Finance and Economics Discussion Series

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

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2022-071

Please cite this paper as:
Tase, Manjola (2022). "Demand Segmentation in the Federal Funds Market," Finance and Economics Discussion Series 2022-071. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/FEDS.2022.071.

Demand Segmentation in the Federal Funds Market

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October 19, 2022

Abstract

This paper outlines a model of demand segmentation in the federal funds market with two types of borrowers - the "interest on reserves (IOR) arbitrage" type and the "regulatory" type - which have different reservation prices and cannot always be separated. When fed funds trade above IOR, the "regulatory" type is revealed and consequently pays an interest rate closer to its real reservation price, pushing the fed funds rate further up. When fed funds trade below IOR, a decrease in the fed funds rate encourages entry in the market for IOR arbitrage purposes thus counteracting the downward pressure on the fed funds rate. We use probit regression models and daily data for the period April 2018 to February 2020 to provide empirical support for this model. We find the following: 1) When fed funds trade above IOR, there is, on average, a 10 percentage points increase in the probability that the fed funds rate increases the following period. Furthermore, analysis using confidential bank-level data shows that this increase in the probability is higher for banks that report their liquidity profile daily and that were present all trading days during this period. 2) When the fed funds trade below IOR, the probability of a decrease in the fed funds rate decreases with the widening of the spread between the fed funds rate and IOR.

Keywords: fed funds, demand segmentation, repo, monetary policy

JEL Classification: E49, E52, G28

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1 Introduction

The nature of the federal funds market has changed substantially since the 2008 financial crisis. Before the crisis, the federal funds market was mostly an interbank market in which the largest players on both the demand and supply sides were domestic commercial banks: institutions with reserve balances in excess of reserve requirements lent excess reserves to depository institutions (DIs) with reserve deficiencies.

During the 2008 financial crisis there were two developments in the Federal Reserve's (Fed's) monetary policy framework that affected the size of and return on reserves, which triggered new trading dynamics in the fed funds market. First, in October 2008, the Fed introduced interest on reserves (IOR) that allowed banks to earn interest on their reserves held at the Fed. Second, the amount of reserves in the system increased dramatically as a result of the Fed's large-scale asset purchase in response to the 2008 financial crisis. While IOR was effective at influencing the effective federal funds rate (EFFR), it did not serve as a hard minimum rate at which all institutions were willing to lend funds. Some institutions, such as Government Sponsored Enterprises (GSEs), are eligible to lend funds in the fed funds market but are not eligible to earn IOR. Bech and Klee (2011) show that if GSEs command low interest rates and their share is sufficiently large, then EFFR would be below the IOR rate. Under these conditions, fed funds market participants who are not eligible to earn IOR on their balances at the Fed (such as the GSEs) become the primary sellers of fed funds. These institutions sell fed funds to DIs who have an incentive to borrow funds at below the IOR rate and hold the funds in their reserve account at the Fed to earn the IOR rate, a trading strategy referred to as IOR arbitrage.

As the Fed's balance sheet normalization progressed during the following monetary policy tightening cycle, fed funds traded closer to or above IOR. Specifically, during the period April 2018 to February 2020, the EFFR was above IOR for 1/3 of the tradings days. If arbitrage were the major motive, then fed funds volumes would decline to low levels when IOR arbitrage is no longer profitable. Contrarily, while the average daily trading volume on these days was lower than when the fed funds rate traded below IOR, such a difference was in line with historical variations in daily trading volume.

We hypothesize that part of the seemingly IOR arbitrage activity could reflect other types of motives which are not distinguishable from IOR arbitrage when IOR arbitrage is profitable. We account for these trading motives by presenting a model of demand segmentation with two types of borrowers - the "IOR arbitrage" type and the "regulatory" type - which cannot always be separated. The "IOR arbitrage" type borrows to earn the spread between the fed funds rate and IOR. Its reservation price is IOR. The "regulatory" type borrows to satisfy reserve requirements or internally set targets about its liquidity portfolio. Its reservation price is the interest rate at the discount window which is higher than IOR. If the fed funds rate is below IOR, then the two types are pooled in as "IOR arbitrage" types with IOR as the reservation price. If the fed funds rate is above IOR, which could be the case during a monetary policy tightening cycle, the "regulatory" type, and its true reservation price, is revealed. As this new information is embedded in the price, the probability of an increase in the fed funds rate increases.

We use market-level data and confidential bank-level data to test the hypothesis that when fund funds trade above IOR, there is an increase in the likelihood of a further increase in the fed funds rate. First, using market-level daily data for the period April 2018 to February 2020, we find that fed funds trading above IOR is associated with a 10 percentage point increase in the likelihood of an increase in the fed funds rate the following period. This market-level analysis likely provides a conservative estimate; banks might not be present in the fed funds market every day, or might not even trade with the same partners, hence decreasing the share of banks revealed as trading for motives other than IOR arbitrage. Using confidential bank-level data where we can account for bank's presence in the fed funds market, we find that for banks participating every trading day, paying a rate higher than IOR is associated with a 15 percentage point increase in the probability of paying a higher rate the following period.

While the reveal of the "regulatory" type increases the probability of an increase in the fed funds rate when fed funds trade above IOR, an increase in demand for IOR arbitrage counteracts the downward pressure on the fed funds rate when fed funds trade below IOR. Specifically, when EFFR is less than IOR, as the spread between EFFR and IOR widens (EFFR-IOR becomes more negative), IOR arbitrage becomes profitable for a larger number of banks inducing an increase in demand for IOR arbitrage. As a result, the initial downward pressure on the fed funds rate is then counteracted by such increase in demand for IOR arbitrage. Indeed, using market-level daily data for the period April 2018 to February 2020, we find that when fed funds trade below IOR, a widening of the $EFFR - IOR$ spread is associated with a decrease in the probability of a decrease in the fed funds rate.

This paper contributes to the broad literature on the fed funds market which has seen significant changes over time. Earlier work as in Hamilton (1996), Ashcraft and Duffie (2007), Afonso and Lagos (2015b), and Afonso and Lagos (2015a) focus on the fed funds market as a market for reserves. This characterization of the market corresponds to the "regulatory" type in this paper. In the models by Bech and Klee (2011) and Schulhofer-Wohl and Clouse (2018) the fed funds rate remains persistently below IOR which in our model corresponds to the case when the "IOR arbitrage" type and the "regulatory" are pooled. Afonso, Kovner, and Schoar (2011) and Ashcraft, McAndrews, and Skeie (2011) look at the fed funds market during the 2007-2008 financial crisis and examine the importance of liquidity hoarding and counterparty risk during that period. Our paper is most closely related to Afonso, Armenter, and Lester (2019). Their model implies 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. In our model, rate dynamics in the fed funds market, as monetary policy tightening puts upward pressure on the fed funds rate, are driven by the known part of the distribution of reserves across banks and the corresponding motives for trading in the fed funds market.

