This is also evident from the fact that our results are identical whether we consider total reserves or excess reserves.

Table 4 further allows the pass-throughs (within each market and FDIC status) to depend on whether a bank is large or small. Both small and large FDIC exempt (foreign) banks display very similar pass-throughs. In contrast, among the FDIC insured(domestic) banks, only the large banks use Eurodollars and fed funds borrowing to fund reserve positions and perform IOR arbitrage, albeit infrequently. The Eurodollar and fed funds pass-throughs for the small insured banks are not statistically different from zero. These banks tend to borrow wholesale funds to settle balances owed to other banks. These results are consistent with Figure 2, which documents that most of the fed funds and Eurodollar borrowing volumes come from FDIC exempt (foreign) banks.

4.2 Features of Overnight Markets

We use the data to answer a few questions about trading in overnight money markets (federal funds and Eurodollar). First, we estimate the premiums paid by different banks, namely the interest rate paid by the average bank in each group over and above the rate paid by the omitted group ("Yes FDIC Small"). Second, for each type of bank (small vs. large, FDIC-exempt vs. FDIC-insured), we quantify the likelihood of participating in each overnight market. Third, we estimate the linkage between the two overnight markets, by estimating the probability of trading in one market conditional on also trading in the other market. Specifically, we run the following regressions:

$$Rate\ ED_{it} = \beta_1\ No\ FDIC_{it} + \beta_2\ LARGE_{it} + \beta_3\ No\ FDIC \cdot LARGE_{it} + \gamma_t + \varepsilon_{it}$$

$$Trade\ ED_{it} = \beta_1\ No\ FDIC_{it} + \beta_2\ LARGE_{it} + \beta_3\ No\ FDIC \cdot LARGE_{it} + \gamma_t + \varepsilon_{it}$$

$$Trade\ ED_{it} = \boldsymbol{\beta} \binom{No\ FDIC}{Yes\ FDIC} \times \binom{Small}{Large} Trade\ FF_{it} + \gamma_t + \varepsilon_{it}$$

where $Trade\ ED_{it}$ is a dummy equal to one if bank i on day t is borrowing any amount in the Eurodollar market, and $Rate\ ED_{it}$ is the volume-weighted overnight rate paid by a bank to borrow overnight in the Eurodollar market.[19]

Similar regressions are run for federal funds trades, where the dependent variables are $Trade\ FF_{it}$ and $Rate\ FF_{it}$.

Table 5 reveals some trading and pricing features of the fed funds and Eurodollars overnight markets.[20] The first two columns deal with pricing of overnight trades only (the few term fed funds and Eurodollars present are disregarded): compared to the omitted group of small FDIC insured(domestic) banks, FDIC exempt (foreign) banks pay about the same interest rate, while large domestic banks pay on average 13 to 17 basis points less. This finding is possibly driven by domestic banks' higher regulatory costs, including FDIC fees and possibly leverage constraints. This is especially notable relative to foreign banks, which do not incur FDIC fees and calculate leverage ratios only at month-ends or quarter-ends, when they significantly deleverage by unwinding their overnight borrowing.

[19] Since there are many banks that on any given day borrow from multiple lenders in each market, for each bank-day pair we calculate a volume-weighted overnight rate. In the panel, about 98% of both fed funds and Eurodollar borrowing volumes are overnight.

[20] In the panel, about 98% of volumes in both markets are overnight.

The third and fourth columns show the trading composition of borrowers in the two markets: both foreign banks and larger banks trade more often in the Eurodollar market, while small domestic and large foreign banks trade more often in the fed funds market.

The cross-market linkages are displayed in the last two columns. In particular, column 5 shows that all but small domestic banks that borrow in the fed funds market are very likely to also borrow in the Eurodollar market on the same day. The tight interest rate connection observed between fed funds and Eurodollars markets is thus unsurprising given the presence of a considerable set of banks active in both markets each day. In contrast, there is no cross-market linkage on the lending side as lenders in the fed funds market are mostly FHLBs, while lenders in the Eurodollar market are mostly MMFs and non-financial corporations.

