Finance and Economics Discussion Series

Federal Reserve Board, Washington, D.C.
ISSN 1936-2854 (Print)
ISSN 2767-3898 (Online)

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2023-071

Please cite this paper as:
Anderson, Alyssa, and Manjola Tase (2023). "LCR Premium in the Federal Funds Market," Finance and Economics Discussion Series 2023-071. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/FEDS.2023.071.

LCR Premium in the Federal Funds Market*

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November 3, 2023

Abstract

We document the existence of a regulatory premium in the federal funds market related to the implementation of the Liquidity Coverage Ratio (LCR). We use difference-in-differences analysis and confidential bank level data on borrowing in the fed funds and Eurodollar markets to compare the interest rates paid by banks subject to daily reporting of their liquidity profile (daily reporters) relative to other banks. We find that, after the implementation of LCR, daily reporters paid a higher rate compared to other banks when borrowing in the fed funds market given the LCR-favorability of many of the lenders in this market. In addition, on the days that banks borrowed in both the fed funds and Eurodollar markets, daily reporters paid a higher rate than other banks for their borrowing in the fed funds market but not for their borrowing in the Eurodollar market.

Keywords: federal funds, Eurodollars, Liquidity Coverage Ratio, market segmentation

JEL Classification: E49, E52, G21, G28

*We thank seminar participants at the Federal Reserve Board for their helpful comments. Elizabeth Getis and Sophia Lochner provided excellent research assistance. The analysis and conclusions set forth are our own and do not necessarily reflect the views of the Board of Governors or the staff of the Federal Reserve System. All remaining errors are our own.

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1 Introduction

Since the Global Financial Crisis (GFC), the landscape of banking regulation has changed significantly with the implementation of a number of new requirements including the Liquidity Coverage Ratio (LCR). The LCR requires banks to hold high-quality liquid assets to cover short-term funding outflows. Because the LCR directly affects the attractiveness of wholesale funding, it has fundamental implications for the determination of short-term interest rates and therefore monetary policy implementation.

In this paper, we document the existence of a regulatory premium in the federal (fed) funds market related to the full implementation of the LCR in January 2017. Given differences in lender composition across overnight funding markets, the LCR treatment of borrowing in these markets varies. In particular, lending in the fed funds market is done primarily by Federal Home Loan Banks (FHLBs), which have a relatively favorable LCR treatment. As a result, we show that banks subject to daily reporting of their liquidity profile are willing to pay higher rates for this funding.

We start by documenting two stylized facts about the fed funds and Eurodollar markets for the period April 2014 to February 2020. These markets are close substitutes as they are both overnight unsecured markets in which banks typically borrow. A key difference however is the lender composition. FHLBs provide the vast majority of lending in the fed funds market and borrowing from them has a lower run-off factor for the LCR than does borrowing from the counterparties that typically lend in the Eurodollar market. Therefore, a bank trying to improve its LCR should be willing to pay a higher rate for fed funds than for Eurodollars. Indeed, the following stylized facts support this hypothesis. First, after the full implementation of the LCR in 2017, daily LCR reporters on average paid a relatively higher rate when borrowing in the fed funds market. Second, in the Eurodollar market, daily LCR reporters on average paid a lower rate than other borrowers after implementation.

Then, we use confidential bank-level data on selected balance sheet items and transaction-level data on borrowing in the fed funds and Eurodollar markets to analyze banks' pricing behavior and establish the existence of an LCR premium in the fed funds market. Our empirical strategy consists of two steps. First, using data for the period April 2014 to February 2020, we use difference-in-differences analysis to establish that, after 2017, daily LCR reporters paid a relatively higher rate compared to other banks when borrowing in the fed funds market. Second, using data from January 2017 to February 2020, and restricting the sample to days when banks participated in both markets, we show that daily LCR reporters paid a higher rate than other banks for their borrowing in the fed funds market but not for their borrowing in the Eurodollar market. These results establish that the premium paid by the daily LCR reporters in the fed funds market is an LCR premium.

Our findings on an LCR premium in the fed funds market are in the spirit of the theoretical model of Bech and Keister (2017), which shows that when banks face the possibility of an LCR shortfall, a regulatory premium arises for rates on longer term funding since this funding has a smaller run-off factor than overnight funding. In our setup, borrowing from FHLBs in the fed funds market has a smaller run-off factor than borrowing from lenders in the Eurodollar market and therefore is akin to longer term funding in Bech and Keister (2017)'s model. On the empirical side, our paper is closest to Bonner and Eijffinger (2012) who study the effect of liquidity regulation on the Dutch interbank market. Using the liquidity rule introduced by De Nederlandsche Bank in 2003 as a proxy for the LCR, they find that banks that were just above (below) their short-term liquidity requirement pay (charge) a higher interest rate for interbank loans.

Our paper contributes to the growing literature on the effects of liquidity regulations such as the LCR. As discussed in the survey paper of Allen and Gale (2017), there is still much to be understood about the purposes and consequences of liquidity regulation. However, several recent papers have looked at the effects of the LCR on monetary policy implementation and financial markets and

institutions. Rezende et al. (2021) estimate the effects of LCR on the tenders that banks submit in Term Deposit Facility operations, a Federal Reserve tool created to manage the quantity of central bank reserves. Their results suggest that liquidity regulation affects bank demand in monetary policy operations. Macchiavelli and Pettit (2021) study the effect of the LCR on broker-dealers and find that, while the LCR brings some financial stability benefits, it also leads to less liquidity transformation by broker-dealers.

Our work also contributes to the broader literature on the fed funds market, which has seen significant changes over time. Hamilton (1996), Ashcraft and Duffie (2007), Afonso and Lagos (2015a), and Afonso and Lagos (2015b) focus on the federal funds market as a market for reserves. Afonso et al. (2011) and Ashcraft et al. (2011) look at the federal funds market during the GFC and examine the importance of liquidity hoarding and counterparty risk during this period. Bech and Klee (2011) show that, following the GFC and the substantial increase in reserve balances in the system, the fed funds market, as a market for reallocating reserves among banks, almost disappeared. Banegas and Tase (2020) focus on the fed funds market in the context of two regulatory changes—the widening of the FDIC assessment base and the introduction of the Basel III leverage ratio. Afonso et al. (2019) develop a model that is capable of reproducing the main features of the fed funds market, as observed before and after the GFC, in a single, unified framework. They find that the evolution of interest rates and trading volume in the fed funds market as the supply of aggregate reserves shrinks is highly sensitive to the dynamics of the distribution of reserves across banks. Kim et al. (2020) find that even at a sufficiently low level of reserves, the costs associated with new banking regulations might hinder the fed funds market from returning to its pre-GFC function.

The paper is organized as follows. In Section 2, we provide some background information on fed funds and Eurodollar markets and the LCR. Section 3 discusses the stylized facts that provide the motivation for this paper. Section 4 describes the data. Section 5 presents our empirical

strategy and discusses the results documenting the LCR premium in the fed funds market. Section 6 concludes.

