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Modelling Overnight RRP Participation

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Abstract

We examine how market participants have used the Federal Reserve's overnight reverse repurchase (ON RRP) exercise and how short-term interest rates have evolved between December 2013 and November 2014. We show that money market fund (MMF) participation is sensitive to the spread between market repo rates and the ON RRP offering rate as well as Treasury bill issuance, government sponsored enterprise (GSE) participation is more heavily driven by calendar effects, dealers tend to only participate when rate spreads are negative, and banks generally do not participate. We also find that the effect of the ON RRP on overnight interest rates is more significant in the collateralized market than the uncollateralized market.

Keywords: repurchase agreements, overnight RRP, monetary policy, federal funds, money market funds, Federal Reserve System operations

JEL Classifications: E52, E58, G21, G23

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1. Introduction

The Federal Reserve began conducting overnight, fixed-rate capped-allotment reverse repurchase agreements (ON RRP) in September 2013 through an extended testing exercise of daily operations. In these transactions, the Federal Reserve borrows from a broad set of counterparties on an overnight basis using Treasury securities as collateral. In this paper, we examine how counterparties have used the ON RRP exercise and how short-term interest rates have evolved during the testing period. We develop an empirical model of ON RRP participation that can be used to better understand the drivers of participation in the exercise and how this participation behavior is evolving over time. The model estimates suggest that money market fund (MMF) participation is sensitive to the spread between market repo rates and the ON RRP offering rate as well as Treasury bill issuance, government sponsored enterprise (GSE) participation is more heavily driven by calendar effects, and dealers tend to only participate when rate spreads are negative. We also find that, while ON RRP usage results in fewer reserves held by the banking system, the effect on interest rates is more significant in the collateralized market than the interbank market for overnight funding.

2. Background on the ON RRP

Prior to the crisis, the Federal Reserve would keep reserves scarce relative to requirements, thus making interbank lending rates sensitive to small adjustments to the amount of reserves in the banking system. The Federal Reserve's large scale asset purchases from 2009 through 2014 increased the reserves held by depository institutions far above the amounts needed to meet reserve requirements.¹ As a result, post-crisis implementation of monetary policy will need to operate through a different mechanism than pre-crisis monetary policy implementation at least for several years.² An important component of the change in policy implementation tools was the introduction of interest on excess reserves (IOER) in October 2008. IOER in itself is not sufficient to distinguish between a scarcity system, like that used prior to the financial crisis, and a system with abundant reserves. Theoretically, with a system of abundant reserves, the willingness of the central

¹ "Depository institutions" refers to banks, thrifts, and credit unions. For brevity, we will use "banks" in this paper.

² Projections of the Federal Reserve's balance sheet indicate that there will be significant excess reserves in the banking system until, under a central forecast, 2021 (Carpenter, Ihrig, Klee, Quinn, and Boote (2015)). For a broad view of monetary policy implementation with a high level of excess reserves, see among others, Ihrig, Meade, and Weinbach (2015) and Chen, Clouse, Ihrig, and Klee (2014).

bank to borrow unlimited quantities at a specified rate should set a floor on the rates at which banks are willing to lend. In the U.S., however, there are many non-bank market participants such as MMFs and GSEs that are statutorily prohibited from earning IOER and may therefore be willing to lend at lower rates. Assuming perfectly competitive money markets and the absence of bank balance sheet costs, banks should arbitrage between IOER and money market rates whenever money market rates are below IOER, making IOER an effective floor. A typical arbitrage trade would involve borrowing in overnight markets and leaving the proceeds on deposit at the central bank. Arbitrage profits are reduced or eliminated, however, by balance sheet costs. Indeed, arbitrage trades increase both banks' assets and liabilities, which trigger additional fees and capital costs.³ As a result of these market frictions, the FOMC's Policy Normalization Principles and Plans, released in September 2014, states that the Committee intends to use a secondary tool, the ON RRP facility, to help control the federal funds rate during normalization of the Federal Reserve's balance sheet.⁴

The Federal Reserve's ON RRP operations are similar to open market operations that were used prior to the financial crisis. In a repurchase transaction, the Federal Reserve either purchases or sells securities with a simultaneous agreement to reverse this transaction after a predetermined time (the next business day in the case of ON RRPs). When the Federal Reserve sells securities and receives cash (which it refers to as a "reverse repurchase agreement"), the funds are debited from the Federal Reserve account of either the counterparty's bank or, if the counterparty is a bank or GSE, the counterparty itself, which reduces the amount of reserves in the system.⁵ The ON RRP provides an alternative option for money market lenders, which may require private market borrowers to bid more aggressively for funds by offering to pay higher interest rates.

A significant difference between ON RRPs and pre-crisis open market operations is that ON RRPs are conducted with an expanded list of counterparties, which includes money market mutual funds, GSEs, and banks in addition to the primary dealers of the Federal Reserve Bank of New York with which the Federal Reserve conducted open market operations prior to the financial crisis. In our analysis, we test whether these additional counterparties participate in statistically

³ FDIC premia are based on banks' total assets while capital charges may be applied to either assets or liabilities.

⁴ See "Policy Normalization Principles and Plans," September 2014 (www.federalreserve.gov/newsevents/press/monetary/20140917c.htm).

⁵ Prior to the financial crisis, most open market operations conducted by the Federal Reserve were purchase, rather than sale, operations. That is, the aggregate amount of reserves in the banking system was generally a little less than needed for the equilibrium federal funds to fall to the target rate.

different ways from the primary dealers. Also in contrast with pre-crisis operations, current operations are conducted through late-day, single-price auctions with all counterparties simultaneously rather than through bilateral trades with primary dealers.

The ON RRP exercise began on September 23, 2013 with a fixed rate of 1 basis point and an individual maximum bid of \$0.5 billion. While the Federal Reserve continues to conduct RRP operations, our analysis includes ON RRP usage only through November 30, 2014 since term RRP operations began in December 2014, which affected the behavior of some counterparties. From the program’s inception through November 30, 2014, the fixed rate ranged from 1 to 10 basis points and the maximum bid ranged from \$0.5 to \$30 billion.⁶ In the ON RRP, counterparties lend cash up to the maximum bid to the Federal Reserve overnight at the exercise’s fixed rate in exchange for Treasury securities that are returned the next day. Over the sample period, the program was open to 140 counterparties, including primary dealers, MMFs, GSEs (including Fannie Mae, Freddie Mac, and some Federal Home Loan Banks), and commercial banks.⁷ The table below shows the number of participants of each type, as well as the average percentage of each type that participate on a given day.

