Responses to the Financial Crisis, Treasury Debt, and the Impact on Short-Term Money Markets*

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The United States introduced several programs in response to the financial crisis. We examine responses involving Treasury debt—the Term Securities Lending Facility (TSLF), Supplementary Financing Program (SFP), Treasury issuance, open-market operations—and associated impacts on collateralized funding markets. We find the TSLF uniquely effective, due primarily to its introduction during the financial crisis. We find some evidence that the SFP helped alleviate funding market stress. This is notable, as the SFP actually drained bank reserves. Our results show that the proper policy response to a financial crisis can involve options beyond an increase in the level of bank reserves.

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1. Introduction

This study examines whether and to what degree policy responses involving supplies of Treasury debt alleviated stress in collateralized

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funding markets over the period of the recent financial crisis. The response to a disruption in the traditional banking system typically follows the widely appreciated concept attributed to Walter Bagehot (1873): to avert a panic, central banks should lend early and freely at high rates, to solvent firms, against good collateral.[1] By 2007, short-term collateralized funding was central to the operations for many of the institutions which came under duress in the recent financial crisis. As these funding markets became impaired, a policy response based on a narrow interpretation of Bagehot's dictum would not have effectively relieved money-market stresses. The impairment in collateralized funding markets called for more high-quality collateral such as Treasury securities, not more cash or bank reserves. We focus on this aspect of the financial crisis in this study.

Since the fall of 2007, various programs together involving trillions of dollars have been introduced in the United States by both fiscal and monetary authorities in response to the financial crisis. In contrast to many other studies, we examine a number of policies in tandem. This paper controls for the full spectrum of concurrent monetary and fiscal policies that had direct impacts on Treasury supplies.

One such program, the Term Securities Lending Facility (TSLF), was introduced in March 2008, as money markets became severely impaired. The TSLF was specifically designed to address dislocations in money markets by exchanging Treasury securities for less-liquid and lower-quality collateral held by market participants. A second program, the Supplementary Financing Program (SFP), introduced in the fall of 2008, was designed to help the Federal Reserve manage bank reserves through the issuance of special Treasury debt, with proceeds held at the Federal Reserve Bank of New York (FRBNY). To the best of our knowledge, this study is the first to examine the SFP.

A third, *fiscal*, policy change occurred as other Treasury debt issuance increased from late 2007 onward, as a result of increased expenditures and lower tax receipts. Other Treasury debt issuance was also tied to the financial crisis through programs such as the Troubled Asset Relief Program (TARP) and Treasury's agency mortgage-backed security (MBS) purchase program. Finally,

[1] As summarized by Tucker (2009).

open-market operations (OMOs)—both temporary and permanent—which increase or decrease holdings of Treasury debt in the Federal Reserve's System Open Market Account (SOMA), also impacted market supplies of Treasury collateral. Over the course of the financial crisis, the Federal Reserve first sold Treasury holdings to maintain the size of its balance sheet to better manage the federal funds rate, and then later bought Treasury securities as part of its Large-Scale Asset Purchase (LSAP) program. While the SFP, OMOs, and programs such as TARP were not aimed directly at dislocations in short-term money markets, they did change publicly available supplies of Treasury securities.

In general, collateralized rates, such as the overnight Treasury general collateral (GC) repurchase (repo) rate, should be similar to but lower than uncollateralized rates, such as the federal funds rate. Repo rates can be of various terms and are backed by various types of collateral. We focus on the overnight Treasury GC repo rate because it represents the rate on the shortest term for the safest and most liquid type of collateral. As such, this rate is a benchmark for other repo rates. Bartolini et al. (2011) document that Treasury GC collateral forms the highest asset class in repo markets.

Over the course of the recent financial crisis, as the quality of non-Treasury collateral came into question, demand for Treasury collateral increased. An outward shift in demand for high-quality Treasury collateral caused Treasury GC rates to plunge relative to other collateralized and uncollateralized rates. While low interest rates are generally considered to be desirable, the low relative Treasury GC rates observed during the crisis were evidence of impaired market functioning for collateralized funds.

The most basic hypothesis that we examine involves the impact of changes in the supply of Treasury collateral on the GC rate.[2] To the extent that market functioning improves as the supply of Treasury collateral increases, a simple supply-demand framework predicts that overnight Treasury repo rates should increase, and the spread to other rates should narrow. Our results confirm this basic intuition. Furthermore, each program we study had different transmission channels, different initiation periods, and different

[2]More formally, our null hypothesis is that changes in the supply of Treasury collateral have no impact on the GC rate.

patterns of changes in supply, allowing us to identify each program's relative impact on the overnight Treasury GC repo market. We therefore refine our analysis to examine the changes in Treasury collateral due to the various programs noted above.[3] The TSLF is found to have the largest impact, while other sources of Treasury collateral yield smaller impacts. Our results further suggest that the TSLF would have a much smaller effect on repo rates during a period of normal market functioning.[4] As well, and of further note, the wind-down of the TSLF does not appear to have resulted in market disruptions. When we allow for non-constant volatility, we also find evidence that the SFP helped alleviate funding market stress. Additional results are provided regarding the impact of Treasury supply on other collateralized funding markets. In particular, our results are consistent with the TSLF helping to normalize the asset-backed commercial paper (ABCP) market.

Our results show that the proper policy response to a financial crisis may include options which do not increase bank reserves. The TSLF program was reserve neutral, while increases in Treasury collateral via the SFP actually drained reserves from the banking system.

The remainder of this paper is structured as follows: section 2 provides background on secured funding markets and policy responses to the financial crisis that involved Treasury debt, highlighting relevant literature; section 3 describes data and methods; section 4 presents regression results; and section 5 concludes.

2. Background

Secured funding markets allow for collateralized borrowing by participants. In these markets, the most common type of transaction is a repurchase agreement, or repo. In a repo, a sale of securities is combined with an agreement to repurchase the same securities at a later date, typically at a higher price. The higher price represents an

[3]Here, our null hypothesis is that Treasury supply impacts on the GC rate are the same across all the programs examined.

[4]This result rejects a null hypothesis of no difference in the relative effectiveness of policy channels for increasing Treasury supplies in normal versus crisis periods.

interest rate paid to the lender of the cash (buyer of the security), from the borrower of the cash (lender of the security). The lender of funds takes possession of the borrower's securities over the term of the loan and can resell them in the event of a borrower default. The borrower retains the spread between the interest rate on the security and the interest rate paid to the lender of cash. Gorton and Metrick (2012) give an excellent description of the repo securitization process. Also, the amount of cash borrowed is a percent of the value of the collateral pledged. Therefore, tightening collateral requirements can cause rapid contractions in repo market activity. In fact, this type of contraction occurred in the recent financial crisis, as shown in Adrian and Shin (2010).

Repo markets display segmentation, as some contracts specify particular collateral to be used while others are "general"; for a general collateral (GC) repo, any given security within an asset category is acceptable as collateral by the lender. For example, a *Treasury GC repo* contains any Treasury security as collateral.[5] Overnight GC repo rates tend to track rates on uncollateralized overnight federal funds loans; the spread between the overnight GC repo rate and the federal funds target rate is typically less than 10 basis points (bps). This reflects the use of GC repos as a mechanism for lending and borrowing money. In recent years, primary dealers have used repos to finance $2–5 trillion in fixed-income securities.[6]

As a general rule, there should be a positive relationship between the supply of collateral and the interest rate that the borrower must pay to obtain funds (this is because scarce collateral is more valuable, and thus the borrower need pay less to borrow funds).[7] In fact, a body of literature on specialness and segmentation has evolved along with the repo market itself, defined both narrowly (as with Duffie 1996; Fleming and Garbade 2004, 2007; and Jordan and Jordan 1997) and broadly to generic bond market demand and supply (as seen in Greenwood and Vayanos 2014). Moreover, demand for particular bonds as collateral is a function of their liquidity, such

[5]For a special collateral repo, the lender of funds seeks a specific security—identified by its particular CUSIP number.

[6]See http://www.newyorkfed.org/markets/primarydealers.html for information on primary dealer financing.

[7]See Fleming, Hrung, and Keane (2009, 2010b) for more details regarding secured financing markets.

that on-the-run issues (the latest issues) hold premium collateral status, as documented in Keane (1996) and Longstaff (2004), and is also related to demand to hedge interest rate risk as found in Graveline and McBrady (2011).

Our study examines both monetary and fiscal policy responses involving Treasury debt supplies simultaneously, so that we examine a number of policies instead of the impact of just a single policy response. Our results also highlight the need to carefully consider the interaction between various policies.[8]

2.1 The Term Securities Lending Facility (TSLF)

The TSLF was introduced on March 11, 2008 "to promote liquidity in the financing markets for Treasury and other collateral and thus to foster the functioning of financial markets more generally."[9] As the financial crisis progressed, funding markets came under unprecedented stress; liquidity and counterparty concerns led many money-market participants to seek out the safety of Treasury securities, and term funding became scarce. As a result, Treasury overnight GC was in high demand, causing its rates to plunge, and the spread between the federal funds target rate and Treasury GC repo rates widened to extraordinary levels, as seen in figure 1.[10] Other repo spreads such as the rate spread between agency and Treasury GC collateral also widened markedly over this period.