2 Background

2.1 Fed Funds and Eurodollar Markets

The fed funds and Eurodollar markets are overnight unsecured markets in which banks borrow. Since the GFC, the lenders in fed funds are almost all FHLBs, while the lenders in Eurodollars are primarily non-depository financial institutions, such as money market funds (MMFs) as well as some corporations.

The nature of trading in these markets changed dramatically following the GFC for two main reasons. First, the Federal Reserve began to pay interest on reserves in October 2008, which allowed banks, but not other money market participants, to earn interest on the reserve balances they held at the Federal Reserve.[1] Second, the amount of reserves in the system increased dramatically as a result of the Feds large-scale asset purchases in response to the financial crisis and subsequent recession.

Before the GFC, the fed funds market was primarily an interbank market, in which banks that were short on reserves, either for their reserve requirements or for intraday payment flows, would borrow from banks that had excess reserves on a given day. However, following the GFC, banks had abundant liquidity and therefore there was minimal need for this type of borrowing.

Instead, during much of the post-GFC period, the fed funds and Eurodollar markets have been characterized by interest on excess reserves (IOER) arbitrage. In this arbitrage trade, banks borrow in these overnight unsecured markets at a rate below IOER and then hold those funds as reserves at the Federal Reserve to earn IOER. This arbitrage emerged following the introduction of IOER since the lenders in these markets are primarily non-bank institutions that do not have access to

[1] For details, see https://www.federalreserve.gov/newsevents/pressreleases/monetary20081006a.htm.

IOER (e.g., FHLBs in fed funds and MMFs in Eurodollars). Furthermore, IOER arbitrage is more profitable for foreign banks (FBOs) than it is for domestic banks.[2] Consequently, borrowing in these markets is dominated by FBOs.[3]

2.2 Liquidity Coverage Ratio

The Basel III LCR rule requires a bank subject to the rule to maintain an amount of high-quality liquid assets (HQLA) (the numerator of the ratio) that is no less than its total net cash outflow amount over the forward-looking 30 calendar-day period (the denominator of the ratio) as in equation 1.

$$\text{LCR} = \frac{\text{Stock of HQLA}}{\text{Total net cash flow over the next 30 days}} \geq 100\% \tag{1}$$

The final U.S. LCR rule was adopted by the Federal Reserve Board, the Office of the Comptroller of the Currency, and the Federal Deposit Insurance Corporation on October 10, 2014 and became effective January 1, 2015.[4] As shown in Figures 1 and 2, the U.S. LCR rule was implemented gradually and by January 1, 2017, LCR reporting banks were required to maintain an LCR of at least 100 percent. LCR banks are required to disclose publicly, on a quarterly basis, quantitative information about their LCR calculation (as daily averages over the quarter) and a discussion of the factors that have a significant effect on their LCR.

In addition, for supervisory purposes, the Federal Reserve Board monitors a banks liquidity profile on a more frequent basis for certain large banking organizations.[5] As we will discuss in the data section, these banking organizations, which include certain domestic banks and U.S. branches

[2]IOER arbitrage expands the size of a banks balance sheet. The cost of expanding the balance sheet is smaller for FBOs compared to domestic banks since FBOs are not subject to the FDIC assessment fee, which, after April 2011, is calculated based on the total size of the balance sheet.

[3]See Anderson et al. (2021) for further discussion of IOER arbitrage and its implications for global banks.

[4]See 79 Federal Register 61440 (October 10, 2014).

[5]On November 17, 2015, the Board adopted the revised FR 2052a Complex Institution Liquidity Monitoring Report to collect quantitative information on selected assets, liabilities, funding activities, and contingent liabilities from certain large banking organizations.

of foreign banks, report variables related to their liquidity profile either at a daily or monthly frequency, based on their size and international exposure. For the purpose of our analysis, we refer to these banks as daily and monthly LCR reporters, respectively. As we discuss below, such daily liquidity reporting requirements could drive demand for certain types of short-term funding that could improve a banks liquidity profile.

3 Motivation

It is common for banks to participate in both the fed funds and Eurodollar markets on a daily basis. For example, as shown in Tables 1 and 2, about 30 percent of the total number of observations corresponds to banks participating in both markets. The overlap in participation is slightly higher for daily reporters.

However, borrowing in fed funds, where the vast majority of lending is done by FHLBs, is more LCR-favorable than borrowing in Eurodollars, where most lending is done by MMFs. Specifically, borrowing either in fed funds or Eurodollars, when used to finance reserves, increases a bank's stock of HQLA (the numerator of the LCR) by that same amount. It also increases the denominator by the amount of the overnight borrowing adjusted by a corresponding run-off factor depending on the counterparty type. Borrowing from FHLBs has a smaller run-off factor than borrowing from non-depository financial institutions (such as MMFs).[6] This makes borrowing in fed funds more favorable from an LCR perspective than borrowing in Eurodollars. For banks reporting liquidity metrics at a daily frequency for supervisory purposes, borrowing in fed funds is an easily accessible market to cover possible LCR shortfalls.

On aggregate, we do not see the emergence of an LCR premium in the fed funds market. That is, we do not see a widening of the spread between the effective federal funds rate (EFFR) and the volume-weighted median Eurodollar rate. Consistent with Duffie and Krishnamurthy (2016), this

[6] See https://www.bis.org/publ/bcbs238.pdf for further details on the calculation of the LCR.

is likely due to the LCR not being binding for most institutions since system liquidity was quite abundant at this time. However, there may be important changes occurring in the cross-section for those institutions that are closer to a binding LCR.

In particular, we explore whether there are any interest rate differentials for the daily versus non-daily reporters when borrowing in the fed funds and Eurodollar markets. Figure 3 plots the average rates paid by daily LCR reporters and other borrowers in the fed funds market. As daily reporters are large banks, we would expect these banks to pay, on average, a lower rate to obtain funding given their market power. Indeed, before the full implementation of LCR in 2017, daily LCR reporters, on average, paid less than other borrowers. However, after 2017, daily reporters experienced a rate increase compared to other banks; that is, rate paid by daily reporters became closer to the rate paid by other borrowers in the fed funds market. On the contrary, as shown in Figure 4, daily reporters paid a lower rate for borrowing the Eurodollar market than other borrowers did after implementation.

These observations support the hypothesis of an LCR premium in the fed funds market: daily LCR reporters should pay a higher rate to obtain funding in fed funds and improve their LCR.

Theoretical support for the existence of an LCR premium can be found in Bech and Keister (2017). They study the impact of the Basel III LCR on interbank interest rates in a model of competitive interbank markets in the tradition of Poole (1968). There are two types of contracts traded in the interbank market: overnight and term loans. The only difference between these two is how they enter a banks LCR calculation: overnight loans have a higher run-off factor than term loans do. They find that when banks face the possibility of an LCR shortfall, the overnight interest rate tends to decrease, while a regulatory premium arises in longer-term rates. For the purpose of our analysis, overnight and term loans in the Bech and Keister (2017) model would be akin to Eurodollar and fed funds trades, respectively, in terms of how they enter the LCR calculation.