The remainder of the paper is organized as follows. The next section motivates and describes a model of demand segmentation and derives testable hypotheses. Section 3 uses market-level data to test these hypotheses. Section 4 provides further analysis of dynamics in the fed funds market using confidential bank-level data. Section 5 concludes.

2 A model of demand segmentation in the fed funds market

2.1 Motivation

If arbitrage were the major motive for trading in fed funds, then fed funds volumes would decline to low levels when IOR arbitrage is no longer profitable. Figure 1 shows that during most of 2018, fed funds volume declined as EFFR, although still remaining lower than IOR, traded closer to IOR.[1] This suggests that, as EFFR started increasing in the target range and got closer to IOR, trading for IOR arbitrage declined.

We then look into summary statistics about fed funds volume broken down into two states: 1) $EFFR \leq IOR$, and 2) $EFFR > IOR$. As shown in Table 1, during the period April 2018 to February 2020, EFFR printed above IOR during 1/3 of the trading days (162 days out of 480). While average daily trading volume on these days was lower than when EFFR printed below IOR, such difference was in line with deviations in daily trading volume. The average daily trading volume when $EFFR \leq IOR$ and $EFFR > IOR$ was $72 billion and $67 billion respectively. While this difference is statistically significant, it is about 1/2 of the standard deviation of daily trading volume. This suggests that part of the seemingly IOR arbitrage activity could reflect other types of motives.

Next we describe a model of demand segmentation in the fed funds market with two types of

[1] On a technical note, EFFR is calculated as a volume-weighted median of overnight federal funds transactions reported in the FR 2420 Report of Selected Money Market Rates. By construction, that implies even when $EFFR \leq IOR$ or $EFFR > IOR$, there are fed funds trades at an interest rate above IOR and below IOR, respectively.

borrowers: the "IOR arbitrage" type and the "regulatory" type.

2.2 Model

There are three types of agents in the economy: the Fed; depository institutions (banks) which are eligible to earn interest on their reserve balances held at the Fed; institutions, such as GSEs, which are not eligible to earn interest on reserves. We will describe Federal Home Loan Banks (FHLBs), a type of GSE, which provide almost all of the lending in the fed funds market. We describe each of these agents, the sequence of events and the equilibrium outcome below.

The Fed. The Fed manages the following facilities. First, since October 2008, the Fed has been paying IOR to depository institutions holding reserve balances at the Fed. Second, since September 2013, the Fed operates an overnight reverse repo (ON RRP) facility that offers an overnight rate $i^{onrrp} < IOR$. The ON RRP facility is available to a broad range of counterparties including depository institutions, primary dealers, money funds and GSEs.[2] The ON RRP rate has a direct effect on the fed funds market as it sets the minimum rate at which GSEs are willing to lend in the fed funds market.[3] Lastly, the Fed lends to banks at the discount window (DW) at an overnight interest rate $i^{dw} > IOR$.

FHLBs. FHLBs manage their liquidity portfolio by participating in the fed funds market, at the ON RRP facility and the private repo market with the ON RRP facility providing the lowest return. FHLBs can always participate at the ON RRP facility and they will lend in the fed fund market only if the fed funds rate (i^{ff}) is larger than the ON RRP rate, $i^{ff} > i^{onrrp}$. An increase in the interest rate in the private repo market negatively affects FHLBs lending in the fed funds market through two channels: 1) portfolio substitution, and 2) funding costs. First, if repo rates are relatively more favorable, then FHLBs might shift part of their liquidity portfolio from fed funds into repo. Second, higher repo rates would also increase the cost of discount notes issued by

[2]See `https://www.newyorkfed.org/markets/rrp_counterparties` for a list of ON RRP eligible counterparties.

[3]Since September 2019, the Fed has been conducting repo operations with the primary dealers, which have an indirect in the fed funds market through the repo rate.

FHLBs which FHLBs use to finance their lending in fed funds.

Banks. There are two types of borrowers in the fed funds market: 1) those who borrow for IOR arbitrage, the demand for arbitrage (D^{arb}), and 2) those who borrow to satisfy regulatory requirements, the regulatory demand (D^{reg}). D^{arb} is driven by the profit from IOR arbitrage defined as the spread a bank earns by borrowing in the fed funds market and holding those funds in reserve balances at the Fed. IOR arbitrage would be profitable if $i^{ff} < IOR$.[4] D^{reg} represents borrowing for satisfying reserve requirements, liquidity metrics or settlement of payments. The main driver of D^{reg} is short-term/unexpected liquidity needs. To satisfy these needs, banks have two alternatives: borrow in fed funds (i^{ff}) or at the Fed's discount window (i^{dw}). Banks will borrow in fed funds if ($i^{ff} < i^{dw}$).

The market demand is $D^{market} = D^{arb} + D^{reg}$. D^{reg} is more interest rate inelastic than D^{arb}.[5] If $i^{ff} < IOR$, banks which form D^{reg} can still earn the IOR arbitrage spread. In this case, D^{reg} and D^{arb} are pooled in and the lender cannot not distinguish between the two types of borrowers. If $i^{ff} > IOR$, arbitrage is not profitable, $D^{arb} = 0$, market demand is $D^{market} = D^{reg}$ and the borrower's type is revealed.

Sequence of events. There are two time periods: today ($t = 0$) and tomorrow ($t = 1$).

At time $t = 0$, EFFR starts to trade above IOR. EFFR surpassing IOR could reflect a gradual increase in EFFR as could be the case during monetary policy tightening, or it could be due to events that would lead to a more abrupt increase in the fed funds rate.[6] In lender - borrower trading pairs at time $t = 0$, the type of the borrower is revealed.

At time $t = 1$, a new trading day starts. Lenders and borrowers are matched and trading pairs are formed. The bank might be paired with the same lender as at time $t = 0$ or not.

[4] We abstract from stigma around the discount window or heterogeneity in terms of cost of balance sheet expansion related to IOR arbitrage (see Banegas and Tase (2020)). The main feature of the model, and the driver of the results, is the two types of borrowers with different reservation prices.

[5] Under constant returns, D^{arb} would be perfectly elastic at IOR (or ($IOR - \gamma$), where γ reflects the marginal cost of balance sheet expansion).