4.3 Window Dressing

Next, we discuss the impact of regulatory arbitrage (window dressing) on our main results. In particular, in 2013 most countries except for the United States adopted the Basel III leverage ratio by calculating either the average of the three month-end leverage ratios over a quarter, or just at the quarter-end.[21] This rule created an incentive for banks in these countries to report less leverage at month-end (and especially at quarter-ends); many of these banks deleverage by reducing overnight fed funds and Eurodollar borrowing on the liability side, with the corresponding drop in reserves on the asset side. The U.S. leverage ratio instead relies on daily averages over the quarter, which does not create any incentive for window dressing on any particular day of the quarter.

[21] See http://www.bis.org/publ/bcbs251.pdf.

In order to study how window dressing affects our results, we first estimate the average percentage change in borrowing at month-end for FDIC-exempt (foreign) banks relative to domestic ones:

$$\%\Delta\, ED\ Issue_{it} = \beta_0\, ME + \beta_1\, WD + \beta_2\, Large + \beta_3\, ME \times WD + \beta_4\, WD \times Large + \beta_5\, ME \times Large + \beta_6\, ME \times WD \times Large + Controls + \varepsilon_{it}$$

where $\%\Delta\, ED\ Issue$ is the percentage change in Eurodollar borrowing relative to the monthly average borrowing, ME is a month-end dummy equal to one on days that fall on month-ends, WD (Window Dressing) take unitary value only for foreign banks that calculate the leverage ratio either at month-ends or quarter-ends; *Large* equals one for the top 15 banks by reserves for each WD status. Finally, *Controls* is a set of fixed effects that capture the average change in borrowing both the day before and the day after month-end, doing so differentially for WD banks and large WD banks. These controls allow for a smoother deleveraging and re-leveraging around month-end, as is usually the case. We also estimate a similar equation with $\%\Delta\, FF\ Issue$ as the dependent variable. The coefficients of interest are β_3 and β_6 .

Secondly, we also check whether IOR arbitrage trades are mainly clustered around month-ends or more evenly spread over the month. Indeed, deleveraging for window dressing purposes can entail a drop in reserves matched by an equal drop in overnight wholesale funding, which resembles the unwinding of an IOR arbitrage trade. The day after month-end there would be an IOR arbitrage trade in the opposite direction: an increase in overnight borrowing coupled with an increase in reserves. To this purpose we run the following regression:

$$\Delta.\, ExRes_{it} = \boldsymbol{\beta} \begin{pmatrix} Group\ 1 \\ Group\ 2 \end{pmatrix} \times \begin{pmatrix} Small \\ Large \end{pmatrix} Net\ ON_{it} + \boldsymbol{\delta} \begin{pmatrix} Group\ 1 \\ Group\ 2 \end{pmatrix} \times \begin{pmatrix} Small \\ Large \end{pmatrix} ME_3\ Net\ ON_{it} + \gamma_t + \varepsilon_{it}$$

where $\Delta.ExRes$ is the daily change in excess reserves, *Group 1,2* can refer to either the FDIC status dummy or the Window Dressing dummy. For each group definition, *Large* refers to the top 15 banks by reserve balances within each group. Net ON (ON stands for overnight) refers to the net issuance of both fed funds and Eurodollars; we sum Net FF and Net ED for ease of exposition and because they display similar pass-throughs. ME_3 is a fixed effect capturing month-end and its two adjacent days. Under the hypothesis that month-ends display larger pass-throughs than other days of the month, $\boldsymbol{\delta}$ would be positive and significant.

Table 6 shows that relative to their U.S. counterparts, foreign banks drop their daily borrowing at month-end, with even more sizable reductions in overnight borrowing by larger foreign banks. That said, the effect is only statistically significant for the largest foreign banks in the Eurodollar market. In other words, foreign banks subject to month-end or quarter-end reporting for the leverage ratio deleverage exactly on those reporting days. It is worth noting that such window dressing is not confined to unsecured markets, as it is also present in the repo market (Anbil, Senyuz (2016)).