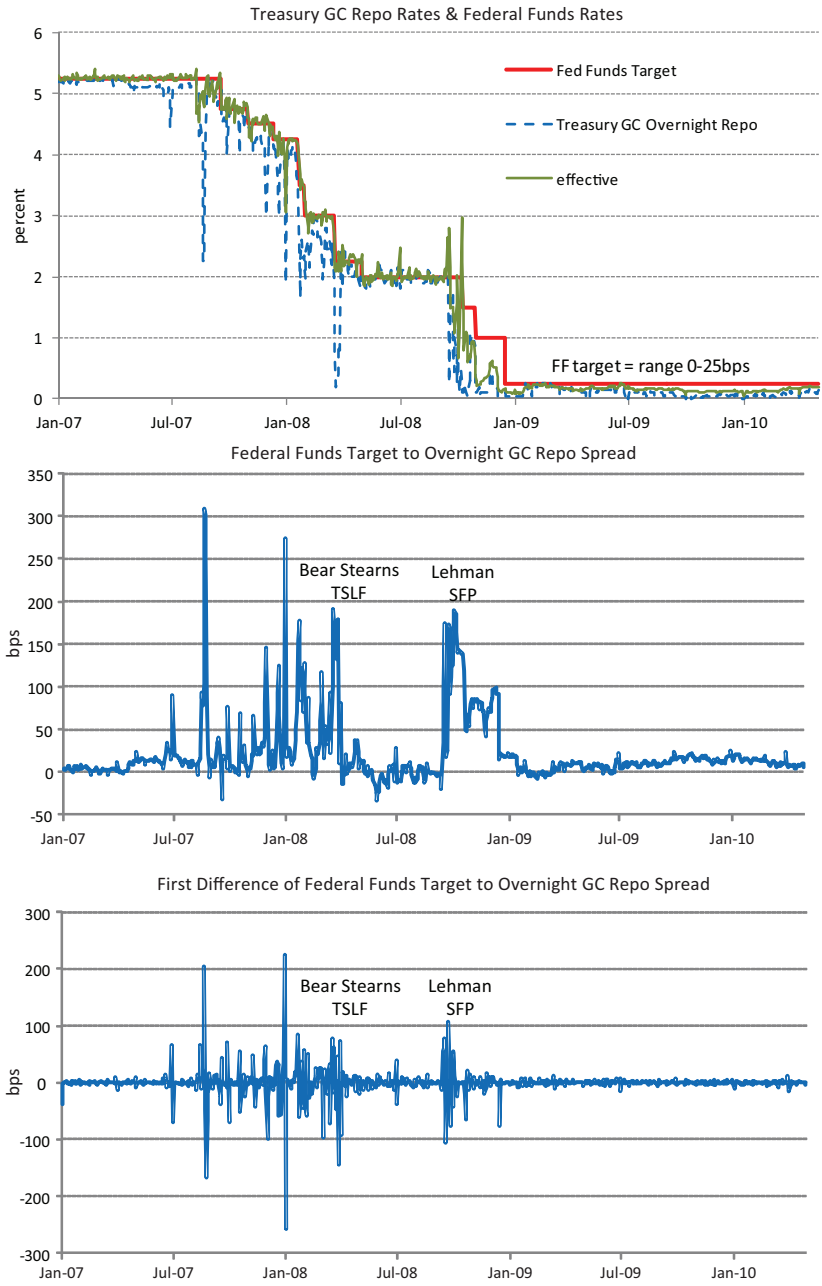
The TSLF addressed widening spreads by increasing the supply of Treasury collateral, which would be expected to increase Treasury GC rates and decrease repo rate spreads. Primary dealers with a trading relationship with the FRBNY were eligible to swap their holdings of less-liquid collateral for Treasury securities held in the System Open Market Account (SOMA) for around twenty-eight

[8]Brunetti, di Filippo, and Harris (2011) considered European Central Bank (ECB) interventions over the financial crisis and found that those failing to target counterparty risk also failed to improve liquidity.

[9]See the Federal Reserve press release announcing the TSLF, at http://www.federalreserve.gov/newsevents/press/monetary/20080311a.htm.

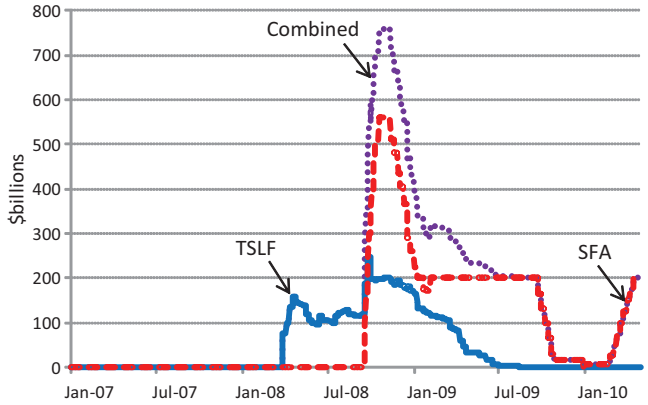
[10]The Treasury GC rates presented in figure 1 are the publicly available rates from Bloomberg. Longstaff (2004) documents pre-crisis flight-to-liquidity premiums somewhat in line with the time t/time s transmission mechanism suggested by Krishnamurthy (2010), though whether these were priced correctly at market circa 2002–7 is debatable—especially in light of the TSLF as a policy innovation.

Figure 1. Daily Repo-Federal Funds Rates and Spread: 2007–10



Source: Federal Reserve Bank of New York and Bloomberg.

Figure 2. The Term Securities Lending Facility and Supplementary Financing Account (Daily)



Source: Federal Reserve Bank of New York and Daily Treasury Statement.

days.[11] The dealers bid a fee via a single-price auction to access the TSLF, with a minimum fee set by the FRBNY.[12]

The TSLF was specifically designed to directly address money-market stresses as it increased the supply of high-quality Treasury collateral and removed less-liquid collateral from the marketplace.[13] Also worth noting, the program's policy design is uniquely elegant, as it involves a *security-for-security* exchange and so does not expand the Federal Reserve's sheet; it is therefore reserve-neutral. Thus there was no need to sterilize the impact of the TSLF and, as a result, the program was able to grow to a substantial size very quickly. This is documented in figure 2.

By mid-April—one month after the first TSLF auction—the facility reached $150 billion in size.[14] The facility briefly peaked

[11]Term lengths ranged from fourteen to thirty-five days, with most ranging between twenty-seven and twenty-nine days.

[12]For more on the TSLF, see Fleming, Hrung, and Keane (2009).

[13]The Federal Reserve also conducted twenty-eight-day single-tranche open-market operations with primary dealers which involved agency MBS collateral. These operations were also targeted at stresses in money markets. We do not examine this program, as it did not involve Treasury collateral.

[14]Note that the maximum amount of Treasury collateral that can be supplied via TSLF is limited to Treasury holdings in the SOMA account. In early March

at almost $250 billion in the fall of 2008 and wound down to zero by early August 2009 as rate spreads in the market contracted and rendered the facility uncompetitive (i.e., expensive relative to market alternatives). The TSLF officially expired on February 1, 2010.[15]

2.2 Supplementary Financing Program (SFP)

While the TSLF impacted supplies of Treasury collateral and less-liquid collateral in the marketplace, the other programs we examine only impacted Treasury collateral. Figure 2 also documents SFP balances over the policy period from 2008 to 2010. The U.S. Treasury announced the SFP on September 17, 2008, two days after the collapse of Lehman Brothers. In just over one month's time, the SFP reached its peak scale of $560 billion. The program was initiated to help the Federal Reserve drain bank reserves accumulating through liquidity facilities introduced during the crisis.[16] Because the level of bank reserves tends to impact the effective federal funds rate, such an offset to the increase in reserves was needed to help the Open Market Trading Desk meet the target federal funds rate set by the Federal Open Market Committee (FOMC).

The program consisted of the issuance of a series of Treasury bills, which were separate and distinct from regular Treasury debt issuance. SFP bills are essentially cash management bills (CMBs). But whereas pricing of CMBs has tended to be punitive as they potentially drain liquid reserves from primary dealers as documented in Seligman (2006) and Simon (1991), SFP proceeds are less likely to be disruptive because bank reserves accumulating at the time were in excess of what would normally have been productive. Further,

2008, the Federal Reserve held around $700 billion in Treasury securities. By the end of April 2008, the Federal Reserve held around $550 billion. We describe the evolution of the SOMA account over our sample period in greater detail below.

[15]The amounts presented and studied include amounts exercised in the TSLF Options Program. For more information on this program, see http://www.federalreserve.gov/newsevents/press/monetary/20080730a.htm.

