Federal Reserve Bank of Chicago

The scarcity value of Treasury collateral: Repo market effects of security-specific supply and demand factors

Stefania D'Amico, Roger Fan, and Yuriy Kitsul

November 2013

WP 2013-22

The scarcity value of Treasury collateral: Repo market effects of security-specific supply and demand factors*

Stefania D'Amico[†], Roger Fan[‡], and Yuriy Kitsul[§]

November 29, 2013

Abstract

In the repo market, forward agreements are security-specific (i.e., there are no deliverable substitutes), which makes it an ideal place to measure the value of fluctuations in a security's available supply. In this study, we quantify the scarcity value of Treasury collateral by estimating the impact of security-specific demand and supply factors on the repo rates of all the outstanding U.S. Treasury securities. Our results indicate the existence of an economically and statistically significant scarcity premium, especially for shorter-term securities. The estimated scarcity effect is quite persistent, seems to be reflected in the Treasury market prices, and could in part explain the flow-effects of the Fed's asset purchase programs. More generally, it provides additional evidence in favor of the scarcity channel of quantitative easing. These findings also suggest that, through the same mechanism, the Fed's reverse repo operations could help alleviate potential shortages of high-quality collateral.

JEL Codes: G1, G12, G19, C23

*We are grateful to Thomas King, seminar participants, and the MOMA group at the Federal Reserve Bank of Chicago for useful discussions and comments. We also thank Scott Konzem, Tanya Perkins and Long Bui for their help with data preparation. All errors and omissions are our sole responsibility. The views expressed in this paper are those of the authors alone and do not necessarily reflect the views of the Federal Reserve Bank of Chicago, the Board of Governors of the Federal Reserve System, the Federal Reserve System, or their staff.

†Federal Reserve Bank of Chicago. Email: sdamico@frbchi.org. Phone: +1 (312) 322-5873

‡Federal Reserve Bank of Chicago. Email: rfan@frbchi.org. Phone: +1 (312) 322-4019

§Federal Reserve Board. Email: yuriy.kitsul@frb.gov. Phone: +1 (202) 452-2967

1 Introduction

A growing literature examines the price impact of expected and unexpected changes in the demand and supply of various securities, including stocks (e.g., Kaul et al., 2000; Wurgler and Zhuravskaya, 2002; Greenwood, 2005) and bonds (e.g., Greenwood and Vayanos, 2010; D'Amico and King, 2013; Lou et al., 2013). However, little direct evidence has been provided on the existence of demand and supply effects in the repurchase agreement (repo) market. In this market, forward agreements are security-specific (i.e., there are no deliverable substitutes), which makes it an ideal place to measure and understand the value of fluctuations in a security's available supply.[1] In this study, by estimating the impact of security-specific demand and supply factors on the repo rates of all the outstanding U.S. Treasury securities, we quantify the scarcity value of Treasury collateral.

A repo is a transaction involving the spot sale of a security coupled with a simultaneous forward agreement to buy back the same security, usually on the next day. Thus, it is similar to a collateralized overnight loan where the party providing the funds earns interest at the repo rate. In general collateral (GC) repos the acceptable collateral can be any of a variety of securities, while in specific or special collateral (SC) repos the contract is specific to the particular asset that serves as collateral. The types of collateral used in the repo market include Treasury securities, agency debt and MBS, as well as other riskier assets. In this study, we limit our attention to Treasury securities.

The Treasury repo market is a vast market where the high quality of the collateral attracts many market participants.[2] GC repos are used by dealers and other levered accounts (such as hedge funds) as an inexpensive way to fund much of their activity. Money market funds, corporate treasurers, and state and local governments are the most frequent cash providers in this market, as GC repos represent a relatively safe and liquid money-market instrument (Gorton and Metrick, 2012). SC repos are used by dealers and hedge funds to establish short positions (Duffie, 1996), that is, to borrow a specific security and sell it spot in anticipation that its price will fall, so that they can buy it back at a lower price to return it to the counterparties. Mutual and pension funds, central banks, and other owners of Treasury securities can then borrow cash at an advantageous rate by lending specific securities, and eventually re-lend the money at a higher GC repo rate, earning the spread between the two rates.

Overall, the repo market, by facilitating market making, hedging, and speculative ac-

[1]We are grateful to Gadi Barlevy for many useful and clarifying conversations about this point.

[2]For example, as of November 14, 2013, the total amount of U.S. Treasury overnight repos and reverse repos entered into by primary dealers was about \$1.6 trillion (FR-2004 data); for comparison, the average daily traded volume in the Treasury cash market over the week ending on November 6 was about \$500 billion.

tivities, has been fundamental in ensuring liquidity of the Treasury cash market. And in particular, by mitigating leverage constraints (Gromb and Vayanos, 2010, among others), it has facilitated arbitrage trading, which is essential to Treasury market efficiency. On the other hand, the smooth functioning of the repo market and prevailing repo rates depend on the availability of the underlying Treasury collateral. The latter relation, which has been little investigated at the security level, is the main object of our study.[3]

In particular, we are unaware of any studies that use repo rates on *all available* U.S. Treasury securities and focus on understanding the impact of *security-specific* demand and supply factors on these rates.[4] This is quite surprising—unless due to the limited availability of data—not only because over the past decades the repo market has grown dramatically in size and popularity, but also because considerations about the availability of close substitutes are crucial when quantifying supply and demand effects on securities' prices. Collateralized transactions are security-specific in the SC repo market, so there are *no* deliverable substitutes. Therefore, the scarcity of the underlying collateral should be one of the main determinants of the transaction's cost, that is, the repo rate.

Such investigation is particularly timely for the following reasons. First, fixed-rate full-allotment reverse repos may become one of the most important tools available to the Federal Reserve (Fed) to both manage money market rates (see July 2013 FOMC Minutes) and alleviate potential shortages of "high-quality" assets.[5] In other words, the Fed, by allowing a wide range of market participants to deposit unlimited amounts of cash at a fixed rate in exchange for Treasury securities held in the System Open Market Account (SOMA) portfolio, could potentially become the largest (and most creditworthy) borrower in the repo market with the power to set a floor on repo rates.[6]

Second, since the end of 2008, the supply and demand dynamics of the "high-quality" assets often used as collateral in repo transactions have changed substantially and have the potential to change even further. For example, on the supply side, there are new factors that have affected the availability of high-quality collateral: The Fed's Large-Scale Asset Purchase (LSAP) programs have reduced the amount of Treasury and agency MBS left to the private investors; increased allotment to official foreign entities at Treasury auctions has effectively

[3]Jordan and Jordan (1997), which uses Treasury auction results on 39 distinct notes from September 1991 to December 1992, is one of a few examples.

[4]Most of previous studies focus on the repo rates of a few on-the-run Treasury securities and use aggregate demand and supply proxies, see Moulton (2004) and Graveline and McBrady (2011).

[5]See the Q3-2013 report by the Treasury Borrowing Advisory Committee, which can be accessed from `http://www.treasury.gov/resource-center/data-chart-center/quarterly-refunding/Pages/TBAC-Discussion-Charts.aspx`, and the May-2013 report by the Committee on the Global Financial System for discussions on various factors that could potentially affect availability of collateral assets.

[6]See `http://www.newyorkfed.org/markets/rrp_faq.html` for more information on the Federal Reserve's fixed-rate repo operations.

reduced issues' post-auction availability, as those investors are not very active in the repo market; and bank holding companies' supplementary leverage and liquidity ratios might have led to a reduced willingness and ability to provide repo transactions. On the demand side, new regulatory developments such as the mandatory central clearing of standardized over-the-counter derivatives will increase demand for high-quality assets to satisfy initial margin requirements.[7]

Third, even traditional demand and supply factors, such as demand for short positions and securities dealers' financing of their inventories (dealer demand for repo financing) seem to have been playing a larger role in recent years. In particular, the Fed's sales of Treasury securities maturing in 3 years or less during the Maturity Extension Program (MEP) have increased primary dealers' inventories of these securities, likely boosting refinancing of these inventories in the repo market. And, during the unconventional monetary policy period, the yield curve slope has often widened to record levels inducing notable short positions in longer-term Treasuries, as investors have taken bets on the curve steepening. In addition, over the same period, mortgage convexity hedging has likely been substantial due to large mortgage refinancing activity triggered by low mortgage rates; and flight-to-quality episodes, which are characterized by elevated demand for safe assets, have been significant. Finally, most of these factors may revert very quickly in anticipation of the unwinding of the current monetary policy easing.

The emergence of new collateral demand and supply factors, such as purchases and sales of Treasury securities under the LSAP programs and the MEPs, as well as the availability of better data on Treasuries' ownership distribution (such as Treasury auction allotments by investor class) and unexpected auction tightness (such as the spread between auction and when-issued rates), allow us to better measure the scarcity value of Treasury collateral through the impact of each of these factors on the security-specific repo rates.

The few studies (Moulton, 2004; Graveline and McBrady, 2011) that analyze the determinants of the repo specialness spread are limited to on-the-run securities and mainly use aggregate measures of factors like interest-rate-risk hedging demand, buy-and-hold investors' demand, and mortgage-convexity hedging demand. Similarly to Jordan and Jordan (1997), the only security-specific variables in these studies are the Treasury auctioned amounts and the corresponding bid-to-cover ratios. This could be due to the fact that security-level demand and supply factors were not available in the sample periods of these studies.

In contrast, our richer sample, which starts on May 1, 2009 and terminates at the end of 2012, contains daily observations on security-specific demand and supply factors and specific repo rates on all the individual Treasury securities outstanding. This enables us to precisely

[7]For more details, see the May-2013 report of the Committee on the Global Financial System.

identify the reaction of these rates to changes in the demand and supply of their underlying collateral. The estimated average elasticities to these factors capture how the borrowing cost of a loan collateralized by a specific bond changes as that bond becomes more or less scarce. Therefore, these elasticities should measure the portion of the repo rate that is solely due to changes in the scarcity of the underlying collateral (i.e., its scarcity value) and not other idiosyncrasies of the specific collateral such as a change in liquidity and/or credit quality. This is also ensured by explicitly controlling for security-level measures of liquidity such as the bid-ask spread, and "credit-quality" measures such as maturity, which determines the length of exposure to interest-rate risk and can be thought of as capturing riskiness across Treasuries.