Finally, Table 7 investigates whether IOR arbitrage occurs evenly over the month, or whether it is concentrated around month-ends. For the sake of exposition, the main explanatory variable is the sum of net issuance in fed funds and Eurodollars, which we refer to as Net ON. We also control for Net CD issuance. In the first four rows we have the average pass-throughs from overnight net issuance to reserves, which are consistent with the results in Table 4. Then, the last four rows display the additional pass-throughs at month-end (including the two adjacent days to month-end). It appears that small foreign banks display more pronounced pass-throughs at month-ends, whereas large foreign and all domestic banks do not. Overall, these results suggest that IOR arbitrage does not just occur on month-ends, but is spread out evenly over the entire month.

5. Concluding Remarks

In the post-crisis reserve-abundant world, most cash lenders in money markets are not eligible to earn interest on reserves, and are therefore willing to lend money at rates below the IOR rate. This creates an arbitrage opportunity for depository institutions that are able to earn interest on their reserve balances. We use confidential data to answer a few questions about these arbitrage trades.

We find that FDIC exempt banks and banks in jurisdictions that calculate the leverage ratio at month- or quarter-end engage in the vast majority of IOR arbitrage trades, both in terms of volume and number of transactions: almost every dollar borrowed in wholesale unsecured markets is held as reserve. Among the FDIC insuredbanks (almost exclusively domestic banks), the largest banks sometimes enter the market to engage in IOR arbitrage, while smaller banks generally do not borrow unsecured funds for IOR arbitrage purposes. Finally, the large degree of cross-market participation seems to guarantee the almost-perfect correlation between the effective interest rates paid in both fed funds and Eurodollars markets.

References

Anbil, Sriya, and Zeynep Senyuz (2016). "Window-dressing and trading relationships in the tri-party repo market."

Banegas, Ayelen, and Manjola Tase (2016). "Reserve balances, the federal funds market and arbitrage in the new regulatory framework." No. 2016-079. Board of Governors of the Federal Reserve System (US), 2016.

Bech, Morten, and Elizabeth Klee (2011). "The mechanics of a graceful exit: Interest on reserves and segmentation in the federal funds market." *Journal of Monetary Economics* 58.5 (2011): 415-431.

Bech, Morten, Antoine Martin, and James McAndrews (2012). "Settlement liquidity and monetary policy implementation—lessons from the financial crisis." *FRBNY Economic Policy Review.*

Frost, Josh, Lorie Logan, Antoine Martin, Patrick McCabe, Fabio Natalucci, and Julie Remache (2015). "Overnight RRP Operations as a Monetary Policy Tool: Some Design Considerations." *Finance and Economics Discussion Series 2015-01*.

Ihrig, Jane E., Ellen E. Meade, and Gretchen C. Weinbach (2015). "Rewriting Monetary Policy 101: What's the Fed's Preferred Post-Crisis Approach to Raising Interest Rates?" *The Journal of Economic Perspectives* 29.4 (2015): 177-198.

Keister, Todd, and James McAndrews (2009). "Why Are Banks Holding So Many Excess Reserves?" *Current Issues in Economics and Finance* 15.8 (2009): 1.

Kroeger, Alexander, John McGowan, and Asani Sarkar (2017). "The pre-crisis monetary policy implementation framework." *Federal Reserve Bank of New York Staff Report, No. 809.*

Lipscomb, Laura, Antoine Martin, and Heather Wiggins (2017). “Why Pay Interest on Excess Reserve Balances?” Federal Reserve Bank of New York Liberty Street Economics (blog), September 27, 2017.

Munyan, Benjamin (2015). "Regulatory arbitrage in repo markets."

