Target practice: Monetary policy implementation in a post-crisis environment[*]

Elizabeth Klee and Viktors Stebunovs[†]

December 10, 2012

Abstract

Traditionally, the Federal Reserve targeted the federal funds rate, expecting this rate to transmit a monetary policy stance to other short-term and longer-term rates. However, at the height of the financial crisis, the pass-through from the federal funds rate to other short-term rates deteriorated. Furthermore, market participants reportedly anticipate that the inception of liquidity requirements might weaken the federal funds market and therefore its linkages with other money markets. At the same time, however, most anticipate that high quality collateral repo markets should remain active. We argue that, in principle, instead of the federal funds rate, the Federal Reserve can target the Treasury General Collateral repurchase agreement rate, and explore the Federal Reserve's capacity to do so empirically. Our results suggest that a target repo rate might be an alternative policy tool to the target federal funds rate in the post-crisis environment.

Keywords: target federal funds rate, Treasury general collateral repo rate, liquidity coverage requirements, liquidity effect, monetary policy implementation framework, open market operations, M3.

1 Introduction

Traditionally, the Federal Reserve targeted the federal funds rate, expecting this rate to transmit its monetary policy stance to other short-term and longer-term rates. However, at the height of the recent financial crisis, the pass-through from the federal funds rate to other short-term rates deteriorated as the zero lower bound set in and money markets underwent structural changes. Furthermore, market participants anticipate that the inception of regulatory liquidity requirements will undermine selected unsecured money markets and their linkages by discouraging short-term financing among banks. Going forward, with the federal funds market potentially experiencing encumbrances, if the Federal Reserve wishes to implement monetary policy by targeting a money market rate, is there a viable alternative to the target federal funds rate?

We argue that, instead of the federal funds rate or term money market rates, the Federal Reserve can target the overnight Treasury General Collateral (GC) repurchase agreement (repo) rate. The Treasury GC repo market is a secured, multi-trillion dollar money market with a much wider set of participants than in the federeal funds market, including depository institutions ("banks"), primary dealers, investment banks, central banks, insurance companies, industrial companies, municipalities, pension funds, hedge funds, and mutual funds.[1] Moreover, the size of the System Open Market Account (SOMA) portfolio of Treasury securities relative to the repo market is substantial, and so in principle, the Federal Reserve can put significant upward pressure on the repo rate if needed. Hence, by targeting the repo rate, the Federal Reserve can affect the cost of funding (or the rate of return) for various institution types, strengthening the cost channel of monetary policy transmission, as well as be liquidity source to a broad set of financial institutions.[2] In addition, institutions still may have counterparty credit risk concerns at the forefront of concern, and looming liquidity regulations may restrict funding flexibility for money market participants. To alleviate these, one option might be to target money market rates for loans with the maturity of over 30 days. But this setup might be unnecessarily complex, possibly requiring retirement of these loans once their remaining maturity reaches 30 days (to satisfy the liqudity coverage requirements), and suffer from pronounced anticipation effects way ahead of the target rate change days.

We perform several empirical exercises to support our conjecture that the repo rate might be a more feasible target rate in a post-crisis environment. First, we document that the size of the Federal Reserve's porfolio of Treasury securities is comparable to that of the triparty repo market, suggesting that the Federal Reserve can potentially drain the entire repo market liquidity by "repoing out" its portfolio. We also show that in the past, there was a reasonably predictable

---

[1] We use the colloquial term "banks" to mean the more accurate term "depository institutions."

[2] The financial crisis also demonstrated that a broader set of financial institutions, rather than just banks, required access to a liquidity source, such as the Federal Reserve. As such, the Federal Reserve established several facilities to provide liquidity directly to borrowers and investors in key credit markets, such as the Primary Dealer Credit Facility, the Term Securities Lending Facility, and the Term Asset-Backed Securities Loan Facility. These facilities alleviated market strains, as shown in Fleming et al. (2009).

high-frequency demand schedule for Treasury general collateral repo that, in particular, suggests a daily "liquidity effect," or a price response to a change in the quantity of collateral. We argue that consequently, there is potential for monetary policy implementation on a daily basis. Second, we show the existence of a limited liquidity effect at lower frequencies, using M3 data. This result points to a relationship between the amount of repo "money" – defined as outstanding repurchase agreement transactions – and interest rates. And third, we show that while there is evidence of a diminished transmission mechanism from the federal funds rate to longer-term interest rates, transmission from repo has remained relatively more intact. This exercise relies on a series of tests of the expectations hypothesis involving the federal funds and Treasury GC repo rates.

The paper proceeds as follows. Section 2 provides background on key overnight funding markets, both secured and unsecured. It also discusses the potential impact of liquidity requirements on these markets as well as monetary policy implementation regimes in areas other than the U.S. Section 3 describes the empirical framework and reports the estimation results for the short-run liquidity effect. It also characterizes the implications of targeting the repo rate for balance sheet of depository institutions and provides back-of-the envelope calculations for upward pressure the Federal Reserve can put on the repo rate through large-scale reverse repos. Section 4 gives evidence of a longer-term liquidity effect in the repo market. Section 5 reports some simple results of transmission of monetary policy across the yield curve. Section 6 concludes.

2   Background

This section reviews basic facts on the repo market and the federal funds market, the potential effects of liquidity requirements on these markets, and monetary policy implementation under different regimes. We discuss each in turn.

2.1   The repo and federal funds markets

2.1.1   Repurchase agreements

A repurchase agreement is a sale of a security coupled with an agreement to repurchase the security at a specified price at a later date. It is economically similar to a collateralized loan, where the lender of cash receives securities as collateral, and the borrower pays the lender interest on the overnight loan the following day. From the perspective of the borrower of cash, the transaction is called a "repo," and from the perspective of the lender of cash, it is a "reverse repo."[3] If the rate on a repurchase agreement is low relative to other market rates, it indicates a relative abundance

---

[3]There is a quirk in nomenclature when discussing the repo market and the Federal Reserve. For the Federal Reserve, repos are defined by the the effect on the counterparty. Therefore, if the Federal Reserve lends securities and borrows cash, it is called a reverse repo, and if the Federal Reserve lends cash and borrows securities, it is called a repo.

3

of cash and a relative shortage of collateral, and as a result, the borrower does not have to pay much interest for using the funds overnight. By contrast, if the rate on a repurchase agreement is relatively high, it signals a relative abundance of collateral and shortage of cash, and the borrower has to pay a higher interest rate in order to obtain funds.

Data on aggregate repo market activity is not generally available.[4] However, there are a few sources of information on repo market volume that can help to characterize its size. One source is statistics compiled by the Federal Reserve Bank of New York (FRBNY) on the triparty repo market. In a triparty repo transaction, there is a custodial bank that acts as agent for buyer and seller in the transaction. The triparty repo market represents a substantial share of the total repo market, but not the entire market. As displayed in figure 1, the triparty market peaked near $3 trillion in 2007, and has since settled around $1.75 trillion.

Another source is statistics compiled by FRBNY on repurchase agreements conducted by the primary dealers, which are the banks and broker-dealers that trade directly with the Open Market Desk (the "Desk") at FRBNY for the purposes of open market operations.[5] As shown in figure 2, within the primary dealer community, total repurchase agreement market volume in Treasury securities averaged about $50 billion in 1994, and then started to climb steadily through the 2000s, peaking at a little below $200 billion. Interestingly, the volume of repos brokers executed outside of the primary dealer community more than quadrupled in 10 years, while the volume within the community only doubled. At the onset of the crisis, repo market volume climbed even higher, but then backed down to pre-crisis levels near the end of 2009 and the start of 2010.

2.1.2 Federal funds

Federal funds are unsecured loans of reserve balances at Federal Reserve banks that account holders at the Federal Reserve make to one another. The rate at which these transactions occur is called the federal funds rate and the market in which these transactions occur is the federal funds market. In many ways, the federal funds market is similar to the repo market, in that they are both used as short-term funding markets, have overlapping participants, and are generally very liquid. But, there are important differences. Traditionally, the federal funds market was used by banks to buy funds in order to satisfy reserve requirements, or to sell funds in excess of those requirements. Banks satisfy reserve requirements on the basis of average balances held over a 14 day period, and previous research shows that funds rate behavior differed according to the day of the maintenance period.[6] Moreover, this research also provided evidence of a short-term "liquidity effect," or a price response to changes in the level of reserve balances. In addition, participation in the federal funds market is more restricted than the repo market in its participants; it is limited to banks, government-

---

[4]Some market observers attempt to estimate the size of the repo market; refer to [Gorton (2010)], for example.
[5]The broker-dealer volume reported here includes both direct trades and triparty trades.
[6]For example, refer to [Hamilton (1996)], [Carpenter and Demiralp (2006a)], and [Judson and Klee (2010)].

sponsored enterprises (GSEs) and selected other entities. This has the important implication that while all financial institutions are theoretically able to participate in the repo market, the federal funds market is restricted only to selected institution types, which could temper opportunities for arbitrage across markets.

Even though the federal funds market has traditionally been very important for monetary policy implementation, the market is quite small and by many measures, federal funds market volume is much lower than repo market volume. Moreover, federal funds volume has dropped considerably since the start of the financial crisis. For example, figure 3 plots federal funds transactions identified in the Fedwire data.[7] Indexing this series to its level at the beginning of 2000, federal funds volume nearly doubled before the start of the financial crisis, before falling to near its value at the start of 2000 in the second quarter of 2012. For reference, federal funds volume growth generally outpaced that of nominal GDP before the crisis, but backed down considerably since then. The decline in federal funds volume could be associated with the large volume of reserves outstanding emerging from the crisis, diminishing the possibility that institutions would be short on reserves. In addition, the introduction of interest on reserves may have also dampened the need for institutions to lend excess cash, as these institutions would still earn interest on excess balances left at the Federal Reserve.

2.1.3 Comparing the two money markets

These observations regarding the size of the federal funds market relative to the size of the repo market suggest that the funds market is quite a bit smaller than the repo market. Indeed, these data are consistent with data from the Call reports, which suggest that commercial bank federal funds market volume is only a small share of total repo market volume, and that commercial banks' federal funds market activity is smaller than the repo market activity. As shown in figure 4, federal funds sold peaked at around $250 billion near the start of the financial crisis, and then dropped to less than half that volume by March 2010. As a percentage of assets, federal funds peaked much earlier, in 2003. Notably, federal funds purchased generally exceeds federal funds sold, indicating that commercial banks are net buyers of funds.[8] Moreover, while federal funds sold stayed relatively steady from 2002 to 2007, securities purchased to resell, or reverse repos, rose

---

[7]The data on federal funds volume are constructed using proprietary transaction-level data from the Fedwire Funds Service, using an algorithm pioneered by [Furfine (1999)] to match and form plausible overnight funding transactions, likely related to the federal funds market. The algorithm matches an outgoing Fedwire funds transfer sent from one account and received by another with a corresponding incoming transfer on the next business day sent by the previous day's receiver and received by the previous day's sender. This pair of transfers is considered a federal funds transaction if the amount of the incoming transfer is equal to the amount of the outgoing transfer plus interest at a rate consistent with the rates reported by major federal funds brokers. However, because we have no independent way to verify if these are actual federal funds transactions, our identified trades and characteristics of these trades are subject to error.

[8]Commercial banks can purchase funds from other instituitons in the federal funds market, including thrift institutions, foreign institutions, and government-sponsored enterprises (GSEs).

at a moderate pace, and then began to rise rapidly through the end of 2008. Repos, or securities sold to be repurchased, peaked noticeably earlier than reverse repos, and at a higher level. Still, for a majority of the sample period, commercial banks had more of their balance sheets in repos than in federal funds, and consequently, were a more prominent share of the portfolio.

Even though the volumes in these markets are quite different and there is imperfect overlap between the two markets, over much of the past decade or so, these rates have moved together quite closely. Figure 5 plots the spread between the federal funds rate and the repo rate from 2002 to 2010. As is evident from the figure, these rates were similar up until 2007. Because federal funds transactions are unsecured while repo transactions are secured, the repo rate is usually a bit below federal funds. Spreads started to widen in the beginning of the financial crisis, from August 2007 onward, and then skyrocketed during the crisis as investors flocked to the relative safety of secured overnight lending in repo.