The results from our daily panel regressions indicate that security-specific demand and supply factors are statistically significant and carry the expected signs. In particular, the coefficient on the amount purchased at the Fed's operations is negative and significant for both on- and off-the-run securities, implying an average effect of -0.8 and -0.4 basis points per billion dollars, respectively. This suggests that as the supply of a particular security available to private investors shrinks, the repo rate decreases as investors are willing to lend money at very low interest rates to obtain that specific security. In addition, our subsample analysis shows that the impact of the Fed purchases on repo rates is larger in shorter-term securities, with an average effect of -2.0 and -0.6 basis points per billion dollars, for on- and off-the-run securities, respectively. We also show that these effects are quite persistent.

This type of scarcity premium, which seems to be reflected in cash market prices, could in part explain the LSAPs' flow-effects estimated in D'Amico and King (2013). As shown by Duffie (1996) and confirmed by Jordan and Jordan (1997) and Buraschi and Menini (2002), bonds that trade special in the repo market should trade at a premium in the cash market. Since in this study we show that part of this specialness premium originates from the Fed purchase operations, our results provide additional evidence in favor of the scarcity channel of this policy tool (Krishnamurthy and Vissing-Jorgensen, 2011; D'Amico et al., 2012, among others).

Furthermore, the coefficient on the sold amount of off-the-run securities at the Fed operations is positive and also significant, implying an average effect of 0.2 basis points per billion dollars. This indicates that an increase in the available supply of Treasury securities pushes repo rates up (and specialness spreads down), suggesting that the Fed's reverse repos could potentially be successful in alleviating shortages of high-quality collateral. In line with these findings, the coefficient for the Treasury issued amount is positive and significant, but its size is twice as big, that is, 0.4 basis points per billion dollars.

We also re-examine the Treasury auction cycle of repo rates on on-the-run securities and, similarly to previous studies, find strong evidence of seasonality around auction dates. However, due to the introduction of two regular reopenings following each auction, the 10-year auction cycle looks quite different and even more interesting. Finally, in the robustness section we replicate some of the analysis done in Jordan and Jordan (1997) and Graveline and McBrady (2011), but augmented with our security-specific demand and supply factors, and find that our factors remain significant in these specifications and retain the expected signs. Among the aggregate demand proxies, the mortgage refinancing index is the most relevant one.

The paper is organized as follows. Section 2 describes the data and the variables used in the empirical analysis, whose results are discussed in detail in Section 3. In Section 4, we present some experiments comparing our results to other studies. And Section 5 concludes.

2 Data and Variables Description

We estimate the effects of changes in various supply and demand factors on Treasury repo rates using a series of panel regressions. Our panel consists of daily changes in average SC repo rates and security-specific demand and supply factors for all outstanding nominal Treasury coupon securities from May 1, 2009 (the day that the repo fail charge was implemented by the Treasury Market Practices Group[8]) to the end of 2012. However, due to data limitations, some of our regressions start on June 23, 2009. We omit securities maturing in more than 15 years because the repo market in longer-term securities is very thin. As a result, our unbalanced panel consists of 347 CUSIPs.

2.1 Repo Data

Our proprietary data set is derived from the repo interdealer-broker market. It includes daily averages of SC repo rates quoted between 7:30 and 10 a.m. (Eastern time). This time window is chosen because trading in the repo market begins at about 7 a.m., remains active until about 10 a.m., and then becomes light until the market closes at 3 p.m. Repo transactions with specific collateral are bilateral and are executed on a delivery versus payment (DVP) basis (i.e., same-day settlement). In these transactions, a collateral security is delivered into a cash lender's account in exchange for funds. The exchange occurs via FedWire or a clearing bank. In contrast, GC repo transactions often occur via the tri-party repo market, in which securities and cash are placed on the balance sheet of a clearing bank.

The repo specialness spread is defined as the difference between the overnight GC repo

[8]See `http://www.newyorkfed.org/tmpg/tmpg_faq_033109.pdf`

rate and the corresponding SC repo rate. This spread measures how special a security is in the repo market. Figure 1 shows the specialness spread for the 10-year on-the-run Treasury security, which, as can be seen, displays a significant amount of variation over our sample. The largest spikes usually coincide with auctions, and in particular reopenings.

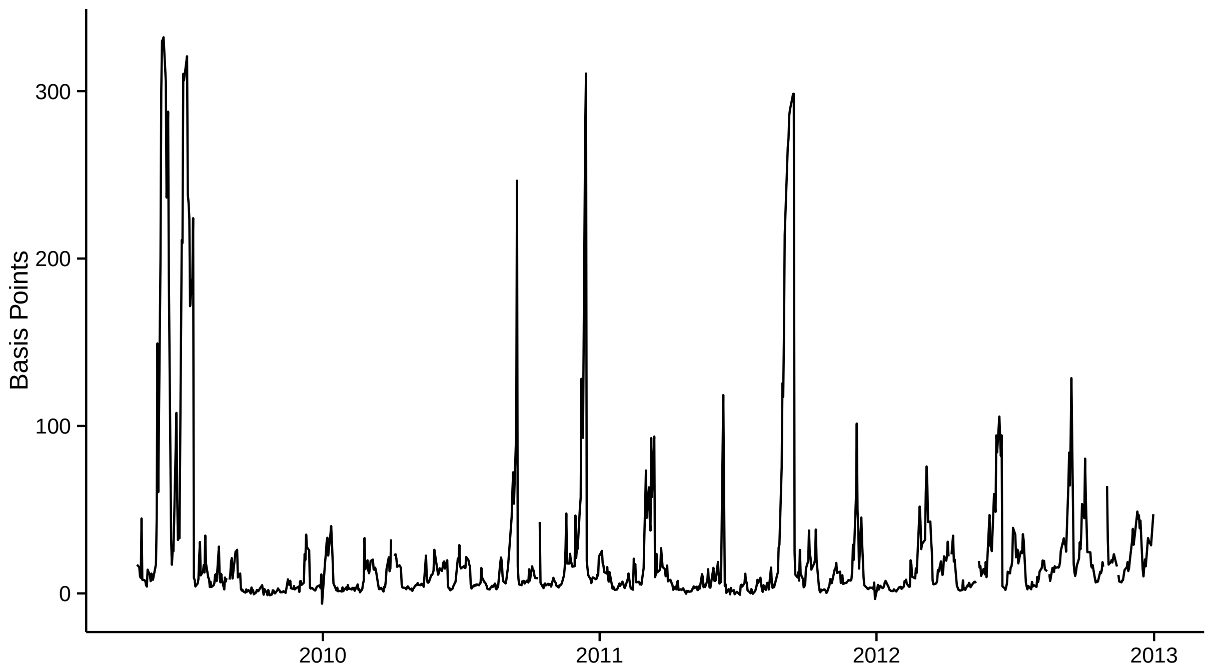

Figure 1: Repo specialness spread for the on-the-run 10-year Treasury security.

To compute this spread, we use two data sources for GC repo rates. The first source is the General Collateral Finance (GCF) Repo, which is a tri-party repo platform maintained by the subsidiary of the Depository Trust & Clearing Corporation (DTCC) called the Fixed Income Clearing Corporation (FICC).[9] This market is characterized as being primarily inter-dealer, although some commercial banks and Fannie Mae also participate. It is a fairly active market although its size is still small compared to that of the overall tri-party repo market. The second source for the Treasury GC repo rate is the daily survey of primary dealers conducted by the Federal Reserve Bank of New York. Dealers are instructed to report Treasury, agency debt, and agency MBS overnight GC repo activity with non-affiliated entities. Bartolini et al. (2011) indicate that these entities are retail customers such as money market funds. The survey does not specify the market segment in which dealers' repo transactions take place, thus the data captures tri-party, GCF and bilateral transactions.

[9]DTCC GCF rate data are publicly available at `http://www.dtcc.com/products/fi/gcfindex/`.

We conduct all of our analysis using the specialness spreads obtained with both GC repo rates[10] (however, we only report the results based on the GCF repo rates because the primary dealer survey data is restricted), and the results are very similar. This is not surprising if we think that in our panel data analysis, after controlling for time dummies, the variation is completely driven by the relative differences in the specific repo rates. This point will become clearer when, in the next section, we compare the results obtained using either changes in the SC repo rates or changes in the repo specialness spreads as the dependent variable. Overall, in this study, the use of the GC repo rate to compute the specialness spread is mainly for graphical purposes and comparisons to previous works, which are done in the robustness section.

2.2 Federal Reserve Operations

Our sample includes the period during which the Fed's LSAP, MEP, and MEP-extension programs were conducted. These programs have significantly altered the available supply and maturity composition of collateral in the Treasury repo market. Thus, some of the most relevant explanatory variables used in this study to capture changes in the available supply are the security-level daily amounts purchased and sold by the Fed under these programs, obtained from the Federal Reserve Bank of New York.[11] In our regressions, to better account for the relative scarcity of each CUSIP, we use the Fed's purchased/sold amount as percentage of the privately-held amount outstanding.[12]

Summary statistics of the Fed operations are shown in Tables 1 through 3. In our sample, the Federal Reserve has conducted 3162 purchases and 810 sales of securities across various operations, where most of the CUSIPs have been purchased or sold multiple times. The average purchase's size is \$420 million or 1.68% of the security's privately-held amount outstanding; while, the average sale's size is about \$710 million or 2.86% of the security's privately-held amount outstanding. The majority of operations were concentrated in off-the-run securities (about 96% of purchases and 98% of sales). However, the average size of on-the-run purchases is well above the average size of off-the-run purchases.

We expect the impact of a sale or purchase operation to differ between on-the-run and off-the-run securities. For example, demand for short positions, a significant driver of repo

[10]For more detail about the differences between GC repo rate and the GCF Repo see Fleming and Garbade (2003).

[11]SOMA operation and holding data by CUSIP is publicly available on the Federal Reserve Bank of New York's website, see for example `http://www.ny.frb.org/markets/pomo/display/index.cfm`.

[12]"Privately held" Treasury securities are defined here as any security not held by the Federal Reserve and is calculated by subtracting the par value held in the SOMA portfolio from the total outstanding par value, which is obtained from CRSP. Source: CRSP®, Center for Research in Security Prices, Booth School of Business, The University of Chicago. Used with permission. All rights reserved. crsp.uchicago.edu.

