ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ
ВЫСШАЯ ШКОЛА ЭКОНОМИКИ

Международный институт экономики и финансов

Vladimir Sokolov

OPEN MARKET OPERATIONS AND VOLATILITY OF BOND RETURNS: MICROSTRUCTURE EVIDENCE

Препринт WP9/2008/01
Серия WP9

Исследования по экономике и финансам
Research of economics and finance

Москва
ГУ ВШЭ
2008

УДК
ББК
S

Редактор серии WP9
«Исследования по экономике и финансам»
(Research of economics and finance)
А.В. Белянин

Sokolov V. Open Market Operations and Volatility of Bond Returns: Microstructure Evidence[*]:
S Working paper WP9/2008/01. – Moscow: State University — Higher School of Economics, 2008. — 44 p.

I examine the relationship between open market operations and the volatility of bond returns at Fed time. Using GovPX transaction data for the year 2000, I present evidence that the Fed's day-to-day monetary policy is not neutral with respect to the bond market. The impact of the Fed's operations is significant on days when regular short-term open market operations are conducted, unlike on days when both short- and long-term operations (an innovation introduced in 2000) are implemented. I demonstrate that the volatility pattern observed in the former case can be attributed to a collateral reassignment problem faced by primary dealers.

JEL classification: G14, G18, G28, E58.

Keywords: open market operations; market impact, repo contracts; volatility.

[*] I have benefited from discussions with Nelson Mark, Tom Cosimano, Maxim Nikitin, Eric Girardin and seminar participants at the SSES Annual Meeting at the University of St. Gallen and Money, Macro and Finance 40th Annual Conference at Birkbeck College. I am especially grateful to Paul Schultz for providing me with GovPX data and to Michael Fleming for providing me with open market operations data. The support of an ICEF Research Grant is gratefully acknowledged.

УДК
ББК

Соколов В. Операции на открытом рынке и волатильность доходности облигаций: микроструктурное исследование: Препринт WP9/2008/01. – М.: Издательский дом ГУ ВШЭ, 2008. — 44 с. (in English)

Автор исследует взаимосвязь между операциями на открытом рынке и волатильностью доходности облигаций во время интервенций американским Центральным банком. Используя базу данных GovPX по транзакциям на рынке облигаций за 2000 г., автор демонстрирует, что ежедневная монетарная политика Центрального банка не является нейтральной по отношению к рынку облигаций. Влияние Центрального банка статистически значимо в те дни, когда он проводит регулярные краткосрочные операции на открытом рынке. В то же время в те дни, когда Центральный банк проводит как регулярные краткосрочные операции, так и долгосрочные операции (новшество, введенное в 2000 г.), влияние Центрального банка на волатильность облигаций не значимо. Показано, что данный эффект объясняется неопределенностью первичных дилеров по распределению заложенных у ЦБ облигаций по операциям репо к частным участникам рынка.

Vladimir Sokolov — Assistant Professor International College of Economics and Finace State University — Higher School of Economics (vsokolov@hse.ru).

Препринты ГУ ВШЭ размещаются на сайте:
http://new.hse.ru/C3/C18/preprintsID/default.aspx.

1 Introduction

This paper is an empirical study of the impact of the Fed's day-to-day monetary policy on financial markets. In particular, I investigate how temporary open market operations conducted by the Fed affect the volatility of government bond returns, bid-ask spreads, and trading volume.

The contribution of the paper is threefold. First, I seek to contribute to the burgeoning literature on the impact of monetary authorities on the bond market [see Fleming and Piazzesi (2005), Andersson (2008), Gurkaynak *et al.* (2005) and reference therein.] Most directly my work is related to Harvey and Huang's (2001) microstructure study of open market operations, which covers the 1982-88 period, when the Fed was operating under the Borrowed Reserves Targeting Operating Procedure. I extend this analysis to a more recent period, and what is more important, to a different Fed Funds Targeting Operating Procedure, which created a new environment for bond market participants[1]. Harvey and Huang (2001) view the Fed as a trader with private information and suggest that open market operations smooth market expectations about the future course of interest rates. This interpretation is correct with respect to the Borrowed Reserves Procedure, which was pursued in the 80s and under which open market operations could provide information to the private sector about the Fed's monetary policy stance by reflecting changes in discount window borrowing pressure. On the contrary, under the current Fed Funds Targeting Procedure, the Fed's open market operations do not carry any pay-off relevant information to the private sector regarding the course of the interest rates but solely adjust the level of liquidity in the banking system in order to keep the interest rates on target. Thus, one expects to observe no discernible pattern of bond returns volatility during the conduct of open market operations.

Second, I evaluate the efficiency of the Fed's day-to-day monetary policy. While promoting its main policy objective of keeping the fed funds rate on target, the Fed seeks to exert minimal influence on the instrument it uses, i.e. the government bond market. It is well documented that the Trading Desk at the New York Fed has been successful in predicting the reserves deficiency in the banking system, with multiple studies [Bartolini *et al.* (2001, 2002), Hamilton (1996, 1997), Carpenter and Demiralp (2004)] showing that

[1] For example, with respect to the federal funds market, Urich and Wachter (2001) find that the increase in the Fed's transparancy about its monetary policy target in 1994 diminished the impact of policy changes on the federal funds rate.