Type	Number of Counterparties	Average Daily Participatation
Dealer	22	14%
MMF	94	43%
GSE	6	70%
Bank	18	9%
Total	140	36%

As seen in counterparty type-level participation data, participation in the ON RRP exercise varies by entity type.⁸ The primary dealers are generally borrowers in money markets so, unless the interest rate offered in the ON RRP is sufficiently above their cost of borrowing and they can arbitrage between the two rates, they are unlikely to be regular participants in the exercise. Money market funds, in contrast, typically have large amounts of cash to lend and are likely to view the

⁶ See the appendix for a timeline of ON RRP parameter changes through November 30, 2014.

⁷ Since November 30, 2014, many counterparties have become eligible to participate in RRP operations, while others have dropped out. See www.newyorkfed.org/markets/expanded_counterparties.html for a full list of the eligible counterparties.

⁸ The Federal Reserve Bank of New York publically releases data on takeup by counterparty type with a one quarter lag. Data is currently available from the start of the exercise through September 30, 2015 at www.newyorkfed.org/markets/omo/DMM/temp/file/Reverse%20Repo%20Data%20by%20Counterparty%20Type.xlsx.

ON RRP as a low return, but risk free, investment relative to their alternative options. The GSEs have similar incentives, although many prefer investments that are returned early in the day, a feature not offered by the ON RRP. Fannie Mae and Freddie Mac, in particular, often have large investment needs in the days leading up to the monthly payments they make to investors in mortgage backed securities. Lastly, since commercial banks earn interest on reserve balances held with the Fed, and that interest rate has been higher than the rates paid on ON RRPs, commercial banks have had little incentive to regularly participate in the exercise, even though quite a few have signed up as counterparties.

For the first year of the testing program, individual counterparties could submit one bid each day up to the stated maximum (which increased over time from \$0.5 billion to \$10 billion) and were fully allocated at the stated fixed rate. An overall size limit of \$300 billion was imposed on September 22, 2014 when the maximum individual bid was raised from \$10 billion to \$30 billion. When imposing the overall limit in the testing program, the FOMC cited concerns about both the scale of the Federal Reserve's role in financial intermediation and the potential financial instability risks the facility might pose during periods of stress.⁹

With the overall limit in place since September 2014, each bidder has been required to submit a minimum acceptable interest rate with their bid. If the total amount of bids is less than or equal to the aggregate maximum of \$300 billion, the exercise operates as before and all counterparties are fully allotted at the current offering rate. However, if the total amount of bids is more than the aggregate maximum of \$300 billion, a single-price auction is used to allocate awards at the stopout rate. This rate is determined by sorting all bids by submitted rate up to the point at which the total quantity of bids equals the overall size limit. All bids at rates less than the stopout rate are fully allocated, all bids at the stopout rate are allocated pro rata based on the dollar amount submitted, and all bids above the stopout rate are not allocated anything. The overall size limit has been hit only once so far. On September 30, 2014, \$407 billion in bids was submitted so only \$300 billion was awarded at a stopout rate of 0 basis points.

⁹ See the minutes from the September 2014 FOMC meeting: www.federalreserve.gov/monetarypolicy/fomcminutes20140917.htm. For a thorough discussion of demand shifts during financial crises, see Carlson, Duygan-Bump, Natalucci, Nelson, Ochoa, Stein, and Van den Heuvel (2014). For further discussion on the design considerations of the ON RRP, Frost, Logan, Martin, McCabe, Natalucci, and Remache (2015).

a. Summary of Usage

MMFs have been the largest participants in the ON RRP exercise so far, averaging over 80 percent of takeup on non-quarter-end days.¹⁰ On quarter-ends, participation by MMFs increases notably. Among other counterparty types, GSEs account for about 10 percent of takeup, primary dealers for about 5 percent, and banks for the remainder. Primary dealer participation has been particularly volatile relative to other counterparty types, with participation depending considerably on the spread between market repo rates and the ON RRP rate. Banks have participated in very small amounts, which is unsurprising given their ability to earn interest on excess reserves (IOER) held at the Federal Reserve. The IOER rate was 25 basis points throughout the sample period, while the ON RRP rate was not higher than 10 basis points.

3. Projections of GCF Interest Rates

Demand for ON RRP is likely to be driven primarily by the rates of return on alternative investments of comparable maturities. As a first step to modeling ON RRP participation, we project alternative investment interest rates using a vector autoregression that includes a repo rate (the GCF rate), the effective federal funds rate, and the 4-week Treasury bill rate.¹¹ While the GCF rate is only directly available to dealers and select other market participants, not MMFs, it has been highly correlated with rates in the broader repo market and yields very similar results in our models.¹² We can then use the one day ahead rate projections as inputs into a demand estimation model developed in Section 4. To avoid the challenges of modeling the market participants' learning about the market dynamics associated with the introduction of the exercise and the market volatility related to the government shut-down in October 2013, we begin with operations on December 23, 2013 when the maximum allotment was raised to \$3 billion per counterparty.

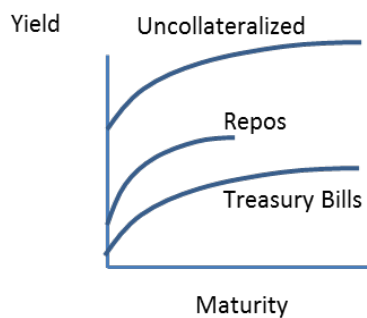
¹⁰ All statistics in this paper are based on data from December 23, 2013 through November 30, 2014.

¹¹ The General Collateral Finance (GCF) repo market, a subset of the triparty repo market, consists primarily of interdealer repo trades. Unlike the broader repo market, GCF transactions are settled on a net basis at the end of each day so participants do not need intraday, trade-for-trade settlement. This netting service is provided by the Fixed Income Clearing Corporation, which provides a daily volume-weighted index of repo interest rates. Netting is conducted for three types of collateral (Treasury securities, agency debt, and agency MBS). In this paper, GCF transactions only refer to those using Treasury collateral.

¹² The GCF rate is used in this analysis because it was the only publically available repo rate during the sample period. Analysis has also been done with proprietary repo rates, including the primary dealer survey rate (collected daily by the New York Fed directly from primary dealers) or the triparty repo rate and the results are qualitatively the same.