4 Data

We combine confidential microdata collected by the Federal Reserve from the FR 2420 ("Report of Selected Money Market Rates) and the FR 2644 ("Weekly Report of Selected Assets and Liabilities of Domestically Chartered Commercial Banks and U.S. Branches and Agencies of Foreign Banks"). We construct the LCR reporting frequency variable (daily, monthly, or other/non applicable) by matching the banks reporting in FR 2420 with reporters of FR 2052a ("Complex Institution Liquidity Monitoring Report).

The FR 2420 report collects transaction-level data on banks' borrowing activity in selected money market instruments on a daily basis. The collection includes, in separate parts, federal funds (as defined by Regulation D); Eurodollars (dollar-denominated liabilities outside the U.S.); certificates of deposit/time deposits; and selected deposits.[7] Reported information includes the trade date, settlement date, maturity date, amount, interest rate, and counterparty type for each transaction.[8] The FR 2420 collection supports the publication of the effective federal funds rate (EFFR), the Federal Reserves policy rate for which the Federal Open Market Committee establishes a target range, and the overnight bank funding rate (OBFR), a reference rate of overnight unsecured bank funding costs.

The FR 2644 report collects weekly data on the outstanding amount of selected bank balance sheet items, including loans, securities, and borrowings, among others, from a sample of domestically chartered commercial banks and U.S. branches and agencies of foreign banks. Data collected

[7] While selected deposits are a significant portion of overnight unsecured borrowing, they are not included in our analysis since data on these transactions were not collected until October 2018. We omit certificates of deposits given our focus on overnight interest rates.

[8] The FR 2420 reporting panel is comprised of U.S. commercial banks, thrifts, and branches and agencies of foreign banks, IBFs and significant banking organizations representing entities actively participating in the federal funds and/or other money markets. Commercial banks and thrifts required to report for a given year are those with $18 billion or more in total assets on the September 30 Call Report of the prior year, or those with between $5 billion and $18 billion in assets that meet certain unsecured borrowing activity thresholds. U.S. branches and agencies of foreign banks required to report the FR 2420 daily are those that had third-party assets of $2.5 billion or more on the September 30 FFIEC 002 of the prior year. IBFs of the above-referenced institutions are required to report daily for Eurodollars only. For further information on the FR 2420, see https://www.newyorkfed.org/banking/reportingforms/FR_2420.html.

on this report parallel the quarterly Consolidated Reports of Condition and Income (Call Reports) but are less granular. Aggregate data are published in the weekly Assets and Liabilities of Commercial Banks in the United States (H.8) statistical release.[9]

We create a dataset of LCR reporting frequency by matching the FR 2420 reporters (or their bank holding company) with the list of banks reporting in FR 2052a. The only information we extract from this match is whether the bank is a daily or monthly LCR reporter. This set of banks includes both domestic banks and U.S. branches of foreign banks (FBOs). Specifically, FBO Large Institution Supervision Coordinating Committee (LISCC) firms and U.S. firms with $700 billion or more in total consolidated assets or $10 trillion or more in assets under custody must submit a report on each business day. We defined these banks as daily LCR reporters. FBOs that are not identified as LISCC firms and are greater than $50 billion in combined U.S. operations and U.S. firms with $50 billion or more in total consolidated assets, but less than $700 billion in total consolidated assets and less than $10 trillion in assets under custody must submit a report monthly. We define these as monthly LCR reporters.

The final dataset used in our main analysis contains bank-level information on fed funds borrowing (volume and rate), Eurodollar borrowing (volume and rate), selected balance sheet items (cash and reserves, deposits, total assets, and total liabilities), LCR reporting frequency (daily, monthly, or other/not applicable), and whether the bank is domestic or foreign. The data is weekly, as of Wednesday each week for the period April 2014 to February 2020.

5 Empirical strategy and results

Our panel analysis has two parts. In the first part, we focus our analysis on the fed funds market for the period April 2014 to February 2020. We use difference-in-differences analysis to test the hypothesis that, when borrowing in the fed funds market, daily LCR reporters paid a relatively

[9]For the reporting form see https://www.federalreserve.gov/apps/reportforms/default.aspx; for the H.8 statistical release see https://www.federalreserve.gov/releases/h8/about.htm.

higher rate following the full implementation of the LCR reporting requirement (January 1, 2017) compared to other borrowers.

In the second part, we juxtapose the fed fund market and the Eurodollar market. We compare pricing behaviour in the fed funds and Eurodollar markets during the period January 2017 to February 2020 restricting the sample to the days when banks participated in both markets. We test the hypothesis that daily reporters paid a premium in the fed funds market, but not in the Eurodollar market.

In the next section, we discuss factors affecting bank's borrowing in the fed funds and the Eurodollar markets. We then continue with the empirical testing of the two hypotheses described above.

5.1 Factors affecting bank's borrowing in the fed funds and Eurodollar markets

Our empirical model accounts for the following channels that are expected to affect the rate a bank pays for borrowing in the fed funds and Eurodollar markets.

LCR implementation and frequency of reporting. As discussed previously, the two periods of interest are before and after the full implementation of the LCR at the beginning of 2017. In terms of reporting frequency, "daily LCR reporters" is the group of interest. We also account for monthly reporters on month-end dates. "Other/non applicable reporters" is our control group.

Funding substitution. Banks use various sources of funding, with deposits making up the largest share. A bank could borrow in fed funds or Eurodollars to cover a temporary deposit outflow. We use a bank's deposit outflow relative to other banks' outflows to capture idiosyncratic shocks to that banks funding. We expect that banks experiencing a relatively large shock would be more likely to pay a higher rate to obtain funding in the fed funds or Eurodollar markets.

Banks liquidity buffer. We measure a bank's liquidity buffer as the ratio of cash and reserve balances, which are the most liquid assets, to total assets. The marginal benefit of increasing the

liquidity buffer decreases with the size of that buffer. As a result, we expect banks with a larger liquidity buffer to pay a lower interest rate to borrow funds.

Market power. We use a bank's market share in each market (fed funds or Eurodollars) to capture its bargaining power in that market. It is reasonable to expect a nonlinear relationship between a bank's market share and the rate it pays: as a bank increases its borrowing, it might have to pay more for a number of reasons, such as needing to reach out to more lenders or having a more inelastic demand. However, once a bank reaches a certain market share, it might be able to use its bargaining power to receive a lower rate. We also control for a banks overall bargaining power as captured by the total size of its balance sheet at the bank holding company level.