[6] See Schulhofer-Wohl (2019) for an illustration of such events.

Equilibrium. FHLBs are willing to lend in the fed funds market as long as $i^{ff} > i^{onrrp}$. The reservation price for D^{arb} type and the D^{reg} type is IOR and i^{dw}, respectively. The $(IOR - i^{onrrp})$ spread is split between FHLBs and the D^{arb} type, and the $(i^{dw} - i^{onrrp})$ spread is split between FHLBs and the D^{reg} type.

Let p be the revealed share of D^{reg}. Then the market fed funds rate, ${i_m}^{ff}$, would be set as in equation 1:

$$ {i_m}^{ff} = (1-p)\left(i^{onrrp} + \alpha_1(IOR - i^{onrrp})\right) + p\left(i^{onrrp} + \alpha_2(i^{dw} - i^{onrrp})\right) \tag{1} $$

where α_1 and α_2 are determined by the relative bargaining power between borrowers and lenders. If the bargaining power does not not vary with the type of the borrower, then $\alpha_1 = \alpha_2$. Furthermore, if the spread is split evenly between the borrower and the lender, then $\alpha_1 = \alpha_2 = 1/2$.

We can distinguish two states:

1. *Borrower's type is revealed.* If there are fed funds trades at a rate greater than IOR, then the borrower's type is revealed and $p \neq 0$ and the market fed funds rate increases. The market fed funds rate is given as in equation 1 above.

2. *Borrower's type is not revealed.* If there are no fed funds trades at a rate greater than IOR, then the borrower's type cannot be revealed and $p = 0$. In this case, equation 1 is simplified as in equation 2 below:

$$ {i_m}^{ff} = i^{onrrp} + \alpha_1(IOR - i^{onrrp}) \tag{2} $$

By construction, i^{onrrp} is the lower bound for the fed funds rate. There is an additional mechanism that pulls the fed funds rate away from the lower bound: potential new entrants for IOR arbitrage purposes. Banks are heterogeneous in terms of funding costs. As a result, the number of banks for which IOR arbitrage is profitable, hence D^{arb}, increases with the widening of the

${i_m}^{ff} - IOR$ spread. When ${i_m}^{ff} < IOR$, the initial downward pressure on the fed funds rate, which led to fed funds trading closer to the lower bound, is then counteracted by the upward pressure on the fed funds rate due to an increase in D^{arb}. This increase in D^{arb} pulls the rate up from the lower bound when exogenous factors put downward pressure on the fed funds rate.

Testable hypotheses.

1. Probability of an increase in the fed funds rate is higher when fed funds trade above IOR.

2. When $EFFR < IOR$, the probability of a decrease in $EFFR - IOR$ decreases with the widening of the $EFFR - IOR$ spread.

3 Empirical testing using market-level data

In this section, we analyze dynamics in the fed funds market using market-level data. First, we discuss factors affecting dynamics in the fed funds market and describe the data. Then we test the following hypotheses: 1) Probability of an increase in $EFFR - IOR$ is higher when $EFFR > IOR$. 2) When $EFFR < IOR$, the probability of a decrease in $EFFR - IOR$ decreases with the widening of the $EFFR - IOR$ spread.

3.1 Factors affecting the fed funds market rate

In our empirical analysis, we account for the following factors affecting the fed funds market rate.

Changes in the repo rate. As described in the discussion about FHLBs, an increase in the repo rate is expected to put pressure on the fed funds rate.[7] Figure 2 plots the $EFFR - IOR$ spread the spread between the repo rate as measured by the Broad General Collateral Rate (BGCR) and the ON RRP rate, respectively. The repo rate is more volatile than the fed funds rate as it reflects trading conditions in a broader market.

[7] See Klee, Senyuz, and Yoldas (2019) for an empirical analysis of comovement in money market rates.

General reserves conditions. Figure 3 plots the aggregate level of reserves. The downward trend in reserves until September 2019 reflects the Fed's balance sheet normalization process which began in October 2017 and concluded in August 2019.[8] In our empirical model, we control for the effect of the level of reserves on the likelihood of an increase in the spread between the fed funds rate and IOR.

Exogenous shocks to the supply of reserves. The aggregate level of reserves is affected by Fed's open market operations and other factors called "autonomous" factors. An increase in the autonomous factors causes reserves to decline, all other things equal. Among these factors, the Treasury General Account (TGA), plotted in Figure 4 is the most volatile.[9] Changes in the TGA can be substantial, especially around tax days, and can cause frictions in the market. We use changes in the TGA to capture these shocks.

3.2 Data

We use daily data for the period April 2018 to February 2020. The following data are publicly available. EFFR and BGCR are from the Federal Reserve Bank of New York; IOR is from the Federal Reserve Board; ON RRP is from Federal Reserve Bank of New York; Treasury General Account (TGA) data is from U.S. Department of Treasury.[10] Daily reserves data are not public. Weekly reserves data are shown in the Federal Reserve's H.4.1 statistical release.[11]

3.3 Empirical specification and results

Hypothesis 1: Probability of an increase in** $EFFR - IOR$ **is higher when** $EFFR > IOR$**.

One implication of the model is that the probability of an increase in the fed funds rate is higher

[8] See `https://www.federalreserve.gov/monetarypolicy/policy-normalization-discussions-communications-history.htm` for details.

[9] See Ihrig, Senyuz, and Weinbach (2020) for a description of "autonomous" factors.

[10] EFFR and BGCR (`https:/www.newyorkfed.org/markets/reference-rates`); IOR (`https://www.federalreserve.gov/datadownload/Choose.aspx?rel=PRates`); ON RRP (`https://apps.newyorkfed.org/markets/autorates/temp`); TGA (`https://fiscaldata.treasury.gov/datasets/daily-treasury-statement/`).

[11] Weekly reserves data (`https://www.federalreserve.gov/releases/h41/`).

when the fed funds rate is above IOR. Once a bank accepts a rate greater than IOR, it reveals its true type and its true reservation price, the DW rate. The lender can use this information to settle on a higher interest rate in the following period. However, the next period, the bank might not participate in the market, or it might not be matched with the same lender. As a result, this increase in the probability of an increase in the fed funds rate embeds both the added information from bank's type reveal as well as the probability of the same lender-borrower pair trading the following period.