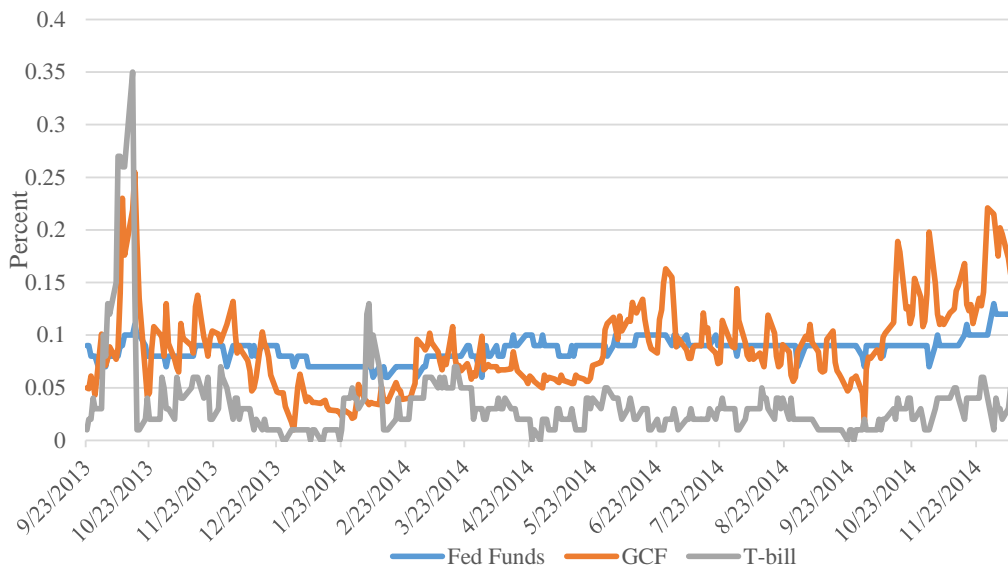
a. The Choice of a VAR

Money market rates are linked by counterparties and collateral types that we summarize in terms of investors' risk of loss of principal. Lending to the Treasury and the Fed is risk-free, lending to private sector entities is considered low risk when collateralized by Treasury securities, and unsecured lending has higher risk. These relationships are shown in the illustrative figure below. Note that the collateralized curve is much shorter than the other curves – borrowers and lenders seeking longer terms generally take outright positions.



In practice, the relationships between these curves have not always reflected the credit exposures illustrated above. Since the beginning of the ON RRP testing, for example, unsecured rates have been lower than secured rates about 40 percent of the time suggesting that market segmentation has not been fully offset by risk-return arbitrage (that is, there is a lack of institutional capacity to complete the arbitrage). The rise in GCF rates in late 2014, shown below, may indicate a shift in market dynamics. While trading volumes have not declined notably, it is possible that there has been a compositional shift towards borrowers who are considered less creditworthy or have fewer alternative sources of funds.

Interest Rates for Three Types of Credit Risk



Source: Bloomberg, Federal Reserve Board

To account for the linkages between short-term markets, we estimate the relationships using a vector autoregression of a single proxy for each curve: a short-term Treasury bill rate for the risk-free rate, the GCF Treasury collateral rate for the collateralized rate, and the fed funds effective for the uncollateralized rate using the following equation:¹³

$$\begin{matrix}
 r_{at} & r_{at-i} & r_{bt-i} & r_{ct-i} \\
 r_{bt} = & r_{bt-i} & + r_{ct-i} & + r_{at-i} \\
 r_{ct} & r_{ct-i} & r_{at-i} & r_{bt-i}
 \end{matrix}$$

+ ON RRP Parameters + Supply Effects + Calendar Effects

where r_a is the GCF interest rate, r_b is the fed funds effective rate, and r_c is the constant maturity 4-week bill rate. Historical GCF rates are available through Bloomberg or directly from DTCC. Both the fed funds effective rate and the 4-week constant maturity rates are available from the Federal Reserve.¹⁴ The results are shown in the table below.

¹³ Note that, as a matter of convenience, we use the 4-week Treasury bill rate for the Treasury rate – it is the shortest maturity of published Treasury rates. We expect that this maturity mismatch is not significant over the period that we consider since expectations were very strong that the level of short term interest rates would not change.

¹⁴ The Federal Reserve reports the fed funds effective and Treasury rates at: www.federalreserve.gov/releases/H15/.

We found two lags to be sufficient to capture fully the auto and cross correlation dynamics. Auto correlation has been strong for all three rates. Cross correlations have been weaker than auto correlations and, in many cases, statistically insignificant. The coefficient on the first lag of the fed funds rate, for example, has been statistically significant at the 99% confidence level for fed funds rate (with a coefficient of 0.65), but statistically insignificant (with a coefficient of 0.07) for the GCF rate. The results for the lagged coefficients suggest limited cross market effects with the most notable, but possibly spurious, cross market relationship between the Treasury bill rates and the fed funds rate. Other effects, discussed below, are statistically significant but generally of a lower magnitude than the lagged coefficients.

b. ON RRP Program Parameters

Over the first year of the exercise, both the ON RRP fixed rate and the ON RRP maximum allotment cap changed occasionally. The offering rate, most frequently set at 5 basis points, was raised or lowered from time to time. The maximum allotment cap was generally raised, from \$500 million at the beginning of the exercise to \$30 billion by the end of September 2014. The effects of these changes were most closely associated with small rate changes in the GCF market. Neither the rate nor the cap had a statistically significant effect on the Treasury rate, while the cap did not have a statistically significant effect on the federal funds rate.

An increase or decrease in the rate paid on ON RRPs was associated with a direct effect of a 9 percent change in the fed funds rate. That is, a 1 basis point change in the ON RRP rate would have been associated with a 0.09 basis point change, in the same direction, in the fed funds rate (note that actual changes in the ON RRP rate were generally just 2 basis points). Our analysis shows that higher ON RRP exercise rates have been associated with higher repo rates. The direct effect of a 1 basis point increase in the ON RRP rate was an increase of 0.27 basis points in the GCF rate and indirectly, from lags in related markets, of almost 0.5 basis point. Even with this effect, however, it is difficult to establish causality because changes in the ON RRP rate often coincided with broader changes in money markets. Our ability to extrapolate from the effects of the ON RRP parameters on interest rates is limited, both because the range of rates in the sample period have been small and because, even if the rate changes were larger, demand has probably been distorted by the low level of rates across money markets.