2.2 Monetary policy implementation

There is a special connection between the federal funds market and the repo market for Federal Reserve monetary policy implementation. In the textbook version of monetary policy implementation, the Federal Reserve buys securities from dealers in the repo market, which gives the dealers cash which they deposit in their bank's accounts, and the banks then proceed to sell the funds in the federal funds market. By sizing this "open market operation" appropriately, the Federal Reserve could ensure that the federal funds rate – the policy rate – was close to the target set by the FOMC.

This operating procedure and target interest rate worked for many years. Repo rates and federal funds rates traded in line with each other, and longer-term interest rates moved up and down with the federal funds rate. According to [Simmons (1954)] , repurchase agreements were used as part of the Federal Reserve System's operations since 1917. In addition, as documented by [Friedman and Schwartz (1963)], as early as the 1920s, open market operations were part of the Federal Reserve's preferred operating procedure. Still, as described by [Meulendyke (1998)], use of temporary open market operations was limited until after the Treasury Acccord in 1951. Furthermore, before the FOMC started announcing an explicit target federal funds rate, market participants would gauge any changes to the target federal funds rate by observing the sizes of the open market operations immediately following an FOMC meeting. Although market participants arguably stopped looking to repos for a signal regarding the stance of policy once target announcements began, open market operations remained an important tool, as the Desk used repos almost daily to adjust the level of reserves so that federal funds would trade close to the target federal funds rate.

Monetary policy implementation changed with the recent financial crisis, although not all at

once. At the start of the crisis in August 2007, the Federal Reserve relied on larger-than-normal repo operations to inject liquidity into the federal funds market. Later, in the fall of 2008, the Federal Reserve conducted reverse repos in order to drain reserves from the system as well as to add some collateral back to the market. However, because reserve balances were elevated, the effective federal funds rate traded well below the target rate. In addition to the reverse repos, the Federal Reserve also conducted 28-day single-tranche repos in which dealers pledged agency MBS collateral. These provided dealers with financing for agency MBS when the spread between one month agency MBS repo and one-month Treasury general collateral repo was particularly wide.[9] Although regular repo activity by the Desk ceased in the early part of 2009, in 2010 and 2011, more recently, the Desk has conducted a series of small value reverse repurchase agreements with a broad set of counterparties as part of its operational readiness program for tools to use in the future to drain reserve balances.[10]

Given the Federal Reserve's history, it seems like it would be a major change to target the repo rate instead of the federal funds rate. But, this development, were it to occur, would not be a radical shift in monetary policy implementation more generally. For example, the Central Bank of Brazil explicitly targets a rate on overnight transactions collaterized by securities issued by the central bank (the Sistema Especial de Liquidao e de Custdia (SELIC) rate) in the market with a wide range of participants inluding commercial banks, universal banks, investment banks, savings banks, dealers and brokers, mutual investment funds, etc. However, as shown in table 1, the practice of targeting an explicit rate, be it either secured or unsecured, is not widespread among advanced foreign economies. In contrast to the Federal Reserve approach, other central banks tend to target money market rates in a more general way. In order to measure their success at reaching a particular target, central banks often consider one or more indicative rates, predominantly on unsecured overnight interbank loans. The only exception to this practice appears to the choice of indicator rates in Canada, where the central bank looks at both the overnight money market financing rate and (to a lesser extent) the Canadian Overnight Repo Rate Average (CORRA).

2.3 Potential impact of liquidity coverage ratios on the repo and federal funds markets

Most of our discussion so far has been focused on the characteristics of the repo and federal funds markets in the past and present; a future development may impact these markets as well. In response to the global financial crisis, the Basel Committee on Banking Supervision introduced the Liquidity Coverage Ratio (LCR), which is intended to measure the amount of liquid assets that are available (the numerator of the LCR formula) to meet the potential outflow of funding over a

---

[9]For details, refer to [Federal Reserve Bank of New York (2009)].

[10]Refer to `http://www.newyorkfed.org/markets/rrp_op_policies.html` for details.

30-day period (the denominator).[11] Compliance with the LCR is achieved by maintaining a greater pool of liquid assets than net outflows of cash (a ratio of 100 percent or greater).

Per the LCR rules, reserve balances of depository institutions at the Federal Reserve and (unencumbered) U.S. Treasury securities are equivalent in the LCR numerator. The numerator consists of narrowly-defined "Level 1" and "Level 2" unencumbered assets that are more likely to generate funds without incurring deep discounts due to fire sales, even in times of acute stress. While Level 1 assets count at 100 percent of their value in the LCR, the contribution of Level 2 assets is set at 85 percent. Level 1 assets include such assets as cash, debt securities rated AA- or higher issued by foreign or domestic sovereigns, foreign or domestic central banks, and central bank reserves. Level 2 assets include such assets as agency debt and mortgage-backed securities. Although reserve balances and (unencumbered) U.S. Treasury securities function similarly in the LCR numerator, carrying Treasury securities on banks' balance sheets appears to be more advantageous than carrying reserve balances, as Treasury securities can be used as collateral in other types of transactions, while lending reserve balances is an unsecured transaction.

The unsecured nature of federal funds lending vis à vis Treasury securities lending is particularly important in the calculation of the denominator of the LCR. The denominator corresponds to a stressed net cash outflow scenario over a 30-day period, incorporating idiosyncratic and market-wide shocks, such as, for example, credit rating downgrades and loss of funding. The cash outflows are simulated by multiplying the amount of balance sheet LCR-eligible liabilities by specific run-off factors. In particular, federal funds borrowings fall under unsecured wholesale funding due to financial institutions and have a 100 percent run-off rate.[12] In contrast, borrowing of U.S. Treasury securities has a zero percent runoff rate. As a result, repo market counts more favorably in the LCR denominator than borrowing in the federal funds market. Consistently, market participants reportedly anticipate that the federal funds and other unsecured money markets might be undermined significantly by the inception of the LCR.

In an appenix available upon request, we work out in several examples the impact of (reverse) repos conducted by the Federal Reserve with depository institutions and extended counterparties (mutual funds and GSEs) on regulatory metrics of depository institutions. Overall, in the target repo rate environment, banks face volatile balance sheets and leverage ratios but stable risk-weighted capital ratios. In addition, cash-adding repos by the Federal Reserve tend to worsen the LCR standing of banks, while cash-draining Fed repos tend to improve it.

---

[11]BCBS "International Framework for Liquidity Risk Measurement, Standards and Monitoring", December 2010.

[12]One exception to this rule is if the two institutions have an established operational relationship.

3 The short-run liquidity effect

In this section, we explore the existence of a short-run liquidty effect in the repurchase agreement market. First, we show that, analogous to the Fed's ability to control the federal funds rate via the adjustment in the level of reserve balances, because the Federal Reserve has a large portfolio of Treasury securities relative to the repo market, the Federal Reserve has a credible position in its ability to sway market rates in one direction or another. Second, similar to research by Lou, Yan, and Zhang[Lou, Yan, and Zhang (2011)] on the (primary) Treasury market, we find that there is a persistent liquidity effect in the (derivative) repo market.

3.1 Preliminaries: The credibility of the Federal Reserve's target repo rate

By analogy with the implementation of the federal funds target rate, the key prerequisite for the proposed monetary policy implementation framework is the credibility of the Federal Reserve's target repo rate.[13] For example, the Federal Reserve, the ultimate supplier of reserve balances in charge of seeting reserve requirements, can impose a structural reserves deficiency on the banking system, and support any level of the federal funds target rate. This setup is credible to such an extent that trades at an anticipated federal funds target rate occur even before a FOMC announcement of the new target, that is, before the Desk at FRBNY implements the new target.[14] So, the question is whether the Federal Reserve's target repo rate might command similar credibility.

To that end, comparing the size of the System Open Market Account portfolio (that includes of Treasury securities, agency debt, and agency MBS) to that of the triparty repo market is instructive. As figure 1 shows, the sizes of the Federal Reserve's of Treasury securities portfolio on its own and of the triparty repo market are comparable, around $1.6-1.75 trillion as of early 2012, indicating that, in principle, the Federal Reserve can drain the repo market out of liquidity entirely (through large-scale reverse repos), hence putting significant upward pressure on the repo rate.[15] If the needs might arise to supply rather than drain liquidity, the Federal Reserve can add as much liquidity to the market as market participants can absorb given their collateral. The capacity to drain or

---

[13] We are well aware of the Lucas critique–that it is naive to try to predict the effects of a change in economic policy entirely on the basis of relationships observed in historical data, especially highly aggregated historical data. In fact, we acknowledge that our work is subject to the Lucas critique. We do not rule out the possibility that a mere announcement that the Federal Reserve might target the repo rate will change the way the repo market functions.

[14] There is ample literature on the anticipation effects in the federal funds market, see for example, Carpenter and Demiralp (2006b) [Carpenter and Demiralp (2006b)].

[15] If the size of the SOMA holdings of Treasury securities (possibly of a particular security type) is not sufficient to conduct a reverse repo of a desired size, the Federal Reserve can increase the size of its portfolio through permament open market operations. Of note, high frequency data for the size of the triparty repo market is not available for the 2002-2008 period; for those years, we interpolated the available low frequency observations. The ratio of the SOMA Treasury securities holdings to the triparty repo market size reached a low of 40 percent when the Federal Reserve shrank its portfolio in order to partially sterilize the credit and liquidity facilities, but, more recently, the ratio has been closer to one.

add enormous liquidity volumes should reinforce the credibility of the Federal Reserve to target any level of the Treasury GC rate.

Having argued that the repo market might be a viable alternative to the federal funds market for monetary policy implementation, we turn to the question whether a stable short-run liquidity effect is present in the Treasury general collateral repo market. This liquidity effect is what might allow the Federal Reserve to target a particular level of the Treasury general collateral repo rate, offsetting shocks to either supply or demand for repos.

In theory, the liquidity effect is a negative relationship between a money measure and an interest rate: there exits a demand curve for some type of money that depends negatively on an interest rate and the liquidity effect refers to the slope of this demand curve. In practice, methodologies and evidence of the liquidity effect are mixed. In lower frequency data, there is often a lack of correlation between monetary aggregates and interest rates. By contrast, in high frequency data, [Hamilton (1997)] and others find a significant liquidity effect.

In a traditional liquidity effect estimation framework, the demand for reserve balances is usually posited as a (possibly nonlinear) function:

$$D_t = F\left(ff_t, S_t, Z_t\right) + e_t$$

where ff_t is the federal funds rate, S_t is an exogenous shifter of cash supply (or its corollary–collateral supply) and Z_t is a set of controls. The empirical specification, however, usually focuses on a change in the interest rate as a function of an exogenous change in the quantity of money. On a daily frequency, [Hamilton (1997)] used the "forecast miss" in the level of the Treasury's General Account at the Federal Reserve to identify the quantity of reserve balances outsanding. Later research, including [Carpenter and Demiralp (2006a)] extended the sample and broadened the definition of the forecast miss and found liquidity effects of varying degrees. In many of these studies, the error term, e_t, is specified as a GARCH process to control for heteroskedasticity in the error-generating process.

We examine the repo market liquidity effects using three measures of S_t, the exogenous shifter of cash supply. Although Treasury bills are reportedly one of the most popular forms of collateral, given the skewed composition of the Fedearal Reserve's portfolio towards Treasury bonds, we document the existence and significance of the liquidity effects attributable to both Treasury bills and bonds.

3.2 Specification

Our tool of choice for evaluating the liquidity effect at a daily frequency is an error-correction model. We posit that the repo rate and the target federal funds rate have the following relationship:

$$\Delta rr_t = \alpha \left(c + \beta f f t a r_{t-1} \right) + \Phi_{rr}(L) \Delta rr_t + \Phi_{ff}(L) \Delta f f t a r_t + \Theta Z_t + \Xi S_t + e_t \qquad (1)$$

where

- rr_t is the repo rate; $f f t a r_t$ is the target federal funds rate;

- c is a cointegrating constant (a proxy for credit risk); β is a cointegrating slope; α is a speed of adjustment coefficient, Φ is a set of distributed lag coefficients;

- S_t is an exogenous shifter of cash/collateral supply such as net issuance of Treasury securities;

- e_t is an error term, possibly modeled with allowances for heteroskedasticity.