General market conditions. We use the spread between the volume-weighted mean fed funds or Eurodollar rate and IOER to capture general trading conditions in these markets.[10]

Trading motives. We use a bank's domicile (foreign or domestic) as a proxy to capture differences in the propensity to trade for IOER arbitrage. Even if a bank borrows at a rate below IOER, we cannot say definitively whether it is engaging in IOER arbitrage or trading for another motive. A large enough spread between a bank's borrowing rate and IOER is a necessary but not sufficient condition for IOER arbitrage trading. For example, a bank might borrow in fed funds to improve its LCR ratio but, if the fed funds rate is less than IOER, it also earns the IOER arbitrage spread. However, as discussed in the Section 2, IOER arbitrage is more profitable for FBOs, which suggests that FBOs would have a higher propensity to trade for IOER arbitrage.

Table 3 shows summary statistics for the variables described above for banks borrowing in the fed funds market and the Eurodollar market broken down by frequency of reporting (daily and non-daily).

In the period prior to 2017, daily and non-daily reporters, on average, showed similar balance

[10] We use volume-weighted mean fed funds rate rather than the EFFR, which is a volume-weighted median, to have more variation in the rates.

sheet composition characteristics as measured by the share of deposits to total liabilities and cash and reserves to total assets. However, we see these two variables diverge in the later period. Specifically, daily reporters increased their average share of cash and reserves balances to total assets from about 23 percent in the earlier period to 29 percent in the later period. Furthermore, daily LCR reporters borrowing in fed funds in the earlier period show similar balance sheet composition to daily LCR reporters borrowing in Eurodollars during the later period. A possible explanation could be that daily reporters borrowing in Eurodollars in the later period and the daily reporters borrowing in fed funds in the earlier period trade for motives other than improving their LCR ratio. If a daily reporter has not changed its balance sheet such that it relies on fed funds for improving its LCR, a daily reporter borrowing the Eurodollars would be more similar to a daily reporter borrowing in fed funds prior to 2017.

In contrast, non-daily reporters decreased their share of cash and reserves balances to total assets from about 29 percent to 17 percent. This implies a preference of daily reporters for holding reserves at a time when total reserves in the banking system were declining.[11].

Furthermore, across these two time periods, the average bank's market share in fed funds increased for daily reporters (from 1.3 percent to 1.6 percent) and decreased for non-daily reporters (from 1.9 percent to 1.7 percent). Meanwhile, general trading conditions in the fed funds market, as capture by the spread between the weighted average fed funds rate and IOER, became less conducive to IOER arbitrage trades as this spread narrowed. This implies that other trading motives, including improving the LCR, became relatively more important in trading activity in the fed funds market.

[11]During the period from October 2017 to July 2019, the Federal Reserve decreased the size of its balance sheet and amount of reserves in the banking system. See https://www.federalreserve.gov/monetarypolicy/policy-normalization-discussions-communications-history.htm.

5.2 Estimation Results

First, we use a difference-in-differences approach to analyze pricing behaviour in the fed funds market before and after the full implementation of the LCR requirement in January 2017. Next we compare pricing behaviour in the fed funds and Eurodollar markets following the full implementation.

Hypothesis 1: When borrowing in the fed funds market, daily LCR reporters paid a relatively higher rate after the full implementation of the LCR reporting requirement (January 2017) compared to other borrowers.

We use a difference-in-differences empirical specification as in 2. We employ a cross-sectional time-series model with panel-corrected standard errors. Specifically, the errors are allowed to be heteroskedastic across panels with panel-specific first order autocorrelation in the disturbances. Data is weekly (Wednesdays) for the period April 2014 to February 2020.

$$\begin{aligned} FFrate_{i,t} - IOER_t = \alpha_0 &+ \alpha_1 DailyReporter_i LCRstart_t \\ &+ \alpha_2 MonthlyReporter_i MonthEnd_t LCRstart_t + \alpha_3 DailyReporter_i \\ &+ \alpha_4 MonthlyReporter_i MonthEnd_t + \alpha_5 LCRstart_t \\ &+ \beta_1 RelativeChangeDeposits_{i,t} + \beta_2 (CashReserves/Assets)_{i,t} \\ &+ \beta_3 MarketShareFedFunds_{i,t} + \beta_4 MarketShareFedFunds_{i,t}{}^2 \\ &+ \beta_5 SmallBank_{i,t} + \beta_7 (FF_t - IOER_t) + \beta_8 Foreign_i + \epsilon_{i,t} \end{aligned} \tag{2}$$

$FFrate_{i,t} - IOER_t$ is the spread between the rate paid by an individual bank i to borrow in fed funds and IOER.[12] $DailyReporter_i$ and $MonthlyReporter_i$ are dummy variables equal to 1 if

[12]Since counterparty type data is available only starting from October 2015, $FFrate_{i,t}$ includes all trades, not just those with FHLBs as a counterparty. However, this does not materially change the results as lending is almost all by FHLBs. As a robustness check, we perform this analysis using data from October 2015. We find similar results when comparing regression results for the period starting from October 2015 using all trades versus using only trades with an FHLB as the lender as shown in Table A.1 in the Appendix.

a bank reports in FR 2052a at a daily or monthly frequency, respectively. $MonthEnd_t$ is equal to 1 if t is a month-end. $LCRstart_t$ is equal to 1 if t is on or after January 1, 2017 when the LCR was fully implemented. $RelativeChangeDeposits_{i,t}$ is the normalized value of the change in bank i's deposits relative to the change in bank deposits across all banks at time t. This variable captures idiosyncratic shocks to bank is sources of funding. $(CashReserves/Assets)_{i,t}$ is the ratio of cash and balances due from depository institutions (including balances held at Federal Reserve banks) to total assets. This variable captures bank is share of most liquid assets. $MarketShareFedFunds_{i,t}$ is the share of bank i's borrowing in fed funds at time t to total fed funds volume at time t. $SmallBank_{i,t}$ is a dummy variable equal to 1 if total assets at the bank holding company level are less than a threshold of $50 billion, which is close to the median of the distribution for our sample.[13] $FF_t - IOER_t$ is the difference between the market-level volume-weighted average rate in fed funds and IOER at time t. $Foreign_i$ equals 1 if bank i is a U.S. branch of a foreign banking organization.

The coefficients of interest are α_1 and α_2: α_1 shows the average change in the $(FFrate-IOER)$ spread that daily LCR reporters were paying to borrow in the fed funds market relative the average change in the $(FFrate-IOER)$ spread paid by other banks after the full implementation of LCR; α_2 shows the corresponding change in the spread for monthly LCR reporters on month-ends.

Table 4 shows the regression results. We find that the $(FFrate - IOER)$ spread for daily reporters increased on average about 4 basis points after 2017 relative to other banks. This spread also increased on average 1.6 basis points for monthly reporters on month-ends. Before 2017, daily and monthly reporters paid about 2.7 and 1.9 basis points less, respectively, than other banks.[14]

[13]The 25^{th}, 50^{th}, 75^{th}, 95^{th}, and 99^{th} percentiles are $23 billion, $43 billion, $107 billion, $427 billion, and $1626 billion, respectively. Results are robust to using other cut offs (such as $250 billion or $500 billion) or more than one category (defining small as banks with assets less than $50 billion and medium as banks with assets greater or equal to $50 billion but less than $250 billion). Across these specifications, the estimated difference-in-differences coefficient α_1 varies from 2.02 to 2.73 and it is significant at 1 percent across all specifications.