<i>Variable</i>	Fed funds effective rate	GCF treasury rate	Short-term t-bill rate
	(Uncollateralized)	(Collateralized)	(Risk-free)
	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
Time lag of rates			
Fed funds effective (-1)	0.645 *** (0.064)	0.073 (0.182)	0.256 (0.176)
Fed funds effective (-2)	0.108 * (0.057)	0.049 (0.161)	-0.410 *** (0.156)
GCF treasury rate (-1)	0.035 * (0.019)	0.836 *** (0.055)	0.026 (0.053)
GCF treasury rate (-2)	0.011 (0.019)	-0.018 (0.054)	0.006 (0.052)
Short-term t-bill (-1)	0.008 (0.024)	0.008 (0.068)	0.739 (0.066) ***
Short-term t-bill (-2)	-0.038 (0.025)	0.045 (0.065)	0.054 (0.067)
ON RRP parameters			
ON RRP interest rate	0.094 ** (0.039)	0.274 ** (0.109)	0.034 (0.106)
ON RRP maximum award (\$100 billion)	0.001 (0.004)	0.028 *** (0.011)	-0.002 (0.010)
Supply effects			
Treasury net bill issuance (\$100 billion)	-0.002 (0.003)	0.027 *** (0.007)	0.011 (0.007)
Treasury gross coupon issuance (\$100 billion)	0.004 * (0.003)	0.022 *** (0.007)	-0.008 (0.007)
Calendar effects			
Thursdays	-0.001 (0.001)	0.012 *** (0.002)	-0.005 ** (0.002)
Mid-month	0.001 (0.002)	0.011 * (0.006)	0.004 (0.006)
Mid-month (+1)	0.000 (0.001)	0.007 * (0.004)	-0.006 (0.004)
Fannie Mae P&I dates (+1)	0.001 (0.001)	0.018 *** (0.004)	0.002 (0.004)
Month end	-0.015 *** (0.003)	0.012 (0.004)	0.002 (0.004)
Month end (-1)	0.003 *** (0.002)	-0.008 (0.006)	0.005 (0.005)
Quarter end dates	-0.018 *** (0.004)	-0.014 (0.012)	0.010 (0.010)
Quarter end dates (-1)	0.011 *** (0.003)	0.002 (0.007)	-0.002 (0.010)
Year end	-0.012 *** (0.004)	-0.032 *** (0.011)	0.002 (0.011)
Year end (-1)	0.011 *** (0.004)	0.036 *** (0.010)	-0.001 (0.010)

Where: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

The cap on the amount that an individual counterparty can lend to the Federal Reserve has been associated with a very small effect on the GCF rate. Changes in the cap have not been more than \$20 billion per counterparty which, given the 0.028 coefficient on the cap for a \$100 billion

cap change, indicates that rate impacts from cap changes have been no more than one-half of a basis point.¹⁵ Curiously, small increases in the caps early in the exercise period actually coincided with *lower* GCF rates. We have not seen this counterintuitive relationship with the more recent increases in the caps. The first two increases in caps occurred just before quarter ends, so there may have been other factors that dominated the rate impacts on announcement days.

c. Collateral Supply

Treasury securities are considered a close substitute for lending through repo for many investors most of the time and lending against Treasury securities plays an important role in the Treasury issuance and placement cycle. The amount of Treasury securities issued on a day often influences the interest rate on repo transactions. The influences on rates have two sources. First, in the Treasury bill market where repo lending is a close substitute for investment in bills, lenders gravitate toward the repo market when the Treasury's borrowing needs decrease, driving repo rates down. Second, when dealers receive securities in Treasury auctions, and particularly auctions for coupon-bearing securities, they need to finance their auction awards through the repo market, driving repo rates up. We control for these opposing effects through separate indicators for Treasury bills and Treasury coupon securities.

Treasury Bills

Treasury bills are issued every Thursday and, occasionally, on other days of the week. Given the high frequency of issuance and maturity, rates are likely to be more sensitive to changes in the net amount of securities than in gross issuance since a large portion of maturing securities are probably bought by the same investors that hold the maturing securities. We currently estimate that it takes a roughly \$40 billion change in net bill issuance to change the repo rate by one basis point. For reference, the average change in net bill issuance was \$16 billion with a standard deviation of \$22 billion.

Treasury Coupon Issuance

In contrast to bill issuance, we use gross issuance of Treasury coupon securities as an indicator of potential pressures in money markets since the issuance of Treasury coupons requires

¹⁵ Note that "counterparty" here most often refers to a single money market mutual fund (a relatively small number are banks or government sponsored enterprises). A mutual fund complex, say of all the funds within Fidelity or Vanguard, may have multiple funds that are counterparties in the ON RRP exercise.

financing by dealers. Many participants in Treasury coupon auctions need to finance their awards in the repo market so new issuance of Treasury coupon securities should influence repo rates. We currently estimate gross coupon issuance to have the same magnitude of effect on repo rates as net bill issuance – roughly \$40 billion of gross issuance raises repo rates by one basis point.

Federal Reserve Purchases

Purchases by the Federal Reserve may influence the GCF rate by reducing the inventory of securities that dealers need to finance. This effect should reduce borrowing needs; a reduced borrowing need by dealers should put downward pressure on the GCF rate as lenders compete for fewer investment opportunities. The effects of purchases, however, were statistically insignificant. Net purchases over the test period declined from \$85 billion per month to zero through incremental reductions that were anticipated by market commentators so the lack of responsiveness may be, in part, attributable to financial intermediaries adapting to the reduction in demand.

d. Calendar Effects

Thursdays

Newly-issued Treasury bills settle each Thursday. For dealers that hold these securities in inventory, the new bills create a financing need that is met in the repo market. As a result, repo rates tend to be slightly higher on Thursdays than other days of the week. The magnitude of this effect has declined since the ON RRP began, but Thursdays are still associated with GCF rates that are 1.0 basis point higher than on other days.

Class A Settlement

A large portion of the MBS trades conducted each month settle around the eighth business day. Similar to Treasury bill issuance, the settling of MBS can create financing needs for dealers that are met in the repo market. The importance of Class A settlement has declined over the ON RRP exercise period, probably due to the declining activity in the MBS market that has resulted from lower refinancing activity. The model currently has a placeholder for a Class A effect, but it has no effect on GCF rates.

Mid-month

Mid-month creates financing pressures for dealers from Treasury coupon settlement and for Freddie Mac, which makes MBS principal and interest payments mid-month. Treasury settlements and Freddie Mac payments are on the 15th if it is a business day; otherwise they are

made on the following business day. The day prior to mid-month also creates funding pressure from Freddie Mac which typically reduces its lending in preparation for its principal and interest payments. Mid-month funding pressures have not been a large driver of repo rates and have had no statistical effect on federal funds or 4-week Treasury bill rates.

Fannie Mae P&I Dates

Fannie Mae makes MBS principal and interest payments on the 25th calendar day of the month (or the following business day). Like Freddie Mac, Fannie Mae reduces lending prior to its MBS payments and this withdrawal of cash causes repo rates to rise. Over the test period, this activity has been associated with GCF rates that are 1.8 basis points higher than would otherwise be the case.