[16]See http://www.treasury.gov/press-center/press-releases/Pages/hp1144.aspx and http://www.newyorkfed.org/markets/statement_091708.html. The liquidity facilities include the Term Auction Facility and swap line agreements to ease dollar funding stress. A full set of Federal Reserve policies over the financial crisis can be found at http://www.newyorkfed.org/research/global_economy/Crisis_Timeline.pdf.

an incidental by-product of the program was that it increased the amount of high-quality collateral available in the market, helping to alleviate the very same supply-side stresses in money markets that the TSLF was designed to address.

Another way in which SFP transactions differ from CMBs is in the utilization of funds from issuance and, therefore, the impact on the composition of Federal Reserve liabilities. CMB proceeds, like regular Treasury issuance and certain classes of tax payments, are deposited in Treasury's General Account (TGA) at the FRBNY, the account that pays most federal outlays; the TGA can be thought of as Treasury's "checking account." In contrast, SFP proceeds are held in the Supplementary Financing Account (SFA), an account that does not accept tax receipts or pay outlays. Since the TGA and SFA are both liability items on the Federal Reserve's balance sheet, increases in either account will drain reserves from the banking system.[17]

Comparing the TSLF and SFP in terms of sheer magnitude, note that the peak amount of Treasury collateral supplied by the SFP was more than double the peak amount supplied by the TSLF ($560 billion versus $223 billion). But while the SFP is a very effective method for quickly draining bank reserves, one drawback to the SFP as a policy instrument is that SFP bills count against the federal debt ceiling; as such, balances were soon reduced.[18] Figure 2 also displays the combined impact of both programs over the period of observation; at their peak in October 2008, the combined magnitude of the two programs exceeded $750 billion.

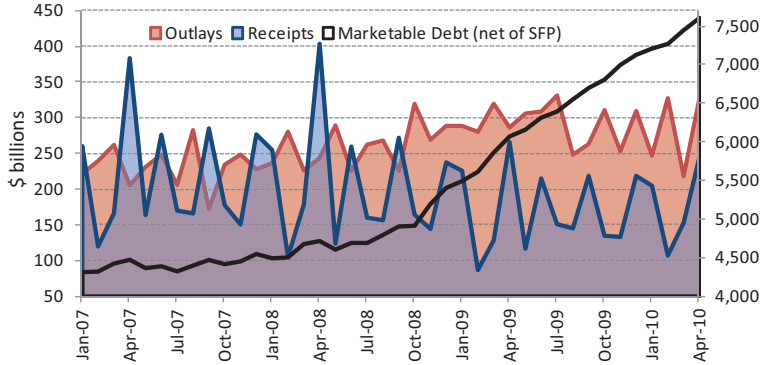
2.3 Treasury Issuance

As in previous recessions, federal tax revenue declines contributed to countercyclical fiscal policy. U.S. federal tax receipts began to

[17]Amounts held in the TGA and SFA can be found on the Daily Treasury Statement and on the Federal Reserve's weekly H4.1 release.

[18]The SFA decreased to $200 billion by early February 2009 and remained at that level into the third quarter of 2009. In mid-September 2009, again driven by concerns related to the debt ceiling, the Treasury announced a further decrease in the SFP balance to $15 billion by the fourth quarter of 2009. The SFA briefly had a zero balance, but after the federal debt ceiling was increased in February 2010, the SFA again increased to $200 billion by mid-April 2010 and remained at that level through the end of our sample period.

Figure 3. Monthly Federal Receipts and Outlays and Daily Marketable Treasury Debt



Source: Daily and Monthly Treasury Statements.
Notes: Outlays and receipts are scaled on the left vertical axis while marketable debt is scaled on the right vertical axis.

fall in late 2007. This required increased debt issuance to cover budgetary shortfalls. In addition, federal outlays increased, widening the budget gap and necessitating a further increase in debt issuance. Beyond both of these traditional "automatic stabilizer" channels, increased outlays due to programs directly related to the financial crisis, such as the Troubled Asset Relief Program (TARP) and Treasury's agency mortgage-backed security (MBS) purchase program, enhanced federal funding requirements. TARP expended around $380 billion and Treasury's agency MBS purchase program purchased a total of $221 billion from September 2008 through December 2009.[19] Figure 3 presents monthly federal receipts and outlays, as well as the daily quantity of marketable outstanding Treasury obligations (net of SFP) from January 2007 to April 2010.

The U.S. Treasury responded to funding needs by increasing the number of different types of securities, as well as increasing the frequency of auctions. Table 1 compares 2009 and 2006 auction policy, documenting the addition of a fifty-two-week bill and a seven-year

[19]Information on TARP and Treasury's agency MBS purchase program can be found at http://www.financialstability.gov.

Table 1. Treasury Issuance: 2006 vs. 2009

Marketable U.S. Treasury Securities				
	2006		**2009**	
Type	**Maturities**	**Schedule**	**Maturities**	**Schedule**
Bills				
	Cash Mgmt. Bills	As Needed	Cash Mgmt. Bills	As Needed
	4 Weeks	Weekly	4 Weeks	Weekly
	13 Weeks	Weekly	13 Weeks	Weekly
	26 Weeks	Weekly	26 Weeks	Weekly
			52 Weeks	Every 4 Weeks
Notes				
	2 Years	Monthly	2 Years	Monthly
	3 Years	Quarterly	3 Years	Monthly
	5 Years	Monthly	5 Years	Monthly
			7 Years	Monthly
	10 Years	8 Times a Year	10 Years	Monthly
Bonds				
	30 Years	2 Times a Year	30 Years	Monthly
Inflation Indexed				
	5-Year Notes	2 Times a Year	5-Year Notes	2 Times a Year
	10-Year Notes	4 Times a Year	10-Year Notes	4 Times a Year
	20-Year Bonds	2 Times a Year	20-Year Bonds	2 Times a Year

Source: U.S. Department of the Treasury.

note. Auction frequencies increased for the three-year, ten-year, and thirty-year issues.

Further, as highlighted in figure 3, the level of outstanding marketable Treasury debt (excluding SFP) increased substantially over the course of 2008–9. Note in the figure that there are seasonal fluctuations in the level of outstanding Treasury debt, so that the level does not monotonically increase. For example, April tax season typically results in net paydowns of Treasury debt and a decrease in the level of outstanding Treasury securities.

2.4 Open-Market Operations (OMOs)

In this section we detail temporary and permanent open-market operations over the period of observation, beginning first with temporary operations.

2.4.1 Temporary Open-Market Operations

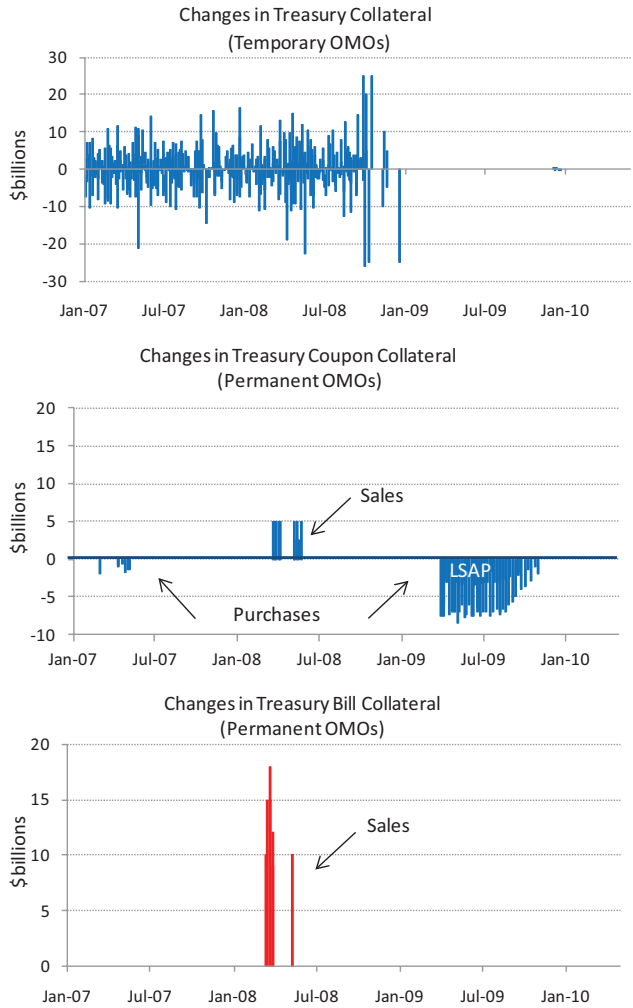
The top panel of figure 4 details the magnitude and frequency of temporary operations impacting Treasury collateral.[20] Temporary OMOs are conducted by the Open Market Trading Desk of the FRBNY to adjust the aggregate supply of bank reserves to foster conditions in the market consistent with the FOMC's policy directive for the federal funds rate. These operations consist of short-term repurchase and reverse repurchase agreements impacting daily trading in the federal funds market. An OMO that drains reserves will add OMO-eligible collateral (Treasury, agency debt, and agency MBS) to the market, and vice versa.[21] Upon maturity of the operation, the movement of collateral is reversed. The term of these operations typically ranges from overnight to twenty-eight (business) days. For more on temporary OMOs, see Carpenter and Demiralp (2006), Friedman and Kuttner (2010), and Hilton and Hrung (2010).