[14]We also estimate the corresponding empirical specification shown in Equation 2 for the Eurodollar market to test the hypothesis that daily reporters did not pay a relatively higher rate after 2017 compared to other borrowers in this market. As shown in Table A.2 in the Appendix, the results support our hypothesis that daily reporters did not pay a relatively higher rate. To the contrary, there is some evidence, though only weakly statistically significant, that daily

The coefficients on the control variables have the expected signs. The coefficient on bank's relative change in deposits is positive but small. Banks experiencing a larger loss in deposits pay on average higher rates. A deposit loss that is 3 standard deviations larger than the average loss is associated with a 0.1 basis point increase in the rate. The interest rate decreases with the liquidity buffer (measured by the ratio of cash and reserves to assets): an increase of 10 percentage points ($\Delta CashReserves/Assets = 0.1$) is associated with 0.3 basis points decrease in the rate. A banks market share has a nonlinear relationship with the rate paid by the bank. Specifically, if a bank's market share stays below 12 percent of the market, then the spread paid by the bank increases as the bank increases its borrowing relative to the market. As most banks are under this cutoff (the average share is less than 2 percent and the standard deviation is about 2.5 percent), the positive relationship is applicable for most banks in the fed funds market. Beyond this cutoff, as the bank's share in fed funds increases, the rate decreases. The other measure of bargaining power, bank size, shows that small banks (assets less than $50 billion) pay on average 3 basis points more than larger banks. Foreign banks, which are not subject to the FDIC fee, pay on average 2.5 basis points more than domestic banks.

Next we compare pricing behaviour in the fed funds and Eurodollar markets for the period following the full implementation. We limit the sample to the days when banks we present in both market and we test the following hypothesis.

Hypothesis 2: Since the full implementation of the LCR reporting requirement (January 2017), on the days when banks borrowed in both the fed funds and Eurodollar markets, daily LCR reporters paid a higher rate than other banks for their borrowing in the fed funds market but not for their borrowing in the Eurodollar market.

We test this hypothesis by using the following empirical approach. For each market (fed funds,

reporters, on average, paid a relatively lower rate following the full implementation of LCR. A likely explanation is that, for daily reporters, borrowing in Eurodollars became more costly from a regulatory/balance sheet perspective than borrowing in fed funds. As such, these banks would require a lower rate to borrow in the Eurodollar market.

Eurodollars), we estimate a cross-sectional time-series model with panel-corrected standard errors as in Equation 3. Specifically, the errors are allowed to be heteroskedastic across panels with panel-specific first order autocorrelation in the disturbances. Data is at a weekly frequency (Wednesdays) for the period January 2017 to February 2020.

$$\begin{aligned} Spread_{i,t} = \alpha_0 &+ \alpha_1 DailyReporter_i + \alpha_2 MonthlyReporter_i MonthEnd_t \\ &+ \beta_1 RelativeChangeDeposits_{i,t} + \beta_2 (CashReserves/Assets)_{i,t} + \beta_3 MarketShare_{i,t} \\ &+ \beta_4 {MarketShare_{i,t}}^2 + \beta_5 SmallBank_{i,t} + \beta_6 MarketSpread_t \\ &+ \beta_7 Foreign_{i,t} + \epsilon_{i,t} \end{aligned} \tag{3}$$

$Spread_{i,t}$ is the spread between the rate paid by bank i to borrow in fed fund/Eurodollars and IOER at time t. $MarketSpread_t$ is the difference between the volume-weighted average market rate in fed funds/Eurodollars and IOER at time t. We use the same set of control variables as defined in Equation 2.

The coefficient of interest is α_1. When comparing daily reporters with other banks on the days when banks participate in both fed funds and Eurodollar markets, we expect daily LCR reporters to pay a premium for borrowing in the fed funds market but not the Eurdollar market if $\alpha_{1,\text{fed funds}} > 0$ and $\alpha_{1,\text{Eurodollar}} \leq 0$.

Table 5 shows the regression results for the sample of banks borrowing in both the fed funds and Eurodollar markets on the same day. When daily LCR reporters borrowed in both fed funds and Eurodollars, they paid on average 2.4 basis points more than other banks for borrowing in fed funds, but they did not pay a premium when borrowing in Eurodollars. Our empirical analysis supports the hypothesis of an LCR premium in the fed funds market: daily LCR reporters pay a relatively higher rate to obtain funding in fed funds in order to improve their LCR.

6 Conclusion

In this paper, we document the existence of a regulatory premium in the fed funds market following the full implementation of the LCR in 2017. After 2017, banks that report their liquidity profile daily paid relatively more than other banks when borrowing in the fed funds market since trades with FHLBs, the primary lender in fed funds, are treated favorably in the LCR. We do not find similar behavior in the Eurodollar market, in which borrowing is not advantageous from an LCR perspective.

With daily reporting banks using the fed funds market to meet their liquidity reporting requirements, the fed funds market has likely become more responsive to the distribution of reserves in the system and the corresponding funding needs of banks even when there are ample aggregate reserves.

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Figure 1: Transition period for the liquidity coverage ratio

Transition period	Liquidity coverage ratio
Calendar year 2015	.80
Calendar year 2016	.90
Calendar year 2017 and thereafter	1.00
Calculation Frequency	
Covered depository institution holding companies with $700 billion or more in total consolidated assets or $10 trillion or more in assets under custody, and any depository institution that is a consolidated subsidiary of such depository institution holding companies that has total consolidated assets equal to $10 billion or more:	
Last business day of the calendar month	Beginning January 1, 2015.
Each business day	Beginning July 1, 2015 and thereafter.
All other covered companies:	
Last business day of the calendar month	Beginning January 1, 2015.
Each business day	Beginning July 1, 2016 and thereafter.