Table 1: Summary Statistics - Fed Operations

	Mean	Std. Dev.	N
percent_bought	1.68	2.57	3162
amt_bought	4.2e+08	7.4e+08	3162
percent_sold	2.86	4.56	810
amt_sold	7.1e+08	9.2e+08	810

Table 2: Summary Statistics - Fed Operations, On-The-Run

	Mean	Std. Dev.	N
percent_bought	7.91	6.45	127
amt_bought	2.3e+09	1.9e+09	127
percent_sold	1.24	1.37	15
amt_sold	4.2e+08	4.8e+08	15

Table 3: Summary Statistics - Fed Operations, Off-The-Run

	Mean	Std. Dev.	N
percent_bought	1.42	1.86	3035
amt_bought	3.4e+08	5.2e+08	3035
percent_sold	2.89	4.59	795
amt_sold	7.1e+08	9.3e+08	795

rates (Duffie, 1996), is usually concentrated in the most liquid securities, as short sellers value the ability to quickly buy back those securities to cover or unwind their positions (Duffie et al., 2007; Vayanos and Weill, 2008). Therefore, we expect the repo rates of on-the-run securities to be more sensitive to supply factors. For this reason, we separately estimate the effects of the Fed operations for on- and off-the-run securities, though the small number of Fed sales of on-the-run securities limits our statistical power.

By reducing the collateral available to the repo market, Fed purchases should decrease the security-specific repo rate and increase the specialness spread of the CUSIP purchased. Fed sales should have the opposite effect. However, it is important to take into account that once the purchased securities entered in the SOMA portfolio, then they became available through the Fed's Securities Lending Program (SLP), under which at noon of each business day the Fed offers to lend up to 65% of the amount of each Treasury security owned by SOMA. This program allows dealers to borrow securities on an overnight basis subject to a minimum fixed fee and per-dealer volume limitations (see Fleming and Garbade, 2007, for more details).[13] The program works through an auction mechanism to make loan pricing a market-driven process. Primary dealers bid for a loan of a security specifying the quantity and the loan fee. The minimum fee is imposed to provide an incentive to borrow securities whose special repo rates are below the GC repo rate. In our regressions, we control for individual uncovered bids at the SLP auctions, as any dealer who was not able to obtain the desired quantity at the SLP to cover their positions would then have to seek the securities in the repo market.

2.3 Auction Cycle

Keane (1995) documents that repo specialness for on-the-run securities exhibits a repeated pattern, that is, it climbs with the time since the last auction until around the announcement of the next auction (usually one week before the auction itself), after which it declines rapidly. Figures 2 and 3 show the auction cycle patterns for securities auctioned monthly (2-, 3-, 5-, and 7-year maturities) and quarterly (10- and 30- year maturities), respectively. In Figure 2, it is easy to note the same pattern documented by Keane (1995) for securities with a monthly auction cycle.

In contrast, Figure 3 shows that the quarterly auction cycle of the 10-year note looks quite different, mainly because the Treasury has introduced two regular reopenings following

[13]See http://www.newyorkfed.org/markets/sec_terms.html and http://www.newyorkfed.org/markets/sec_faq.html for details about the Securities Lending Program. Data on this program is available to the public on the Federal Reserve Bank of New York's website: http://www.newyorkfed.org/markets/securitieslending.html.

each 10-year Treasury note auction. Therefore, it is possible to observe three separate auction sub-cycles: the most dramatic run-up in specialness spread takes place before the first reopening; a second run-up, similar in shape but smaller in magnitude, immediately follows and peaks just before the second reopening; and finally, during the third sub-cycle the specialness spread is practically flat. This would suggest that the increased availability of the on-the-run security after each reopening strongly diminishes the impact of the seasonal demand for short positions around these dates (Sundaresan, 1994).

In order to control for these auction-cycle effects, we construct a set of dummy variables that track the time elapsed since issuance for both the monthly and quarterly cycles.

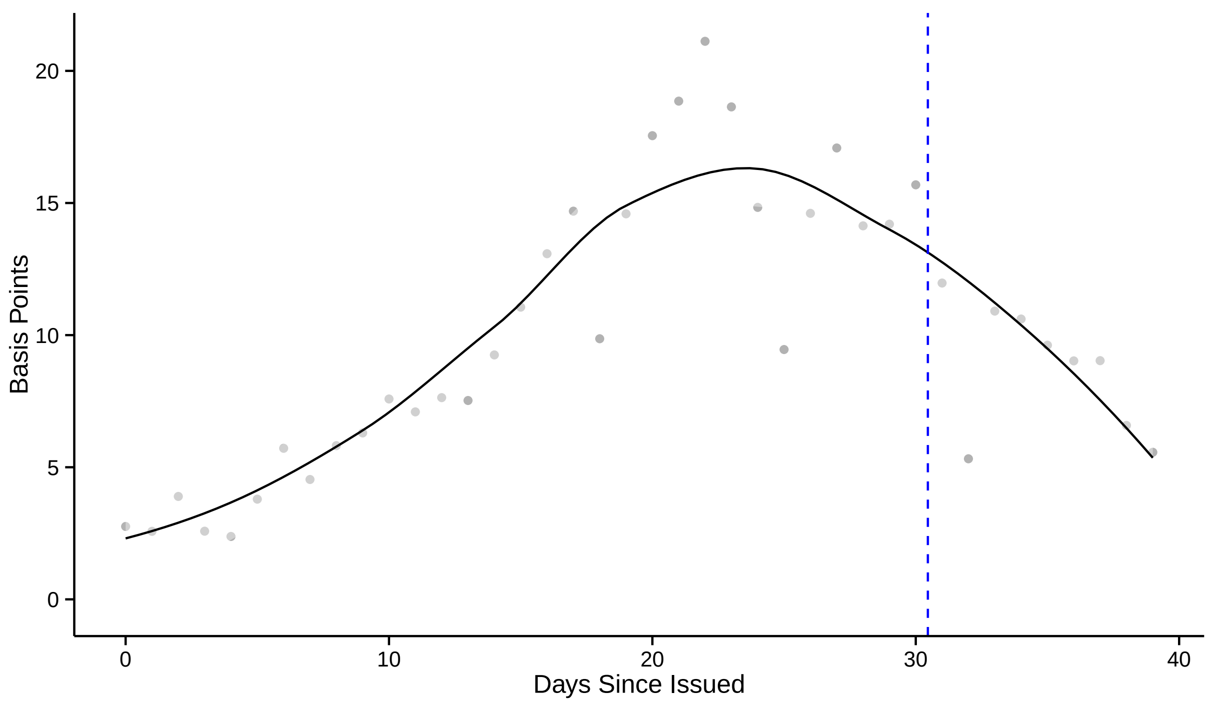

Figure 2: Average repo specialness spread for Treasury securities with a 1-month auction cycle (2-, 3-, 5-, and 7-year maturities). Grey dots are the average specialness spread on each day since the issue date, and the line is a fitted LOESS curve. The vertical blue dashed line marks the average time of the auction of the next security with the same maturity.

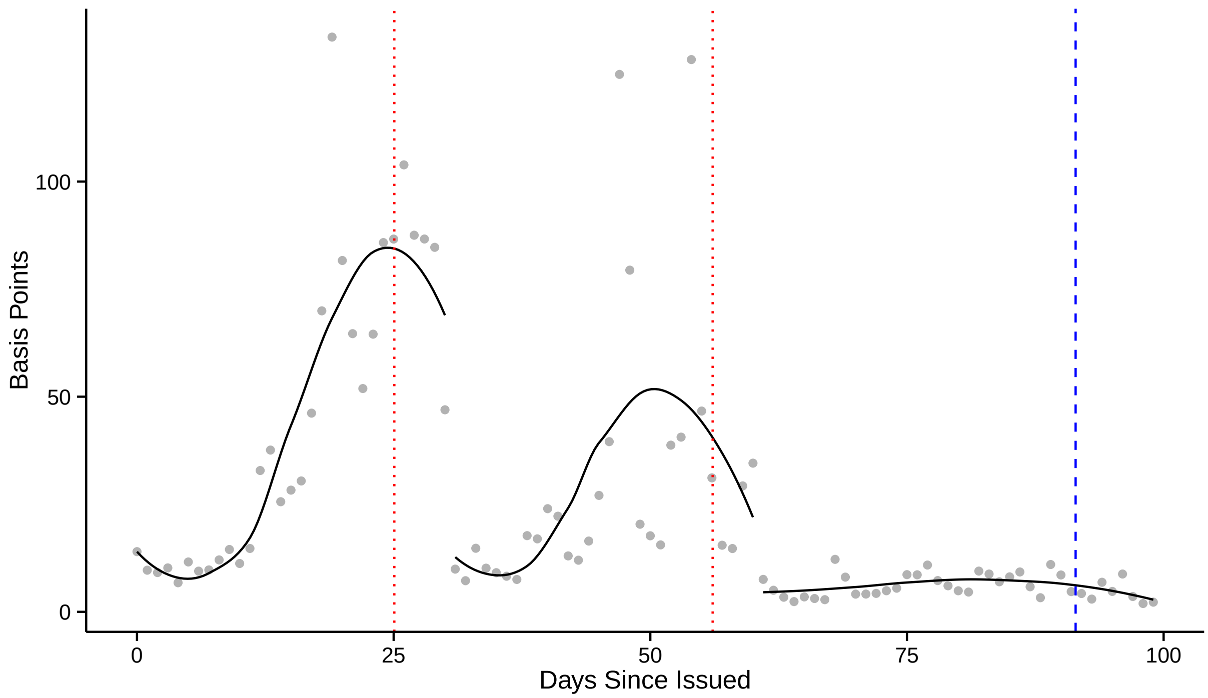

Figure 3: Average repo specialness spread for 10-year Treasury securities. Grey dots are the average specialness spread on each day since the issue date, and the line is a fitted LOESS curve. Vertical red dotted lines mark the average times of reopening auctions, while the vertical blue dashed line denotes the average time of the auction of the next security with the same maturity.

2.4 Demand for Short Positions and Other Controls

As well as quantifying changes in the available supply of collateral, we also aim to capture one of the most important demand factors in the repo market: demand for short positions. Duffie (1996), Duffie et al. (2007), and Vayanos and Weill (2008) all suggest that agents who create short positions prefer to trade securities that are expected to be liquid in the future, and often use reverse repo contracts to create these positions because they are less expensive than other options. Therefore, for a given supply of the security, the extent of specialness should be increasing in the demand for short positions. To measure daily demand for short positions at the security level, on any given day and for each CUSIP, we compute the total amount of transactions initiated as reverse repos by 10 a.m. and subtract the total amount of transactions initiated as repos over the same time interval. This imbalance, which should capture the security's excess demand, can create price pressures in the specific security and might make it run special.