We use a probit regression model to estimate the effect on the probability of $EFFR - IOR$ spread increasing at time t, if EFFR was trading above IOR at time $t-1$. The empirical specification is shown in equation 3.

$$\begin{aligned} P[Spike_t^{EFFR}] = F[&\alpha_0 + \alpha_1 RevealType_{t-1} \\ &+ \alpha_2 Spike^{(repo_t - i_t^{ONRRP})} + \alpha_3 ln(reserves_t) + \alpha_4 shockReserves_t] \end{aligned} \tag{3}$$

where $Spike_t^{EFFR} = 1$ if $\Delta(EFFR_t - IOR_t) > 0$, 0 otherwise; $RevealType_t = 1$ if $EFFR_t > IOR_t$, 0 otherwise; $Spike^{(repo_t - i_t^{ONRRP})} = 1$ if $\Delta(repo_t - i_t^{ONRRP}) > 0$, 0 otherwise, where repo is the Broad General Collateral Rate (BGCR), a measure of rates on overnight Treasury general collateral repurchase agreement (repo) transactions; $ln(reserves_t)$ is the aggregate level of reserve balances; $shockReserves_t = -\Delta ln(TGA_t)$, where Treasury General Account (TGA), captures supply shocks (an increase in TGA leads to a decrease in reserves).

Table 2 shows the regression coefficients and marginal effects. The coefficients have the expected sign and are statistically significant across various specifications. EFFR trading above IOR in the prior period ($RevealType = 1$), an increase in the repo rate, and negative shock to reserves are associated with a increase in the likelihood of an increase in the $EFFR - IOR$ spread.

Looking at the marginal effects, there is a 10 percentage points increase in the probability of an increase in the $EFFR - IOR$ spread when $EFFR > IOR$. As a comparison, an increase in the repo rate relative to the ONRRP rate is associated with about 15 percentage points increase in the probability of the $EFFR - IOR$ spread increasing the same period. This implies that if EFFR increases above IOR in the current period, there is higher likelihood that it will continue to further increase in the following period controlling for other confounding factors affecting the fed funds market. These regression results provide a conservative estimate as the share of the revealed D^{reg} type is less than the actual share of the D^{reg} type. These two would be the same if the same lender-borrower pair would be trading every period. Even if individual lenders and borrowers were present in each period, they might not be always matched (when a match is formed) to form the same pair.[12]

Hypothesis 2: When $EFFR < IOR$, probability of a decrease in $EFFR - IOR$ decreases with the widening of the $EFFR - IOR$ spread.

A decrease in the fed funds rate relative to IOR would make IOR arbitrage profitable for a larger number of banks leading to an increase in their demand to borrow in the fed funds market. This increase in demand would imply a decrease in the probability of a decrease in the fed funds rate in the following period.

We use a probit regression model to test whether the probability of a drop in $EFFR - IOR$ at time t is negatively associated with the $EFFR - IOR$ spread at time $t - 1$ while controlling for other factors affecting the fed funds rate. We use $EFFR - IOR$ spread in the prior period to capture the increase in D^{arb}.

The empirical specification is given in the equation 4 below.

[12]For example, conditional on a bank being matched, if matches are random and independent across time periods, there is a $(1/n) * (1/n)$ chance of a bank getting matched with the same lender at time $t = 0$ and at time $t = 1$, where $n = 11$ is the number of FHLBs. However, given relationship lending, we would expect the probability of the same trading pair across different time periods to be higher than what would be suggested by random matches.

$$P[Drop^{EFFR_t}] = F[\alpha_0 + \alpha_1(EFFR_{t-1} - IOR_{t-1})$$
$$+ \alpha_2 Drop^{(repo_t - i_t^{ONRRP})} + \alpha_3 ln(reserves_t) + \alpha_4 shockReserves_t] \quad (4)$$

where $Drop^{EFFR_t} = 1$ if $\Delta(EFFR_t - IOR_t)) > 0$, 0 otherwise; $Drop^{(repo_t - i_t^{ONRRP})} = 1$ if $\Delta(repo_t - i_t^{ONRRP}) < 0$, 0 otherwise, where repo is the Broad General Collateral Rate (BGCR), a measure of rates on overnight Treasury general collateral repurchase agreement (repo) transactions; $ln(reserves_t)$ is the aggregate level of reserves balances; $shockReserves_t = -\Delta ln(TGA_t)$, where Treasury General Account (TGA), captures supply shocks (an increase in TGA leads to a decrease in reserves).

Table 5 shows the regression coefficients and marginal effects. A decrease in the $EFFR - IOR$ spread is associated with a decrease in the probability of a decrease in EFFR when EFFR is trading below IOR. This coefficient is statistically significant across various specifications. A positive shock in reserves is associated with a higher probability of a drop in the fed funds rate. A decrease in the repo rate and the level of reserves are not statistically significant.

Figure 5 plots the estimated probabilities from the probit model for various values of the $EFFR - IOR$ spread. As shown in Figure 5 the probability of a drop in the fed funds rate decreases as the $EFFR - IOR$ spread widens. The increase in demand for IOR arbitrage as the EFFR-OIR spread widens counteracts the exogenous downward pressure in the fed funds market. Furthermore, as shown in Figure 5, the probability of a decrease in fed funds rate approaches zero as fed funds trade 4 basis point below IOR or lower. [13] This result implies that when EFFR is about 4 basis points below IOR, IOR arbitrage would be profitable for most banks: IOR arbitrage is a trading strategy that expands the banks balance sheet and banks incur costs related to balance sheet expansion. In addition, as domestic banks are subject to FDIC fees which increase with

[13]During the period April 2018 to March 2020, conditioning on $EFFR < IOR$, the IOR-EFFR spread had a mean of 3.5 basis points and a standard deviation of 1.6 basis points.

the size of the balance sheet, IOR arbitrage is more expensive for domestic banks than for foreign banks.[14]

4 Empirical testing using bank-level data

In this section, we use bank-level data to analyze rate dynamics when the bank's type is revealed. We test the following hypotheses: 1) Probability of an increase in the fed funds rate paid by the bank increases if the bank paid a rate higher than IOR in the previous period. 2) The more frequently the bank participates in the market, the stronger the effect of revealing the bank type on the probability of an increase in the rate paid by that bank. First, we discuss factors affecting the fed funds rate paid by a bank and describe the data. Then we discuss the empirical specification and results.

4.1 Factors affecting the fed funds rate paid by a bank

In our empirical analysis, we account for the following factors affecting the interest rate paid by a bank when borrowing in the fed funds market.

General trading conditions in the fed funds market. We use the spread between EFFR and IOR to capture general trading conditions in the fed funds market.