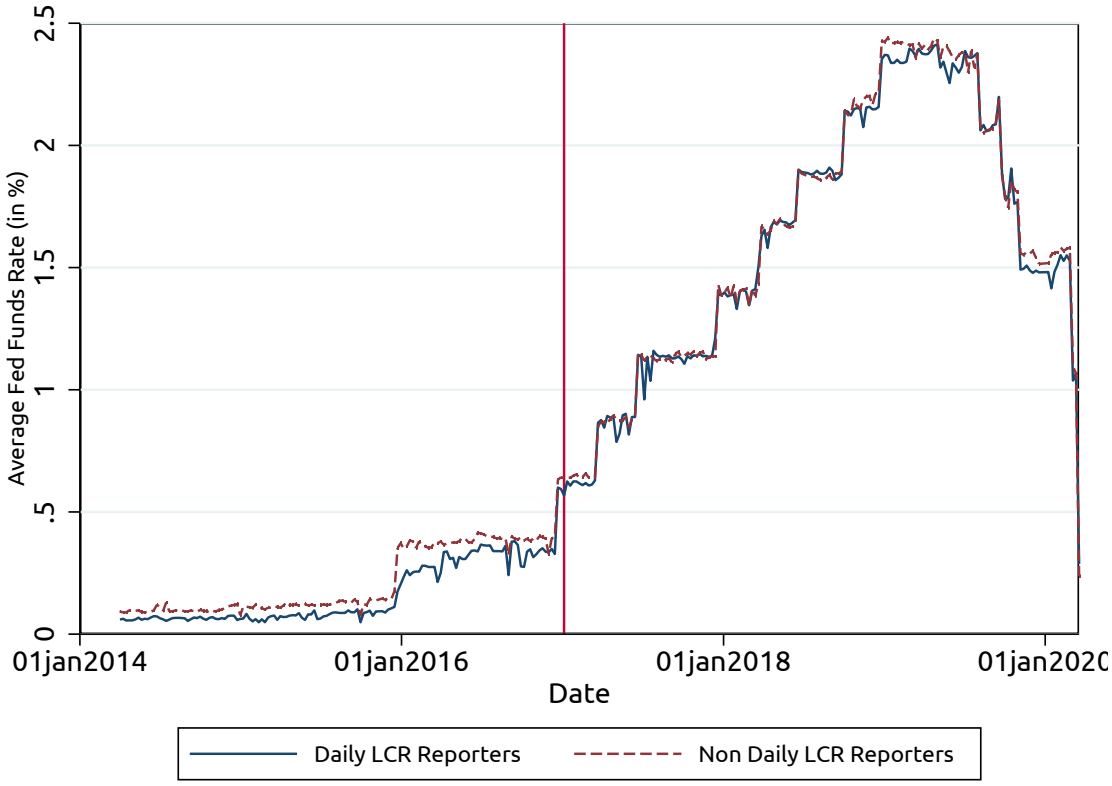
Source: Federal Register, Vol. 79, No. 197, Friday, October 10, 2014, Rules and Regulations: Table 5.

Figure 2: Transition period for the modified liquidity coverage ratio

Transition period		Liquidity coverage ratio
Calendar year 2016		.90
Calendar year 2017 and thereafter		1.00
Calculation Frequency		
All modified LCR holding companies	Last business day of the calendar month.	Beginning January 1, 2016 and thereafter.

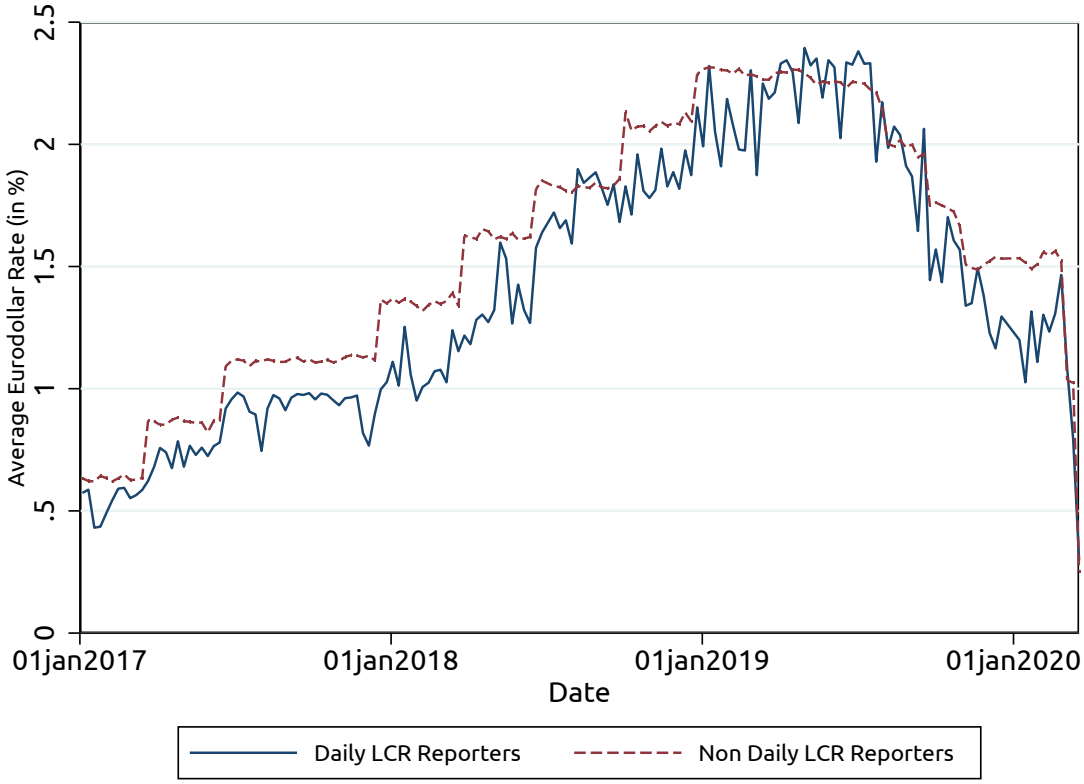
Source: Federal Register, Vol. 79, No. 197, Friday, October 10, 2014, Rules and Regulations: Table 6.

Figure 3: Interest rate paid for borrowing in the fed funds market



Note: This figure plots the average interest rate by daily and non-daily reporters for borrowing in the fed funds market. Daily reporters refers to bank reporting FR 2052a at a daily frequency. The tripwire denotes the start of LCR implementation on January 1, 2017.

Figure 4: Interest rate paid for borrowing in the Eurodollar market



Note: This figure plots the average interest rate by daily and non-daily reporters for borrowing in the Eurodollar market. Daily reporters refers to bank reporting FR 2052a at a daily frequency.

Table 1: Borrowing frequency for all banks

	Eurodollars		
Fed funds	0	1	Total
0	0	2,691	2,691
1	5,213	3,010	8,223
Total	5,213	5,701	10,914

Notes: This table shows the overlap of trading between the fed funds and Eurodollars markets for all banks in our sample. Observations are at the bank and time level. Fed funds equals 1 if a bank trades in the fed funds market in a given week and Eurodollars equals 1 if a bank trades in the Eurodollar market in a given week. Data is weekly (Wednesdays) for the period January 2017 to February 2020.

Table 2: Borrowing frequency by daily LCR reporters

	Eurodollars		
Fed funds	0	1	Total
0	0	680	680
1	148	445	593
Total	148	1,125	1,273

Notes: This table shows the overlap of trading between the fed funds and Eurodollars markets for daily LCR reporter banks. Observations are the bank and time level. Fed funds equals 1 if a bank trades in the fed funds market in a given week and Eurodollars equals 1 if a bank trades in the Eurodollar market in a given week. Data is weekly (Wednesdays) for the period January 2017 to February 2020.