Finally, since liquidity and specialness are often correlated (Duffie, 1996), especially for on-the-run securities, we explicitly control for securities' liquidity using individual bid-ask

Table 4: Summary Statistics - Operation Days

	On-The-Run		Off-The-Run		Total	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
repo_avgrate	5.54	21.9	14.2	7.48	14	8.22
delta_repo	-.188	6.83	.017	2.95	.0123	3.1
repo_spread	11.1	21.1	2.77	3.22	2.96	4.69
delta_repo_spread	.136	6.56	-.0779	2.67	-.0729	2.82
repo_volume_sprd_pct	-8.53	14.9	-.862	2.43	-1.04	3.5
bidaskspread_pct	.0433	.0118	.0345	.0153	.0347	.0153
delta_bidaskspread_pct	-.000079	.00625	-.000107	.0146	-.000106	.0144
N	2028		85293		87321	

spreads.[14] Securities with low bid-ask spreads are more liquid, therefore we expect them to have higher specialness spreads and lower repo rates.

3 Empirical Results

We now turn to the estimated impact of the security-specific supply and demand factors described in the previous section on SC repo rates and repo specialness spreads. Various empirical specifications are estimated at a daily frequency where the dependent variable is the change in either the SC repo rate or the specialness spread. Unlike previous studies, we use changes rather than levels because these variables exhibit a high degree of serial correlation.

Another important advantage of using changes in this study is that they mitigate endogeneity concerns, which are typical of exercises in which a price variable (the repo rate) is regressed on demand and supply factors. The reason why the use of changes should allow us to eliminate endogeneity is based on the time at which repo rates are collected relative to the time at which Fed operations, Treasury auctions, and SLP auctions are conducted. The SC repo rates are collected every morning from 7:30 to 10:00 a.m., while the regular Fed purchase and sale operations start at 10:15 a.m. and end at 11:00 a.m. with the announcement of the operation results. In some cases, there can be a second operation between 1:15 and 2 p.m. of the same day. The SLP auctions start at 12 p.m. and end at 12:15 p.m.; and, the

[14]Security-level bid-ask spreads are obtained from the Center for Research in Security Prices. Source: CRSP®, Center for Research in Security Prices, Booth School of Business, The University of Chicago. Used with permission. All rights reserved. crsp.uchicago.edu.

Treasury auction results for notes and bonds are also announced at 12 p.m. This sequence of events implies that only the repo rate of the following morning will reflect information from these operations. At the same time, the change in the repo rate will not be factored into the Fed's and Treasury's operational decisions, as the next day's repo rate is not observed until the following morning. Therefore, while the change in the repo rate from the morning of any given day to the next will reflect that day's operations, it will not affect the operations' implementation on the same day.

3.1 Regression Specification

The following specification is estimated using only days when Fed operations were conducted.[15] Our sample starts after the introduction of the fail charge on May 1, 2009 to avoid a structural break in the series.[16] However, due to data availability, specifications that include information on whether transactions were initiated as repos or reverse repos are estimated on a slightly shorter sample starting on June 23, 2009.

Our basic panel regression specification is:

$$\Delta SCR_{i,t} = \alpha + \beta_1 SF_{i,t} + \beta_2 DF_{i,t} + \beta_3 L_{i,t} + \beta_4 D_{i,t} + \gamma_t + \epsilon_{i,t} \quad (1)$$

where for each security i at time t, ΔSCR is the change in the SC repo rate in basis points; SF represents supply factors such as amount purchased and sold at each Fed operation rescaled by the security's privately-held amount outstanding; DF represents demand factors such as our proxy for short positions rescaled by the security's privately-held amount outstanding and the amount of uncovered bids at the SLP auctions; L are controls for the liquidity characteristics such as the change in the bid-ask spread, maturity and maturity squared; D are dummies that control for the auction cycle that we have discussed in the previous section; and γ_t are daily time dummies that control for the evolution over time of common market-wide factors. Indeed, they should completely absorb the variation in specialness spreads due to the variation in the GC repo rate, which summarizes the overall trading conditions in the repo market.

In addition, some variables are interacted with a dummy that divides the sample into two mutually exclusive subsamples: on-the-run vs. off-the-run securities. Finally, because Fed operations settle on the following day, we also use the two-day changes in the SC repo rate and specialness spread as dependent variables in our regressions. The rationale is that

[15] However, we obtain very similar results if we use all days in the sample.

[16] Fleming et al. (2012) show that the introduction of fails charge triggered striking changes in willingness to receive negative interest rates on cash pledged to secure borrowing of certain securities.

the impact of these operations might not be felt until the day in which the investors have to actually deliver or receive the security to or from the Fed.

3.2 Results

The results from the SC repo rate panel regression estimated starting on May 1, 2009 are reported in the first column of Table 5, while the second column shows the results for the two-day change in the same dependent variable.[17] Both on- and off-the-run Fed purchases have negative and statistically significant effects on SC repo rates, although the effect of on-the-run purchases appears to be considerably larger. The coefficient of -0.234 suggests that buying one percent of a security's outstanding par value would decrease the SC repo rate by 0.234 basis points, implying that on average a $1 billion purchase of on-the-run securities would decrease the SC repo rate by 0.75 basis points. In contrast, the coefficient for the off-the-run securities implies a decline of 0.35 basis points for a purchase of the same size. This suggests the existence of a scarcity effect, as a reduction in the available supply of a specific security would push its repo rate down, indicating that on average investors would be willing to loan money at lower rates to obtain that specific security. And owners of those specific securities would have access to financing at a more attractive rate.

The coefficients for the same variables in the second column are slightly larger, suggesting that on the settlement day the impact from these operations not only persists but even increases. The impact of Fed sales is positive and significant only for the off-the-run securities, which is not surprising given the small number (15) of on-the-run sales in our sample. The coefficient of 0.048 suggests that selling one percent of a security's outstanding would increase the SC repo rate by 0.048 basis points, implying that a $1 billion sale would increase the SC repo rate by 0.2 basis points. The cumulative impact is again slightly bigger on the settlement day. None of the other variables shown, except for maturity, are statistically significant.

The results from the same specification but augmented with the proxy for short positions and therefore estimated starting on June 23, 2009 are reported in Table 6. The demand for short positions has a negative and statistically significant impact on SC repo rates, although the coefficient's size is much smaller than that one of the Fed purchases. In this case, the split in on- and off-the-run securities (not shown) does not affect its magnitude. Since all the other coefficients remain practically unchanged when estimated in this slightly shorter sample period, for the remainder of this section we focus only on the results obtained using this sample.

[17] For brevity, we do not show the coefficients for the time and auction cycle dummies.

Table 5: Specific Repo Rate Regressions, from May

	(1) d_repo	(2) d2_repo
percent_bought_offtherun	-0.0792***	-0.103***
	(-6.50)	(-6.63)
percent_sold_offtherun	0.0480***	0.0542***
	(3.90)	(5.33)
percent_bought_ontherun	-0.234***	-0.281***
	(-5.09)	(-4.23)
percent_sold_ontherun	-0.153	-0.305
	(-0.37)	(-0.46)
SLP_pct_uncovered_off	-0.00302	0.00498
	(-0.94)	(1.34)
SLP_pct_uncovered_on	-0.0115	0.0642
	(-0.34)	(1.63)
delta_bidaskspread_pct	0.149	0.675
	(0.49)	(1.68)
maturity	0.0175***	0.0190***
	(3.86)	(3.45)
maturity2	-0.00123***	-0.00132**
	(-3.63)	(-3.28)
N	89614	88821
R^2	0.730	0.729
adj. R^2	0.729	0.728

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Specific Repo Rate Regressions

	(1) d_repo_spread	(2) d2_repo_spread
percent_bought_offtherun	-0.0850***	-0.107***
	(-6.58)	(-6.44)
percent_sold_offtherun	0.0485***	0.0547***
	(3.92)	(5.38)
percent_bought_ontherun	-0.220***	-0.266***
	(-4.38)	(-3.63)
percent_sold_ontherun	-0.202	-0.156
	(-0.50)	(-0.27)
SLP_pct_uncovered_off	-0.00322	0.00480
	(-1.00)	(1.29)
SLP_pct_uncovered_on	-0.00780	0.0467
	(-0.22)	(1.22)
repo_volume_sprd_pct	-0.0193**	-0.0111
	(-2.85)	(-1.13)
delta_bidaskspread_pct	0.139	0.754
	(0.45)	(1.94)
maturity	0.0116*	0.0155**
	(2.47)	(2.65)
maturity2	-0.000827*	-0.00110**
	(-2.39)	(-2.61)
N	87337	86551
R^2	0.735	0.737
adj. R^2	0.734	0.736

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Specific Repo Rate Regressions, 1-day Change

	(1) 0-3 Years	(2) 3-7 Years	(3) 7-15 Years
percent_bought_offtherun	-0.138**	-0.0700***	-0.0796***
	(-3.26)	(-3.45)	(-3.61)
percent_sold_offtherun	0.0456***		
	(3.70)		
percent_bought_ontherun	-0.549***	-0.0921**	-0.439
	(-3.94)	(-2.90)	(-0.99)
percent_sold_ontherun	-0.334		
	(-0.70)		
SLP_pct_uncovered_off	-0.00408*	0.00876	0.00526
	(-2.11)	(0.13)	(0.39)
SLP_pct_uncovered_on	-0.00268	-0.127	0.00605
	(-0.06)	(-1.15)	(0.11)
repo_volume_sprd_pct	-0.0203*	-0.0211*	-0.00890
	(-2.05)	(-2.37)	(-0.48)
delta_bidaskspread_pct	0.310	-0.209	-0.189
	(0.71)	(-0.41)	(-0.18)
maturity	0.0888**	-0.00804	-0.0120
	(2.78)	(-0.09)	(-0.17)
maturity2	-0.0180*	0.00102	0.000508
	(-2.03)	(0.11)	(0.16)
N	45886	30194	11257
R^2	0.766	0.749	0.641
adj. R^2	0.763	0.745	0.625

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Specific Repo Rate Regressions, 2-day Change

	(1) 0-3 Years	(2) 3-7 Years	(3) 7-15 Years
percent_bought_offtherun	-0.214***	-0.0846***	-0.0877***
	(-3.56)	(-3.53)	(-3.54)
percent_sold_offtherun	0.0530***		
	(5.12)		
percent_bought_ontherun	-0.614**	-0.109*	0.269
	(-3.02)	(-2.02)	(0.60)
percent_sold_ontherun	-0.394		
	(-0.57)		
SLP_pct_uncovered_off	-0.000299	0.102	0.0153
	(-0.10)	(1.87)	(0.78)
SLP_pct_uncovered_on	0.0652	0.0511	0.0290
	(1.33)	(0.56)	(0.43)
repo_volume_sprd_pct	-0.0274	-0.0275*	0.0524
	(-1.62)	(-2.38)	(1.96)
delta_bidaskspread_pct	0.894	0.0665	0.307
	(1.70)	(0.10)	(0.23)
maturity	0.135***	0.0582	0.228*
	(3.52)	(0.45)	(2.41)
maturity2	-0.0272*	-0.00574	-0.0101*
	(-2.42)	(-0.45)	(-2.40)
N	45474	29963	11114
R^2	0.775	0.745	0.649
adj. R^2	0.773	0.741	0.634

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We next break our data into three subsamples based on the securities' maturity. In particular, we consider possible differences between securities with shorter maturities that were eligible for both sale and purchase operations conducted by the Fed (during the MEP the Fed sold only securities maturing in 3 years or less), those with medium-term maturities (3 to 7 years), and securities with longer maturities (7 to 15 years). Table 7 presents the results for these subsamples. The coefficients for on- and off-the-run Fed purchases are both significantly larger for shorter-term securities, implying an average effect of -2.0 and -0.6 basis points per billion dollars, respectively. Again, the strong economic and statistical significance of these results confirm the existence of scarcity effects.