Liquidity management motives. Some banking organizations, which include certain domestic banks and U.S. branches of foreign banks, report variables related to their liquidity profile either at a daily or monthly frequency, based on their size and international exposure.[15] Daily liquidity reporting requirements could drive demand for certain types of short-term funding which improve a banks liquidity profile. Anderson and Tase (2022) find that, starting from 2017, daily reporters paid on average more than other banks when borrowing in the fed funds market. We would also

[14] See Banegas and Tase (2020) for details on the FDIC fee and profitability of IOR arbitrage for domestic versus foreign banks.

[15] On November 17, 2015, the Federal Reserve 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.

expect this type of demand to be less elastic and result in a higher likelihood of a rate increase.

Differences in IOR arbitrage profitability. We use a bank's domicile (foreign vs. domestic) to capture differences in profitability from IOR arbitrage. Foreign banks are not subject to the FDIC assessment fee which decreases the profitability of transactions that lead to an increase the size of the bank's balance sheet (Banegas and Tase (2020)).

4.2 Data

We use daily data for the period April 2018 to February 2020. Bank-level data on borrowing in the fed funds market is from confidential microdata collected by the Federal Reserve from the FR 2420 form (Report of Selected Money Market Rates). We construct the LCR/liquidity metrics reporting frequency variable by matching the banks reporting in FR 2420 with reporters of FR 2052a (Complex Institution Liquidity Monitoring Report). We provide more details on these datasets below.

The FR 2420 report is filed by banks on a daily basis and collects transaction-level data on their borrowing activity in selected money market instruments that were executed on the report date. 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. Reported information includes the trade date, settlement date, maturity date, amount, interest rate, and counterparty type for each transaction.[16] The FR 2420 collection supports the publication of the EFFR, the Federal Reserves target policy rate, and the overnight bank funding rate (OBFR). Microdata from the FR 2420 are considered confidential and are not published.[17]

[16]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.

[17]https://www.newyorkfed.org/banking/reportingforms/FR_2420.html

We create a dataset of liquidity profile 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 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 US 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; 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.[18]

4.3 Empirical specification and results

We use a probit model as shown in equation 5.

$$\begin{aligned} P[Spike^{i^{ff}_{i,t}}] = F[&\alpha_0 + \alpha_1 RevealBankType_{i,t} \\ &+ \alpha_2 Spike^{(EFFR_t - i^{IOR}_t)} + \alpha_3 DailyReporter_i + \alpha_4 foreign_i] \end{aligned} \tag{5}$$

where $Spike^{i^{ff}_{i,t}} = 1$ if $\Delta(i^{ff}_{i,t} > IOR_t) > 0$, 0 otherwise $RevealBankType_{i,t} = 1$ if $i^{ff}_{i,t} > IOR_t$, 0 otherwise; $Spike^{(EFFR-IOR)}_t = 1$ if $\Delta(EFFR_t - IOR_t) > 0$, 0 otherwise; $foreign_i = 1$ if bank i is a foreign banking organization; $DailyReporter = 1$ if bank i reports its liquidity profile daily.

The coefficient of interest, α_1, estimates the effect on the probability of an increase in the fed funds rate paid by bank i at time t, if the fed funds rate paid by bank i at time $t-1$ is higher than IOR.

Table 3 shows the regression coefficients and marginal effects for three subsamples: each subsample corresponds to different levels of bank's presence in the fed funds market. Specifically, there is a total of 480 trading days in our sample period, April 2018 to February 2020. We capture

[18] https://www.federalreserve.gov/apps/reportingforms/Report/Index/FR_2052a

bank's presence by the number of trading days the bank participates in the market: at least 240 days, 360 days and 480 days which correspond to a bank participating in the market at least 1/2, 2/3 or all trading days respectively. We would expect that the more frequent a bank's presence in the market, the more often the lender can observe the behavior of that bank under different trading conditions and the higher the quality of the information revealed.

The coefficients have the expected signs. If a bank pays a fed funds rate higher than IOR, then it is revealed as a D^{reg} type. This bank type reveal is associated with a higher probability that the rate paid by the bank will increase. We also control for other factors affecting the fed fund rate paid by the bank, such as general trading condition and liquidity reporting requirements.

Looking at the marginal effects, for banks present in the market at least 1/2 of time, if the bank type is revealed as D^{reg}, there is a 11 percentage point increase in the probability that the rate paid by the bank increases. For banks present at least 2/3 of the time or all the time, the increase in the probability is 12 and 15 percentage points respectively.

The probability of a rate spike is higher for banks that report their liquidity profile daily with the largest effect reported for the subsample of banks that were present in all trading days during this period. This could be explained by liquidity reporting motives, hence less rate sensitive trades, driving borrowing by these banks. This is consistent with the findings in Anderson and Tase (2022) that, starting from 2017, daily reporters paid on average more than other banks when borrowing in the fed funds market. In addition, in this paper we find that they also are the more likely to see a rate increase.

5 Conclusion

Changes in the target range for the fed funds rate is the Fed's primary means of adjusting the stance of monetary policy.[19] As such, understanding trading motives in the fed funds market and

[19] https://www.federalreserve.gov/newsevents/pressreleases/monetary20220126c.htm

the resulting dynamics are of particular interest. This paper points to the implications of different trading motives under two states of the fed funds market: 1) If $EFFR < IOR$, the "IOR arbitrage" type and the "regulatory" type are pooled, and the market is likely to stay in that state. 2) If $EFFR > IOR$, which could be the case during monetary policy tightening, as trading motives are revealed, there is an increase in the probability of an increase in the fed funds rate. This implies that once the fed funds rate is above IOR, there is an increase in the likelihood that fed funds continue to trade above IOR. This propensity for the fed funds rate to continue to remain above IOR could have implications for the setting of IOR relative to the target range for the fed funds rate.

References

AFONSO, G., R. ARMENTER, AND B. LESTER (2019): "A Model of the Federal Funds Market: Yesterday, Today, and Tomorrow," Review of Economic Dynamics, 33, 177–204.

AFONSO, G., A. KOVNER, AND A. SCHOAR (2011): "Stressed, not Frozen: The Federal Funds Market in the Financial Crisis," The Journal of Finance, 66, 1109–1139.

AFONSO, G., AND R. LAGOS (2015a): "The Over-the-Counter Theory of the Feds Funds Market: A primer," Journal of Money, Credit and Banking, 47, 127–154.

——— (2015b): "Trade Dynamics in the Market for Federal Funds," Econometrica, 83, 263–313.

ANDERSON, A., AND M. TASE (2022): "Regulatory Premium in the Federal Funds Market," Unpublished manuscript.

ASHCRAFT, A., AND D. DUFFIE (2007): "Systemic Illiquidity in the Federal Funds Market," The American Economic Review, 97, 221–225.