Table 3: Summary statistics

Banks borrowing in the fed funds market

	Daily reporters				Non-daily reporters			
	Apr.2014 - Dec.2016		Jan.2017- Feb.2020		Apr.2014 - Dec.2016		Jan.2017- Feb.2020	
Variables	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Dep/Liabilities	0.668	0.226	0.562	0.293	0.626	0.300	0.708	0.262
CashReserves/Assets	0.227	0.141	0.288	0.226	0.289	0.310	0.168	0.214
Market Share	0.013	0.025	0.016	0.026	0.019	0.028	0.017	0.024
Total Assets ($bill)	881	650	560	683	100	103	89	105
FF-IOER (bps)	-13.1	2.6	-3.4	5.3	-13.1	2.6	-3.4	5.3
No. of Obs.	673		593		5,979		7,630	

Banks borrowing in the Eurodollar market

	Daily reporters				Non-daily reporters			
	Apr.2014 - Dec.2016		Jan.2017- Feb.2020		Apr.2014 - Dec.2016		Jan.2017- Feb.2020	
Variables	mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Dep/Liabilities	0.717	0.188	0.654	0.290	0.519	0.276	0.498	0.270
CashReserves/Assets	0.181	0.119	0.177	0.127	0.358	0.296	0.314	0.240
Market Share	0.079	0.110	0.029	0.036	0.030	0.046	0.023	0.035
Total Assets ($ bill)	931	615	883	703	91	102	74	94
Eurodollar-IOER (bps)	-12.0	2.5	-5.0	4.2	-12.0	2.5	-5.0	4.2
No. of Obs.	849		1,125		2167		4,576	

Notes: This table shows summary statistics for banks that borrow in the fed funds market and the Eurodollar market. Daily reporters are banks reporting FR 2052a at a daily frequency, while non-daily reporters are all others. $Dep/Liabilities$ is the share of total deposits to total liabilities. $CashReserves/Assets$ is the ratio of cash and balances due from depository institutions (including balances held at Federal Reserve Banks) to total assets. $MarketShare$ is the share of a bank's borrowing in fed funds relative to total fed funds volume. $TotalAssets$ is the total assets at the bank holding company level. $FF - IOER$ is the spread between volume-weighted mean market fed funds rate and IOER. $Eurodollar - IOER$ is the spread between the volume-weighted mean market Eurodollar rate and IOER. Data is at a weekly frequency (Wednesdays) for the period April 2014 to February 2020.

Table 4: Difference-in-differences regression: Banks borrowing in the fed funds market

Variables	(1) Fed Funds Spread	(2) Fed Funds Spread
DailyReporter*LCRstart	3.983***	4.017***
	(0.508)	(0.507)
MonthlyReporter*MonthEnd*LCRstart		1.662***
		(0.404)
DailyReporter	-2.769***	-2.675***
	(0.362)	(0.356)
MonthlyReporter*MonthEnd		-1.895***
		(0.340)
LCRstart	0.187	0.243
	(0.214)	(0.212)
RelativeChangeDeposits	0.0321**	0.0312**
	(0.0145)	(0.0145)
CashReserves/Assets	-3.019***	-3.108***
	(0.428)	(0.428)
MarketShareFedFunds	79.23***	80.75***
	(4.530)	(4.566)
MarketShareFedFunds^2	-473.3***	-481.0***
	(39.56)	(39.91)
SmallBank	3.175***	3.215***
	(0.239)	(0.231)
FF-IOER	0.801***	0.785***
	(0.00906)	(0.00961)
Foreign	2.354***	2.477***
	(0.290)	(0.283)
Constant	-4.962***	-5.268***
	(0.269)	(0.258)
Observations	13,884	13,884
Number of Banks	103	103

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is the spread between the rate paid by an individual bank to borrow in fed funds and IOER. *DailyReporter* and *MonthlyReporter* are dummy variables equal to 1 if a bank reports in FR 2052a at a daily or monthly frequency, respectively. *MonthEnd* is equal to 1 on month-ends. *LCRstart* is equal to 1 on or after January 1, 2017. *RelativeChangeDeposits* is the normalized value of the change in a bank's deposits relative to the change in deposits across all banks. (*CashReserves/Assets*) is the ratio of cash and balances due from depository institutions (including balances held at Federal Reserve Banks) to total assets. *MarketShareFF* is the share of a bank's borrowing in fed funds to total fed funds volume. *SmallBank* is a dummy variable equal to 1 if total assets at the bank holding company level are less than $50 billion. $FF - IOER$ is the difference between the volume-weighted mean market rate in fed funds and IOER. *Foreign* equals 1 if a bank is a U.S. branch of a foreign bank organization. Data is at a weekly frequency (Wednesdays) for the period April 2014 to February 2020.

Table 5: Fed funds versus Eurodollars after LCR implementation

Variables	(1) Fed Funds	(2) Fed Funds	(3) Eurodollar	(4) Eurodollar
DailyReporter	2.397***	2.418***	-2.102	-2.105
	(0.559)	(0.561)	(2.720)	(2.721)
MonthlyReporter*MonthEnd		-0.215		0.227
		(0.308)		(0.533)
RelativeChangeDeposits	0.00392	0.00323	0.0614	0.0618
	(0.0298)	(0.0299)	(0.0692)	(0.0692)
CashReserves/Assets	-0.709	-0.743*	-5.435***	-5.404***
	(0.434)	(0.436)	(1.244)	(1.246)
MarketShare	54.73***	54.36***	98.49***	98.38***
	(8.139)	(8.170)	(12.23)	(12.24)
MarketShare^2	-284.8***	-282.8***	-381.8***	-381.2***
	(81.55)	(81.78)	(66.30)	(66.27)
SmallBank	0.339	0.388	-1.235**	-1.236**
	(0.256)	(0.256)	(0.494)	(0.495)
MarketSpread	0.905***	0.902***	0.666***	0.670***
	(0.0148)	(0.0159)	(0.0330)	(0.0341)
Foreign	12.05***	12.05***	9.413***	9.402***
	(0.600)	(0.602)	(1.220)	(1.219)
Constant	-14.29***	-14.32***	-9.500***	-9.480***
	(0.626)	(0.626)	(1.153)	(1.152)
Observations	2,966	2,966	2,966	2,966
Number of Banks	34	34	34	34

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is the spread between the rate paid by an individual bank to borrow in fed funds (Eurodollars) and IOER ($Spread_{i,t}$). *DailyReporter* and *MonthlyReporter* are dummy variables equal to 1 if a bank reports in FR 2052a at a daily or monthly frequency, respectively. *MonthEnd* is equal to 1 on month-ends. *RelativeChangeDeposits* is the normalized value of the change in a bank's deposits relative to the change in deposits across all banks. (*CashReserves/Assets*) is the ratio of cash and balances due from depository institutions (including balances held at Federal Reserve banks) to total assets. *MarketShare* is the share of a bank's borrowing in fed funds (Eurodollar) to total fed funds (Eurodollar) volume. *SmallBank* is a dummy variable equal 1 if total assets at the bank holding company level are below $50 billion. *MarketSpread* is the difference between the volume-weighted average rate in fed funds (Eurodollar) and IOER. *Foreign* equals 1 if bank is a U.S. branch of a foreign bank organization. Data is at a weekly frequency (Wednesdays) for the period January 2017 to February 2020. The sample is limited to banks participating in both both markets on the same day.