Further, in the case of shorter-term securities, the coefficient on off-the-run uncovered bids at the SLP is negative and significant, suggesting that if the investors were unable to obtain the desired quantity of a specific security at the SLP, then on average they were willing to loan money in the repo market at a relatively lower rate in exchange of that particular security. Table 8 shows results from the same regressions but using the two-day change in the SC repo rate. Similarly to before, on the settlement day the magnitude of all the significant coefficients is a bit bigger.

The next four tables, Tables 9 through 12, report the results for the same set of regressions presented in the previous 4 tables with the exception that now the dependent variable is the change in the repo specialness spread. As discussed earlier, since we are using time dummies, it is only the variation in the specific repo rates that drive our estimates, which are extremely similar to the previous regressions except for the flipped sign. This is because any factor that pushes the SC repo rate down will push the corresponding specialness spread up, and vice versa.

Table 9: Repo Spread Regressions, from May

	(1) d_repo_spread	(2) d2_repo_spread
percent_bought_offtherun	0.0796***	0.103***
	(6.55)	(6.64)
percent_sold_offtherun	-0.0480***	-0.0545***
	(-3.90)	(-5.36)
percent_bought_ontherun	0.234***	0.260***
	(5.09)	(4.14)
percent_sold_ontherun	0.253	0.310
	(0.63)	(0.50)
SLP_pct_uncovered_off	0.00304	-0.00502
	(0.95)	(-1.35)
SLP_pct_uncovered_on	-0.000852	-0.0579
	(-0.02)	(-1.48)
delta_bidaskspread_pct	-0.142	-0.628
	(-0.46)	(-1.63)
maturity	-0.0159***	-0.0185***
	(-3.57)	(-3.36)
maturity2	0.00111***	0.00130**
	(3.33)	(3.22)
N	89598	88815
R^2	0.678	0.657
adj. R^2	0.676	0.655

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: Repo Spread Regressions

	(1) d_repo_spread	(2) d2_repo_spread
percent_bought_offtherun	0.0854***	0.107***
	(6.64)	(6.44)
percent_sold_offtherun	-0.0484***	-0.0550***
	(-3.92)	(-5.42)
percent_bought_ontherun	0.220***	0.234***
	(4.39)	(3.42)
percent_sold_ontherun	0.303	0.171
	(0.76)	(0.31)
SLP_pct_uncovered_off	0.00324	-0.00481
	(1.01)	(-1.30)
SLP_pct_uncovered_on	-0.00488	-0.0403
	(-0.13)	(-1.06)
repo_volume_sprd_pct	0.0183**	0.0165
	(2.82)	(1.72)
delta_bidaskspread_pct	-0.130	-0.706
	(-0.42)	(-1.90)
maturity	-0.0102*	-0.0138*
	(-2.20)	(-2.36)
maturity2	0.000718*	0.00100*
	(2.10)	(2.39)
N	87321	86546
R^2	0.686	0.668
adj. R^2	0.684	0.666

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: Repo Spread Regressions, 1-day Change

	(1) 0-3 Years	(2) 3-7 Years	(3) 7-15 Years
percent_bought_offtherun	0.137**	0.0714***	0.0796***
	(3.24)	(3.53)	(3.61)
percent_sold_offtherun	-0.0457***		
	(-3.71)		
percent_bought_ontherun	0.549***	0.0882**	0.438
	(3.94)	(2.78)	(0.99)
percent_sold_ontherun	0.336		
	(0.71)		
SLP_pct_uncovered_off	0.00408*	-0.00893	-0.00526
	(2.12)	(-0.13)	(-0.39)
SLP_pct_uncovered_on	0.00274	-0.0315	-0.00606
	(0.06)	(-0.21)	(-0.11)
repo_volume_sprd_pct	0.0203*	0.0191*	0.00870
	(2.05)	(2.42)	(0.47)
delta_bidaskspread_pct	-0.289	0.215	0.187
	(-0.66)	(0.42)	(0.18)
maturity	-0.0844**	0.0488	0.0120
	(-2.69)	(0.53)	(0.17)
maturity2	0.0176*	-0.00503	-0.000513
	(2.03)	(-0.57)	(-0.16)
N	45878	30189	11254
R^2	0.729	0.691	0.579
adj. R^2	0.726	0.686	0.560

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12: Repo Spread Regressions, 2-day Change

	(1) 0-3 Years	(2) 3-7 Years	(3) 7-15 Years
percent_bought_offtherun	0.216***	0.0853***	0.0894***
	(3.60)	(3.56)	(3.63)
percent_sold_offtherun	-0.0531***		
	(-5.14)		
percent_bought_ontherun	0.525**	0.105*	-0.210
	(2.87)	(1.97)	(-0.47)
percent_sold_ontherun	0.447		
	(0.66)		
SLP_pct_uncovered_off	0.000289	-0.102	-0.0152
	(0.10)	(-1.87)	(-0.79)
SLP_pct_uncovered_on	-0.0633	-0.0498	-0.0160
	(-1.30)	(-0.55)	(-0.24)
repo_volume_sprd_pct	0.0337	0.0254*	-0.0328
	(1.79)	(2.04)	(-1.50)
delta_bidaskspread_pct	-0.957	0.167	-0.473
	(-1.83)	(0.27)	(-0.37)
maturity	-0.148***	-0.0384	-0.214*
	(-3.77)	(-0.30)	(-2.29)
maturity2	0.0314**	0.00358	0.00939*
	(2.76)	(0.29)	(2.28)
N	45472	29962	11112
R^2	0.712	0.661	0.603
adj. R^2	0.709	0.656	0.585

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

3.3 Persistency

In addition to looking at the immediate impact of the security-specific demand and supply factors on SC repo rates, we also investigate their dynamic effects. Because the Fed's purchased and sold amounts can be perceived by the market participants as a long lasting reduction or increase in a security's available supply (conditional on their expectations about the time and implementation of the potential unwinding of the Fed balance sheet expansion), and because SC repo contracts rule out the possibility of delivering a close substitute security, we would expect these effects to be quite persistent.

To test this hypothesis, Figure 4 shows, for the change in the SC repo rates, the cumulative response to the Fed off-the-run purchases in the N-day period following the purchases ($N = 1, \ldots, 100$) and the corresponding 99% confidence interval.[18] In the dynamic specification, in addition to the variables used in the baseline regressions (see Section 3.1), we also control for any future purchases that took place over the N-day time period. It can be seen that the effect is quite persistent, as it converges toward zero very slowly and stays significant for over a month. We repeat the same exercise for the coefficient on the amount sold at Fed operations. As shown in Figure 5 the effect is less persistent for sales, as it remains significant for about 10 business days.

Indeed, analysis of the cumulative SC repo rate changes on subsequent days, summarized by the estimated impulse responses for the coefficient on the Fed's purchases and sales, confirms the existence of a significant scarcity premium for high-quality collateral that does not seem to dissipate fast, at least in our sample. It certainly persists longer than the flow effects of the Fed's first LSAP in the Treasury cash market estimated by D'Amico and King (2013). These can be due to the security-specific nature of a repo contract.

[18] The small sample size for the on-the-run securities limits our ability to test for dynamic effects.

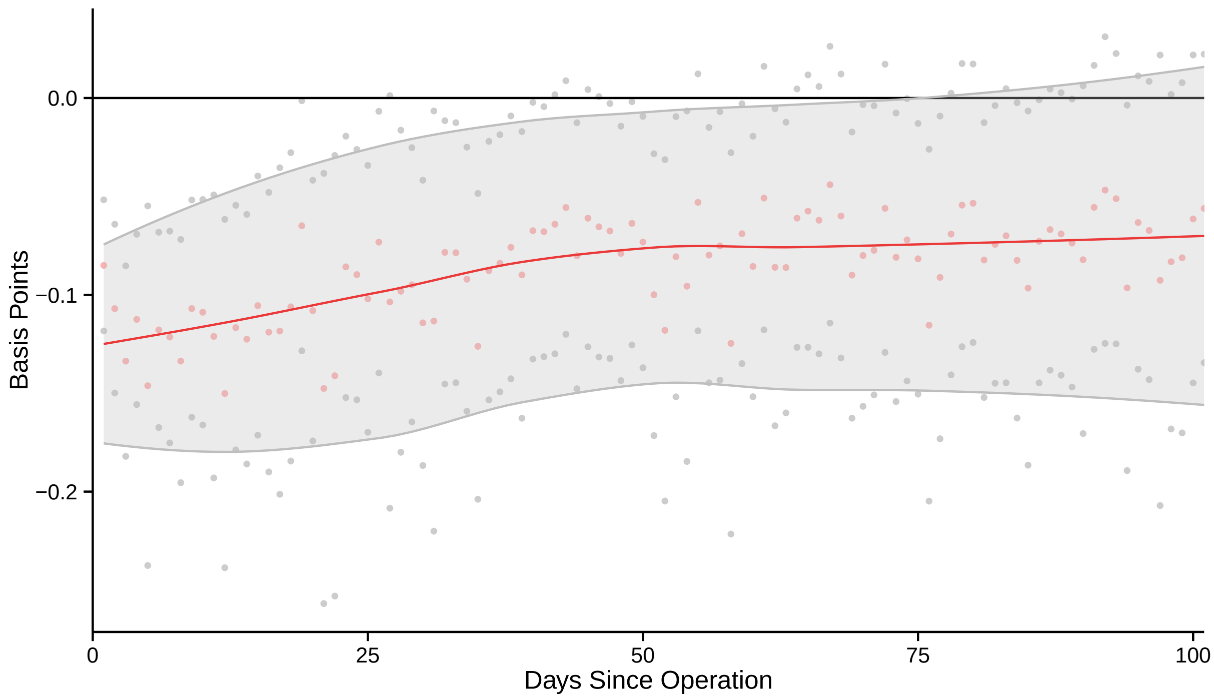

Figure 4: Coefficients on the percent bought by the Fed from regressions using, as the dependent variable, cumulative changes in the SC repo rate over the N-day period following each operation. Red points indicate the estimated effect for each period. Grey points indicate the 99% confidence interval for each of those regressions. Red and grey lines are fitted LOESS curves.