ASHCRAFT, A., J. MCANDREWS, AND D. SKEIE (2011): "Precautionary Reserves and the Interbank Market," Journal of Money, Credit and Banking, 43, 311–348.

BANEGAS, A., AND M. TASE (2020): "Reserve Balances, the Federal Funds Market and Arbitrage in the New Regulatory Framework," Journal of Banking and Finance, 118.

BECH, M., AND E. KLEE (2011): "The Mechanics of a Graceful Exit: Interest on Reserves and Segmentation in the Federal Funds Market," Journal of Monetary Economics, 5, 415–431.

HAMILTON, J. D. (1996): "The Daily Market for Federal Funds," Journal of Political Economy, 104(1), 26–56.

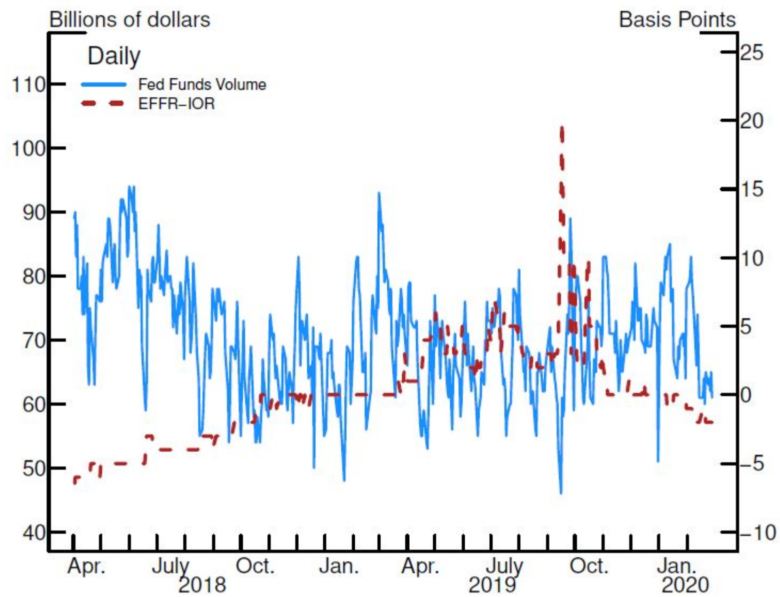
IHRIG, J., Z. SENYUZ, AND G. C. WEINBACH (2020): "The Fed's "Ample-Reserves" Approach to Implementing Monetary Policy," Finance and Economics Discussion Series, 2020-022.

Klee, E., Z. Senyuz, and E. Yoldas (2019): "Effects of Changing Monetary and Regulatory Policy on Money Markets," International Journal of Central Banking, 15, 165–205.

Schulhofer-Wohl, S. (2019): "Understanding Recent Fluctuations in Short-Term Interest Rates," Chicago Fed Letter, (423).

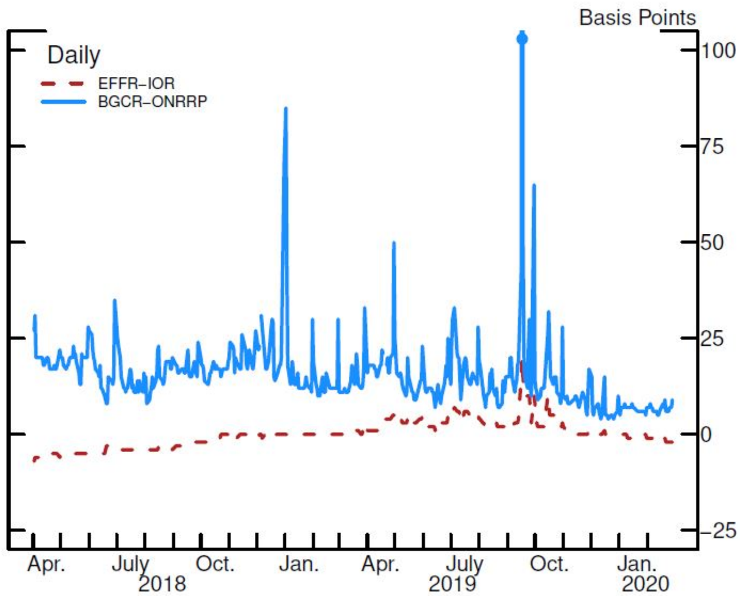
Schulhofer-Wohl, S., and J. A. Clouse (2018): "A Sequential Bargaining Model of the Fed Funds Market with Excess Reserves," FRB of Chicago Working Paper.

Figure 1: Trading volume and interest rate in the fed funds market



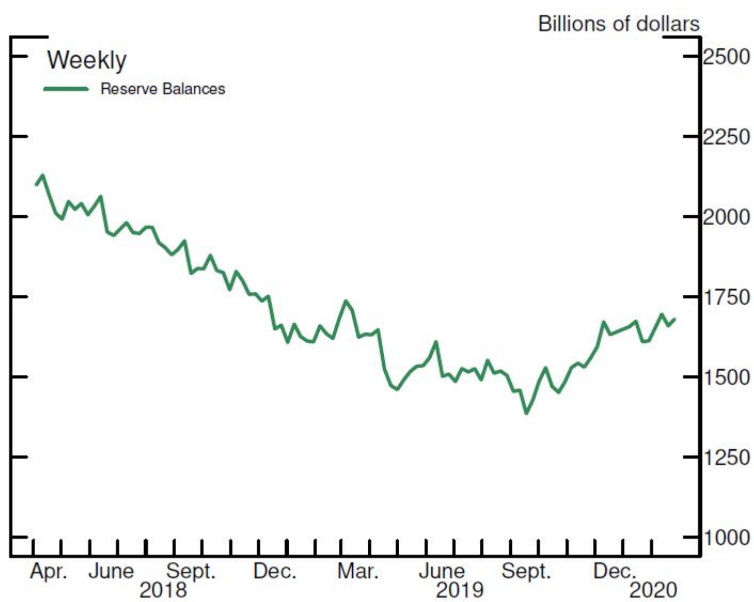
Note: This figure plots fed funds trading volume and the spread between the effective fed funds rate (EFFR) and the interest on reserves (IOR). Data is daily for the period April 2018 to February 2020. Data sources: EFFR and fed funds volume (Federal Reserve Bank of New York); IOR (Federal Reserve Board).