Reporting Dates (month, quarter and year ends)

On reporting dates, financial firms typically seek to reduce the amount of leverage on their books and reduce their exposures to higher risk entities. The increased demand for low-risk securities may cause the interest rate on Treasury securities to fall. In unsecured markets, borrowers have tended to reduce their positions leading to a decline in the average fed funds rate. Additionally, reduced leverage causes the GCF interest rates to rise since it is harder for borrowers to find lenders. These effects appear to be less severe for month ends than quarter ends, and less severe for quarter ends than for year ends so each is controlled for separately. While statistically significant, particularly for the federal funds rate, these controls are obviously weak since the test period is less than a full calendar year.

e. Interest Rate Summary

The combination of the auto-correlation, supply, and calendar effects generates a reasonably good fit of the rates, shown in the summary statistics below. This fit is important for projections of ON RRP usage because, as developed in the next section, GCF rates are a significant input into demand for ON RRPs.

	<u>Fed funds effective rate</u> (Uncollateralized)	<u>GCF treasury rate</u> (Collateralized)	<u>Short-term t-bill rate</u> (Risk-free)
R-squared	0.860	0.898	0.680
Adj. R-squared	0.847	0.888	0.649
Sum sq. resids	0.004	0.028	0.027
S.E. equation	0.004	0.012	0.011
Akaike AIC	-8.071	-5.993	-6.053

4. Participation Model

In this section, we discuss our model of individual take-up, which can be used to better understand ON RRP participation behavior. We estimate take-up using interval regressions from December 23, 2013 to November 30, 2014 given that term RRP operations began in December 2014 and modified some participation behavior.^{16, 17} The model is run on a panel of daily observations over 234 days for each of the 140 counterparties, for a total of 32,760 observations.¹⁸

Interval regressions are a generalization of censored regressions that allow for a time-varying censor. Given the cap on individual take-up, actual demand may in fact be higher than what is seen in the data when a counterparty submits a maximum bid. A censored model assumes that actual take-up is represented by a latent variable, $Takeup^*$, such that:

$$Takeup_{i,t} = \begin{cases} Takeup_{i,t}^* & \text{if } Takeup_{i,t}^* < MaxBid \\ MaxBid & \text{if } Takeup_{i,t}^* \geq MaxBid \end{cases}$$

The interval model approach is a generalization of this setup that is particularly suitable for the ON RRP dataset because the maximum bid allowed in the ON RRP is not constant; it rose from \$0.5 billion to \$30 billion over the sample period. In an interval regression, data is represented with two dependent variables. For most observations in this analysis, both variables are equal to each other since we have a point estimate of individual take-up. However, when individual take-up is equal to the maximum bid, one dependent variable is equal to the realized take-up (the maximum bid), while the second is undefined since true demand is unbounded. In particular, the two dependent variables, $Takeup^L$ and $Takeup^R$, are defined as follows:

¹⁶ The first two months of data are excluded from the model since the behavior of participants was markedly different in the early period as they were still adapting to the introduction of the ON RRP. December 23, 2013 marks the first day of the \$3 billion individual cap, as well as a change to a 3 basis point fixed rate. Analysis stops on November 30, 2014 since, in December 2014, the Fed also began testing term RRP, which was a substitute for the ON RRP leading up to year end, resulting in significant declines in ON RRP participation.

¹⁷ Data on aggregate take-up, number of participants, and stopout rate (when applicable) is publically available for the full duration of the exercise (September 23, 2013 to present) at <https://apps.newyorkfed.org/markets/autorates/temp>. Data on take-up by counterparty type is publically released with a one quarter lag at www.newyorkfed.org/markets/omo/DMM/temp/file/Reverse%20Repo%20Data%20by%20Counterparty%20Type.xlsx.

¹⁸ New counterparties were added in December 2014 and over the course of 2015, bringing the total number of eligible counterparties to a little over 160. However, for the duration of this analysis, the number of eligible counterparties was 140.

$$\begin{aligned}
Takeup_{i,t}^L &= \begin{cases} Takeup_{i,t}^* & \text{if } Takeup_{i,t}^* < MaxBid \\ MaxBid & \text{if } Takeup_{i,t}^* \geq MaxBid \end{cases} \\
Takeup_{i,t}^R &= \begin{cases} Takeup_{i,t}^* & \text{if } Takeup_{i,t}^* < MaxBid \\ . & \text{if } Takeup_{i,t}^* \geq MaxBid \end{cases}
\end{aligned}$$

The five primary factors affecting individual counterparty ON RRP demand in our analysis are lagged (prior day's) takeup, counterparty types, rate spreads, bill issuance, and calendar effects. First, lagged takeup is important because participation in the ON RRP has been highly persistent for individual counterparties. Market commentary suggests that borrowers and lenders have incentives to maintain their relationships. Therefore, lenders appear to be reluctant to switch between borrowers or between a private market borrower and the Fed unless there are clear, persistent reasons for doing so. As such, ON RRP takeup is comparatively less sensitive to day-to-day movements in market conditions, but is sensitive to the relative conditions over time.

Second, different counterparty types have varying incentives to participate in the ON RRP exercise. Money market funds typically are large cash lenders and are likely to use the ON RRP as one of the several safe, short-term assets in which they regularly invest, particularly when private options are limited. GSEs are also cash lenders and are likely to participate in the ON RRP depending on their alternative investments. In addition, Fannie Mae and Freddie Mac often have large cash flows leading up to their monthly MBS payments, which we control for separately, as discussed below. On the other hand, primary dealers are generally borrowers in money markets so, unless market rates are very low and they can arbitrage, they are unlikely regularly participate in the ON RRP. Lastly, commercial banks have little reason to participate given that they earn interest on reserves held at the Fed, which has been higher than the rate paid on ON RRP.

Third, ON RRP participation, especially for certain counterparty types, depends on the spread between the rate offered in the exercise and the alternative rates available to potential lenders. The rates on other repurchase agreements, in particular, are important determinants of ON RRP participation. As discussed in the previous section, we project GCF repo rates and then use them as inputs into the demand equation for projections of ON RRP usage.

Fourth, Treasury bill issuance may affect ON RRP participation since Treasury bills could be an alternative investment to the ON RRP. MMFs, in particular, seek short-term safe assets in which to invest. While Treasury bills have a longer duration than overnight repo, they are highly

liquid and have a similar risk profile. When bill issuance is low, cash investors may have more demand for alternative investments such as the ON RRP.