We include the target federal funds rate into the model to control for the intended level of money market rates. We envisage that in the environment where the Federal Reserve targets the repo rate, the credibility of the institution, the size of its portfolio of Treasury securities, and, ultimately, the possibility of intervention if the repo rates deviates too much from its target will make the target repo rate credible, ensuring that the repo rate follows the target over time. In that environment, the cointegrating relationship will be between the market repo rate and its target.

In addition to the lagged values of the repo rate and the target federal funds rate, the other variables included are factors that likely shift the demand schedule for repos on a daily basis. These factors are captured in the $\mathbf{Z_t}$ vector, with coefficients to be estimated, Θ. We specify $\mathbf{Z_t}$ as

$$Z_t = (\text{repo market factors}_t, \text{risk}_t)$$

where the two terms represent groups of variables that proxy for financial market risk measures (a few are similar to those used in [Collin-Dufresne et al. (2001)], plus some factors that are specific controls for the funds market and for the repo market.

The first group of factors includes factors related to the repo market, for example, a measure of how heavily weighted primary dealers' books are towards trades with other dealers versus with non-dealers.[16] This gives some idea of market concentration in the Treasury market. To address market functioning, delivery fails in Treasury securities are included as an independent variable; these are reported by primary dealers to the Federal Reserve Bank of New York on a weekly basis. In addition, actions on the SOMA Treasury portfolio are added as controls, including the level of Treasury securities lent through the SOMA securities lending programs. Securities lending tends to increase during times of market stress and for particular CUSIPs that are considered to be trading on "special" in the market.

---

[16]This variable is defined as transactions outside the dealer community as a share of total transactions. The data source is the FR2004.

The second group controls for overall indications of financial risk. Over the estimation period, market sentiment changed dramatically with the advent of the financial crisis. As a result, indicators such as the Libor-OIS spread, and the monetary policy outlook – as proxied by the slope of the yield curve (the 10-year Treasury rate less the 2-year Treasury rate) – generally reflected more negative sentiment about the financial markets and the economy towards the the second half of the sample.

We use net issuance of Treasury securities or net issuance of Treasury bills or net issuance of Treasury coupon securities as an exogenous shifter of cash/collateral supply in the repo market. The U.S. Treasury issues its securities according to a predetermined and well-publicized schedule. The composition of Treasury security issuance is not dictated by the developments in the repo market, and, to a large extent, it is guided by the financing needs of the Federal government. Reportedly, issuance of Treasury bills has a more profound effect on the repo market than that of Treasury coupon securities, so to examine this suggestion formally we estimate models with either bill or coupon issuance. Because repo rates experience pronounced movements on Treasury issuance days, and these effects generally linger for a few days before and after the issuance, we include net Treasury issuance, both contemporaneous and lagged by a day.

A casual observation of the repo rates indicates several periods with volatility clustering; in addition, preliminary estimation results suggest that there exists heteroskedasticity of the residuals for which controls are needed. As a result, in conjunction with the mean equation described above, we also estimate a variance equation with GARCH components.

To estimate the error correction model with a GARCH error process, we employ a two-stage estimation procedure similar to [Engle and Granger (1987)]. In the first stage, we test for cointegration of the repo rate and the federal funds rate and construct the cointegrating term using ordinary least squares. In the second stage, we estimate an error correction equation with a GARCH/TARCH error term via maximum likelihood. Although it is possible that some efficiency is lost using this procedure, it allows us to use a GARCH specification relatively easily in the second stage estimation. We determine the number of lags to use in each specification as suggested by the Schwarz Information Critierion (SIC) test.[17] Furthermore, significance of all coefficients is reported with respect to Bollerslev-Wooldridge robust standard errors.

Because we are interested in the stability of the demand schedule for repos over different time periods, we estimate the error correction model over three samples: the benchmark period from January 2002 to July 2007 and the crisis period from August 2007 to June 2009. Over the post-crisis period from July 2009 to August 2012, the target federal funds rate stayed at the effective lower bound of 0-25 basis points; as a result, there is no variation and identifying a cointegrating relationship is not possible. For this period, we fit an autoregressive model with the same set

---

[17]Although some tests occasionally reveal statistically significant autocorrelated lags further out, these are generally ten business days or more in the past. We try to balance a more parsimonious specification versus controlling for all of these lags, and moreover, we feel that movements more than two weeks previous are likely irrelevant once other controls are included in the specification.

of controls and cash/collateral supply shifters and a GARCH error process as we use in the error correction models.

3.3 Data description

The daily data used in this study are observations on the target federal funds rate and the overnight Treasury general collateral repo rate from January 2, 2002 to August 15, 2012. The Treasury general collateral repo rate is a collateral-weighted average of a survey of all primary dealers conducted daily between 8:00 a.m. and 9:00 a.m.[18] Over most of the sample period, the repo rate has a unit root, as confirmed by a battery of Dickey-Fuller and Phillips-Perron tests. In previous work such as [Bech et al. 2012], we established cointegrating relationships between the effective federal funds rate and the repo rate. In the current work, we test for cointegration between the target federal funds rate and the repo rate. Tests for the pre-crisis and crisis samples show that the series are cointegrated; however, a test of this kind does not make as much sense for the post-crisis period, as the target federal funds rate did not change during this time.

3.4 Results

Table 2 displays the estimated cointegrating relationship formulated in equation (1). In the benchmark period, the repo rate almost perfectly followed the target federal funds rate, with an estimated β coefficient close to 1, and a constant term, or long-run average deviation of the Treasury GC repo rate from the target federal funds rate, of less than one basis point. Consistent with this, the specification explains over 99 percent of the variation in the repo rate over time. By stark contrast, in the August 2007 through June 2009 crisis period, the coefficient on the target federal funds rate drops to 0.94, and the spread between the repo rate and the target rate widens to nearly 20 basis points. The amount of variation in the repo rate explained by this specification drops about 9 percentage points, to 91 percent. Still, although the correlation between the target federal funds rate and the repo rate deteriorated in the crisis, it did not fade away completely.

As described above, we construct the residuals from the results of the estimated equation reported in table 2, and use the lag of the residual as an independent variable in the estimation of equation (1). This, along with our proxies for Treasury market supply as well as controls for market conditions more generally gives us our estimated liquidity effects, shown in table 3. Each time period has three set of results, one for each of our exogenous shifters of cash/collateral supply in the repo market: net issuance of all types of Treasury securities, net issuance of Treasury bills, and net issuance of Treasury coupon securities. We model all three issuance groups because we are interested in whether there is a liquidity effect from net issuance of Treasury securities in general,

---

[18]The DTCC GCF Repo Index, that recently became available, appear to track rather well the survey repo rate. The two series are extremely highly correlated conditional on calendar effects.

13

but also, whether this effect is attributable to the issuance of Treasury bills or Treasury coupon securities. In addition, we explore timing patterns of the liquidity effect. First and foremost, we are interested in identifying a contemporaneous liquidity effect; however, we also want to investigate how long liquidity effects might linger.

3.4.1 Benchmark: January 2002-August 2007

As shown in the left set of columns, in the benchmark period of normal times, the coefficient on the cointegration term suggests that the half-life of a one unit disequilibrium in the relationship between the repo rate and the target federal funds rate is between four and five days.[19] This result is in line with that reported in [Bech et al. 2012], which suggested that disequilibria between the effective federal funds rate and the Treasury GC repo rate disappeared relatively quickly, as both rates readjusted to reach equilibrium during normal times. In addition, the negative coefficient on the autoregressive lags shown in the bottom rows of the table suggest that there is some reversion to baseline in the Treasury GC repo series; the effects of positive changes in the repo rate dissipate with time. Of course, in the case of the target federal funds rate and the Treasury GC repo rate, the target rate moves infrequently, and therefore, all of the adjustment occcurs through the repo rate, perhaps slowing down the adjustment relative to the effective federal funds rate, which may have moved along with the repo rate in reaction to similar factors.

Our key results concerning the liquidity effect are presented in the second line of the table. The coefficient suggests a modest contemporaneous liquidity effect of 1 basis point per $50 billion of net Treasury issuance. However, the models with net Treasury bill and coupon securities issuance suggest that lingering effects might exist; the effect on the repo rate of $50 billion in net issuance is about 1.5 basis points. On net, the pattern and magnitude of the liquidity effects identified through net Treasury securities issuance reflect that of net Treasury coupon issuance, as evidenced by the results reported in the next two columns. Our estimation results suggest that repo rates soften with bill issuance, but firm considerably with coupon issuance. Much of the effect of coupon issuance fades the next day, while rates tend to firm somewhat the day after bill issuance. Even with some of these differences in patterns across asset types, the results point to a significant effect of Treasury supply on the repo rate.

Turning next to indicators of market risk, neither changes in the Libor-OIS spread nor in the slope of the Treasury yield curve appear to have much significant effect on changes in the repo rate. As for the factors that control for repo market conditions, a larger share of Treasury repo transactions by dealers tend to be associated with upward pressure on the repo rate. The intuition behind this result could be that if dealers need to do a large number of transactions in repo, then

---

[19]As explained in [Bech et al. 2012], the half-life of a shock to the cointegrating relationship is the number of periods it takes for 50 percent of a one unit deviation from equilbrium to fade. This is solved for by simple recursive substitution using the coefficient α.

collateral is likely fairly plentiful, and cash relatively scarce, pushing up the repo rate.

The next three lines show the effect of changes in the target rate on the repo rate. The results suggest both contemporaneous changes in the repo rate as well as anticipatory changes in the repo rate as a result of changes in the target federal funds rate. Interestingly, there appears to have been positive anticipatory changes in the repo rate, while on the actual day of the change, repo rates actually softened a bit. This subsample period encompassed the "measured pace" tightening cycle in domestic monetary policy. As documented by [Carpenter and Demiralp (2006b)] and [Judson and Klee (2010)], there were notable anticipation effects in the federal funds market during this period; as such, the repo rate may have also moved higher along with the funds rate in advance of the actual firming of the target federal funds rate.

The error process for the repo rate exhibits marked heteroskedasticity as well as some significant asymmetries. As indicated by the coefficient on the squared residual term, volatility tends to persist in the repo market. In addition, as shown by the leverage term, a negative shock to the repo rate is generally associated with increased volatility relative to a positive shock to the repo rate, largely consistent with observations on leverage effects in other financial markets.

Finally, this specification explains a little under 25 percent of the variation in changes in the Treasury GC repo rate over the sample period. While this is certainly not the plurality of variation in the repo rate, this analysis does point to factors that were associated systematically with changes in the repo rate over this period. Notably, we do not include calendar effects in this specification. The additional variation explained by these calendar effects are less than 5 percentage points as measured by the R-squared statistic. In addition, as will be explained below, calendar effects became much less important in the subsequent subsamples, and in order to promote comparability across time periods, we eliminate them from the analysis.

3.4.2 Crisis: August 2007 to June 2009

The relationship between these two rates changed markedly with the advent of the financial crisis. Over the crisis period, as shown in the three middle columns of table 2, the adjustment speed from disequilibrium slowed to a crawl, with the coefficients suggesting about 28 business days until about half of a one-point deviation in the long-run relationship between the repo rate and the target rate would be resolved. Given that the target federal funds rate moved at nearly every FOMC meeting, and many of the intervening periods were only about 30 business days in length, the estimate suggests that even though the repo rate still remained cointegrated with the target rate, moves in the target were slow to translate into changes in the repo rate.

While the adjustment speed of the repo rate slowed considerably, the sensitivity to Treasury issuance jumped. Overall, the effect of $50 billion in issuance nearly doubled to a firming of 3.5 basis points, suggesting a much more sensitive response of rates to changes in the amount of collateral. This effect was much stronger in bills than in coupons, consistent with heightened

demand for short-dated, liquid, very safe instruments that characterized the height of the financial crisis. Demand for newly-issued coupons was much more muted; in fact, the contemporaneous effect has the "wrong sign" and the lagged effect suggests that all effects dissipate within one day. [20]

The next few lines show the correlation of changes in the repo rate with general market conditions. The change in the Libor-OIS spread has a large impact on the change in the Treasury GC repo rate; for each 10 basis point increase in this spread, the repo rate falls by 2 basis points. Similarly, the widening in the spread between the 10 year Treasury rate and the 2 year Treasury rate was associated with a fall in the repo rate, consistent with rates in the near term falling quickly as conditions worsened in financial markets.