As the top panel of figure 4 highlights, the active daily management of bank reserves via temporary OMOs by the Trading Desk is concentrated prior to and through the initial phases of the crisis. By

[20] Excluded are operations involving agency debt and MBS.

[21] Operations during our sample period that drained reserves only involved Treasury collateral.

Figure 4. Daily Open-Market Operation Impacts on Treasury Collateral, 2007–10



Source (all three graphs): Federal Reserve Bank of New York.

the end of 2008, when the FOMC adopted a target range of 0–25 bps for the federal funds rate instead of an explicit target rate, the Trading Desk stopped conducting temporary OMOs for the remainder of the sample period, aside from some small-scale operations

at the end of 2009. More detailed information on the breakdown of Treasury collateral provided for OMOs (e.g., bills vs. notes and bonds) is not publicly available.

2.4.2 Permanent Open-Market Operations

The Federal Reserve's SOMA portfolio traditionally consists primarily of Treasury securities, and these holdings tend to grow over time so as to roughly match growth in currency demand. A permanent OMO to purchase Treasury securities decreases the amount of Treasury collateral available for private parties to utilize in Treasury-secured repo finance. Figure 4 shows that prior to the crisis in the fall of 2007, the Federal Reserve conducted a number of OMOs, of which the permanent OMOs were all confined to be purchases under $5 billion in size.

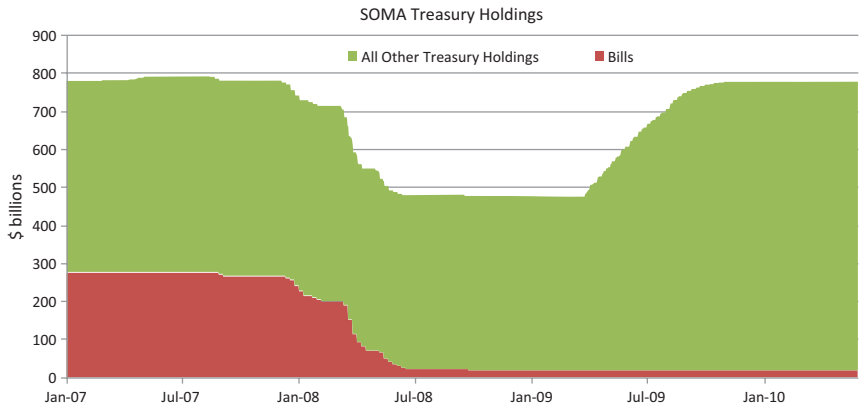
As the crisis intensified, the Federal Reserve's balance sheet began to take on riskier assets as emergency liquidity facilities were introduced. These assets collateralized the funds provided to financial institutions via the liquidity facilities. In an effort to maintain the size of its balance sheet, the Federal Reserve began to allow its Treasury holdings to mature and to sell its holdings. This increased the supply of Treasury collateral available to the public, and decreased bank reserves. As the bottom two panels of figure 4 reveal, the Federal Reserve sold a greater amount of its Treasury-bill holdings than coupon holdings.[22] In the fall of 2008, the Federal Reserve no longer sought to maintain the size of its balance sheet, and Treasury redemptions/sales were discontinued.

Within our observation period, there are only *seven* OMOs involving bill sales and *no* transactions involving bill purchases, so it is difficult to identify the full relationship between repo rates and changes in bills availability due to SOMA transactions. By contrast, the SOMA both purchased and sold meaningful quantities of Treasury coupon holdings over our sample period.

In March 2009, the FOMC announced that it would purchase $300 billion in longer-dated Treasury securities as part of

[22] Coupon holdings refer to holdings of both notes and bonds.

Figure 5. Daily SOMA Treasury Holdings: 2007–10



Source: Federal Reserve Bank of New York.

its Large-Scale Asset Purchase (LSAP) program.[23] The purpose of these purchases was to "help improve conditions in private credit markets," not the repo market.[24] These purchases, which removed Treasury collateral from market, commenced later that month and were completed by the end of October 2009. By the end of the purchases, total SOMA Treasury holdings were similar to their pre-crisis levels, albeit with a different maturity composition weighted more toward coupon holdings. Figure 5 documents the changes in relative composition over this period. As seen in the figure, bills declined from comprising roughly three-eighths of Treasury holdings pre-crisis to a much smaller component.

Table 2 summarizes the above programs, the various sources of Treasury collateral, their primary motivation, and our related hypotheses.

[23]See http://www.federalreserve.gov/newsevents/press/monetary/20090318a.htm for the announcement. The Federal Reserve also purchased $1.25 trillion in agency MBS and around $172 billion in agency debt.

[24]See http://www.newyorkfed.org/markets/funding_archive/lsap.html. Gagnon et. al (2011) examine the impact of LSAPs on domestic interest rates, and Neely (2010) examines their impact on foreign interest rates and exchange rates.

Table 2. Summary of Programs Impacting Treasury Collateral

Program	Primary Purpose	Expected Impact on Federal Funds-Repo Spread (regression coefficient)
TSLF	Alleviate Stresses in Funding Markets	$\beta_{TSLF} < 0$
SFP	Drain Reserves from the Banking System	$\lvert\beta_{TSLF}\rvert \geq \lvert\beta_{SFP}\rvert$
Treasury Issuance	Fund Government Expenditures	$\lvert\beta_{TSLF}\rvert \geq \lvert\beta_{bills}\rvert \geq \lvert\beta_{notes\ and\ bonds}\rvert$
Open-Market Operations		
Temporary	Target Federal Funds Rate	$\lvert\beta_{TSLF}\rvert \geq \lvert\beta_{TOMO}\rvert$
Permanent (includes large-scale asset purchases)	Fund Currency Demand Adjust Federal Reserve Balance Sheet Reduce Long-Term Interest Rates	$\lvert\beta_{TSLF}\rvert \geq \lvert\beta_{POMO\ bills}\rvert \geq \lvert\beta_{POMO\ notes\ and\ bonds}\rvert$

The final column of this table presents our prediction of the respective program's impact on the effective federal funds-GC rate spread relative to the TSLF. These will be discussed further in the next section. Since all of the programs in table 2 impacted the supply of Treasury collateral, the table highlights the need to carefully consider the impact of policies beyond their intended target. For example, consider the SFP and LSAP programs. The SFP was primarily intended to the help drain the level of bank reserves, while LSAP purchases helped lower long-term U.S. interest rates. Regarding collateral impacts, the SFP reinforced collateral injections from the TSLF, while LSAP purchases work to remove Treasury collateral from market.

3. Data and Methods

We analyze daily (business day) data from January 2007 through May 2010. This time frame extends from a period pre-crisis through

the period over which the several direct and indirect policies described in the last section manifest: the TSLF and LSAP program, the initiation of the SFP, and the rapid expansion of outstanding publicly held Treasuries from below $5 trillion to close to $8 trillion dollars.

Our dependent variable is the change in the spread between the overnight Treasury GC repo rate and the effective federal funds rate ("the spread," or the "FF-repo spread"). Employing a Dickey-Fuller test over the time period of study, we reject the null of a unit root. Differenced data is employed for economic rather than for econometric reasons, because changes in market actions and policy actions are likely to impact the magnitudes of changes in rates and spreads.[25] Examining spreads, rather than simply the GC repo rates alone accounts for the role the federal funds rate typically serves—as a ceiling for repo rates. (Federal funds transactions are uncollateralized, and collateralized borrowing is typically less expensive.[26]) So the federal funds rate affects repo rates irrespective of the level of relevant collateral.

Data for GC rates come from the Federal Reserve's primary dealer survey, and the effective federal funds rates are available from the Federal Reserve Bank of New York. Overnight GC rates are impacted by the amount of collateral available on a given day, meaning expectations and other potential sources of endogeneity are less of a concern.[27]

[25]Consider the dependent variable as depending on states of the world (as reflected by amounts in the TSLF, for example); then the dependent variable will only change if the state of the world changes. This motivates a specification based on differences instead of levels.

[26]The different markets for the various types of borrowing can result in cases when collateralized borrowing is more expensive than uncollateralized borrowing. For example, money-market mutual funds tend to invest in repo, while banks operate in the federal funds market, changing relative dynamics as the composition of demand for liquidity varies across intermediaries. Over the course of the crisis, as money-market mutual funds faced massive redemptions and pulled away from the repo market, repo rates for all types of collateral rose and even GC rates occasionally traded above the effective federal funds rates.

[27]For example, results of TSLF auctions were released a day or two before settlement, so that amounts settling were known in advance. The overnight GC rate is only impacted by the TSLF settlement, not the announcement of the auction results.