Lastly, calendar effects, including reporting dates (month- and quarter-ends) as well as Fannie Mae and Freddie Mac payment dates, affect participation by affecting the amount of alternative investments and amount of investment funds in the market. New regulatory requirements, in particular the leverage ratio, may contribute to this behavior, especially among many foreign banking organizations, as these requirements need to be met only on reporting dates.¹⁹ Additionally, on reporting dates, many financial institutions pull back from the repo market to reduce their leverage and improve the appearance of their balance sheets. Given the reduction in borrowing demand, lenders may find it harder to place their cash in the private repo market and therefore turn to the ON RRP. Additionally, the lead up to GSE payment dates affects ON RRP participation. Freddie Mac and Fannie Mae pay principal and interest on their MBS securities every month on the 15th and 25th, respectively. During their float period (typically the 5 business days ahead of payment), they build up cash reserves, which they hold at the Federal Reserve or invest in safe liquid assets such as repos or the ON RRP. This behavior leads to changes in ON RRP takeup both directly, since Fannie and Freddie are participating more, and indirectly, since this increase in cash in the market leads to lower rates, which in turn may affect the participation decisions of other counterparties.

a. Model Specification

Demand for ON RRPs should depend on the rates of return on, and the availability of, alternative investments. Since these alternatives vary by counterparty type, we assume demand is counterparty-type specific. In addition to counterparty type, the primary variables are lagged takeup (which could be due to either switching costs or institutional inertia), interest rates on alternative investments, bill issuance (since Treasury bills are a close substitute for repos backed by Treasury securities), and calendar effects that result in known, large cash flows. The model is defined as follows:

¹⁹ US dealers have less incentive to change their allocations on reporting dates since their supplementary leverage ratio (SLR) is averaged over the entire reporting period.

$$\begin{aligned}
Takeup_{i,t} = & \alpha Takeup_{i,t-1} + \sum_{i=1}^4 \beta_i Type_i + \\
& \sum_{i=1}^4 \gamma_i Spread_t Type_i + \theta HighSpread_t Dealer + \\
& \sum_{i=1}^4 \sigma_i NewBills_t Type_i + \\
& \sum_{i=1}^4 \delta_i QE_t Type_i + \delta QE_{t-1} + \sum_{i=1}^4 \rho_i ME_t Type_i + \rho ME_{t-1} + \sum_{\tau=t+1}^5 \mu_\tau PI_\tau GSE + \varepsilon_{i,t}
\end{aligned}$$

Different types of participants use the ON RRP in different ways. To account for these distinctions, the model includes indicator variables ($Type_i$) for each of 4 types of counterparty: MMFs, primary dealers, GSEs, and banks. These indicators are also interacted with other model parameters, as discussed below, to account for differences in sensitivities to other relevant factors.

The primary interaction of interest is the relationship between ON RRP takeup and spread to the market rate. *Spread* is defined as the difference between the GCF repo rate and the ON RRP rate.²⁰ When projecting future takeup, the market rate comes directly from the projections of the rate model described in the previous section of this paper. The difference between these two rates captures the relative competitiveness of the ON RRP exercise. In addition to spread itself, the model also includes interactions between spread and indicators for each counterparty type to account for differences in rate sensitivity across counterparties.

When spreads are particularly low or even negative, the ON RRP is more attractive to investors and takeup increases significantly, especially among dealers, resulting in a nonlinear relationship between spread and takeup. To account for the nonlinearity in the relationship between takeup and spreads, an indicator variable is created, which equals one when the spread is greater than 2 basis points.²¹ The variable *HighSpread* is equal to the product of this indicator and *Spread*. Initially, *HighSpread* was interacted with each counterparty type. However, more

²⁰ Additional market repo rates were also considered, including an average cost of borrowing for primary dealers using Treasury securities as collateral and the midpoint of the brokered GC bid/ask at the time of the ON RRP operation. The results using these alternative rates are very similar to those presented here.

²¹ Alternative methods for capturing the nonlinear relationship between spread and takeup were also considered. These include alternative thresholds besides two basis points, a linear spread variable conditional on spread being below some threshold, and quadratic and cubic functions of spread. However, the two basis point threshold specification performed best, despite a relatively weak fit directly around the threshold.

recently, this strong, nonlinear relationship between spread and takeup has only been significant for primary dealers.

Treasury bill supply is also an important factor, especially for MMFs and GSEs. *NewBills* is the net bill issuance on a given day. In addition to the indirect effects of bill supply on repo rates, as discussed in the next section, bill supply also affects ON RRP participation directly by providing an alternative investment option that, for some investors, has similar attractiveness. When the supply of Treasury bills decreases, the ON RRP becomes more attractive, as lenders have fewer outside options.

Lastly, we control for several calendar effects, including quarter- and month-end reporting dates, and Fannie Mae and Freddie Mac MBS principal and interest (P&I) payment dates.²² Takeup in the ON RRP is particularly affected by quarter ends so they are controlled for separate from month ends. Indicator variables for the five days leading up to the 15th and 25th of each month (PI_t) are interacted with the indicator variable for GSEs to account for their behavior around P&I dates. Fannie and Freddie tend to build up their reserve balances in the several days before their payment dates and participate in the ON RRP heavily during this time. Subsequently, their participation tends to drop off on the day just before their P&I date as they prepare to make their payment.²³

b. Results

The table below shows the results of the participation regression.²⁴ By far, the most important variable in the model is lagged takeup, which accounts for the majority of the explanatory power of the model.²⁵ After the first several months of the exercise, as counterparties became more comfortable with the program, certain counterparties became more persistent and regular users of the ON RRP, which is part of the reason the first months of the exercise are excluded from our analysis.

²² For reasons discussed in the rate model section, indicators for Thursdays and Class A settlement were also included initially, but were insignificant so are no longer included in the model. These effects are likely captured sufficiently by the market rate.

²³ Different numbers of lag as well as lead variables were considered, but five gave the strongest results.

²⁴ Very similar results are found when using other repo rates, including the primary dealer survey rate or the midpoint of the GC bid and ask at the time of the ON RRP operation.

²⁵ The model currently only includes one lag for takeup. Multiple lags were considered, up to five days, but the single day lag gave the strongest results.