Figure 2: Fed funds and repo rate



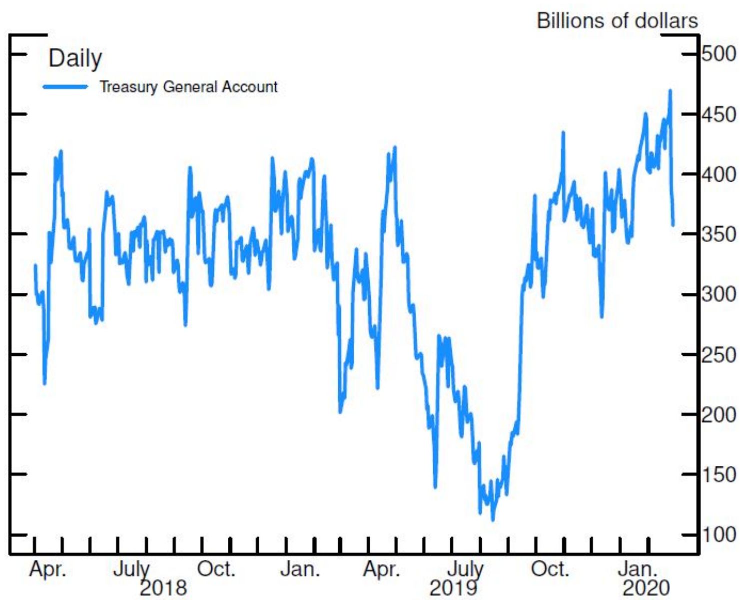
Note: This figure plots the spread between Effective Fed Funds Rate (EFFR) and the Interest on Reserves (IOR), and the spread between the the Broad General Collateral Rate (BGCR) and the overnight reverse repo with the Fed (ONRRP) rate. Data is daily for the period April 2018 to February 2020. The figure does not plot the September 17, 2019 data point when the BGCR-ONRRP spread reached 325 bps. Data sources: EFFR, BGCR and ONRRP (Federal Reserve Bank of New York); IOR (Federal Reserve Board).

Figure 3: Aggregate level of reserves



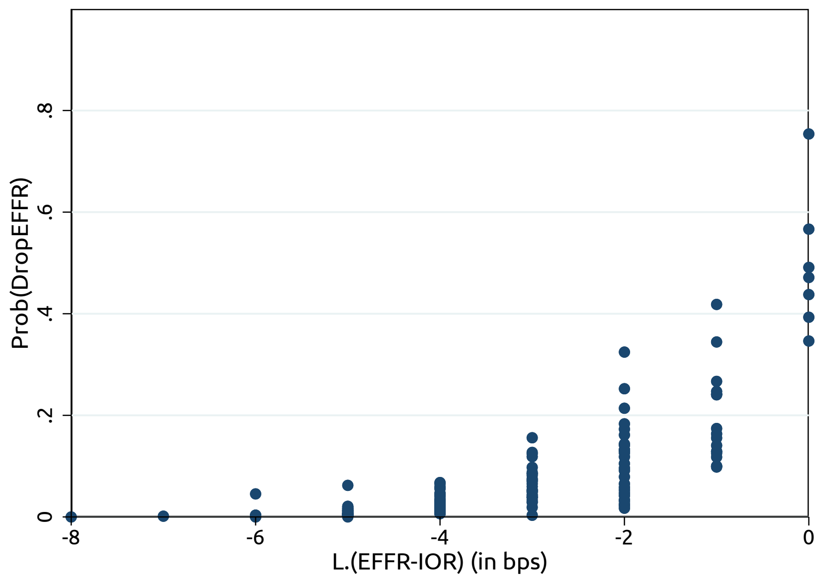
Note: Data is weekly for the period April 2018 to February 2020. Data source: Federal Reserve Board, H.4.1 statistical release.

Figure 4: Treasury General Account



Note:Data is daily for the period April 2018 to February 2020. Data source: U.S. Department of Treasury (Daily Treasury Statement).

Figure 5: Estimated probabilities of a drop in EFFR: April 2018 - February 2020, $EFFR < IOR$



Note: The estimated probabilities are from $P[Drop^{EFFR_t}] =$
$F[\alpha_0 + \alpha_1(EFFR_{t-1} - IOR_{t-1}) + \alpha_2 Drop^{(repo_t - i_t^{ONRRP})} + \alpha_3 ln(reserves_t) + \alpha_4 shockReserves_t]$ for the period April 2018 to February 2020. Regression results are shown in Table 5.

Table 1: Fed funds volume: Summary statistics (in $ bill)

State	Obs	Mean	Std. Dev.	Min	Max
EFFR $\leq$ IOR	318	72	9	48	94
EFFR $>$ IOR	162	67	7	46	89

Note: This table shows for the fed fund volume when: 1) EFFR $\leq$ IOR; 2) EFFR $>$ IOR. Data is daily for the period April 2018 to February 2020. Data sources: EFFR and fed funds volume (Federal Reserve Bank of New York); IOR (Federal Reserve Board).

Table 2: Probit regression results: Market-level data.

	Regression coefficients			
	(1)	(2)	(3)	(4)
	$Spike^{EFFR}$	$Spike^{EFFR}$	$Spike^{EFFR}$	$Spike^{EFFR}$
$RevealType$	0.491***	0.458***	0.520**	0.544**
	(0.158)	(0.163)	(0.224)	(0.228)
$Spike^{(repo-i^{ONRRP})}$		0.861***	0.871***	0.795***
		(0.167)	(0.163)	(0.169)
$ln(reserves)$			0.359	0.545
			(1.044)	(1.038)
$shockReserves$				-2.140**
				(0.992)
$constant$	-1.459***	-1.860***	-11.99	-17.21
	(0.106)	(0.166)	(29.44)	(29.26)
Observations	480	480	480	480
Pseudo R^2	0.030	0.118	0.119	0.139

	Marginal effects			
	(1)	(2)	(3)	(4)
$RevealType$	0.094***	0.077***	0.088**	0.092**
	(0.032)	(0.280)	(0.042)	(0.043)
$Spike^{repo-i^{ONRRP}}$		0.155***	0.157***	0.139***
		(0.032)	(0.031)	(0.032)
$ln(reserves)$			0.054	0.080
			(0.158)	(0.155)
$shockReserves$				-0.316**
				(0.0146)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: This table shows probit regression coefficients. $Spike_t^{EFFR} = 1$ if $\Delta(EFFR_t - IOER_t) > 0$, 0 otherwise; $RevealType_t = 1$ if $EFFR_{t-1} > IOER_{t-1}$, 0 otherwise; $Spike_t^{(repo-i^{ONRRP})} = 1$ if $\Delta(repo - i^{ONRRP})_t > 0$, 0 otherwise; $ln(reserves_t)$ is the aggregate level of reserves balances; $shockReserves_t = -\Delta ln(TGA_t)$. Data is daily for the period April 2018 to February 2020.