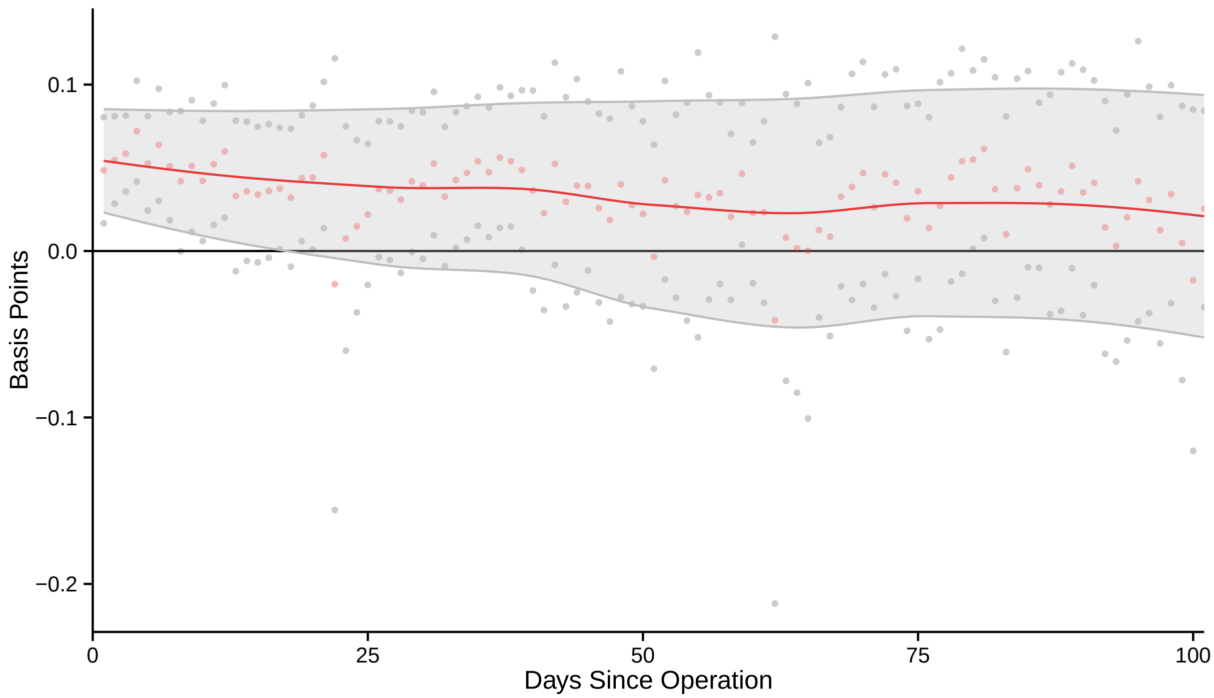

Figure 5: Coefficients on the percent sold by the Fed from regressions using, as the dependent variable, cumulative changes in the SC repo rate over the N-day period following each operation. Red points indicate the estimated effect for each period. Grey points indicate the 99% confidence interval for each of those regressions. Red and grey lines are fitted LOESS curves.

3.4 Cash Market Effects

In light of the recent literature's findings that even perfectly anticipated changes in supply could have effects on Treasury cash prices when they occur (as shown by Lou et al., 2013, for Treasury auctions and D'Amico and King, 2013, for the Fed's asset purchase programs), and given the existence of well-documented links between securities' price premiums in the cash market and specialness spreads in the repo market (Duffie, 1996; Jordan and Jordan, 1997; Buraschi and Menini, 2002), it is natural to hypothesize that some of the LSAPs' price effects in the cash market might reflect the changes in repo specialness spreads due to the Fed operations that we estimate in this study. In this section, we attempt to test this conjecture.

We begin by showing that, in our sample, a specific Treasury bond's cash price premium (relative to securities with the same coupon and maturity) indeed reflects the extent of specialness measured by the size of its repo specialness spreads, and that this relation also becomes stronger on the days of Fed purchase/sale operations. Since we already showed that the Fed's asset purchases are associated with higher repo specialness spreads and that these effects are quite persistent, the above relation to the cash price premium provides some support for our hypothesis that one channel through which LSAPs affect Treasury prices (on the days of the actual operations) could be by impacting the scarcity value of Treasury collateral in the repo market. This can also help explain why purchase/sale operations that were announced in advance, and whose total size and eligible securities were fairly predictable, might still trigger statistically significant responses in bond prices, known as pace- or flow-effects.

In particular, table 13 shows results of a panel regression, motivated by the work of Jordan and Jordan (1997), in which levels of the securities' cash price premiums are regressed on their repo specialness spreads, while controlling also for liquidity differentials through the bid-ask spread, on-the-run dummy, and maturity squared. As a measure of a specific security's price premium in the cash market over generic securities with similar maturities, we use the deviation of its observed yield from the yield implied by a smooth curve fitted to all outstanding off-the-run securities and based on the functional form proposed by Svensson (1994). A higher spread implies that a security is more expensive than the curve would predict, and therefore is embodying a premium related to its specific characteristics, such as liquidity and repo financing advantages. As shown in the first column, running this regression in the full sample produces a positive and significant coefficient on the specialness spread.[19] Further, this coefficient becomes larger if we restrict the sample to the days of Fed

[19]In our regressions, we discard observations for which the cash price premium exceeded 50 basis points in absolute value. This threshold choice seems reasonable, since the 1% and 99% percentiles of price premium

operations, shown in the second column.

Table 13: Cash Market Premium, Levels

	(1) All Days	(2) Operations
repo_spread	0.0540***	0.0687***
	(30.66)	(27.81)
bidaskspread	0.106***	0.103***
	(14.18)	(10.77)
ontherun	1.641***	1.102***
	(23.74)	(11.62)
maturity2	0.220***	0.240***
	(107.62)	(79.04)
N	170734	92324
R^2	0.268	0.248
adj. R^2	0.262	0.242

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In addition, when we try to quantify the pass-through of the collateral scarcity value estimated in our baseline regression (summarized in Table 5) to the cash market prices, using only the change in the specialness spread explained by the amount purchased and sold by the Fed, we find that a one basis point increase in the predicted repo specialness spread translates on average into a cash price premium of 0.1 basis points. In other words, Fed asset purchase program not only affect Treasury security prices directly though the stock effect, but also indirectly by increasing the scarcity value of the Treasury collateral in the repo market, which in turn increases the current and future specialness of a security and is discounted in the cash market resulting in a higher price premium for relatively scarcer securities.

4 Comparisons to Other Studies

4.1 Treasury Auction-Level Regressions

Similar to Jordan and Jordan (1997), we also run regressions at Treasury-auction frequency to examine the impact of issued amounts and demand at auctions on future specialness spreads. In particular, they show that both the auction tightness and the distribution of

measures are about -16 bps and 22 bps, respectively, while their 0.1% and 99.99% percentiles are -116 and 44 basis points, respectively.

ownership of the issue have significant effects on on-the-run specialness spreads and that these effects can last as long as four weeks after the auction.

Again, we omit the 30-year Treasury auctions because long-term treasuries are rarely traded on the repo market. This leaves us with 257 Treasury auctions (including reopenings) from May 1, 2009 to Dec 31, 2012. The data on Treasury auctions are from the Treasury Direct website.[20] For each auction in our sample, we construct the average specialness spread in the jth week ($j = 1, 2, 3, 4$) after the security is issued and the average for the month after issuance.

To measure an unexpectedly large demand for the auctioned security, we use the spread between the 1 p.m. when-issued (WI) rate and the yield at the auction. The WI market is a forward market in which trading begins approximately two weeks before the security's auction and contracts are settled when the security is issued. As Duffie (1996) notes, short positions created in this market are often covered with securities obtained at the auction. An auction yield lower than the prevailing WI rate indicates an unexpectedly strong demand at the auction. Short-sellers unable to cover their positions at the auction will turn to the cash or repo markets, which can potentially push SC repo rates lower and specialness spreads higher. Previous studies have used the bid-to-cover ratio, which is defined as the total dollar amount of received bids divided by the total dollar amount of accepted bids. It does not, however, necessarily measure the unexpected auction tightness. Instead, since the 1 p.m. WI rate is a reliable measure of the rate expected to prevail at the auction, the spread between the WI rate and the auction yield better captures the unexpected component of the auction demand.

Duffie (1996) also notes that some institutional investors are unable or reluctant to lend their securities in the repo market (e.g., insurance companies, pension funds, and foreign central banks), while other investors like dealers and brokers are major participants in the repo market and routinely use it to finance their positions. Therefore, similarly to Jordan and Jordan (1997), we expect a high fraction of issuance awarded to dealers to be readily available as collateral in the repo market, though this supply may decrease over time as dealers sell their inventories to clients and no longer need repo financing.

In contrast, foreign official investors usually buy and hold their securities and are often legally prohibited from supplying them as collateral to the repo market. In recent years, many foreign governments and central banks, particularly those with elevated current accounts surpluses, have held substantial international reserves in the form of Treasuries. Foreign holdings of U.S. Treasury securities amount to about $5.5 trillion, roughly half of the total

[20]See http://www.treasurydirect.gov/RI/OFGateway. When-issued rate data is obtained from Tradeweb.

marketable Treasury debt. This suggests that a significantly smaller portion of Treasury collateral is available to more active investors in the repo market, such as dealers.