The change in the rate spread is related to changes in Treasury collateral, broken into TSLF, SFP, Treasury bills, and Treasury coupon securities, temporary OMOs, SOMA bills, and SOMA coupon securities.[28] Data on the TSLF, temporary OMOs, SOMA bills, and SOMA coupon securities are available from the Federal Reserve Bank of New York, and data on Treasury debt are available from the Daily Treasury Statement.

While all Treasury securities are eligible to serve as collateral in a Treasury GC repo, the different types of securities could have different impacts on GC rates. For example, comparing TSLF and SFP, the TSLF was targeted at and introduced during a time of great stress in funding markets. As a result, Treasury securities lent out via the TSLF were very likely to have been used as collateral in repo transactions. Similarly, the SFP was initiated in the fall of 2008, when funding markets faced unprecedented stress following the bankruptcy of Lehman Brothers. While SFP was not directed at stresses in funding markets, at its peak it provided more than twice the amount of Treasury collateral as the TSLF. By virtue of magnitude and time of introduction, the SFP may have also impacted FF-repo spreads.

Also worth considering, bills (including SFP bills) may impact funding markets more than notes or bonds. Previous research has shown that primary dealers purchase over 90 percent of CMBs and nearly 85 percent of four-week Treasury bills, while the percentage for longer-term Treasury securities is around 60 percent (Fleming 2007). As dealers tend to hold CMB purchases, it is likely that shorter-maturity securities are more likely to be pledged as collateral in funding markets (Fleming and Rosenberg 2007). Also, some investors, such as money-market mutual funds, need to hold down the weighted-average maturity of their portfolios. Therefore, they typically invest in short-term instruments such as repo or Treasury bills, but not Treasury notes and bonds. As a result, an increase in bills can divert funds away from repo markets and drive up repo

[28]The TSLF auctions alternated in terms of the types of collateral which could be exchanged for Treasury securities. Previous studies (Fleming, Hrung, and Keane 2010a, 2010b) have examined the two types, or "schedules," separately. However, we are concerned only with the amount of Treasury collateral supplied, not the type of collateral withdrawn from the market, so we do not distinguish between the different schedules.

rates. On the other hand, a corresponding increase in notes and bonds will likely not result in a direct diversion of funds from repo markets. And finally, buy-and-hold investors, such as insurance companies and sovereign entities, may prefer longer-duration Treasury securities, and these investors are unlikely to use their Treasury securities as collateral for repo transactions.

As controls, we include data documenting daily changes in measures of stress such as the Chicago Board Options Exchange Volatility Index (VIX), which measures the implied volatility of the S&P 500 index, the Merrill Lynch Global Financial Bond index option-adjusted spread (OAS), the change in the one-month spread between AA financial and non-financial commercial paper (CP), and the change in the one-month LIBOR-OIS (LOIS) spread. The CP rate data comes from the Federal Reserve Board, and the remaining variables were extracted from Bloomberg. We further include calendar dummy variables for the beginning and end of quarters and years—times when demand for collateral may be impacted by reporting requirements.[29]

Table 3 presents summary statistics for the variables studied. Note the wide disparities between the mean values and the minimum and maximum values for the variable levels as well as changes of the variables in the table. This range reflects the extreme distortions in financial markets experienced over our sample period,

[29]The year-end and year-start dummy variables are additive to the quarter-end and quarter-start dummy variables, respectively. Sundaresan and Wang (2009) discuss seasonality in the spread between overnight repo rates and the federal funds target rate. LIBOR stands for the London Interbank Offered Rate, which is a daily reference rate for interbank unsecured borrowing. OIS stands for overnight indexed swap, which is referenced to the daily federal funds rate.

Taylor and Williams (2009) employ a LOIS spread as a dependent variable; however, they express some concern about LIBOR validity due to the self-reported nature of rates by surveyed banks. McAndrews, Sarkar, and Wang (2008) document LIBOR reports in line with expected market reactions. Similarly, Gorton and Metrick (2012) devote a good deal of work to documenting LOIS and several other asset-class spreads and include documentation of exploding haircuts in their descriptive analysis of several dimensions of the 2007–8 period. As compared to our current work, all three papers focus primarily on the early 2007–8 time period, and in the cases of the first two papers, the Term Auction Facility, which was introduced by the Federal Reserve in late 2007. Because of debate regarding the veracity of LIBOR rates, as a robustness check for our results, we have run specifications that simply omit the LOIS variable—results do not fundamentally vary.

Table 3. Summary Statistics

Variables	Mean	Std. Dev.	Min.	Max.
(Effective FF-GC Rate) (bps)	13.230	35.63	−46.7	273.3
OAS (bps)	266.5	169.6	59.0	686.0
VIX (%)	26.5	12.6	9.9	80.9
One-Month AA Financial/ Non-Financial CP (bps)	16.2	26.7	−14.0	236.0
One-Month LIBOR-OIS (bps)	35.9	49.2	3.7	337.8
Δ(Effective FF-GC Rate) (bps)	−0.041	24.53	−174.0	191.3
ΔTSLF ($b)	0.000	4.99	−47.2	75.0
ΔTsy Bills ($b)	0.833	10.54	−55.0	70.0
ΔTsy Notes and Bonds ($b)	3.167	14.54	−54.8	99.0
ΔSFP ($b)	0.234	10.01	−75.0	60.0
ΔSOMA Bills ($b)	0.104	1.18	0.0	18.0
ΔSOMA Notes and Bonds ($b)	−0.297	1.54	−8.5	5.0
ΔShort-Term OMOs ($b)	0.024	4.38	−26.0	25.0
ΔOAS (bps)	0.218	4.58	−37.0	41.0
ΔVIX (percentage points)	0.024	2.56	−17.4	16.5
ΔOne-Month AA Financial/ Non-Financial CP (bps)	0.008	14.69	−106.0	146.0
ΔOne-Month LIBOR-OIS (bps)	0.007	6.20	−44.2	50.4

Notes: Sample: January 2, 2007–May 28, 2010. Observations = 854 (diffs obs. = 853).

during which large aberrations are fairly common. In fact there are eighty-three occurrences (nearly 10 percent of our observations) for which the absolute value of the *change* in spread was greater than 25 bps.[30]

Employing the data represented in table 3, we consider our hypotheses regarding the impacts of generic and program-specific Treasury supply changes for money markets. We estimate the following regression, and the results are presented in table 4:

$$\Delta[FF_{effective} - r_{GC}]_t = \alpha + \beta \Delta USTR_t + \gamma \Delta X_t + \varepsilon_t, \qquad (1)$$

where $FF_{effective}$ represents the effective federal funds rate and r_{GC} represents the collateralized private repo market rate for general U.S. Treasury collateral. The variable(s) *USTR* take on three variant designs—first as a single variable that combines all sub-types of collateral in keeping with our most generic hypothesis, second as a vector of differentiated policy sources of Treasury collateral. (This disaggregation will allow us to test the null hypothesis that all public policies were essentially equivalent in terms of their impact on the FF-repo spread.) Third and finally, we include the various sources of Treasury collateral interacted with the one-month Treasury GC-agency MBS spread to control for market stress. If the degree of impact varies with increases in market spread, the interaction terms will systematically absorb impacts on spreads when market stress is relatively high, allowing us to distinguish between generic collateral impacts and any additional crisis-period impacts.

Vector X contains the controls listed above. We employ the VIX and the other interest rate spreads as controls due to their associations with funding market stress. We focus on the one-month spreads because term funding became particularly scarce as counterparty and liquidity concerns escalated. We expect that changes in the VIX and the various interest rate spreads will be positively related to the change in the spread. Parameters $\{\alpha, \beta, \gamma\}$ are the subjects of estimation and ε represents an error term.

[30]Of the eighty-three cases, in forty-one we observe changes less than –25 bps, while in the remaining forty-two cases, the observed change was greater than 25 bps.