Turning to the factors that proxy for conditions in overnight secured funding markets, securities lending operations by the Federal Reserve, which provide more collateral to the market, are assoicated with upward movements in the Treasury GC repo rate. Although the coefficients are slightly smaller than those on net Treasury issuance, the differences are minimal and suggest a similar effect of provision of collateral on repo markets, regardless of the source.

Somewhat surprisingly, as shown in the next few lines of the table, repo rates plummet on days with target rate changes. During this period, financial markets were in turmoil and surprise rate changes occurred more frequently than they had in recent times. As a result, the demand for safe collateral likely increased markedly. In addition, most of these moves were downward shifts in the level of rates, suggesting that the repo rate fell along with the target federal funds rate. Anticipation effects were somewhat more muted during the crisis period, perhaps as more changes in the target rate were either at unscheduled FOMC meetings or of magnitudes not expected by market participants.

The autoregressive terms suggest some continued persistence of changes in the Treasury GC repo rate, although to a lesser extent than in normal times. However, as measured by the coefficients on the GARCH terms, volatility apparently increased from normal times, with both the coefficients on the ARCH and GARCH terms as well as the leverage terms increasing in magnitude. Perhaps as a result of the increased volatility during this period, our specification explains only about 10 percent of the variation of change in the Treasury GC repo rate during this period.

3.4.3   Post-crisis period

The last three columns of 2 display results on the post-crisis period. Because the target federal funds rate did not move over this period, we do not include a cointegration term or controls for days with target rate changes.

Interestingly, in the post-crisis period the effect of bill issuance on the repo rate again becaome

---

[20] [Fleming et al. (2010)] estimate the slope coefficient on Treasury securities issuance/redemption of 1 basis point per $1 billion. The difference in the estimates is likely attributed to differences in specification and control variables.

less important than coupon issuance, consistent with the pre-crisis period. in fact, the overall coefficients are somewhat close to those observed pre-crisis, consistent with relatively stable demand for Treasury GC repo over time. From a monetary policy implementation perspective, should the Committee decide to target the Treasury GC repo rate, this stable demand may be comforting, as it suggests that the underlying demand for the instrument does not change radically, even if general market conditions do.

Consistent with relatively unchanged demand for Treasury collateral over time, changes in the Libor-OIS spread are associated with changes in the Treasury GC repo rate with approximately the same magnitude during the crisis as in the post-crisis period. Indeed, even though strains in financial markets dissipated in the post-crisis period relative to during the acute part of the crisis, some pressures were still evident and the Treasury GC repo rate moved in a similar manner as a result.

With the stability of the target federal funds rate over this subsample, the persistence of changes in the Treasury GC repo rate increased. Our specification suggests that changes in the repo rate continued to have effects up to 7 business days after they occurred. While this seems like quite a long time, as evidenced by figure 6, the Treasury GC repo rate was remarkably stable over this time, moving withing a relatively tight range for much of the period. Volatility of the Treasury GC repo rate also declined; the model was estimated without leverage effects as comarpsions of the Akaike information criterion (AIC) across specifications suggested that the leverage effects did not improve the fit of the model. The fit of the model as measured by the R-squared statistic reverted back to its pre-crisis level, with this specification explaining about a quarter of the variation in changes in the Treasury GC repo rate.

3.5 Implications and back-of-the-envelope estimates of upward pressure on the repo rate

Although the demand schedule for repos appears to be rather flat, the size of the System Open Market Account portfolio of Treasury securities relative to the repo market size is substantial, indicating that, in principle, the Federal Reserve can put significant upward pressure on the repo rate through large-scale reverse repos.[21]

We compute two back-of-the-envelope estimates for upward pressure on the repo rate that the Federal Reserve potential can achieve by doing a large scale reverse repo. The first estimate is based on the current size of the Federal Reserve's portfolio of Treasury securities. As of September 2012, the size of the Federal Reserve's Treasury securities portfolio was about $1.6 trillion. Multiplying this size by the contemporaneous estimate for the liquidity effect gives an estimate of 80 basis points (0.05 basis point per $1 billion·$1600 billion) for the upward pressure the Federal

---

[21]Large-scale repos, which add balances, do not require the Federal Reserve to pledge any collateral.

Reserve can orchestrate. The second estimate is based on the size of that portfolio under "normal circumstances", that is, when currency in circulation is the main determinant of the size of the Federal Reserve's portfolio. As of September 2012, currency in circulation was about $1.1 trillion, giving the estimate of the upward pressure from a reverse repo of 55 basis points. If the size of the SOMA holdings of Treasury securities (possibly of a particular security type) is not sufficient to conduct a reverse repo of a desired size, the Federal Reserve can increase the size of its portfolio through permament open market operations.

Obviously, a reverse repo of such enormous size (of either $1 trillion or $1.6 trillion) might drive up the repo rates much higher than the estimated 50-80 basis points for two reasons. First, the demand schedule for repos might be very steep over the region with very little cash going around the repo market. In the worst case scenario, these enormous repos might cause significant disruptions in the repo market driving repo rates to extremely high levels, at least in the short run. Second, our simple exercise does not take into account the propagation mechanism (the lag structure, the repo multiplier effect, the cross effects with other money markets) of a change to supply of cash/collateral to the repo market. As we discuss below, the multiplier effect might be rather sizeable.

4 The longer-run liquidity effect and money demand

Against the backdrop of our finding of a short-term liquidity effect, we now turn to look for one in lower-frequency data and over a longer period, as well as evidence of a relationship between the repo rate and money demand more generally.[22]

4.1 The longer-run liquidity effect

Typically, researchers fail to find a liquidity effect at low frequency for various money measures.[23] In fact, the absence of the liquidity effect at lower frequency at a first glance appears to be somewhat puzzling. However, as [Carpenter and Demiralp (2008)] argue, much of the research into the link between money and interest rates suffers from misspecification – that is, the measure of money and the measure of interest rates are not always well matched. In our exercise above, we show that using an appropriate proxy of short-run changes in cash supply in the repo market–net issuance of Treasury securities–we find some evidence of a liquidity effect. If net issuance is positive, cash is drained from the repo market and repo rates rise. Likewise, if net issuance is negative, cash is added to the market and the repo rate should fall. As such, there is a clear liquidity effect that we can document.

---

[22]The lower-frequency liquidity effects are of interest because of their relevance for Federal Reserve's longer-term repos.

[23]For a summary, refer to [Friedman and Kuttner (2010)].

Besides the short-term liquidity effect from Treasury issuance, we are interested in a broader liquidity effect–the liquidity effect from cash inflow into the short-term repo component of M3. M3 is the broadest measure of money that was published by the Federal Reserve.[24] M3 includes M2, as well as all large time deposits, institutional money-market funds, short-term repurchase agreements (as they show up in banks' liabilities), along with other liquid assets.

To provide information on the magnitude of M3 and its non-M2 components, figure 7 plots the evolution of the two measures from 1970 to 2006. The growth in non-M2 M3 components picked up in the late 1970s, in a high inflation environment, as new short-term investment vehicles such as money-market funds, emerged. The volume of short-term repurchase agreements nearly quadrupled between the early 1990s and the mid-2000s from about $140 billion to $550 billion. Towards the end of the sample period, the share of short-term repurchase agreements in the non-M2 M3 components, became rather sizable and reached about 15 percent.

Economic intuition tells us that the broader liquidity effect should be larger than the Treasury securities liquidity effect because of the rehypothecation multiplier effect. An additional dollar of cash flowing into the repo market can be used to buy an additional dollar worth of collateral, which in turn can be rehypothecated subject to a haircut, RR percent, and the proceeds from the rehypothecation, (1-1·RR) dollars, can be used for next collateral purchase, and so on. In the limit, assuming the subsequent haircuts does not vary, the multiplier will result in 1/RR dollars of cash being created. In particular, the rehypothecation multiplier is analogous to the money multiplier in a fractional-reserve banking system. It should be noted, that, in practice, the multiplier is much small than 1/RR as the rehypothecation practice is rather limited in the U.S. In the triparty repo market, collateral is safely tucked away at a clearing bank and only accesibly to the cash lender in case of the borrower default. In the bilateral repo market, though rehypothecation might be widespread, and for at least the earlier years of our sample period for this particular excercise, bilateral trades were likely dominant in the market. However, we do expect that there would be some multiplier effect of Treasury issuance observed in the money data.

In order to investigate whether there exists a liquidity effect at a lower frequency, we use weekly and monthly specifications to investigate the relationship between the repo rate and the repo component of M3. The data are weekly averages of the repo rate and the target federal funds rate described above over the period from 1998 (when fails data become available) to February 2006. The M3 data availability determines the end point of our sample. Over this period, unit root tests suggest that the the repo rate and the target federal funds rate are nonstationary and the Johansen test implies that the rates are cointegrated.

We use a similar specification in our medium-run liquidity effect investigation to that used for

---

[24]The publication of the M3 monetary aggregate on the H.6 release was discontinued in March 2006. At that time, M3 did not appear to convey any additional information about economic activity that was not already embodied in M2 and had not played a role in the monetary policy process for many years. Consequently, the Federal Reserve Board judged that the costs of collecting the underlying data and publishing M3 outweighed the benefits.

the short-run liquidity effect. Specifically, we use an error correction model, with a model setup similar to that used for studying high-frequency liquidity effects above:

$$\triangle rr_t = \alpha \left(c + \beta f f t a r_{t-1} \right) + \Phi_{rr}(L)\Delta rr_t + \Phi_{ff}(L)\Delta f f t a r_t + \Xi S_t + e_t,$$

where

- rr_t is the repo rate, $fftar_t$ is the target federal funds rate, S_t is an exogenous shifter of cash supply;

- c is a cointegrating constant, β is a cointegrating slope, α is a speed of adjustment coefficient, Φ is a set of distributed lag coefficients;

- e_t is an error term.

Unlike a very short-run liquidity effect based on Treasury issuance only, we believe that there may be some endogeneity in the amount of repo money available given the repo rate. In particular, we believe that cash inflows into short-term repo agreements might be sensitive to the repo rate: a higher repo rate might attract additional cash investors, so that the repo rate and cash inflows might have (spurious) positive correlation. Hence, we estimate a set of models using instrumented cash inflows. After a series of specification tests, we settle on net Treasury issuance as our instrumental variable. Net Treasury issuance is set well in advance by the Treasury and reflects an exogenous supply-side shock to repo money available. The shifts in the supply curve allow us to trace out the demand curve, and hence the change in the repo rate to a shift in cash available in the market. Moreover, as a result of the possibility of a multiplier effect and in the spirit of a classic money demand model, we estimate the model in terms of percent changes in the amount of repo cash available to the market.

The second stage estimation results of liquidity effects are shown in table 4. As in table 3, we separate our analysis according to the collateral type, that is, into all securities, bills only, and coupons only. We note that we are limited in the choice of controls. For example, the Libor-OIS spread is highly correlated with changes in the repo and federal funds rates and the slope, so it had to be omitted. Moreover, changes in Treasury debt outstanding have some seasonality, which precludes having calendar effects in the model.

Similar to the results concerning the short-run liquidity effect, the contemporaneous liquidity effects of total Treasury securities issuance and of Treasury bills issuance are rather close—between 0.07 and 0.1 basis point per \$1 billion of issuance—and remain statistically significant. Most of this result appears to be driven by Treasury bills, as the effect from Treasury coupon issuance is not statistically significant.

The next row down shows the liquidity effect as identified by the instrumented repo component of M3, which is a measure of cash supply to the repo market. We instrument by two lags of total

net Treasury borrowing, bills, and coupons in the first, second, and third columns respectively. By contrast to the contemporaneous liquidity effect of securities issuance, the contemporaneous liquidity effect of cash supply is statistically significant and is an order of magnitude larger than that of Treasury issuance —about 1 basis point per \$1 billion in increase in cash supply. This magnitude difference illustrates the possibility of a multiplier effect in the creation of repo "money" as discussed above.