Using auction allotment data obtained from the Treasury, we control for the security's share awarded to dealers and foreign investors in our regressions.[21] Securities with larger fractions awarded to dealers, are expected to have lower specialness spreads as they are more readily available in the repo market, while the opposite is expected for securities with larger fractions awarded to foreign participants.

Similarly to Graveline and McBrady (2011), we also include the amount issued at each auction, as larger issues should be in greater supply in the repo market. Finally, we include dummies for auctions of each maturity in our sample (2-, 3-, 5-, 7-, and 10-year) and a dummy variable that tracks if the auction is a reopening. Summary statistics for our dependent variables are shown in Table 14.

Table 14: Summary Statistics - Treasury Auctions

	Mean	Std. Dev.
foreign_pct	22	10.4
dealer_pct	53.2	9.57
amt_issued	3.0e+10	9.3e+09
whenissued_spread	-4.63	1.94
N	257	

Regression results for the average specialness spread are presented in Table 15. The first column shows the results for the first week after issuance. The coefficients on the dealer and foreign allotment percentages are significant and have the expected signs, with higher dealer allotments resulting in lower specialness and larger foreign allotments resulting in higher specialness. Further, in week four the foreign allotment's effect size quadruples, suggesting that when the demand for on-the-run securities is already high due to the auction cycle (which is discussed in Section 2.3), then this type of supply constraint magnify the rise in repo specials. The effect of the amount issued is negative and significant, and persists throughout the inter-auction period, with much larger effect sizes in weeks three and four. In contrast, the coefficient on the spread between the WI rate and the auction yield is negative but not statistically significant.

[21] Investor class auction allotment data is available at `http://www.treasury.gov/resource-center/data-chart-center/Pages/investor_class_auction.aspx`. "Dealers and brokers" includes primary dealers, dealer departments at commercial banks, and other non-bank dealers and brokers. "Foreign investors" includes private foreign investors, foreign central banks, and other non-private foreign entities.

Table 15: Treasury Auctions: Average Specialness Spread by Week

	(1) Week 1	(2) Week 2	(3) Week 3	(4) Week 4	(5) Total
dealer_pct	-0.0949^{+}	-0.0723	0.137	0.296	0.0840
	(-1.81)	(-0.81)	(0.56)	(1.11)	(0.58)
foreign_pct	0.139*	0.132	0.140	0.579*	0.252^{+}
	(2.20)	(1.10)	(0.59)	(2.09)	(1.71)
amt_issued	-3.85e-10**	-3.48e-10^{+}	-1.04e-09^{+}	-1.76e-09*	-8.52e-10*
	(-2.95)	(-1.65)	(-1.78)	(-2.51)	(-2.42)
WI_auction_spread	-0.255	-0.437	-2.071	-2.420	-1.302
	(-1.13)	(-0.78)	(-1.28)	(-1.62)	(-1.52)
dummy_reopening	-2.393*	-3.663	-16.85^{+}	-39.87**	-16.67**
	(-2.19)	(-1.58)	(-1.74)	(-3.12)	(-2.79)
N	257	257	257	257	257
R^2	0.262	0.153	0.136	0.205	0.201
adj. R^2	0.232	0.119	0.101	0.173	0.168

Heteroskedasticity-consistent t statistics in parentheses
$^{+}$ $p < .10$, * $p < .05$, ** $p < .01$

We largely confirm the conclusions of Jordan and Jordan (1997) regarding the effects of Treasury auction characteristics on repo specialness. Our results also provide support for Duffie's conjecture that repo specialness should exhibit a non-linear behavior due to the determination of its equilibrium value (see Figures 2 and 3 in Duffie, 1996). When collateral supply exceeds its demand, the normal situation, small supply shifts should not affect specialness, which remains in a corner solution close to zero. However, during periods of excess demand, such as at the peak of the auction cycle (week four), we expect supply shifts to have large and significant impacts. Consistent with this theory, we find that the estimated effects of foreign allotments and amounts issued are much stronger during the third and fourth weeks after issuance, when securities are usually on special due to the Treasury auction cycle.

4.2 On-The-Run Regressions

We also estimate a set of regression specifications similar to those presented in Graveline and McBrady (2011), where the panel consists only of on-the-run Treasuries. Following their empirical analysis, we do not use time-fixed effects and instead include aggregate demand factors, but we augment those specifications with our security-specific demand and supply factors.

We control for mortgage-convexity hedging demand, as when mortgage refinancing activity increases, to offset the decline in duration, portfolio managers typically buy Treasuries, which can lead to higher demand for repos (if those positions need to be financed) and/or lower demand for reverse repos (if demand for long positions increases). As a result, the SC repo rate should increase and the specialness decrease. Similarly, flight-to-quality episodes are generally associated with larger demand for long rather than short positions in the most liquid Treasuries and therefore should be associated with lower specialness (Moulton, 2004). To proxy these two sources of demand, we use the volume index of mortgage refinancing applications from MBA/Haver Analytics and the S&P500 implied volatility index (VIX) from Wall Street Journal/HaverAnalytics, respectively. Alternatively, we also include the change in the spread between 3-month commercial paper and Treasury bills rates to capture asset demand from investors placing an extra value on liquid and safe assets.

We also control for the bid-to-cover ratios at Fed purchase or sale operations. These are not security-specific, but instead track the characteristics of the entire operation, which usually involve multiple securities. Thus, they should proxy for overall demand for Treasury securities by primary dealers, as they are the only investors allowed to bid at these operations. When overall demand is high, there will be fewer bids at Fed purchase operations resulting in lower bid-to-cover ratios, while there would be a larger amount of bids at sale operations resulting in higher bid-to-cover ratios. Excess demand should translate into higher specialness spreads, so we expect the coefficients on the bid-to-cover ratio to be negative at purchase operations and to be positive at sale operations.

Table 16 presents regressions of one- and two-day changes in specialness spreads of on-the-run securities on our security-specific demand and supply factors and the above mentioned aggregate variables.

As expected, the change in the mortgage refinancing application index displays a negative and significant coefficient, suggesting that when mortgage refinancing activity increases, net demand for short positions decreases leading to lower specialness spreads. The coefficients for the bid-to-cover ratios at Fed operations are in the expected directions and mostly statistically significant. As for the spread between commercial paper and T-bill rates, differently from Graveline and McBrady (2011), the estimated coefficient is not statistically significant. More importantly, these results confirm the importance of the security-specific supply factors even when we control for various aggregate proxies used in previous studies, as indicated by the positive and statistical significant coefficient on the amount purchased at Fed operations. Finally, similarly to the baseline regressions described in Section 3, the coefficient on the amount sold is not significant due to the very low number of Fed sales concentrated in on-the-run securities.

Table 16: On-The-Run Securities

	(1) d_repo_spread	(2) d2_repo_spread
percent_bought	0.360***	0.325***
	(3.69)	(3.85)
percent_sold	-0.305	-0.343
	(-0.48)	(-0.42)
SLP_pct_uncovered	0.0582	-0.0301
	(1.61)	(-0.52)
repo_volume_sprd_pct	-0.00540	0.00400
	(-0.35)	(0.17)
delta_bidaskspread_pct	11.49	24.08
	(0.45)	(0.60)
soma_bidcover_purc	-0.140**	-0.135*
	(-2.70)	(-2.14)
soma_bidcover_sale	0.120*	0.108
	(2.13)	(1.48)
delta_mortgage_refiapp_pct	-0.0728***	-0.129***
	(-4.13)	(-4.74)
delta_cp_tbill_spread	-0.0518	-0.137
	(-0.79)	(-1.41)
N	4110	4106
R^2	0.058	0.084
adj. R^2	0.043	0.069

Heteroskedasticity-consistent t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5 Conclusion

In this study we show that security-specific demand and supply factors affect the scarcity value of Treasury collateral in the special repo market. To the extent that such scarcity value is reflected in the cash market prices, our demand and supply factors will also affect prices of Treasury securities. As such, our results further corroborate previous evidence on the existence of flow- and local-supply effects of the Federal Reserve's asset purchase programs (D'Amico and King, 2013; Cahill et al., 2013, among others). Our findings also suggest that one of the mechanisms behind the flow-effects could be the change in the relative scarcity value of the purchased securities used as collateral in the repo market. More generally, we contribute to the literature by studying the price impact of expected and unexpected changes in the demand and supply of Treasury securities in the "special" repo market, which is particularly well-suited for such an exercise.

References

Adrian, T., Begalle, B., Copeland, A., and Martin, A. (2011). Repo and securities lending. Staff Report 529, Federal Reserve Bank of New York. Retrieved from http://www.nyfedeconomists.org/research/staff_reports/sr529.pdf.

Ajello, A., Benzoni, L., and Chyruk, O. (2012). No-arbitrage restrictions and the U.S. Treasury market. *Economic Perspectives*, 36(2):55–74. Federal Reserve Bank of Chicago.

Bartolini, L., Hilton, S., Sundaresan, S., and Tonetti, C. (2011). Collateral values by asset class: Evidence from primary securities dealers. *Review of Financial Studies*, 24(1):248–278.

Buraschi, A. and Menini, D. (2002). Liquidity risk and specialness. *Journal of Financial Economics*, 64:243–284.

Cahill, M. E., D'Amico, S., Li, C., and Sears, J. S. (2013). Duration risk versus local supply channel in Treasury yields: Evidence from the Federal Reserve's asset purchase announcements. Working Paper 35, Finance and Economics Discussion Series, Board of Governors of the Federal Reserve System.

Cherian, J. A., Jacquier, E., and Jarrow, R. A. (2004). A model of the convenience yields in on-the-run Treasuries. *Review of Derivatives Research*, 7:79–97.

Committee on the Global Financial System (May 2013). Asset encumbrance, financial reform and the demand for collateral assets. *CGFS Papers*, 49.

D'Amico, S., English, W., López-Salido, D., and Nelson, E. (2012). The Federal Reserve's large-scale asset purchase programmes: Rationale and effects. *The Economic Journal*, 122:415–446.

D'Amico, S. and King, T. B. (2013). Flow and stock effects of large-scale Treasury purchases: Evidence on the importance of local supply. *Journal of Financial Economics*, 108:425–448.

Duffie, D. (1996). Special repo rates. *Journal of Finance*, 51:493–526.

Duffie, D., Gârleanu, N., and Pedersen, L. H. (2002). Securities lending, shorting, and pricing. *Journal of Financial Economics*, 66:307–339.

Duffie, D., Gârleanu, N., and Pedersen, L. H. (2007). Valuation in over-the-counter markets. *Review of Financial Studies*, 20(6):1865–1900.