Table 4. Effective Federal Funds-Treasury General Collateral Repo Rate Spread Analysis

Variables	1		2		3	
	Full Period January 2007–May 2010					
U.S. Treasury Issuance, Total	−0.167***	(0.057)				
Term Securities Lending Facility			−.667**	(0.324)	0.095	(0.064)
Supplemental Financing Program			−0.124	(0.173)	0.014	(0.012)
U.S. Treasury Issuance, Bills			−0.194**	(0.0760)	−0.0171*	(0.00969)
U.S. Treasury Issuance, Notes and Bonds			−0.0903*	(0.0511)	−0.0387***	(0.00656)
Temporary Open-Market Operations			−0.326	(0.303)	0.214***	(0.0431)
System Open Market Account Transactions, Bills			2.625***	(0.763)	−1.565	(8.353)
SOMA Transactions, Notes and Bonds			0.190	(0.304)	0.172***	(0.0532)
TSLF by (GC-MBS)					−0.00701**	(0.00356)
SFP by (GC-MBS)					−0.000660	(0.00166)
T-Bill by (GC-MBS)					0.000425	(0.000736)
T.NB by (GC-MBS)					0.00215*	(0.00129)
STOMO by (GC-MBS)					−0.0105***	(0.00239)
SOMA.Bill by (GC-MBS)					0.0396	(0.0978)
SOMA.NB by (GC-MBS)					−0.0518***	(0.0168)
General Collateral–Mortgage-Backed Security Repo Spread					0.0256***	(0.00846)

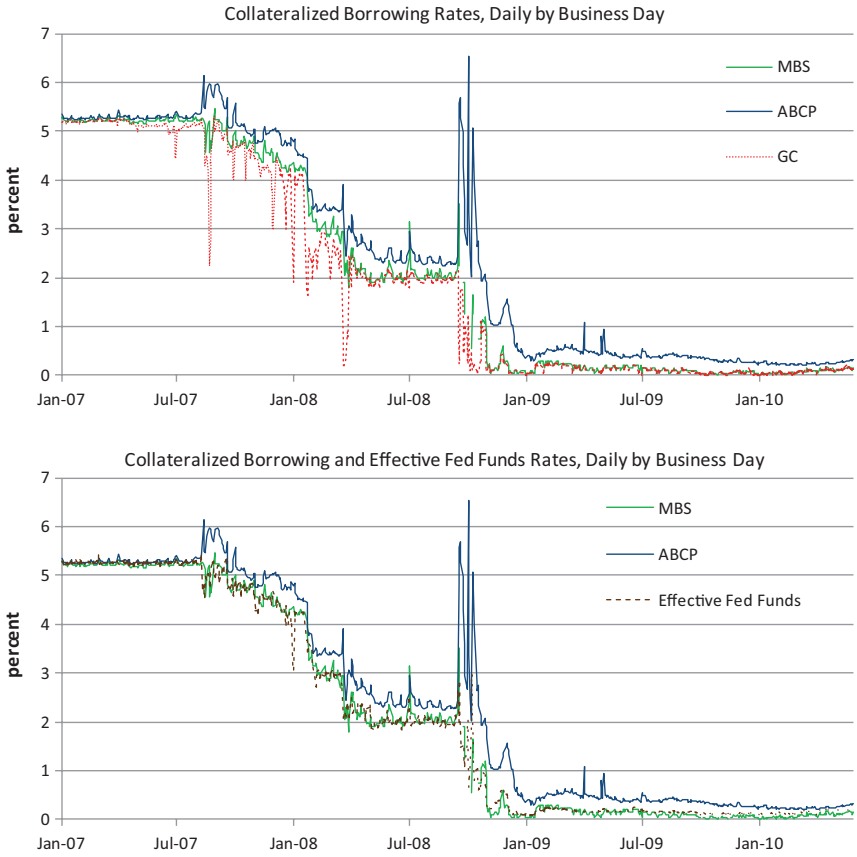
(continued)

Table 4. (Continued)

Variables	1		2		3	
	Full Period January 2007–May 2010					
Global Financial Bond Index Option-Adjusted Spread	0.776**	(0.346)	0.774**	(0.387)	0.00398	(0.0274)
Options Exchange Volatility Index	−0.01	(0.312)	−0.0737	(0.307)	0.0824**	(0.0395)
AA (Financial/Non-Financial) Commercial Paper	0.0546	(0.063)	0.0397	(0.0685)	−0.00123	(0.0154)
London Interbank Offered Rate–Overnight Index Swap	0.495*	(0.252)	0.560**	(0.248)	0.464***	(0.0211)
Lagged Federal Funds GC Repo Spread	0.227***	(0.054)	−0.234***	(0.0492)	−0.318***	(0.0179)
Quarter End	52.95***	(13.230)	50.24***	(12.70)	9.670***	(0.805)
Quarter Start	−37.36***	(9.905)	−36.94***	(9.990)	−7.441***	(1.360)
Year End	−0.268	(34.680)	−1.240	(36.21)	−8.194	(7.446)
Year Start	−2.595	(24.120)	−3.582	(23.80)	0.901	(1.885)
Constant	3.295***	(0.606)	3.030***	(0.567)	0.725***	(0.108)
ARCH					1.163***	(0.109)
TARCH					0.0916	(0.147)
GARCH					0.429***	(0.0196)
Constant					0.329**	(0.145)
Number of Observations	853		853		853	

Notes: All variables are expressed as first differences unless noted. Newey-West standard errors are in parentheses. ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

Figure 6. Selected Daily Collateralized Borrowing Rates: 2007–10



Source (top graph): Bloomberg and Federal Reserve Board of Governors.
Source (bottom graph): Bloomberg, Federal Reserve Bank of New York, and Federal Reserve Board of Governors.

3.1 Other Funding Markets

It is possible that the various policies that we investigate were able to alleviate stresses beyond the funding market for Treasury collateral. Figure 6 presents overnight MBS repo, ABCP, and GC rates, as well as the effective federal funds rate. Agency repo rates are not shown, as they exhibit similar dynamics to MBS rates.

Ideally, we would be able to offer strong priors on impacts in other funding markets. However, theoretic predictions in this area can be confounded by countervailing forces. For example, consider agency debt and agency MBS. To the extent that lenders of funds became wary of housing-related collateral, agency and MBS repo rates would have increased.[31] Therefore, if increases in Treasury collateral helped heal funding markets in general, these rates would have decreased and we would expect spreads to GC to narrow more than the FF-GC spread. However, to the extent that agency securities are substitutes for Treasury securities and OMO collateral in general was subject to flight-to-quality flows, agency and MBS repo rates would have fallen along with Treasury repo rates as the crisis deepened, and risen with Treasury repo rates as funding market stresses abated.[32] In terms of the spread of agency rates to GC, the compression in response to increases in Treasury collateral would then be smaller in magnitude than the FF-GC spread. So unfortunately, theory provides little guidance in terms of prediction—almost any result would be consistent with Treasury collateral-related policies having an impact on funding markets for agency securities.

Funding markets for less-liquid collateral will likely provide clearer results. Therefore, we also investigate the overnight AA-rated ABCP rate, as ABCP is not OMO eligible.[33] As shown in figure 6, this rate increased substantially as the financial crisis deepened and

[31]Comparing the MBS repo rates and GC rates in figure 6 (top panel), the dynamics for GC rates differ from MBS repo rates, as the MBS rates do not exhibit the steep drops that characterize GC rate movements starting in the second half of 2007. The dynamics for MBS rates are more similar to those for the effective federal funds rate (bottom panel), but there are still periods of noticeable divergence between the two rates. The same characterization generally applies to the ABCP rates in figure 6, though more pronounced. Spreads between the ABCP and effective federal funds rate after the fall of 2007 are notably wider through the end of 2009.

[32]Krishnamurthy, Nagel, and Orlov (forthcoming, figure 7) suggests that both factors were present over the course of the crisis for agency debt, with agency rates exceeding the federal funds rate in the fall of 2007 and mid-2008, but falling below the federal funds rate after the Lehman bankruptcy, while corporate debt and private-label asset-backed security repo rates spiked substantially after the Lehman bankruptcy.

[33]Commercial paper rates are compiled by the Federal Reserve Board. See Adrian, Kimbrough, and Marchioni (2011) for a discussion of the commercial paper market during the financial crisis.

the commercial paper market came under immense stress. For this rate spread to GC, if increases in Treasury collateral helped stabilize this funding market, the ABCP rate would be expected to fall while the GC rate increases. Therefore, the ABCP-GC spread would narrow to a greater extent than the FF-GC spread. Note that if we utilized the FF-ABCP spread instead, we would anticipate a positive coefficient for Treasury collateral as evidence of an abatement of stresses in the ABCP market, and we focus on the ABCP-GC spread to ease comparability with our other results.

4. Results

4.1 Effective FF-GC Repo Spread

Table 4 presents results over the full sample period from January 2007 through May 2010. Columns 1 and 2 present ordinary least squares (OLS) regression results. The first column combines all sources of Treasury collateral, and in line with our first hypothesis, the observed relationship with our dependent spread variable is negative and statistically significant. Each billion dollars of Treasury supply are associated with a 0.167 bps reduction in the FF-GC repo spread.

The second column breaks out the sources of Treasury collateral into seven categories: TSLF, SFP, Treasury bills, Treasury notes and bonds, temporary OMOs, SOMA bills, and SOMA notes and bonds. We can reject the more refined null hypothesis of equal coefficients between types of collateral at the 95 percent confidence level. The largest estimated reductions in spread are associated with the TSLF program, a program designed to relieve funding market stresses. Every $1 billion increase in Treasury collateral due to TSLF is correlated with a 0.667 bps narrowing of the FF-repo spread. As the TSLF was reserve neutral, our results show that a proper policy response to a financial crisis includes options which do not increase bank reserves.