5   Transmission of the repo rate to the short end of the yield curve

As the recent financial crisis has demonstrated, seemingly resilient linkages between financial markets may suddenly weaken or disappear. Often assumed to work seamlessly is the first step in this transmission—the transmission of the monetary policy stance from the federal funds market to other money markets. Bech, Klee, and Stebunovs (2012) examines this most immediate step: the paper focuses on the transmission of the monetary policy stance from the overnight federal funds market to the overnight U.S. Treasury GC repo market. The federal funds and Treasury GC repo markets have been tightly linked, in part, because of the U.S. monetary policy implementation framework. As the participants in the federal funds market and other short-term markets frequently overlap, controlling for risk, collateral, and other frictions, all rate differences should be arbitraged quickly away. The federal funds rate, being controlled by the Federal Reserve, should lead this rate tandem. Their results suggest that pass-through from the federal funds rate to the repo deteriorated somewhat during the crisis and zero lower bound periods, likely due to limits to arbitrage and idiosyncratic market factors. In addition, during the early part of the crisis, the pricing of federal funds relative to repurchase agreements indicated a marked jump in perceived credit risk. Moreover, the liquidity effect in the federal funds market weakened with the increase in reserve balances over the crisis, implying a non-linear demand curve for federal funds. In contrast, the liquidity effects in the Treasury GC repo market, on balance, has remained unchanged. Consequently, emerging from the crisis, the two money market interest rates appear to commove not as tightly as they had before the crisis. However, the presence of the liquidity effects in both the federal funds and repo markets implies that hypothetical liquidity draining by the Federal Reserve, for example, via large-scale reverse repos, may boost somewhat the two money market rates in absence of an increase in the policy rates, such as the target federal funds rate, the primary credit rate, or the rate paid on reserves.

We now turn to the transmission up each security's "own" yield curve. In this section, we explore the transmission of the repo rate to the short end of the yield curve. In particular, if the repo rate is to be the "new" targeted monetary policy rate, then it should have better "transmission"

properties to the rest of the curve than the federal funds rate.

In order to investigate this issue further, we perform a few simple tests of the expectations hypothesis for term federal funds and repo rates, as well as for the three-month t-bill rate. The expectations hypothesis asserts that the rate earned on a long-term investment should be equal to the rate earned on a series of shorter-term investments, plus a term premium. With this definition, as in [Campbell, Lo and MacKinlay (1997)], we can express a long-term interest rate $r_{t,t+k}$ from date t to date $t + k$ as a function of the short rate s on days $j, j = t, ..., t + k - 1$ plus a term premium ρ as

$$r_{t,t+k} = E_t \left[\prod_{j=t}^{t+k-1} (1 + s_j) - 1 \right] + \rho_{t,t+k}^m \tag{2}$$

Many, many authors have found that this relationship does not hold for longer-dated tenors of the yield curve. That said, [Longstaff (2000)] found that this relationship help surprisingly well for very short term rates, defined as rates on securities with less than three months maturity. He tested his hypothesis on the repo market specifically. Following Longstaff's empirical specification, we can rewrite equation (2) equivalently as

$$\overline{S_{t+k}} - r_{t,t+k} = \rho_{t,t+k} + \beta r_{t,t+k} + \epsilon_{t+k} \tag{3}$$

where $\overline{S_{t+k}} = E_t \left[\prod_{j=t}^{t+k-1} (1 + s_j) - 1 \right]$. If the expectations hypothesis holds, then there should be no additional information contained in the long-term interest rate $r_{t,t+k}$ and so the hypothesis that the estimated coefficient β is equal to zero should not be rejected. The error term ϵ is necessarily correlated across the maturity tenor being tested. In order to control for this, we report Newey-West standard errors with a lag length equal to $t + k - 1$ in all our results.

We estimate equation (3) using data from Bloomberg over the same sample period as that for the daily liquidity effect regressions. Table 5 displays the estimation results. As shown in the top half of the table, before the crisis, in general, it appears that the expectations hypothesis was satisfied for the repo rate at all tenors, and for the federal funds rate, at some tenors. In addition, there appeared to be about a 3 basis point term premium in repo, but no discernable term premium in federal funds. That said, even though there was some significant correlation in federal funds, the magnitude of the correlation was fairly small and around a basis point. Moreover, at the 30 and 60 day tenors, there was no such correlation.

These patterns changed markedly at the start of the crisis for federal funds, but not nearly as much for repo. In particular, the correlation at all tenors was now significant for the federal funds rate. In addition, the magnitude of the coefficient was many multiples what it was during the crisis, reflecting over half oa percentage point and nearly a percentage point in some cases. The term premium also increased significantly, to about 8 basis points in the three month security.

By contrast, the transmission across the repo yield curve remained intact. Indeed, although the

term premium increased slightly from the 3 basis points before the crisis to about 4 or 5 basis points, this change is not particularly material and at least is suggestive of a continued well-functioning tranmission from the overnight rate to the short end of the yield curve.

6   Conclusion

Going forward, we argue that past experience with the federal funds and repo rates suggest the Federal Reserve can target the Treasury General Collateral repurchase agreement rate because of several reasons.

Our analysis, summarized below in points, suggests that financial market conditions in the past may well have been able to support such a regime. First, we argue that the SOMA portfolio of Treasury securities is about the same size as that for the U.S. triparty repo market, suggesting that the Federal Reserve can potentially drain the entire repo market of liquidity by "repoing out" its portfolio of Treasury securities. We also note that the Federal Reserve can add as much liquidity to the market as market participants can absorb given their collateral. The capacity to add or drain enormous liquidity volumes should reinforce the credibility of the Federal Reserve to target any level of the Treasury GC rate. Second, we show that there is a fairly predictable demand schedule for Treasury general collateral repo at both daily and monthly frequencies. Third, the schedule is downward sloping, and the estimates of the schedule slope appear to be rather stable over time. We find that the daily liquidity effect in the repo market (identified through the impact of net issuance of Treasury securities) is about 0.04 basis point per $1 billion, which is an order of magnitude smaller than the daily liquidity effect in the federal funds market before the financial crisis (0.3 to 0.5 basis point per $1 billion) but is somewhat larger than that after the crisis (about 0.01 basis point per $1 billion). We estimate that the monthly liquidity effect (identified through the impact of net issuance of Treasury securities) is about 0.07 to 0.1 basis point per $1 billion, while taking into account the repo multiplier effect, the monthly liquidity effect (identified through instrumented cash supply) is an order of magnitude larger (about 1 basis point $1 billion). The latter estimated liquidity effects are of the same order of magnitude smaller as that in the federal funds market over the pre-crisis period. ([Judson and Klee (2010)]). Fourth, although the demand schedule is rather flat, the size of the System Open Market Account (SOMA) portfolio of Treasury securities relative to the repo market size is substantial, between 50 and 80 basis points, indicating that the Federal Reserve can put significant upward pressure on the repo rate through large-scale reverse repos. This estimated range clearly understates the likely impact of draining all of the liqudity from the repo market. Taken together, these findings suggest the the Federal Reserves can target a givel level of the repo rate on a daily or term basis, offsetting shocks to supply of either cash or collateral to the market.

Moreover, the Federal Reserve has a capacity to do large scale repos with a wide array of the repo

market participants, including broker-dealers and money market funds, and a facility in place—the SOMA securities lending program offers securities for loan from the SOMA portfolio—to address some repo market strains, such as particular Treasury securities trading "special". We submit that the target repo rate might prove to be a more effective policy tool than the target federal funds rate in the future because of a broader set of repo market participants. By targeting the repo rate, the Federal Reserve can affect the cost of funding (or the rate of return) for various institution types, strengthening the cost channel of monetary policy transmission.

We leave exploration of macroeconomic implications of targeting a secured rate for future research. For now, we will bring up just a few points. Before the recent financial crisis, with counterparty credit concerns muted, there was no material spread between secured and unsecured money market rates. Hence, it did not matter what type of rate the Federal Reserve targeted. But as the crisis demonstrated, the central bank should not rely on these rates moving together tightly. In fact, a central bank might face a dilemma whether to judge (and pursue) its monetary policy stance based on a relatively risk-free real interest rate (such as the repo rate minus a measure of expected inflation) or based on a real interest rate which reflects both a general risk-free real interest rate (which is more relevant for the entire economy) and a counterparty credit risk premium.[25] Arguably, targeting the latter might introduce a distortion into policy making: is it a particular risk premium that the policy makers are after or a particular real interest rate. It also appears that the targeted repo rate might be a better benchmark interest rate for another set of reasons. For example, given its size, the repo market is less suceptible to manipulation.

Our proposal is, of course, subject to the Lucas critique. The Federal Reseve's active involment in the repo market might likely change the way this market functions. However, the change might be to the Federal Reserve's advantage: it might be sufficient for the Federal Reserve to announce a target rate and, given its potentially high credibility through the threat of large-scale liquidity additions or draining, trades will cluster around the target rate.

References

[Bartolini et al.] Bartolini, L., S. Hilton, S. Sundaresan, and C. Tonetti 2010. "Collateral values by asset class: Evidence from Primary Securities Dealers," Review of Financial Studies, forthcoming.

[Bech et al. 2012] Bech, M., E. Klee, and V. Stebunovs. 2012. "Arbitrage, liquidity, exit: The repo and federal funds markets before, during, and after the financial crisis", Finance and Economics Discussion Series (FEDS) 2012-21, Federal Reserve Board.

---

[25]Recall that at this point the share of federal funds loans in bank liabilities is very small. Moreover, non-bank providers of retail or wholesale credit cannot have federal funds liabilities by definition.

[Brunnermeier and Pedersen] Brunnermeier, M. and L. Pedersen. 2009. "Market Liquidity and Funding Liquidity," Review of Financial Studies," vol. 22, no. 6, pp. 2201-2238.

[Campbell, Lo and MacKinlay (1997)] Campbell, John Y., Lo, Andrew W. and MacKinlay, A. Craig. 1997. *The Econometrics of Financial Markets*, Princeton: Princeton University Press.

[Carpenter and Demiralp (2006a)] Carpenter, Seth and Demiralp, Selva. 2006. "The Liquidity Effect in the Federal Funds Market: Evidence from Daily Open Market Operations," *Journal of Money, Credit, and Banking*, vol. 38, no. 4, p. 900-920.

[Carpenter and Demiralp (2006b)] Carpenter, Seth, and Demiralp, Selva. 2006. "Anticipation of Monetary Policy and Open Market Operations," *International Journal of Central Banking*, vol. 2, no. 2, p. 25-63.

[Carpenter and Demiralp (2008)] Carpenter S. and S. Demiralp. 2008. "The Liquidity Effect in the Federal Funds Market: Evidence at the Monthly Frequency," Journal of Money, Credit, and Banking, vol. 40, pp. 1-24.

[Coffey, Hrung and Sarkar] Coffey, N., W. Hrung, and A. Sarkar 2009. "Capital Constraints, Counterparty Risk, and Deviation from Covered Interest Rate Parity," Federal Reserve Bank of New York Staff Report no. 393, September

[Collin-Dufresne et al. (2001)] Collin-Dufrense, P., R. Goldstein, J. Martin. 2001. "The Determinants of Credit Spread Changes," *Journal of Finance*, vol. 56, no. 6, pp. 2177-2207.

Duffie, D. 1996. "Special Repo Rates," Journal of Finance, vol. 51, no 2, p. 493-526, June

[Engle and Granger (1987)] Engle, R. and C. Granger. 1987. "Cointegration and Error-Correction Model: Representation, Estimation, and Testing," Econometrica, vol. 55, no. 2, pp. 251-276

[Federal Reserve Bank of New York (2009)] Federal Reserve Bank of New York. 2009. *Domestic Open Market Operations during 2008*, January.

Federal Reserve Bank of New York 2010. "Tri-party Repo Infrastructure Reform," May 17.

Fisher M. 2002. "Special repo rates: An introduction," Economic Review, Federal Reserve Bank of Atlanta, Second quarter

[Fleming et al. (2010)] Fleming, M., W. Hrung, and F. Keane. 2010. "Repo Market Effects of the Term Securities Lending Facility," *American Economic Review: Papers and Proceedings*, vol. 100, p. 591-596, May.

[Fleming et al. (2009)] Fleming, M., W. Hrung, and F. Keane. 2009. The Term Securities Lending Facility: Origin, Design, and Effects. *Current Issues in Economics and Finance*, vol. 15, no. 2.

25

[Friedman and Kuttner (2010)] Friedman, B., and Kuttner, K. 2010. "Implmenetation of Monetary Policy: How do Central Banks Set Interest Rates?" in Friedman and Woodford (eds.), *Handbook of Monetary Economics,* vol. 38.

[Friedman and Schwartz (1963)] Friedman, M. and A. Schwartz. 1963. *A Monetary History of the United States.* Cambridge: NBER.