A Appendix: Robustness Analysis

Table A.1: Difference-in-differences regression: Banks borrowing in the fed funds market: All lenders vs FHLB lenders

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	All	All	All	All	FHLBs	FHLBs
DailyReporter*LCRstart	3.983***	4.017***	1.506*	1.483*	0.727*	0.713*
	(0.508)	(0.507)	(0.790)	(0.786)	(0.410)	(0.408)
MonthlyReporter*MonthEnd*LCRstart		1.662***		1.967***		0.729***
		(0.404)		(0.486)		(0.210)
DailyReporter	-2.769***	-2.675***	-2.329***	-2.070***	-1.036***	-1.048***
	(0.362)	(0.356)	(0.783)	(0.776)	(0.107)	(0.106)
MonthlyReporter*MonthEnd		-1.895***		-2.041***		-1.477***
		(0.340)		(0.403)		(0.180)
LCRstart	0.187	0.243	0.755***	0.827***	0.525***	0.637***
	(0.214)	(0.212)	(0.260)	(0.260)	(0.0878)	(0.0894)
RelativeChangeDeposits	0.0321**	0.0312**	0.0220	0.0216	-0.00293	-0.00922
	(0.0145)	(0.0145)	(0.0221)	(0.0221)	(0.0154)	(0.0151)
Cash_Assets	-3.019***	-3.108***	-4.289***	-4.512***	-0.908***	-1.042***
	(0.428)	(0.428)	(0.638)	(0.637)	(0.221)	(0.220)
MarketShare	79.23***	80.75***	128.1***	131.4***	15.39***	16.14***
	(4.530)	(4.566)	(7.765)	(7.788)	(2.955)	(2.939)
MarketShare2	-473.3***	-481.0***	-904.0***	-926.4***	-73.42**	-72.17**
	(39.56)	(39.91)	(81.04)	(81.40)	(30.96)	(30.88)
SmallBank	3.175***	3.215***	4.243***	4.452***	1.124***	1.111***
	(0.239)	(0.231)	(0.300)	(0.294)	(0.0872)	(0.0881)
FF-IOER	0.801***	0.785***	0.787***	0.771***	0.915***	0.893***
	(0.00906)	(0.00961)	(0.0111)	(0.0118)	(0.00503)	(0.00553)
foreign	2.354***	2.477***	0.575	0.834**	-1.055***	-0.998***
	(0.290)	(0.283)	(0.384)	(0.379)	(0.102)	(0.103)
Constant	-4.962***	-5.268***	-5.634***	-6.103***	-0.769***	-0.995***
	(0.269)	(0.258)	(0.370)	(0.361)	(0.108)	(0.110)
Observations	13,884	13,884	10,388	10,388	6,942	6,942
Number of banks	103	103	91	91	66	66

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is the spread between the rate paid by an individual bank to borrow in fed funds and IOER. The specification labels *All* and $FHLBs$ correspond to including trades with all counterparties and only those with FHLBs, respectively. $DailyReporter$ and $MonthlyReporter$ are dummy variables equal to 1 if a bank reports in FR 2052a at a daily or monthly frequency, respectively. $MonthEnd$ is equal to 1 on month-ends. $LCRstart$ is equal to 1 on or after January 1, 2017. $RelativeChangeDeposits$ is the normalized value of the change in a bank's deposits relative to the change in deposits across all banks. $(CashReserves/Assets)$ is the ratio of cash and balances due from depository institutions (including balances held at Federal Reserve banks) to total assets. $MarketShare$ is the share of a bank's borrowing in fed funds to total fed funds volume. $SmallBank$ is a dummy variable equal to 1 if total assets at the bank holding company level are less than $50 billion. $FF - IOER$ is the difference between the volume-weighted mean market rate in fed funds and IOER. $Foreign$ equals 1 if a bank is a U.S. branch of a foreign bank organization. The data is at a weekly frequency (Wednesdays). Specifications 1 and 2 start in April 2014; specifications 3 through 6 start in October 2015. The end date in all specifications is February 2020.

Table A.2: Difference-in-differences regression: Banks borrowing in the Eurodollar market

Variables	(1) Eurodollar	(2) Eurodollar
DailyReporter*LCRstart	-4.135*	-4.108*
	(2.119)	(2.120)
MonthlyReporter*EndOfMonth*LCRstart		1.149*
		(0.630)
DailyReporter	1.741	1.747
	(2.016)	(2.014)
MonthlyReporter*EndOfMonth		-0.656
		(0.536)
LCRstart	0.174	0.111
	(0.385)	(0.394)
RelativeChangeDepTotal	0.0567	0.0535
	(0.0370)	(0.0373)
Cash/Assets	-4.035***	-4.026***
	(0.761)	(0.764)
MarketShareEurodollar	51.26***	51.56***
	(5.032)	(5.090)
MarketShareEurodollar^2	-137.1***	-137.2***
	(19.02)	(19.11)
SmallBank	-0.426	-0.487
	(0.371)	(0.386)
Eurodollar-IOER	0.667***	0.671***
	(0.0181)	(0.0194)
Foreign	10.48***	10.66***
	(1.017)	(1.020)
Constant	-12.04***	-12.08***
	(0.997)	(0.996)
Observations	8,383	8,383
Number of banks	48	48

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: The dependent variable is the spread between the rate paid by an individual bank to borrow in Eurodollar and IOER. *DailyReporter* and *MonthlyReporter* are dummy variables equal to 1 if a bank reports in FR 2052a at a daily or monthly frequency, respectively. *MonthEnd* is equal to 1 on month-ends. *LCRstart* is equal to 1 on or after January 1, 2017. *RelativeChangeDeposits* is the normalized value of the change in a bank's deposits relative to the change in deposits across all banks. (*CashReserves/Assets*) is the ratio of cash and balances due from depository institutions (including balances held at Federal Reserve banks) to total assets. *MarketShare* is the share of a bank's borrowing in Eurodollar to total Eurodollar volume. *SmallBank* is a dummy variable equal to 1 if total assets at the bank holding company level are less than $50 billion. $Eurodollar - IOER$ is the difference between the volume-weighted mean market Eurodollar rate and IOER. *Foreign* equals 1 if a bank is a U.S. branch of a foreign bank organization. Data is at a weekly frequency (Wednesdays) for the period April 2014 to February 2020.