ON RRP Takeup

(\$billions)

<i>Variable</i>	<i>Coefficient</i>	<i>(SE)</i>
Time lag of takeup	0.92 ***	(0.002)
Counterparty type		
Dealer	0.11 ***	(0.02)
MMF	0.11 ***	(0.01)
GSE	0.27 ***	(0.04)
Bank	0.04 **	(0.02)
Rates		
Spread*Dealer	-0.052 ***	(0.02)
Spread*MMF	-0.006 ***	(0.002)
Spread*GSE	-0.011 *	(0.01)
Spread*Bank	0.000	(0.004)
HighSpread*Dealer	0.043 **	(0.02)
Supply effects		
New Bills*Dealer	-0.32	(0.97)
New Bills*MMF	-1.58 ***	(0.47)
New Bills*GSE	0.66	(1.88)
New Bills*Bank	-0.63	(1.07)
Calendar effects		
Quarter End*Dealer	-0.21 *	(0.11)
Quarter End*MMF	1.46 ***	(0.05)
Quarter End*GSE	1.42 ***	(0.2)
Quarter End*Bank	-0.10	(0.12)
Quarter Begin	-0.76 ***	(0.04)
Month End*Dealer	-0.22 ***	(0.06)
Month End*MMF	0.29 ***	(0.03)
Month End*Bank	-0.11	(0.13)
Month End*GSE	-0.01	(0.07)
Month Begin	-0.26 ***	(0.03)
5 days before P&I*GSE	0.68 ***	(0.08)
4 days before P&I*GSE	0.12	(0.08)
3 days before P&I*GSE	-0.12	(0.08)
2 days before P&I*GSE	0.20 ***	(0.08)
1 day before P&I*GSE	-0.92 ***	(0.08)

Where: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

We also find a strong negative relationship between takeup and spread among dealers, MMFs, and, to a lesser extent, GSEs. However, the magnitude of this relationship is quite small. A 1 basis point decrease in spread will lead to an increase in takeup of only about \$1.8 billion across all counterparties.²⁶ Furthermore, the role of spreads has decreased over the course of the sample period (not shown) as participation has become more persistent and takeup has been consistently high despite spreads of typically at least several basis points.

The effect of nonlinearity in spread is pronounced for dealers, who generally only participate in the ON RRP if spreads are near or below zero, resulting in an almost L-shaped demand curve. The results imply that, if for instance there is a negative spread between the ON RRP and GCF rates, a 1 basis point decrease in spread will lead to a \$1.15 billion increase in takeup across all dealers. When the spread is negative, dealers are more likely to participate since they are net borrowers in the repo market and they can arbitrage the two rates by borrowing in the market and then lending to the Fed in the ON RRP. However, if the spread is greater than 2 basis points, a 1 basis point decrease in spread will lead to only a \$200 million increase in takeup for all dealers.

As expected, there is a negative relationship between ON RRP takeup and Treasury bill supply for MMFs given that the ON RRP and Treasury bills are substitute investments for these counterparties. However, again the magnitude is relatively small. Overall, a \$1 billion increase in Treasury bills results in about a \$152 million net decrease in ON RRP takeup across all counterparty types.²⁷

Quarter- and month-ends have a strong positive affect for MMFs and, to a lesser extent, GSEs. Major borrowers, such as dealers and foreign banking organizations (FBOs), have a tendency to pare their balance sheets on reporting dates in an effort to improve market participants' views of their balance-sheet risk and to allow themselves more balance-sheet flexibility. This pullback leaves cash investors, including MMFs and GSEs, with limited investment opportunities, making the ON RRP particularly attractive on these dates. This is particularly true on quarter-ends, resulting in larger participation effects on those dates.

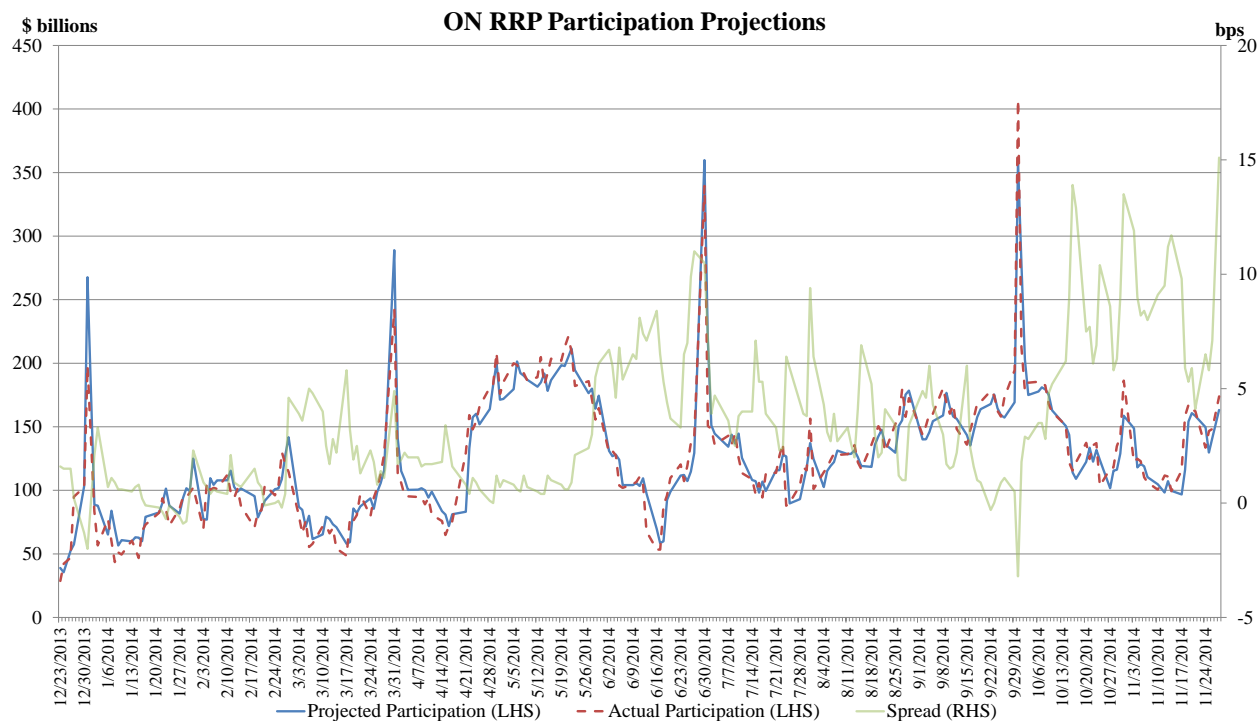
²⁶ Note the participation regressions are run at the individual counterparty level. To get aggregate effects such as this and those mentioned later in this section, takeup for a representative individual counterparty of each of the four types is estimated, then multiplied by the number of counterparties of that type, as shown in the table in Section 2.

²⁷ The model current only includes concurrent changes in Treasury bill supply. Lagged and lead changes were also considered, but the concurrent change gives the strongest result. Any persistent effect of a change in bill supply is likely captured in the lagged takeup term.