Figures

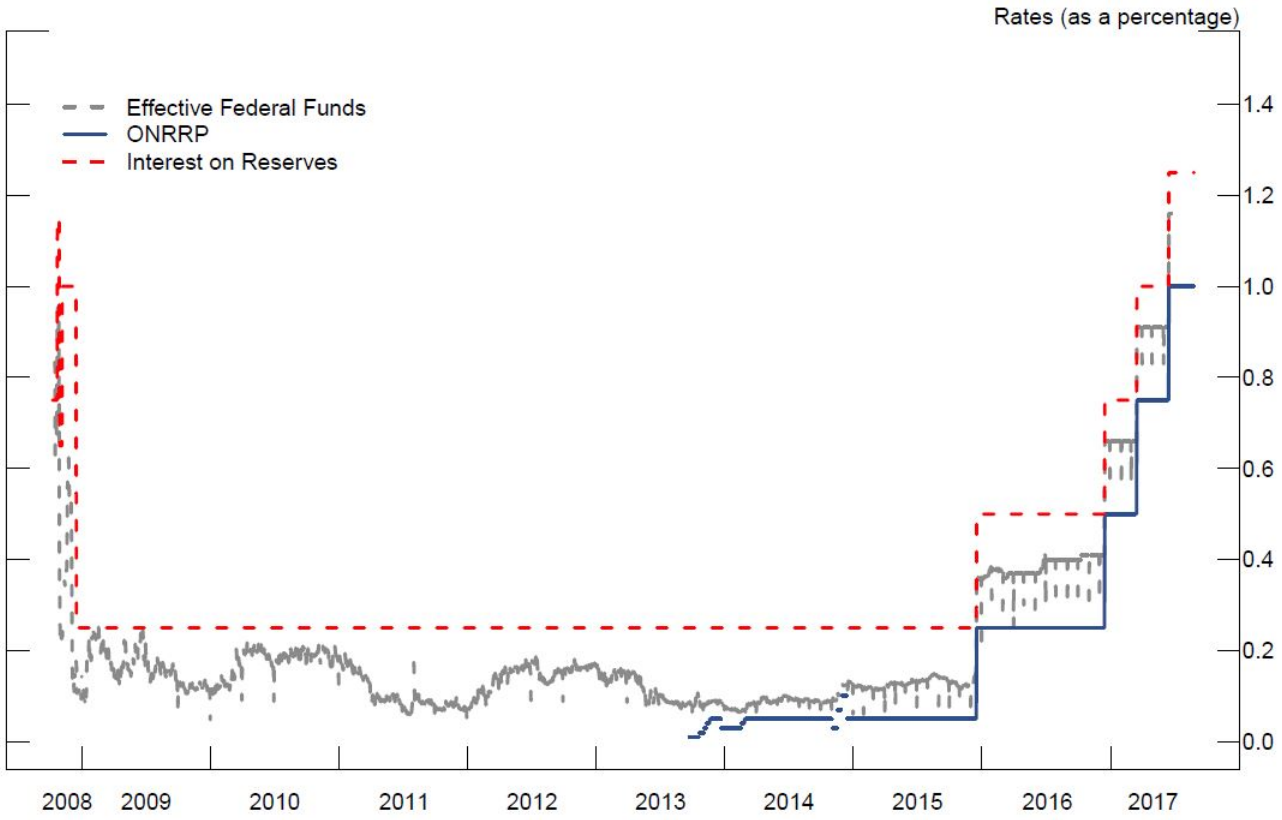

Figure 1: Evolution of selected rates from the inception of IOR.