Eldor, R., Hauser, S., Kahn, M., and Kamara, A. (2006). A search-based theory of the on-the-run phenomenon. *Journal of Business*, 79(4):2067–2097.

Elton, E. J. and Green, T. C. (1998). Tax and liquidity effects in pricing government bonds. *Journal of Finance*, 53(5):1533–1562.

Fisher, M. (2002). Special repo rates: An introduction. *Economic Review*, 87(2):27–43. Federal Reserve Bank of Atlanta.

Fleming, M. J. (2002). Are larger Treasury issues more liquid? Evidence from bill reopenings. *Journal of Money, Credit and Banking*, 34(3):707–735.

Fleming, M. J. and Garbade, K. D. (2003). The repurchase agreement refined: GCF Repo®. *Current Issues in Economics and Finance*, 9(6). Federal Reserve Bank of New York.

Fleming, M. J. and Garbade, K. D. (2004). Repurchase agreements with negative interest rates. *Current Issues in Economics and Finance*, 10(5). Federal Reserve Bank of New York.

Fleming, M. J. and Garbade, K. D. (2007). Dealer behavior in the specials market for US Treasury securities. *Journal of Financial Intermediation*, 16:204–228.

Fleming, M. J., Hrung, W. B., , and Keane, F. M. (2010). Repo market effects of the Term Securities Lending Facility. Staff Report 426, Federal Reserve Bank of New York. Retrieved from `http://www.newyorkfed.org/research/staff_reports/sr426.pdf`.

Fleming, M. J., Krishnan, N., and Reed, A. V. (2012). The effects of Treasury fails charge on market functioning. Working Paper.

Fleming, M. J. and Rosenberg, J. V. (2007). How do Treasury dealers manage their positions? Staff Report 299, Federal Reserve Bank of New York. Retrieved from `http://www.newyorkfed.org/research/staff_reports/sr299.pdf`.

Fontaine, J.-S. and Garcia, R. (2012). Bond liquidity premia. *Review of Financial Studies*, 25(4):1207–1254.

Gorton, G. and Metrick, A. (2012). Securitized banking and the run on repo. *Journal of Financial Economics*, 104:425–451.

Graveline, J. J. and McBrady, M. R. (2011). Who makes on-the-run Treasuries special? *Journal of Financial Intermediation*, 20:620–632.

Greenwood, R. (2005). Short- and long-term demand curves for stocks: Theory and evidence on the dynamics of arbitrage. *Journal of Financial Economics*, 75(3):607–649.

Greenwood, R. and Vayanos, D. (2010). Price pressure in the government bond market. *American Economic Review*, 100(2):585–590.

Gromb, D. and Vayanos, D. (2010). Limits of arbitrage: The state of the theory. Working Paper 15821, National Bureau of Economic Research. Retreived from `http://www.nber.org/papers/w15821`.

Heller, D. and Vause, N. (June 2011). Expansion of central clearing. *BIS Quarterly Review*.

Jordan, B. D. and Jordan, S. D. (1997). Special repo rates: An empirical analysis. *Journal of Finance*, 52(5):2051–2072.

Kaul, A., Mehrotra, V., and Morck, R. (2000). Demand curves for stocks do slope down: New evidence from an index weights adjustment. *Journal of Finance*, 55(2):893–912.

Keane, F. (1995). Expected repo specialness costs and the Treasury auction cycle. Research Paper 9504, Federal Reserve Bank of New York. Retrieved from `http://www.newyorkfed.org/research/staff_reports/research_papers/9504.pdf`.

Krishnamurthy, A. (2002). The bond/old-bond spread. *Journal of Financial Economics*, 66:463–506.

Krishnamurthy, A. and Vissing-Jorgensen, A. (2011). The effects of quantitative easing on interest rates: Channels and implications for policy. Working Paper 17555, National Bureau of Economic Research. Retrieved from `http://www.nber.org/papers/w17555`.

Longstaff, F. A. (2000). Arbitrage and the Expectations Hypothesis. *Journal of Finance*, 55(2):989–994.

Lou, D., Yan, H., and Zhang, J. (2013). Anticipated and repeated shocks in liquid markets. *Review of Financial Studies*, 26(8):1891–1912.

Mazzoleni, M. (2013). Treasury yields and auction cycle management. Job Market Paper.

Moulton, P. C. (2004). Relative repo specialness in U.S. Treasuries. *Journal of Fixed Income*, 14(1):40–47.

Musto, D., Nini, G., and Schwarz, K. (2011). Notes on bonds: Liquidity at all costs in the Great Recession. Working paper. Retrieved from `http://www.fma.org/Napa/Papers/Notes_on_Bonds.pdf`.

Nautz, D. (1997). How auctions reveal information: A case study on German REPO rates. *Journal of Money, Credit and Banking*, 29:17–25.

Sundaresan, S. (1994). An empirical analysis of U.S. Treasury auctions: Implications for auction and term structure theories. *Journal of Fixed Income*, 4(2):35–50.

Sundaresan, S. and Wang, Z. (2009). Y2K options and the liquidity premium in Treasury markets. *Review of Financial Studies*, 22(3):1021–1056.

Svensson, L. E. (1994). Estimating and interpreting forward interest rates: Sweden 1992-1994. Working Paper 4871, National Bureau of Economic Research. Retreived from `http://www.nber.org/papers/w4871`.

Vayanos, D. and Weill, P.-O. (2008). A search-based theory of the on-the-run phenomenon. *Journal of Finance*, 63(3):1361–1398.

Wurgler, J. and Zhuravskaya, E. (2002). Does arbitrage flatten demand curves for stocks? *Journal of Business*, 75(4):583–608.

Working Paper Series

A series of research studies on regional economic issues relating to the Seventh Federal Reserve District, and on financial and economic topics.

Working Paper Series *(continued)*

Complex Mortgages WP-10-17
Gene Amromin, Jennifer Huang, Clemens Sialm, and Edward Zhong

The Role of Housing in Labor Reallocation WP-10-18
Morris Davis, Jonas Fisher, and Marcelo Veracierto

Why Do Banks Reward their Customers to Use their Credit Cards? WP-10-19
Sumit Agarwal, Sujit Chakravorti, and Anna Lunn

The impact of the originate-to-distribute model on banks
before and during the financial crisis WP-10-20
Richard J. Rosen

Simple Markov-Perfect Industry Dynamics WP-10-21
Jaap H. Abbring, Jeffrey R. Campbell, and Nan Yang

Commodity Money with Frequent Search WP-10-22
Ezra Oberfield and Nicholas Trachter

Corporate Average Fuel Economy Standards and the Market for New Vehicles WP-11-01
Thomas Klier and Joshua Linn

The Role of Securitization in Mortgage Renegotiation WP-11-02
Sumit Agarwal, Gene Amromin, Itzhak Ben-David, Souphala Chomsisengphet, and Douglas D. Evanoff

Market-Based Loss Mitigation Practices for Troubled Mortgages
Following the Financial Crisis WP-11-03
Sumit Agarwal, Gene Amromin, Itzhak Ben-David, Souphala Chomsisengphet, and Douglas D. Evanoff

Federal Reserve Policies and Financial Market Conditions During the Crisis WP-11-04
Scott A. Brave and Hesna Genay

The Financial Labor Supply Accelerator WP-11-05
Jeffrey R. Campbell and Zvi Hercowitz

Survival and long-run dynamics with heterogeneous beliefs under recursive preferences WP-11-06
Jaroslav Borovička

A Leverage-based Model of Speculative Bubbles (Revised) WP-11-07
Gadi Barlevy

Estimation of Panel Data Regression Models with Two-Sided Censoring or Truncation WP-11-08
Sule Alan, Bo E. Honoré, Luojia Hu, and Søren Leth–Petersen

Fertility Transitions Along the Extensive and Intensive Margins WP-11-09
Daniel Aaronson, Fabian Lange, and Bhashkar Mazumder

Black-White Differences in Intergenerational Economic Mobility in the US WP-11-10
Bhashkar Mazumder

Working Paper Series *(continued)*

Working Paper Series *(continued)*

Working Paper Series *(continued)*

Financial Incentives and Educational Investment: The Impact of Performance-Based Scholarships on Student Time Use *Lisa Barrow and Cecilia Elena Rouse*	**WP-13-07**
The Global Welfare Impact of China: Trade Integration and Technological Change *Julian di Giovanni, Andrei A. Levchenko, and Jing Zhang*	**WP-13-08**
Structural Change in an Open Economy *Timothy Uy, Kei-Mu Yi, and Jing Zhang*	**WP-13-09**
The Global Labor Market Impact of Emerging Giants: a Quantitative Assessment *Andrei A. Levchenko and Jing Zhang*	**WP-13-10**
Size-Dependent Regulations, Firm Size Distribution, and Reallocation *François Gourio and Nicolas Roys*	**WP-13-11**
Modeling the Evolution of Expectations and Uncertainty in General Equilibrium *Francesco Bianchi and Leonardo Melosi*	**WP-13-12**
Rushing into American Dream? House Prices, Timing of Homeownership, and Adjustment of Consumer Credit *Sumit Agarwal, Luojia Hu, and Xing Huang*	**WP-13-13**
The Earned Income Tax Credit and Food Consumption Patterns *Leslie McGranahan and Diane W. Schanzenbach*	**WP-13-14**
Agglomeration in the European automobile supplier industry *Thomas Klier and Dan McMillen*	**WP-13-15**
Human Capital and Long-Run Labor Income Risk *Luca Benzoni and Olena Chyruk*	**WP-13-16**
The Effects of the Saving and Banking Glut on the U.S. Economy *Alejandro Justiniano, Giorgio E. Primiceri, and Andrea Tambalotti*	**WP-13-17**
A Portfolio-Balance Approach to the Nominal Term Structure *Thomas B. King*	**WP-13-18**
Gross Migration, Housing and Urban Population Dynamics *Morris A. Davis, Jonas D.M. Fisher, and Marcelo Veracierto*	**WP-13-19**
Very Simple Markov-Perfect Industry Dynamics *Jaap H. Abbring, Jeffrey R. Campbell, Jan Tilly, and Nan Yang*	**WP-13-20**
Bubbles and Leverage: A Simple and Unified Approach *Robert Barsky and Theodore Bogusz*	**WP-13-21**

Working Paper Series *(continued)*

The scarcity value of Treasury collateral:
Repo market effects of security-specific supply and demand factors **WP-13-22**
Stefania D'Amico, Roger Fan, and Yuriy Kitsul