As expected, the primary driver of GSE participation is the lead up to Fannie Mae and Freddie Mac’s P&I dates. Their ON RRP participation tends to be highest in the several days before their P&I payment, then subsequently drops off the day before the payment.

c. Performance of Model Projections

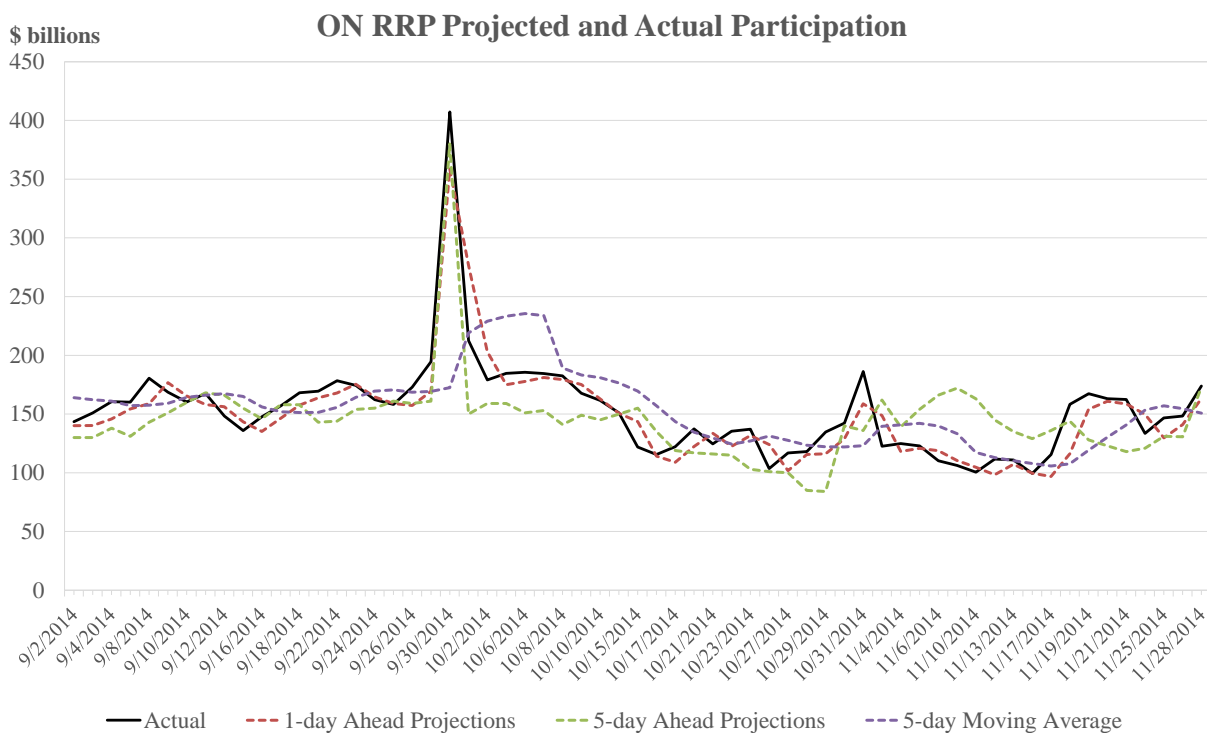
The results of the interval regression are used to project daily usage of the ON RRP exercise by counterparty type. Specifically, the takeup for a representative individual counterparty of each of the four types is projected. These projections are multiplied by the number of counterparties of each type and summed together to get a projection of aggregate takeup. The projected aggregate takeup relative to actual takeup and the spread between the average market repo rate and the ON RRP rate is shown in the figure below. It is important to note that, while these projections are quite close to actual takeup, they are only made one day ahead.



To assess model performance, we compare our projections to both the previous day’s takeup and a simple 5-day moving average of takeup, where the expected takeup is equal to the average takeup over the previous week. Looking specifically at participation over the last three

months of the period, the model performs significantly better than just lagged takeup and about twice as well as the 5-day moving average despite a high level of stability in overnight rates during this period.

We also consider the model’s performance over a somewhat longer horizon. To project takeup over more than one day, the projection for individual takeup on day $t+1$ is used as the lagged takeup for that counterparty on day $t+2$. Projections of individual counterparty takeup are then aggregated as before to get a projection of aggregate takeup. The 5-day ahead performance over this period has been less accurate, which may be due to a changing role of the ON RRP in market participants’ portfolio management strategy, but is similar to the performance when using the 5-day moving average.



The absolute average 1-day ahead error over the 3-month projection period shown above was about \$12 billion, or around 7% of total takeup. Even excluding the month-end observations (when participation tends to spike making the moving average less accurate), the model errors are, on average, between 20 and 50 percent lower than they are when using the previous day’s takeup or a simple moving average.

Average Forecast Error (\$ Billions; Sep 1 - Nov 28, 2014)	
Model	
1-day Ahead	\$12
5-days Ahead	\$24
Previous Day's Takeup	
All Observations	\$19
Excluding Month Ends	\$15
5-day Moving Average	
All Observations	\$23
Excluding Month Ends	\$19

5. Discussion

The projection model generates relatively good estimates of aggregate takeup amounts and short-term interest rates over the very short run. The relationships described above adequately explain the GCF rate and the participation level. The model outperformed the simple average despite a high level of stability in overnight rates during this period.

As the ON RRP evolves and the FOMC begins raising interest rates, the relationships modeled above will need to be reevaluated over time. Even among the relationships explicitly analyzed, large changes in interest rates, Treasury issuance, or ON RRP parameters would cause us to reevaluate the model since our estimations have been made in a very narrow interest rate environment with relatively small changes to the stocks of Treasury securities in the private sector. Additionally, we have analyzed the ON RRP as a standalone facility. The introduction of an intermittent simultaneous term RRP exercise in December 2014 greatly changed the demand for overnight RRP.²⁸ The initial term operations suggest a near one-to-one substitution between the overnight and term programs. Future analysis will look at the interactions of ON and term RRPs, and their joint effects on counterparty behavior.

²⁸ On December 1, 2014, the Federal Reserve announced they would offer four term RRPs over December that crossed year-end (www.newyorkfed.org/markets/opolicy/operating_policy_141201.html). These operations were held each Monday from December 8 through December 29 and all matured on January 5, 2015. Subsequent term RRPs were offered in February and early March 2015, as well as over each subsequent quarter-end.

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Appendix

ON RRP Parameter Changes				
Date	Fixed Rate (basis points)	Maximum Individual Bid (\$ billions)	Overall Size Limit (\$ billions)	Time of Operation
9/23/2013	1	0.5	NA	11:15 - 11:45 am
9/27/2013		1		
10/21/2013	2			
11/4/2013	3			
11/12/2013	4			
11/19/2013	5			
12/23/2013	3	3		
1/15/2014				12:45 - 1:15 pm
1/30/2014		5		
2/18/2014	4			
2/26/2014	5			
3/5/2014		7		
4/7/2014		10		
9/22/2014		30	300	
9/30/2014				8:00 - 8:30 am
10/1/2014				12:45 - 1:15 pm
11/3/2014	3			
11/17/2014	7			