Source: FRBNY, https://www.newyorkfed.org/markets/openmarket.html

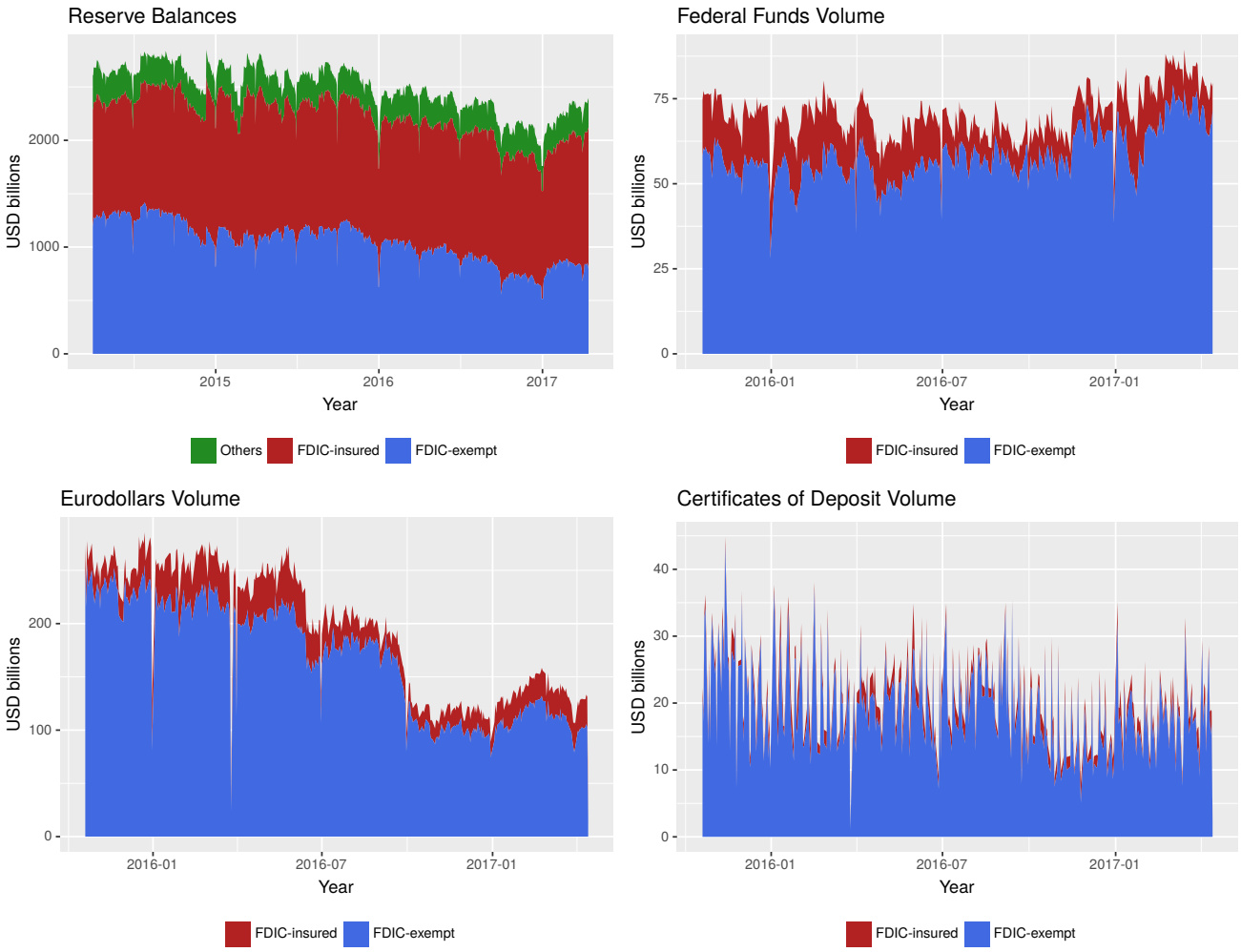

Figure 2: Reserve Balances and Unsecured Borrowing.

Sources: Federal Reserve accounting system for reserve balances, FR2420 – Report of Selected Money Market Rates for borrowing volumes.

Tables

Table 1: Summary Statistics (Nov 2015 - Mar 2017)

	Panel A: FDIC Exempt (81 banks)					
	Obs.	Mean	St.Dev.	p25	p50	p75
Total Reserves	30,388	11.232	13.294	1.274	5.651	16.970
Excess Reserves	30,388	11.010	13.027	1.256	5.578	16.537
CD Borrowing	14,307	0.480	0.696	0.050	0.220	0.614
ED Borrowing	11,775	5.136	8.271	0.227	1.087	5.981
FF Borrowing	8,637	2.452	2.084	0.600	1.918	3.969
	Panel B: FDIC Insured (105 banks)					
	Obs.	Mean	St.Dev.	p25	p50	p75
Total Reserves	39,002	11.316	39.295	0.157	1.014	4.712
Excess Reserves	39,002	10.667	37.359	0.089	0.828	4.534
CD Borrowing	11,139	0.066	0.184	0.002	0.007	0.040
ED Borrowing	3,839	2.523	3.914	0.150	0.670	2.927
FF Borrowing	12,214	0.363	0.751	0.019	0.101	0.420

Notes: All variables are expressed in $ billion. The daily sample runs from April 2014 to October 2016. CD, ED and FF Borrowings disregard bank–day observations without any trading in the respective market, namely only actual trades are displayed. All the FDIC Exempt banks are U.S. subsidiaries of foreign banks; however, the opposite is not necessarily the case.