Table 3: Probit regression results: Bank-level data (no bank fixed effects).

Regression coefficients			
	(1)	(2)	(3)
	$Spike^{iff}$	$Spike^{iff}$	$Spike^{iff}$
$RevealBankType$	0.399***	0.450***	0.638***
	(0.0818)	(0.0923)	(0.196)
$Spike^{(EFFR-IOR)}$	0.595***	0.590***	0.638***
	(0.0633)	(0.0743)	(0.163)
$foreign$	0.084	0.139	0.359
	(0.101)	(0.119)	(0.234)
$DailyReporter$	0.289*	0.555***	0.970***
	(0.155)	(0.113)	(0.162)
$constant$	-1.194***	-1.236***	-1.659***
	(0.0980)	(0.113)	(0.162)
Observations	20,631	16,368	5,269
Pseudo R^2	0.041	0.046	0.084
No. periods (total)	480	480	480
Bank presence (no. periods)	≥ 240	≥ 360	$= 480$
No. banks	53	37	11
Bank FE	no	no	no

Marginal effects			
	(1)	(2)	(3)
$RevealBankType$	0.107***	0.121***	0.146***
	(0.0218)	(0.0241)	(0.0504)
$Spike^{(EFFR-IOR)}$	0.188***	0.184***	0.177***
	(0.0224)	(0.0258)	(0.0467)
$foreign$	0.023	0.037	0.082
	(0.0267)	(0.0312)	(0.0585)
$DailyReporter$	0.085*	0.176***	0.296***
	(0.0494)	(0.0363)	(0.0517)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: This table shows probit regression coefficients using bank level data. $Spike^{iff}_{i,t} = 1$ if $\Delta(i^{ff}_{i,t} - IOER_t) > 0$, 0 otherwise; $RevealType_{i,t} = 1$ if $i^{ff}_{i,t-1} > IOER_{t-1}$, 0 otherwise; $Spike^{(EFFR-IOR)}_t = 1$ if $\Delta(EFFR - IOR)_t > 0$, 0 otherwise; $foreign_i = 1$ if bank i is a foreign banking organization; $DailyReporter = 1$ if bank i reports its liquidity profile daily. Standard errors are clustered at bank-level. Data is daily for the period April 2018 to February 2020.

Table 4: Probit regression results: Bank-level data (bank fixed effects)

Regression coefficients			
	(1)	(2)	(3)
	$Spike^{iff}$	$Spike^{iff}$	$Spike^{iff}$
$RevealBankType$	0.451***	0.434***	0.556***
	(0.064)	(0.074)	(0.169)
$Spike^{(EFFR-IOR)}$	0.638***	0.643***	0.696***
	(0.068)	(0.080)	(0.166)
$foreign$	0.914***	-0.352***	0.398***
	(0.011)	(0.007)	(0.114)
$DailyReporter$	-0.139***	-0.146***	0.478***
	(0.010)	(0.022)	(0.159)
$constant$	-1.813***	-0.541***	-1.174***
	(0.036)	(0.022)	(0.159)
Observations	20,631	16,368	5,269
Pseudo R^2	0.106	0.103	0.132
No. periods (total)	480	480	480
Bank presence (no. periods)	≥ 240	≥ 360	$= 480$
No. banks	53	37	11
Bank FE	yes	yes	yes

Marginal effects			
	(1)	(2)	(3)
$RevealBankType$	0.111***	0.107***	0.113***
	(0.016)	(0.019)	(0.035)
$Spike^{(EFFR-IOR)}$	0.190***	0.190***	0.180***
	(0.024)	(0.028)	(0.053)
$foreign$	0.243***	-0.079**	0.0821 ***
	(0.003)	(0.001)	(0.024)
$DailyReporter$	-0.031***	-0.032***	0.115**
	(0.002)	(0.005)	(0.047)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: This table shows probit regression coefficients using bank level data. $Spike^{iff}_{i,t} = 1$ if $\Delta(i^{ff}_{i,t} - IOR_t) > 0$, 0 otherwise; $RevealType_{i,t} = 1$ if $i^{ff}_{i,t-1} > IOER_{t-1}$, 0 otherwise; $Spike^{(EFFR-IOR)}_t = 1$ if $\Delta(EFFR - IOR)_t > 0$, 0 otherwise; $foreign_i = 1$ if bank i is a foreign banking organization; $DailyReporter = 1$ if bank i reports its liquidity profile daily. Standard errors are clustered at bank-level. Data is daily for the period April 2018 to February 2020.

Table 5: Probit regression results: Market-level data, $EFFR < IOR$

	Regression coefficients			
	(1)	(2)	(3)	(4)
	$Drop^{EFFR}$	$Drop^{EFFR}$	$Drop^{EFFR}$	$Drop^{EFFR}$
$L.(EFFR - IOR)$	0.425***	0.428***	0.677***	0.641***
	(0.145)	(0.146)	(0.221)	(0.223)
$Drop^{(repo - i^{ONRRP})}$		-0.201	-0.267	-0.351
		(0.340)	(0.342)	(0.354)
$ln(reserves)$			6.865	5.932
			(4.214)	(4.134)
$shockReserves$				4.158***
				(2.125)
$constant$	-0.301	-0.366	-193.628	-167.443
	(0.318)	(0.342)	(118.593)	(116.347)
Observations	175	175	175	175
Pseudo R^2	0.227	0.231	0.258	0.276

	Marginal effects			
	(1)	(2)	(3)	(4)
$L.(EFFR - IOR)$	0.035***	0.034***	0.054***	0.047***
	(0.010)	(0.010)	(0.019)	(0.018)
$Drop^{(repo - i^{ONRRP})}$		-0.016	-0.021	-0.026
		(0.028)	(0.029)	(0.028)
$ln(reserves)$			0.544	0.431
			(0.390)	(0.335)
$shockReserves$				0.303**
				(0.162)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: This table shows probit regression results. $Drop^{EFFR_t} = 1$ if $\Delta(EFFR - IOR)_t < 0$, 0 otherwise; $Drop_t^{(repo - i^{ONRRP})} = 1$ if $\Delta(repo - i^{ONRRP})_t < 0$, 0 otherwise; $ln(reserves_t)$ is the aggregate level of reserves balances; $shockReserves_t = -\Delta ln(TGA_t)$. Data is daily for the period April 2018 to February 2020.