[Furfine (1999)] Furfine, C. 1999. "The Microstructure of the Federal Funds Market," *Financial Markets, Institutions, and Instruments,* vol. 8, no. 5, pp. 24-44.

[Friedman and Kuttner (2010)] Friedman, Benjamin, and Kuttner, Kenneth. 2010. "Implementation of monetary policy: How do central banks set interest rates?" *Handbook of Monetary Economics*, vol. 3, p. 1345-1438.

Griffiths, M. and D. Winters. 1997. "The effect of Federal Reserve accounting rules on the equilibrium level of overnight repo rates," Journal of Business Finance and Accounting, vol. 24, no. 6, pp. 815-832.

[Gorton (2010)] Gorton, Gary. 2010. "Questions and Answers about the Financial Crisis," Remarks prepared for the U.S. Financial Crisis Inquiry Commission

[Hamilton (1996)] Hamilton, J. 1996. "The daily market for federal funds," Journal of Political Economy, vol. 104, no. 1, pp. 26-56.

[Hamilton (1997)] Hamilton, J. 1997. "Measuring the liquidity effect," American Economic Review, vol. 87, no. 1, pp. 80-97.

Happ, S. 1986. "The behavior of rates on federal funds and repurchase agreements," The American Economist, vol. 30, no. 2, pp. 22-32

[Johansen (1995)] Johansen, S. 1995. "Identifying restrictions of liner equations with applications to simultaneous equations and cointegration," *Journal of Econometrics*, vol. 69 (1), pp. 111-132

[Judson and Klee (2010)] Judson, Ruth A., and Klee, Elizabeth. 2010. "Whither the liquidity effect?: The impact of Federal Reserve open market operations in recent years," *Journal of Macroeconomics*, vol. 32, no. 3, p. 713-731.

[Krishnamurthy (2002)] Krishnamurthy, A. 2002. "The bond/old bond spread," *Journal of Financial Economics*, vol. 66, pp. 463-506

[Longstaff (2000)] Longstaff, Francis. A. 2000. "The term structure of very short-term rates: New evidence for the expectations hypothesis," *Journal of Financial Economics*, vol. 58, p. 397-415.

[Lutkepohl (2007)] Lutkepohl, H. 2007. New Introduction to Multiple Time Series Analysis. Berlin: Springer-Verlag.

[Lou, Yan, and Zhang (2011)] Lou, Dong, Yan, Hongjun, and Zhang, Jinfan. 2011. "Anticipated and Repeated Shocks in Liquid Markets," London School of Economics, June.

[Meulendyke (1998)] Meulendyke, Anne-Marie. 1998. *U.S. Monetary Policy and Financial Markets,* available for download at http://www.newyorkfed.org/education/addpub/monpol.

[Simmons (1954)] Simmons, E. 1954. "Sales of Government Securities to Federal Reserve Banks Under Repurchase Agreements," The Journal of Finance, vol. 9, no. 1, pp. 23-40.

[Stigum and Credenzi (2007)] Stigum, M. and A. Credenzi. 2007. *The Money Market.* McMillian: New York.

[Thornton (2004)] Thornton, D. 2004. "Tests of the expectations hypothesis: Resolving some anomalies when the short-term rate is the federal funds rate," *Journal of Banking and Finance*, vol. 29, pp. 2541-2556.

Figure 1: **Triparty repo market**

SOMA Treasury Holdings and Repo Market Size
Apr. 2002 – Present
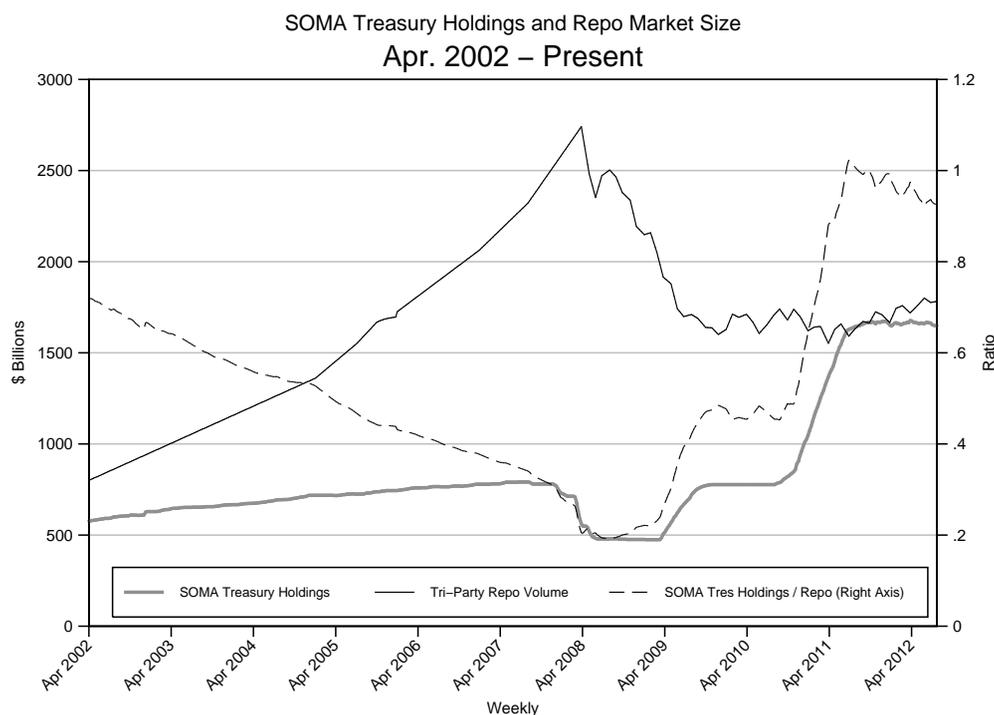
Figure 2: **Primary dealers repurchase agreement volume**

Volume of Treasury, Agency Debt, and MBS Repos with Inter–Dealer Brokers

Volume of Treasury, Agency Debt, and MBS Repos with Others

Source. FR2004.

28
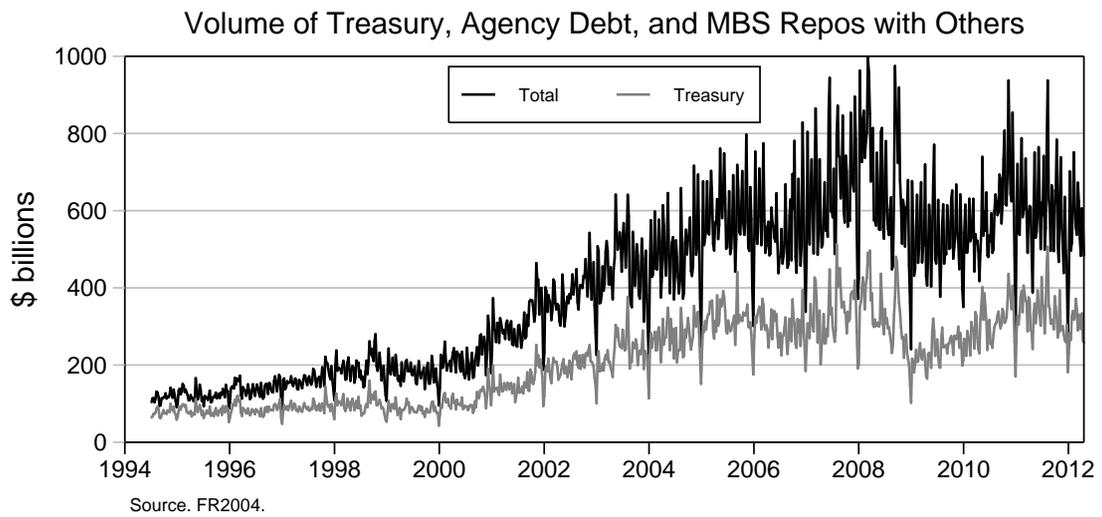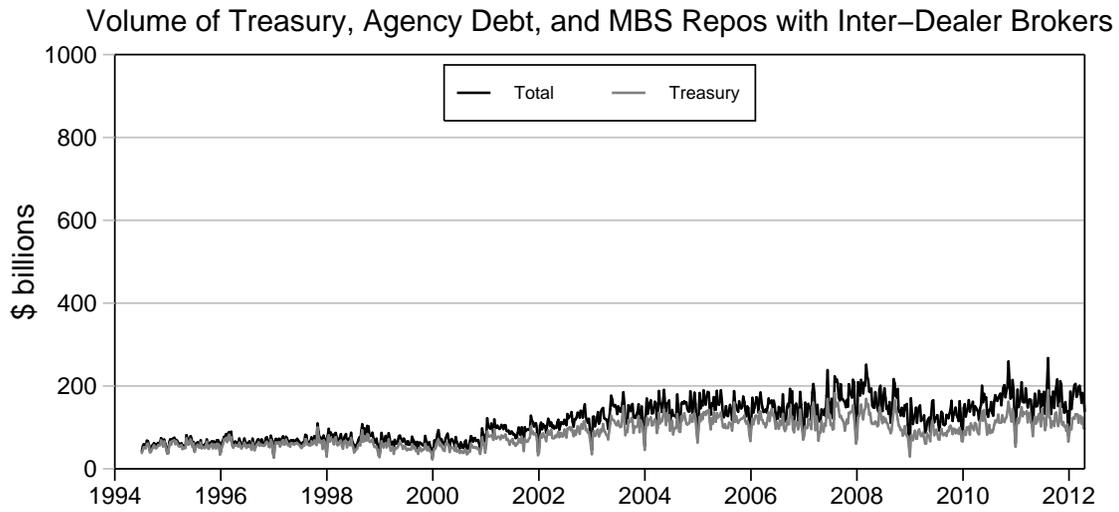
Figure 3: **Federal funds market volume**

Fed Funds Volume vs NGDP
2002 – Present
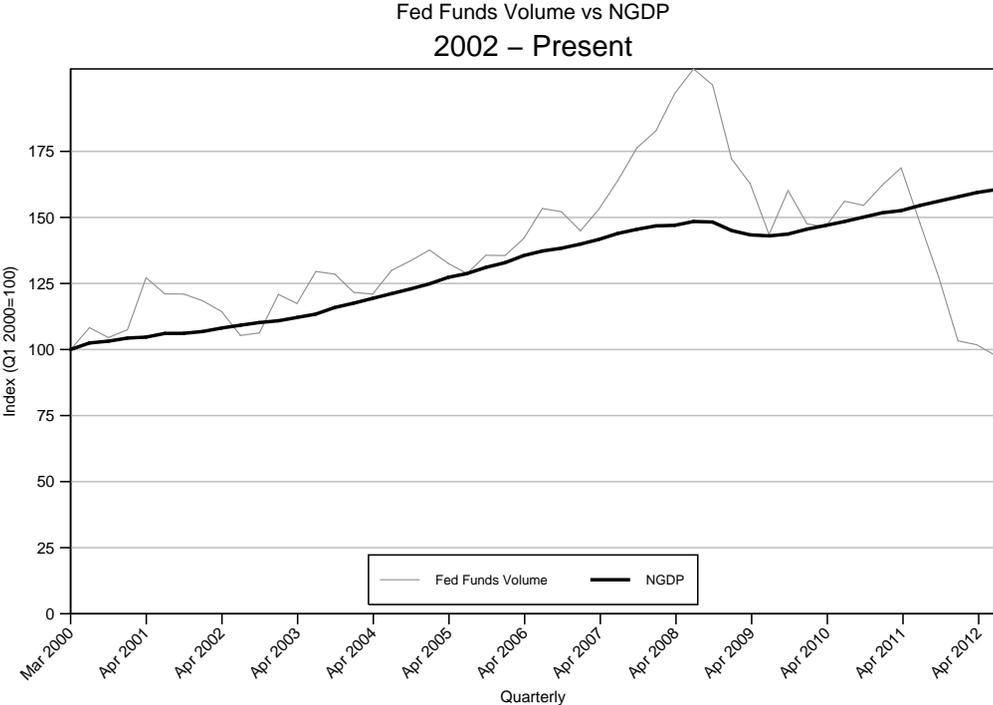
Figure 4: **Federal funds and repos at commercial banks: Quarterly**