Table 2: IOR Arbitrage Across Markets (Nov 2015 - Mar 2017)

	(1)	(2)	(3)	(4)
	D.TotRes	D.ExRes	D.TotRes	D.ExRes
Net CD	0.717***	0.713***	0.721***	0.718***
	(0.074)	(0.073)	(0.071)	(0.071)
Net ED	0.997***	0.997***	0.986***	0.986***
	(0.060)	(0.060)	(0.058)	(0.058)
Net FF	0.764***	0.763***	0.735***	0.735***
	(0.109)	(0.108)	(0.110)	(0.110)
N	69,389	69,389	69,389	69,389
Day FE	No	No	Yes	Yes
Cluster Level	Bank	Bank	Bank	Bank
# Clusters	186	186	186	186

Clustered standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: IOR Arbitrage Across Markets and FDIC Status (Nov 2015 - Mar 2017)

	(1)	(2)	(3)	(4)	(5)	(6)
	D.TotRes	D.ExRes	D.TotRes	D.ExRes	D.TotRes	D.ExRes
No FDIC X Net CD	0.743***	0.742***	0.744***	0.743***	0.729***	0.728***
	(0.074)	(0.074)	(0.071)	(0.072)	(0.043)	(0.043)
Yes FDIC X Net CD	0.380	0.343	0.424	0.387	0.403	0.367
	(0.337)	(0.308)	(0.337)	(0.309)	(0.261)	(0.263)
No FDIC X Net ED	1.007***	1.007***	0.996***	0.996***	0.979***	0.979***
	(0.067)	(0.067)	(0.066)	(0.066)	(0.036)	(0.036)
Yes FDIC X Net ED	0.938***	0.938***	0.932***	0.932***	0.936***	0.936***
	(0.096)	(0.096)	(0.102)	(0.101)	(0.086)	(0.086)
No FDIC X Net FF	0.823***	0.823***	0.784***	0.784***	0.760***	0.760***
	(0.121)	(0.121)	(0.123)	(0.123)	(0.044)	(0.044)
Yes FDIC X Net FF	0.593**	0.592**	0.595**	0.595**	0.598***	0.598***
	(0.272)	(0.271)	(0.273)	(0.273)	(0.113)	(0.114)
N	69,389	69,389	69,389	69,389	69,389	69,389
Day FE	No	No	Yes	Yes	Yes	Yes
FDIC#Day FE	No	No	No	No	Yes	Yes
Cluster Level	Bank	Bank	Bank	Bank	FDIC#Day	FDIC#Day
# Clusters	186	186	186	186	760	760

Notes: No FDIC means that a bank is exempt from paying the FDIC fee. Yes FDIC refers to the opposite case. Clustered standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: IOR Arbitrage: Large vs Small Banks (Nov 2015 - Mar 2017)