Treasury issuance was another channel for increasing available supplies of Treasury instruments in repo markets. Bills in particular are robustly (99 percent confidence level) associated with reductions of 0.194 bps per $billion. The strong and positive SOMA bills coefficient is not easily interpreted, prima facia. As noted earlier, SOMA

bills sales occur on only seven dates—between March 10 and May 8, 2008—and there are no bills purchases during our sample period (see figure 4, bottom panel). The coefficient is likely a spurious artifact.[34]

The lack of significance for the SFP coefficient may not be altogether surprising given that the SFP also drained bank reserves. Because the SFP placed upward pressure on the effective federal funds rate while increasing the supply of Treasury collateral, the program moved the effective federal funds rate and the GC repo rate in the same direction, and its net impact depends on the relative magnitude of each effect.[35]

As regards other coefficients in column 2, the OAS and LOIS spread coefficients are positive, consistent with a flight to quality. The coefficient for changes in the VIX is small and not statistically significant. The lagged spread coefficient suggests some degree of reversion in these data so that, for example, a widening of the spread on any given day is followed by a somewhat mitigating reduction on the following day, all else equal.[36]

The various sources of Treasury collateral might be expected to behave differently outside of a collateral crisis; column 3 differentiates impacts by the degree of funding market stress. We interact the Treasury supply channels with the level of the one-month Treasury GC-to-agency MBS repo rate spread—a measure of market stress which compares two term-collateralized funding rates. Column 3's specification also incorporates the threshold ARCH (TARCH) model of Glosten, Jagannathan, and Runkle (1993). Threshold ARCH

[34]The results for this variable found in column 3 supports this view. Additionally of note, virtually no temporary OMOs were conducted in the latter half of our period of observation. In regressions not presented here, the temporary OMO variable is dropped as a generic robustness check on our remaining estimated coefficients. No coefficients change in terms of magnitude or statistical significance in any meaningful way. Another robustness check of the specification addresses the concern in Taylor and Williams (2009) regarding LIBOR. As noted in footnote 29, when we simply omit the LOIS variable, results do not fundamentally vary.

[35]Since excess reserves can affect trading in the federal funds market, we include the change in the level of excess reserves as an additional independent variable in the table 4 specifications. The coefficient for this variable was positive but not statistically significant. The other variable coefficients were not notably impacted, so the results are not presented.

[36]In the appendix, table 8 employs public data to replicate column 2 of table 4, presenting results using publicly available repo data. Results are generally consistent with those found in table 4.

procedures accommodate asymmetric variations in our dependent variables' volatility over our sample period (see figure 1, bottom panel). Specifically, we utilize the TARCH model to account for any asymmetric responses to positive and negative innovations in volatility.[37] Our motivation for employing this model rests in an attempt to distinguish whether the impacts of TSLF and other supply responses were more or less specific to the circumstances under which they were implemented, while also taking into account non-constant volatility.

Regarding the timing of TSLF implementation, the TSLF coefficient in column 2 embeds both a crisis and a general collateral impact, whereas the same coefficient in column 3 estimates just a general collateral impact (with the GC-MBS spread set to a de-minimus level), while the TSLF*(GC-MBS spread) coefficient reports a crisis impact.

The TSLF stand-alone coefficient (0.095) is not significant at any standard confidence level. By comparison, the TSLF interaction coefficient (−0.007) is significant at the 95 percent confidence level. The TSLF interaction coefficient suggests a sizable impact of the program during times of funding market stress. To illustrate, a $70 billion TSLF settlement with the GC-MBS spread at 200 bps (the values around the time of the Lehman bankruptcy) implies a reduction in the FF-repo spread of almost 100 bps.

The results in column 3 suggest that the TSLF program had a large impact on the FF-repo spread because it was introduced and operated at a time of stress when spreads were unusually wide. The TSLF would have had a much smaller impact if it had been introduced during times of normal market functioning. Note that this impact is not present for the SFP, which was introduced at the height of the financial crisis and reached a peak size that was double that of the TSLF.

[37] The test statistic for ARCH effects had a value of 118.03, so we can reject the null hypothesis of no ARCH effects at the 99 percent level. Since the dependent variable is composed of two market rates, an asymmetric response may be less likely in this specification if both rates respond in a similar manner. However, in unreported results utilizing publicly available repo rates, the TARCH coefficient is statistically significant at the 95 percent level. Moreover, an asymmetric response may be more likely when we investigate the spread between the federal funds target and the GC rate (table 6), since the target rate will not respond to innovations in volatility. We retain the TARCH specification here for consistency across the analyses.

4.2 Other Funding Markets

In table 5, we investigate the impact of Treasury collateral on other funding rates relative to the GC rate.

The first column in table 5 reports the results from column 2 of table 4 as a reference. Column 2 shows corresponding results for the agency-GC spread and column 3 reports results for the MBS-GC spread.[38] Compared with column 1, the TSLF coefficient in these columns remains negative, but is smaller in magnitude and no longer statistically significant. This result is consistent with agency securities being closer substitutes for Treasury collateral than less-liquid collateral. The results for the other coefficients are generally similar.

Column 4 reports results for the ABCP-GC spread. Compared with column 1, the TSLF coefficient is negative, larger in magnitude, and still statistically significant. This suggests that the TSLF did have an impact beyond funding markets for Treasury collateral by helping lower ABCP rates while increasing GC rates. Some of the coefficients for other sources of Treasury collateral are also larger in magnitude than the corresponding coefficients in column 1. Notably, the coefficient for temporary OMOs is much larger and now statistically significant at the 10 percent level.

4.3 Target FF-GC Repo Spread

Table 6 employs the target federal funds rate in place of table 4's effective rate. While employing the federal funds target better isolates the impact of Treasury collateral, as the target rate is set by the FOMC and is not impacted by the level of bank reserves, the dependent variable is no longer a spread between two market rates. For the sub-period where the federal funds target was the range of 0–25 bps (mid-December 2008 forward), we set the target rate to 25 bps.[39]

As shown in table 6, the results are similar when employing the target rate. One notable difference from the results in table 4 is that the SFP stand-alone coefficient now exhibits the expected negative

[38]Data for these rates also come from the primary dealer survey.

[39]In an alternate specification not reported here for the sake of brevity, we employ a midpoint of 12.5 bps as the target rate in the target-range period from December 16, 2008 to May 28, 2010. Results are essentially equivalent.

Table 5. Other Collateral Spreads

Dependent Variable	(Table 4, Col. 2) **Δ(Effective − GC)**	**Δ(Agency − GC)**	**Δ(MBS − GC)**	**Δ(ABCP − GC)**
Variables	**Full Observation Range of January 2007–May 2010**			
Term Securities Lending Facility (TSLF)	−0.667**	−0.156	−0.281	−0.738**
	(0.32)	(0.12)	(0.24)	(0.36)
Supplemental Financing Program (SFP)	−0.124	−0.130	−0.104	−0.303
	(0.17)	(0.11)	(0.13)	(0.20)
U.S. Treasury Issuance, Bills (T.Bill)	−0.194***	−0.226***	−0.248***	−0.393***
	(0.08)	(0.07)	(0.08)	(0.15)
U.S. Treasury Issuance, Notes and Bonds (T.NB)	−0.09*	−0.092	−0.096	−0.083
	(0.05)	(0.06)	(0.07)	(0.09)
Temporary Open-Market Operations (STOMO)	−0.326	−0.250	−0.288	−0.865*
	(0.30)	(0.20)	(0.22)	(0.53)
System Open Market Account Transactions, Bills (SOMA.Bill)	2.62***	1.92*	2.40***	1.66*
	(0.76)	(1.11)	(0.92)	(1.00)
SOMA Transactions, Notes and Bonds (SOMA.NB)	0.190	0.044	−0.036	−0.025
	(0.30)	(0.28)	(0.31)	(0.54)
Number of Observations	853	853	853	853

Notes: All variables are expressed as first differences unless noted. Newey-West standard errors are in parentheses. ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively. Other coefficients are not presented in order to conserve space.

Table 6. Target Federal Funds-Treasury General Collateral Repo Rate Spread Analysis

Variables	1		2		3	
	Full Period January 2007–May 2010					
U.S. Treasury Issuance, Total	−0.157***	(0.048)				
Term Securities Lending Facility			−0.731**	(0.290)	0.109	(0.0677)
Supplemental Financing Program			−0.0936	(0.104)	−0.0838***	(0.0263)
U.S. Treasury Issuance, Bills			−0.148**	(0.0697)	−0.0194*	(0.0111)
U.S. Treasury Issuance, Notes and Bonds			−0.123**	(0.0575)	−0.0555***	(0.00575)
Temporary Open-Market Operations			0.148	(0.144)	0.0293	(0.0285)
System Open Market Account Transactions, Bills			1.600**	(0.679)	−1.453	(23.11)
SOMA Transactions, Notes and Bonds			−0.0661	(0.230)	−0.0172	(0.0674)
TSLF by (GC-MBS)					−0.0106**	(0.00504)
SFP by (GC-MBS)					0.00212	(0.00149)
T-Bill by (GC-MBS)					−0.00658***	(0.000760)
T.NB by (GC-MBS)					0.000955	(0.000740)
STOMO by (GC-MBS)					0.00477***	(0.00177)
SOMA.Bill by (GC-MBS)					0.0218	(0.273)
SOMA.NB by (GC-MBS)					−0.0535***	(0.0123)
General Collateral–Mortgage-Backed Security Repo Spread					−0.0474***	(0.00853)