Federal Funds Purchased

Percent of Liabilities

Federal Funds Sold

Percentage of Assets

Securities Purchased to Resell

Percent of Assets

Securities Sold to be Repurchased

Percent of Liabilities
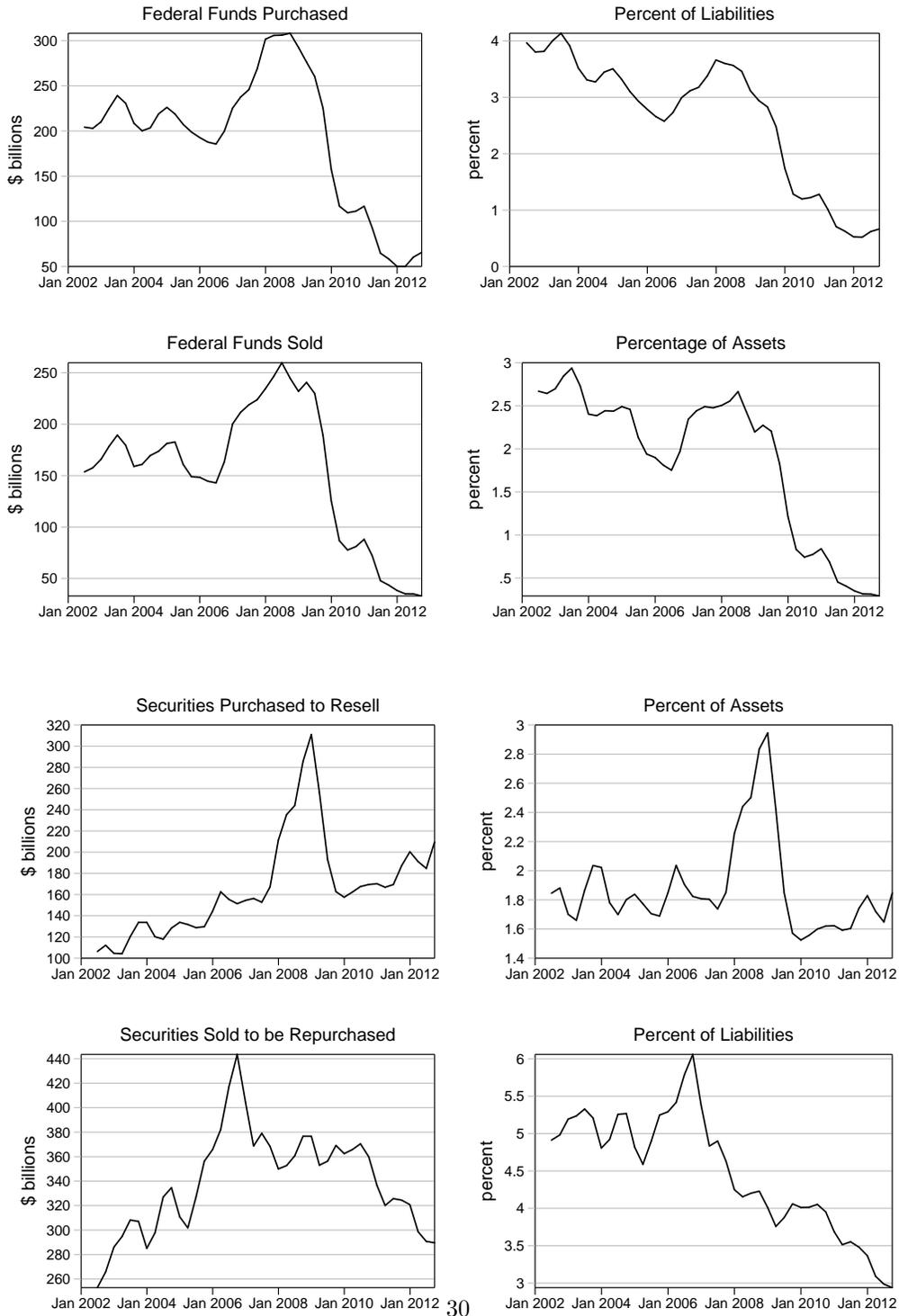
Figure 5: **Spread between federal funds and Treasury GC repo**

Federal Funds–Overnight GC Repo Spread

Daily.

31
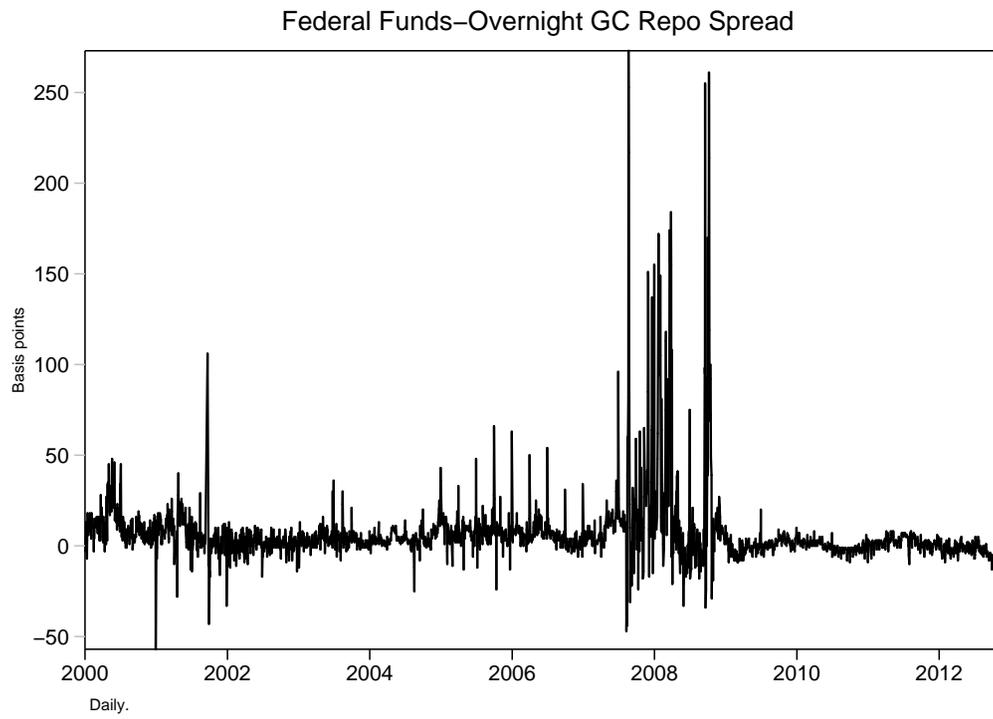
Figure 6: **Treasury GC repo rate**

Overnight Repo Rates
Jan. 2002 – Sep. 2012
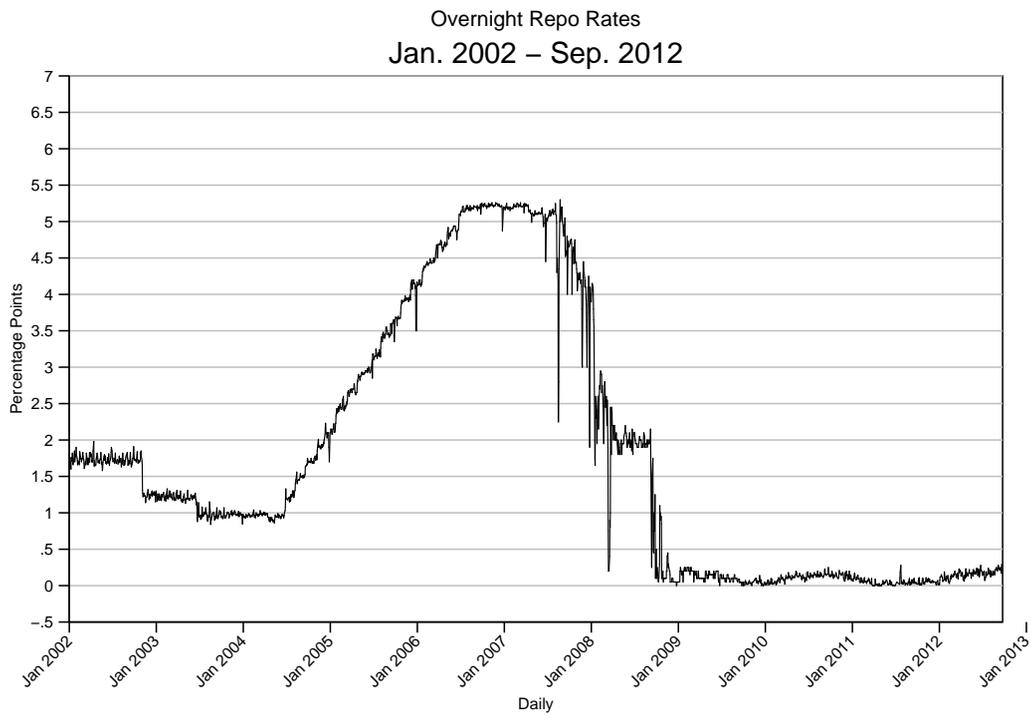
Figure 7: **M2, M3, and the repo component of M3**

Monetary and Repo Trends

1970 – Present

Table 1: Monetary policy implementation across countries
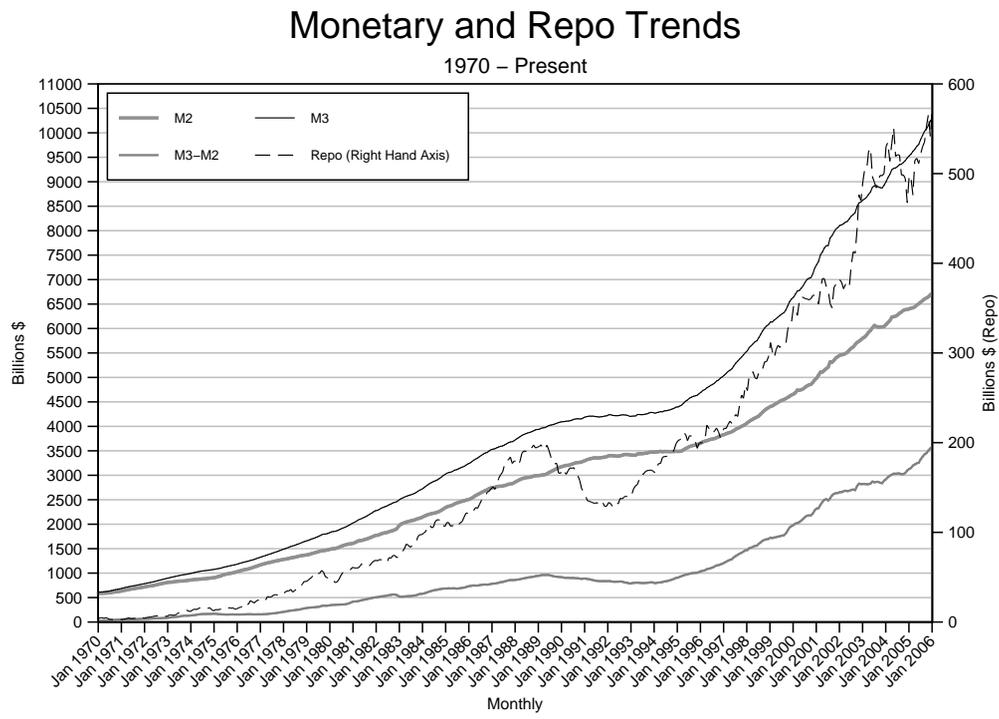
Country	Target/indicator rate		Construction	Underlying instruments
	Rate	Description		
Australia	Cash rate	The Reserve Bank of Australia's measure of the cash rate is the interest rate which banks pay or charge to borrow funds from or lend funds to other banks on an overnight unsecured basis. [The RBA also surveys banks about their overnight secured lending and borrowings.]	**Transaction-based.** The Reserve Bank of Australia (RBA) calculates and publishes this cash rate each day on the basis of data collected directly from banks. The Bank of Australia conducts a daily survey of actual transactions recorded by around 20 out of the 50 or so banks with active settlement accounts; the survey participants comprise around 90 percent of daily flows through the RBA's Real-Time Gross Settlement system.	**Unsecured.**
Canada	Two proxies (indicator rates)	(1) The overnight money market financing rate (2) The Canadian Overnight Repo Rate Average (CORRA)	(1) **Survey.** Derived from an end-of-day survey of major participants in the collateralized market. Some counterparties in this market, such as pension funds, do not have access to the Bank of Canada's deposit facility. (2) **Quoted.** Coverage is limited to on-screen repo transactions.	**Collaterized.** The uncollateralized interbank market accounts for a very small proportion of overnight lending activity.
Euro area	EONIA	The EONIA, the "Euro OverNight Index Average" rate, is the indicator rate.	**Survey.** The EONIA rate is based on reported transactions in the interbank market initiated by a panel of around 50 contributing banks active in the euro area. The panel members are subject to the ECB's reserve requirements and would normally have access to ECB 's refinancing operations and standing facilities. All specified transactions initiated during the business day are reported by the panel banks in aggregate, so then the EONIA rate is a weighted average of these aggregates.	**Unsecured.** The EONIA rate is based on overnight unsecured lending transactions in the interbank market initiated by a panel of around 50 contributing banks active in the euro area.
Japan	Call rate	The uncollateralized overnight call rate, which is the Bank's target interest rate, is the value-weighted average rate for transactions made through tanshi companies (money market brokers). [The Bank of Japan also tracks an overnight repo rate.]	**Transaction-based.** The Bank of Japan receives data from its counterparties (major participants in money markets, such as banks, securities companies, and tanshi companies) and releases the aggregated data to the public.	**Unsecured.** The uncollateralized overnight call rate is a daily weighted average of transactions in the uncollateralized overnight market. Participants in the market include domestic city, regional, and trust banks, foreign banks, securities companies, and other firms dealing in Japanese money markets.
Norway	Two proxies (indicator rates)	(1) A main measure of next-day funding costs, called effective NIBOR (Norwegian Interbank Offered Rate), is published by Reuters (2) An unoffical measure: Rates derived from quotes on the Reuters Dealing trading platform of the Norwegian krone/ U.S. dollar tomorrow-next exchange rate and a corresponding tomorrow-next U.S. dollar interest rate.	(1) **Survey.** NIBOR is based on indicative rates of borrowing costs quoted by a panel of banks active in the Norwegian market. (2) **Quoted.** Because foreign banks established outside of Norway can trade on this platform, this measure implicitly includes the transactions of counterparties without access to sight deposit accounts at Norges Bank.	(1) **Unsecured.** NIBOR is intended to reflect the interest rate level lenders require for unsecured money market lending in the Norwegian krone. (2) Currency swaps.
Sweden	STIBOR	The main measure of short-term interbank rates in Sweden is the STIBOR (the Stockholm Interbank Offered Rate), a next-day rate.	**Survey.** This represents a trimmed mean of rates for uncollateralized borrowing reported by major commercial banks in the market, and thus is not based on actual transactions.	**Mixed.** Short-term funding (funding with maturities ranging from overnight to up to a week) is primarily obtained through unsecured interbank deposit contracts, repurchase agreements, or foreign exchange swap arrangements, with the three types of arrangements comprising roughly equal shares of total activity.
U.K.	SONIA	The condition of money markets is typically gauged with reference to the sterling overnight interbank average (SONIA) rate.	**Transaction-based.** The transactions included in the average are those brokered in London by Wholesale Markets Brokers' Association members between midnight and 4:15 p.m., with a minimum deal size of £25 million.	**Unsecured.** The SONIA rate is a weighted average of unsecured sterling overnight transaction rates. These transactions may involve participants that are not reserve account holders and/or deposit facility members, such as small banks, local authorities, and some corporations.
U.S.	Effective federal funds rate	The effective federal funds rate is the average of interest rate at which depository institutions and government sponsored enterprises actively trade balances held at the Federal Reserve, typically overnight.	**Transaction-based.** The transactions included in the average are those brokered by federal funds brokers in N.Y.	**Unsecured.**