	(1)	(2)	(3)	(4)	(5)
			D.ExRes		
No FDIC X Small X Net CD	0.722***	0.724***	0.721***	0.725***	0.704***
	(0.085)	(0.083)	(0.082)	(0.083)	(0.083)
No FDIC X Large X Net CD	0.765***	0.765***	0.762***	0.766***	0.753***
	(0.095)	(0.091)	(0.091)	(0.091)	(0.081)
Yes FDIC X Small X Net CD	0.444***	0.543***	0.546***	0.544***	0.421***
	(0.086)	(0.117)	(0.118)	(0.118)	(0.084)
Yes FDIC X Large X Net CD	0.315	0.350	0.347	0.344	0.446
	(0.373)	(0.378)	(0.377)	(0.379)	(0.371)
No FDIC X Small X Net ED	0.979***	0.961***	0.959***	0.959***	0.941***
	(0.104)	(0.102)	(0.102)	(0.102)	(0.099)
No FDIC X Large X Net ED	1.022***	1.014***	1.012***	1.015***	0.957***
	(0.067)	(0.065)	(0.065)	(0.065)	(0.054)
Yes FDIC X Small X Net ED	0.0593	0.0264	0.0276	0.0208	0.0668
	(0.140)	(0.142)	(0.142)	(0.153)	(0.140)
Yes FDIC X Large X Net ED	0.999***	0.996***	0.996***	0.996***	0.989***
	(0.048)	(0.053)	(0.054)	(0.053)	(0.056)
No FDIC X Small X Net FF	0.833***	0.785***	0.785***	0.785***	0.785***
	(0.162)	(0.157)	(0.157)	(0.157)	(0.156)
No FDIC X Large X Net FF	0.821***	0.793***	0.786***	0.795***	0.666***
	(0.154)	(0.164)	(0.162)	(0.164)	(0.203)
Yes FDIC X Small X Net FF	0.087	0.100	0.100	0.100	0.088
	(0.263)	(0.268)	(0.268)	(0.268)	(0.264)
Yes FDIC X Large X Net FF	1.011***	1.004***	1.005***	1.004***	0.968***
	(0.042)	(0.033)	(0.033)	(0.033)	(0.055)
N	69,389	69,389	69,389	69,389	69,389
Day FE	No	Yes	Yes	Yes	Yes
Bank FE	No	No	No	Yes	No
FDIC#Large FE	No	No	Yes	No	Yes
FDIC#Large#Day FE	No	No	No	No	Yes
Cluster Level	Bank	Bank	Bank	Bank	Bank
# Clusters	186	186	186	186	186

Notes: No FDIC means that a bank is exempt from paying the FDIC fee. Yes FDIC refers to the opposite case. Large refers to the top 15 banks by reserves account for each FDIC status; Small refers to the residual group. Clustered standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Features of the two Overnight Markets: Trading and Pricing (Nov 2015 - Mar 2017)

	(1)	(2)	(3)	(4)	(5)	(6)
	Rate ED	Rate FF	Trade ED	Trade FF	Trade ED	Trade FF
No FDIC	0.008	0.008	0.264***	-0.148***		
	(0.025)	(0.024)	(0.052)	(0.056)		
Large	-0.129*	-0.165**	0.372***	-0.094		
	(0.067)	(0.078)	(0.111)	(0.096)		
No FDIC X Large	0.172**	0.173**	0.042	0.616***		
	(0.070)	(0.078)	(0.145)	(0.129)		
No FDIC X Small X Trade FF					0.469***	
					(0.110)	
No FDIC X Large X Trade FF					0.647***	
					(0.090)	
Yes FDIC X Small X Trade FF					-0.062	
					(0.051)	
Yes FDIC X Large X Trade FF					0.526**	
					(0.215)	
No FDIC X Small X Trade ED						0.123
						(0.089)
No FDIC X Large X Trade ED						0.543***
						(0.086)
Yes FDIC X Small X Trade ED						0.566***
						(0.117)
Yes FDIC X Large X Trade ED						0.141
						(0.155)
N	15,614	20,849	69,390	69,390	69,390	69,390
Day FE	Yes	Yes	Yes	Yes	Yes	Yes
Cluster Level	Bank	Bank	Bank	Bank	Bank	Bank
# Clusters	57	113	186	186	186	186

Notes: No FDIC means that a bank is exempt from paying the FDIC fee. Yes FDIC refers to the opposite case. Large refers to the top 15 banks by reserves account for each FDIC status; Small refers to the residual group. Trade ED equals one if a bank borrows Eurodollars in a certain day; similarly, Trade FF equals one if a bank borrows fed funds in a certain day. Rate ED is the overnight volume-weighted interest rate paid (in percentage points) on the overnight Eurodollar borrowing; Rate FF is similarly defined for overnight fed funds borrowing. Around 98% of fed funds and Eurodollars borrowing volumes are overnight. Clustered standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Window Dressing and Basel III Implementation (Nov 2015 - Mar 2017)