(continued)

Table 6. (Continued)

Variables	1		2		3	
	Full Period January 2007–May 2010					
Global Financial Bond Index Option-Adjusted Spread	0.738**	(0.238)	0.755***	(0.264)	0.0234	(0.0228)
Options Exchange Volatility Index	−0.064	(0.253)	−0.0959	(0.270)	−0.0707*	(0.0387)
AA (Financial/Non-Financial) Commercial Paper	0.0121	(0.047)	−0.00571	(0.0473)	0.00299	(0.0122)
London Interbank Offered Rate–Overnight Index Swap	0.387*	(0.210)	0.414*	(0.212)	0.00167	(0.0202)
Lagged Federal Funds GC Repo Spread	−0.145***	(0.044)	−0.149***	(0.0447)	−0.0963***	(0.00685)
Quarter End	42.46***	(8.468)	41.47***	(8.523)	15.61***	(0.972)
Quarter Start	−32.42***	(7.717)	−32.39***	(7.737)	−12.35***	(2.522)
Year End	43.07	(59.410)	42.86	(60.47)	−8.779	(12.49)
Year Start	−36.03	(43.730)	−35.51	(43.38)	4.225	(4.433)
Constant	3.534***	(0.726)	3.332***	(0.777)	1.343***	(0.126)
ARCH					0.964***	(0.0890)
TARCH					1.100***	(0.158)
GARCH					0.265***	(0.0117)
Constant					1.494***	(0.236)
Number of Observations	853		853		853	

Notes: All variables are expressed as first differences unless noted. Newey-West standard errors are in parentheses. ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

(and significant) coefficient in column 3. Previously, the impact of the SFP on the FF-repo spread was confounded by the fact that SFP bills simultaneously drained bank reserves and increased the supply of Treasury collateral. Here, the SFP has no impact on the federal funds target rate set by the FOMC, so we observe just the GC repo rate impact. Based on the results in table 6, we conclude that there is some evidence that the SFP was able to help alleviate funding market stresses.

4.4 Sub-Sample Analysis

Table 7 presents results over three sub-periods of our observation period, early (January–July of 2007), mid (August 2007–December 2008), and late (January 2009–May 2010). Panel A replicates Treasury collateral impacts over the sub-periods. Panel B distinguishes between injections and extractions of Treasury collateral. Panel C demonstrates an ability to reject the null hypothesis of a unit root over each sub-period.

The first and fifth columns in panel A replicate full sample results presented in tables 4 and 6, for the reader's convenience. Notice that the middle and late periods are most associated with statistically significant effects. Amplitudes in the middle period were higher than in the late period by an order of magnitude. This is not surprising, as the late period coincides with the target federal funds range of 0–25 bps; there is less scope for large movements in the repo rate spread in either direction during this period. Note that a more refined breakdown of Treasury supply by program is not possible, as some sources of Treasury collateral were not available in all sub-periods. For example, the TSLF was not initiated until the middle period.

When injections and extractions are treated separately, injections are generally statistically significant and economically meaningful, especially over the mid-crisis period (August 2007–December 2008). Extraction impacts are statistically indistinguishable from zero. These results suggest that injections generated the desired impacts, while extractions caused little to no money-market disruption.

Finally, concerning stationarity of these data, panel C considers an additional time period. This allows the reader to be assured

Table 7. Alternate Periods for Analysis and Dickey-Fuller Test Results

	Effective minus GC				**Target minus GC**			
	1/07–5/10	**1/07–7/07**	**8/07–12/08**	**1/09–5/10**	**1/07–5/10**	**1/07–7/07**	**8/07–12/08**	**1/09–5/10**
Variables	**Full**	**Early**	**Mid**	**Late**	**Full**	**Early**	**Mid**	**Late**
A. Replication of Results over Sub-Periods								
U.S. Treasury Issuance, Total	−0.167*** (0.057) (Table 4, Col. 1)	−0.115 (0.074)	−.241* (0.124)	−.0343*** (0.007)	−0.157*** (0.048) (Table 6, Col. 1)	−0.043 (0.059)	−.227** (0.105)	−.0538*** (0.007)
B. Injections and Extractions Treated Separately								
Injections of U.S. Treasury Collateral	−.0195** (0.080)	−.403** (0.188)	−.324* (0.194)	.0465*** (0.007)	−.170** (0.067)	−0.248 (0.185)	−.297* (0.164)	.0667*** (0.008)
Extractions of U.S. Treasury Collateral	−0.08 (0.078)	0.115 (0.071)	−0.03 (0.137)	0.012 (0.016)	−0.116 (0.081)	0.117 (0.074)	−0.052 (0.124)	−0.006 (0.016)
C. Stationarity of Data								
	1/07–5/10	**1/07–7/07**	**8/07–12/08**	**1/09–5/10**	**1/07–5/10**			
	Full	**Early**	**Mid**	**Late**	**Mid-Late**			
Dickey-Fuller Test for Unit Root	−10.7***	−6.613***	−7.349***	−8.277***	−9.675***			
Number of Obs.	853	146	355	352	707			
1% Critical Values	−3.430	−3.452	−3.452	−3.452	−3.430			

Data Source: Federal Reserve Bank of New York.

Notes: All variables are expressed as first differences unless noted. Panels A and B: Other coeffiecients are not presented. Newey-West standard errors are in parentheses. ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively. Panel C: Results for Effective minus GC spread, t-statistics based on asymptotic Dickey-Fuller distribution; *** denotes $p < 0.01$.

that over the whole of the TSLF policy period (over the mid-to-late period, combined), the data are suitable for the econometric analysis undertaken.

5. Conclusion

This study has investigated the impact of policies involving the supply of Treasury debt on overnight Treasury GC repo rates, an important benchmark rate in collateralized funding markets. In general, we find that increases in Treasury collateral supplies increase repo rates and narrow the spread between repo rates and the effective federal funds rate. Since flight-to-quality flows over the course of the recent financial crisis drove GC rates to relatively low levels, this narrowing of the spread is interpreted as a reduction in market stress. Broadly, we find U.S. Treasury supplies were useful, the method of injection to market mattered, and policies targeting short-term stress were effective both in terms of introduction and exit.

More specifically, we find that the TSLF, which was introduced to address stresses in short-term funding markets, was effective in alleviating the dislocations due to the increased demand for Treasury collateral as the crisis progressed. We also provide evidence that the TSLF had an impact beyond the funding market for Treasury collateral. In particular, our results are consistent with the TSLF having alleviated stress in the ABCP market. When we isolate changes in the GC-repo market from changes in the effective federal funds rate and allow for non-constant volatility, we also find that the SFP, which was designed to drain bank reserves, contributed to funding market stabilization. In addition, we find that the TSLF would likely have a much smaller effect on repo rates if the program had been introduced in a period of normal market functioning. Finally, our results suggest that the extraction of Treasury collateral did not disrupt funding markets in any significant way.

An implication of our results is that a proper policy response to a financial crisis may require responses other than increases in bank reserves. The TSLF program was very effective at alleviating short-term money-market stresses during the financial crisis and this program was reserve neutral. Furthermore, the SFP actually drained reserves from the banking system.

Our results also suggest a modified interpretation of Bagehot's dictum. During the financial crisis, securitized lending markets experienced an upheaval not only because of a lack of cash but also because of a lack of high-quality collateral, and thus increasing supplies of this type of collateral facilitated market functioning.

Appendix

Table 8 presents regression results with the dependent variable set as the change in the spread between the overnight Treasury GC repo rate via Bloomberg and the effective federal funds rate.

Table 8. Effective Federal Funds-(Public) Treasury General Collateral Repo Rate Spread Analysis

Variables		
Term Securities Lending Facility	−0.925**	(0.38)
Supplemental Financing Program	−0.071	(0.17)
U.S. Treasury Issuance, Bills	−0.140**	(0.07)
U.S. Treasury Issuance, Notes and Bonds	−0.092**	(0.04)
Temporary Open-Market Operations	−0.412	(0.37)
System Open Market Account Transactions, Bills	2.515**	(0.92)
SOMA Transactions, Notes and Bonds	0.387	(0.28)
Global Financial Bond Index Option-Adjusted Spread	0.508	(0.37)
Options Exchange Volatility Index	−0.077	(0.30)
AA (Financial/Non-Financial) Commercial Paper	0.0252	(0.06)
London Interbank Offered Rate–Overnight Index Swap	0.59**	(0.27)
Lagged Federal Funds GC Repo Spread	−.242***	(0.05)
Quarter End	44.49***	(11.75)
Quarter Start	−36.06***	(13.55)
Year End	−9.914	(26.36)
Year Start	4.23	(21.28)
Constant	4.11***	(0.66)
Number of Observations	853	

Notes: All variables are expressed as first differences unless noted. Newey-West standard errors are in parentheses. ***, **, and * denote $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively.

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