Table 2: **Estimated cointegrating relationship**
Dependent variable: Treasury GC repo rate

	Benchmark		Crisis	
	Coeff.	Std. err.	Coeff.	Std. err.
Target	0.987**	0.001	0.944**	0.014
Constant	-0.997**	0.386	-19.233**	3.761
Adjusted R-sq	0.998		0.908	
Observations	1410		475	

∗∗ indicates significant at the 5 percent level.

Table 3: **The short-run liquidity effect in the repo market**

Dependent variable: Change in Treasury GC repo rate

	Benchmark: January 2002-August 2007						Crisis: August 2007-June 2009						Post-crisis: July 2009-August 2012					
	All		Bills		Coupons		All		Bills		Coupons		All		Bills		Coupons	
	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.
Mean equation																		
Cointegration term	-0.13**	0.01	-0.13**	0.01	-0.11**	0.01	-0.02**	0.01	-0.03**	0.01	-0.06**	0.03						
Net par marketable borrowing	0.02**	0.01					0.07**	0.01					0.05**	0.00				
Lag(Net par marketable borrowing)	0.03**	0.01					-0.03**	0.01					-0.01**	0.01				
Net par bills			-0.03**	0.01					0.21**	0.02					0.00	0.01		
Lag(Net par bills)			0.07**	0.01					0.07**	0.03					0.01	0.01		
Net par coupons					0.15**	0.01					-0.12**	0.06					0.05**	0.00
Lag(Net par coupons)					-0.14**	0.01					0.12	0.13					-0.02**	0.01
D(Libor-OIS spread)	-0.01	0.07	0.01	0.07	-0.05	0.07	-0.22**	0.03	-0.18**	0.04	-0.38**	0.08	-0.18*	0.10	-0.23**	0.10	-0.22**	0.10
D(Treasury yield curve slope)	-0.01	0.02	-0.01	0.02	0.00	0.02	-0.08**	0.02	-0.07**	0.04	-0.05	0.05	-0.01	0.02	-0.01	0.02	-0.01	0.02
Securities lending	-0.01	0.03	-0.05	0.03	0.00	0.03	0.05*	0.03	0.14**	0.04	0.07	0.08	-0.01	0.01	0.00	0.01	0.01	0.01
Share of Treasury repos	0.09**	0.03	0.08**	0.03	0.07**	0.03	0.07	0.11	0.17	0.16	-0.23	0.32	0.01	0.04	0.02	0.03	0.02	0.04
Treasury fails	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02**	0.00	-0.01	0.01	0.01**	0.01	0.01**	0.01	0.01	0.01
Change in target rate	-1.04**	0.35	-1.21**	0.35	-6.89**	0.69	-30.40**	2.45	-24.46**	2.16	-16.87**	6.06						
Lead(Change in target rate)	3.28**	0.36	2.98**	0.35	11.72**	0.43	1.75	2.53	3.95**	1.84	-3.53	8.30						
Lead2(Change in target rate)	3.94**	1.01	3.95**	0.99	8.31**	0.39	-4.37	6.18	-3.91	3.70	-2.83	12.14						
AR(1)	-0.25**	0.03	-0.25**	0.02	-0.22**	0.03	-0.28**	0.03	-0.10**	0.03	-0.05	0.05	-0.26**	0.05	-0.24**	0.05	-0.23**	0.05
AR(2)	-0.15**	0.02	-0.15**	0.02	-0.13**	0.02	-0.28**	0.04	-0.26**	0.03	-0.13*	0.08	-0.25**	0.04	-0.26**	0.04	-0.25**	0.04
AR(3)	-0.12**	0.02	-0.12**	0.02	-0.11**	0.02	-0.15**	0.02	-0.12**	0.02	0.00	0.07	-0.27**	0.04	-0.27**	0.04	-0.27**	0.04
AR(4)	-0.12**	0.02	-0.12**	0.02	-0.11**	0.02	-0.03*	0.02	-0.03*	0.02	0.00	0.07	-0.21**	0.04	-0.22**	0.04	-0.20**	0.04
AR(5)	-0.06**	0.02	-0.06**	0.02	-0.06**	0.02	-0.01	0.02	-0.02	0.01	-0.06	0.07	-0.14**	0.04	-0.15**	0.04	-0.13**	0.04
AR(6)	-0.08**	0.02	-0.08**	0.02	-0.09**	0.02							-0.14**	0.04	-0.20**	0.04	-0.13**	0.04
AR(7)													-0.16**	0.04	-0.17**	0.04	-0.16**	0.04
Constant	-5.96**	2.19	-5.11**	2.21	-4.97**	2.06	-4.99	8.30	-13.05	11.73	17.22	23.05	-0.59	2.63	-1.08	2.47	-1.68	2.63
Variance equation																		
Constant	9.82**	0.44	9.56**	0.40	8.01**	0.37	3.86**	1.27	10.58**	1.65	0.84**	0.40	3.66**	0.42	4.21**	0.53	3.69**	0.46
Resid(-1)^2	0.81**	0.09	0.79**	0.09	0.55**	0.07	1.42**	0.17	1.33**	0.18	0.26**	0.05	0.24**	0.05	0.22**	0.04	0.18**	0.05
Resid(-1)^2*(Resid(-1)<0)	0.50**	0.14	0.51**	0.14	0.98**	0.13	2.14**	0.45	2.10**	0.43	0.09	0.08						
Garch(-1)	0.00	0.01	0.00	0.01	0.03*	0.02	0.15**	0.03	0.09**	0.03	0.77**	0.01	0.18**	0.08	0.19**	0.09	0.15*	0.08
N	1401		1401		1401		469		469		469		775		775		775	
R-squared	0.23		0.22		0.2		0.07		0.12		0.12		0.24		0.15		0.24	
AIC	5.82		5.81		5.73		8.05		7.99		8.2		4.63		4.78		4.62	

Table 4: **The long-run liquidity effect in the repo market**
Dependent variable: Change in Treasury GC repo rate

Second stage: Instrumental variable regressions for M3 repo component liquidity effect			
	All	Bills	Coupons
	D.repo	D.repo	D.repo
Lag(cointerm)	-88.619*	-83.962*	-87.008*
	(6.098)	(8.399)	(6.503)
Net par marketable borrowing	0.095*		
	(0.021)		
Net par bills		0.072*	
		(0.025)	
Net par coupons			0.008
			(0.069)
D.(Repo M3)	-0.453	-1.189**	0.209
	(0.404)	(0.577)	(0.297)
D(slope of yield curve)	-0.279	-0.380**	-0.244
	-0.197	-0.183	-0.195
Treasury fails	-0.038	-0.050**	-0.014
	(0.023)	(0.025)	(0.019)
Change in federal funds target	1.025*	0.976*	1.020*
	(0.095)	(0.113)	(0.078)
Constant	1.051	1.72	-0.563
	(1.209)	(1.300)	(0.909)
Observations	421	421	421

Newey-West heteroskedastic-autocorrelation robust errors in parentheses.

+ significant at 10%; ** significant at 5%; * significant at 1%

Table 5: **Testing the expectations hypothesis**

	Federal funds						Treasury GC repo					
	7	14	21	30	60	90	7	14	21	30	60	90
Before												
One week	-0.015**						0.001					
	(0.005)						(0.001)					
Two weeks		-0.014**						0				
		(0.005)						(0.002)				
Three weeks			-0.014*						-0.002			
			(0.006)						(0.002)			
One month				-0.013						-0.003		
				(0.007)						(0.003)		
Two months					-0.015						-0.003	
					(0.008)						(0.005)	
Three months						-0.020*						-0.006
						(0.010)						(0.009)
Constant	0.004	-0.004	-0.009	-0.018	-0.032	-0.041	0.025**	0.032**	0.036**	0.036**	0.03	0.023
	(0.015)	(0.014)	(0.015)	(0.018)	(0.023)	(0.032)	(0.004)	(0.006)	(0.008)	(0.011)	(0.018)	(0.027)
Observations	2368	2368	2368	2368	2368	2368	2368	2368	2368	2368	2368	2368
After												
One week	-0.425**						-0.068					
	(0.036)						(0.064)					
Two weeks		-0.505**						-0.075				
		(0.066)						(0.091)				
Three weeks			-0.535**						-0.09			
			(0.107)						(0.109)			
One month				-0.627**						-0.093		
				(0.092)						(0.108)		
Two months					-0.765**						-0.087	
					(0.112)						(0.148)	
Three months						-0.835**						-0.118
						(0.086)						(0.192)
Constant	0.035**	0.038**	0.037	0.049*	0.076*	0.085**	0.051**	0.049**	0.047**	0.046**	0.040*	0.038
	(0.006)	(0.013)	(0.022)	(0.022)	(0.031)	(0.029)	(0.006)	(0.008)	(0.010)	(0.011)	(0.016)	(0.022)
Observations	752	752	752	752	752	752	752	752	752	752	752	752

Newey-West standard errors in parentheses
* significant at 5%; ** significant at 1%