	(1)	(2)	(3)	(4)
	%Δ ED Issue	%Δ FF Issue	%Δ ED Issue	%Δ FF Issue
Month-end X Window Dress	-15.04	-18.05	-15.52	-18.10
	(20.403)	(32.446)	(20.708)	(32.271)
Month-end X Window Dress X Large	-39.19***	-24.46	-38.68***	-24.65
	(12.498)	(23.229)	(12.946)	(22.993)
N	19,182	29,655	19,182	29,655
Month-End, L.Month-End, F.Month-End	Yes	Yes	Yes	Yes
L.Month-End X Window Dress	Yes	Yes	Yes	Yes
F.Month-End X Window Dress	Yes	Yes	Yes	Yes
L.Month-End X Window Dress X Large	Yes	Yes	Yes	Yes
F.Month-End X Window Dress X Large	Yes	Yes	Yes	Yes
Window Dress # Large	Yes	Yes	No	No
Bank # Month FE	No	No	Yes	Yes
Cluster Level		Window Dress # Day		
# Clusters	758	758	758	758

Notes: %Δ ED Issue is the daily change in Eurodollar borrowing divided by the bank's average ED daily borrowing over the current month; a similar logic applies to %Δ FF Issue for the fed funds market. Month-End is a dummy that equals one only at month-end. Window Dress is a dummy equal to one if the bank belongs to a country in our sample where the Basel III leverage ratio is calculated using month-end or quarter-end snapshots; namely, Australia, Austria, Belgium, Canada, France, Germany, Italy, Japan, Norway, Spain, Sweden, Switzerland, and UK. Clustered standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: IOR Arbitrage: Pass-Throughs at Month-End (Nov 2015 - Mar 2017)

	(1)	(2)	(3)	(4)
	D.ExRes		D.ExRes	
	Group1= No FDIC		Group1=Window Dress	
	Group2=Yes FDIC		Group2= No Window Dress	
Group1 X Small X Net ON	0.646***	0.646***	0.621***	0.621***
	(0.088)	(0.043)	(0.082)	(0.040)
Group1 X Large X Net ON	0.901***	0.901***	0.902***	0.902***
	(0.074)	(0.033)	(0.076)	(0.033)
Group2 X Small X Net ON	0.082	0.082	0.169	0.169*
	(0.194)	(0.089)	(0.229)	(0.087)
Group2 X Large X Net ON	0.984***	0.984***	0.992***	0.992***
	(0.032)	(0.086)	(0.032)	(0.086)
Group1 X Small X Month-End X Net ON	0.332**	0.332***	0.381***	0.381***
	(0.136)	(0.075)	(0.127)	(0.070)
Group1 X Large X Month-End X Net ON	0.054	0.054	0.071	0.071
	(0.129)	(0.072)	(0.129)	(0.075)
Group2 X Small X Month-End X Net ON	-0.016	-0.016	-0.081	-0.081
	(0.088)	(0.139)	(0.184)	(0.124)
Group1 X Large X Month-End X Net ON	0.009	0.009	-0.084	-0.084
	(0.147)	(0.186)	(0.193)	(0.214)
N	69,389	69,389	69,389	69,389
Group#Size#Day FE	Yes	Yes	Yes	Yes
Group#Size#Month-End#Net CD	Yes	Yes	Yes	Yes
Cluster Level	Bank	Group#Day	Bank	Group#Day
# Clusters	186	760	186	760

Notes: Net ON is the sum of Net FF and Net ED. No FDIC means that a bank is exempt from paying the FDIC fee. Yes FDIC refers to the opposite case. Window Dress follows the definition of Table 6. Large refers to the top 15 banks by reserves account for each Group (1 or 2); Small refers to the residual group. Month-End is a dummy equal to one for month-end and its two adjacent days. Clustered standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$