the daily volatility of the fed funds rate is low and increases only by the end of the reserves maintenance period. Hilton and Hrung (2007) analyze the impact of the reserves level on the intra-day behavior of the fed funds rate over the recent time period. Moschitz (2004) and Wurz (2003) present an empirical model of the spread between the European overnight rate and the key policy rate of the European Central Bank. All of these studies address the main objective of day-to-day monetary policy under the interest rate targeting operating procedure, which is accommodating money demand shocks in order to keep the interest rate on target. However, remarkably little attention has been paid to the efficiency of the Fed's policy implementation[2]. Given the large scale of the outstanding short-term temporary operations[3] and the fact that the Fed's refinancing is only available to a few primary bond dealers, the efficiency of policy implementation can significantly influence both the private market participants involved in the transactions and the success of achieving the main day-to-day monetary policy objective. I attempt to cover this gap and examine the assumption that the Fed's temporary open market operations have a negligible impact on the bond market and document patterns of bond returns volatility resulting from the Fed's interventions. In my study, which draws on data from 2000, I find that bond return volatility increased significantly at official *Fed time* (9:30 am) on days when the Fed conducted short-term open market operations. This finding is somewhat puzzling as refinancing of the existing position in a security should not affect the price formation process of that security. At the same time, I find that the volatility of bond returns was not significantly higher on days when the Fed used both regular short-term repos and longer 28-days term repurchase agreements - which were introduced in the course of 2000 - than on days without open market operations.

Finally, I expand on the interdealer broker (IDB) market literature devoted to the treasury market [Huang *et al.* (2002), Fleming and Garbade (2007)] by examining how the outcomes of the Fed's repurchase agreements are related to the higher bond return volatility observed during the Fed's in-

[2]The cited literature on money markets, however, indicates that there is awareness about the policy implementation efficiency issue. For example Bartolini *et al.* (2002) point out that the Fed can undertake temporary open market operations only if the market counterparts have sufficient collateral, which makes Fed's operations constrained by its past decisions. Also Fleming (1997) reports that the volume of treasury bond trading during the officially scheduled *Fed time* is about half of its 8:30 am peak.

[3]For example, Bindseil (2004) has estimated that the average daily change in short-term Fed's repos was $3.5 billion per day in 2001.

terventions. These agreements are organized through pay-your-bid auctions among primary dealers and offer dealers an opportunity to refinance their leveraged positions at a lower cost than using the private repo market. On the one hand this allows Fed to rely on a stable demand from bond dealers for funding but on the other hand this mechanism may create an incentive for dealers to submit a larger portion of securities for refinancing with the Fed than could be satisfied on a given auction. In order to gauge the impact of primary bond dealers' bidding for Fed's funding on the bond market volatility I construct two measures of outcomes of the Fed's repo auctions. One is the difference between submitted orders for refinancing by the dealers and fulfilled by the Fed. This variable indicates the aggregate imbalance in the dealers' repo book after an auction. The second is the spread between the effective fed funds rate on a day of the Fed's repo auction and the weighted-average repo rate established during the auction. The bigger the spread the higher is an incentive for dealers to bid for Fed's refinancing. I show that these measures are significantly associated with volatility of bond returns at *Fed time* on days with short-term open market operations. This happens because a considerable number of submitted securities by the primary bond dealers is not refinanced by the Fed, and after the auction this collateral needs to be reassigned to a private repo market. I also find that no such connection is present on days when both long- and short-term repo operations are conducted. These results demonstrate that extending the duration of term repo contracts and intervening more than once per day improves the efficiency of monetary policy implementation as the collateral reassignment uncertainty faced by the primary dealers wanes.

The remainder of the paper proceeds as follows. Section 2 provides an overview of the institutional set-up of the US bond and money market, the Fed's open market operations and the primary dealer's collateral reassignment problem. Section 3 reports the half-hour bond returns volatility, bid-ask spreads and trading volume patterns at *Fed time* in 2000. Section 4, further, empirically investigates the linkage between the outcome of open market operations and bond market volatility. Section 5 looks into the degree of the bond dealers' repo book imbalance. Section 6 provides conclusions.

2 Institutional Set-up of the Fed's Day-to-day Monetary Policy

The Fed may conduct two kinds of open market operations. First, it may seek to accommodate temporary exogenous shocks to the reserves level in the banking system by removing the pressure either from the spot fed funds rate under Funds Rate Targeting Regime or from the amount of discount window borrowing under Borrowed Reserve Targeting Regime. This type of open market operations is called *defensive.* Second, the Fed may seek to intervene for the purpose of adjusting the level of the interest rate target, and in this way, enforce a broader spectrum of interest rates in the economy. This type of operations is called *dynamic.*

Defensive operations belong to the authority of the Trading Desk at the New York Fed. The Desk estimates exogenous shocks, formulates the size of operations, and projects their further impact on the money market, on a daily basis. Dynamic open market operations are considered "higher-level policy decisions" (see Woodford (2002)) and fall under the authority of the Federal Open Market Committee.

In 1994 the policy of the Fed changed in that it started disclosing the fed funds target through speeches and testimonies. All Fed's open market operations are nowadays *defensive* in nature and do not carry any information about the future stance of monetary policy. The Fed's policy change removed the whole profession called "Fed watchers", who monitored balances in the banking system and the scope of Fed's interventions in order to forecast the direction of interest rates. Nowadays, the private sector forecasts the future fed target on the basis of macroeconomic fundamentals rather than the amount of reserves in the banking system.

My study examines the neutrality of defensive open market operations with respect to the government bond market. Let me, at this stage, narrow down the asset classes considered in the paper. For the bond market analysis, I use only 2-years and 5-years maturity *treasury notes.* As regards the money market, I focus on two instruments: *repurchase agreements* (repo), which are collateralized credit against bonds and *federal funds*, which are unsecured inter-bank credit. In the next subsection, I clarify the intra-day interaction between the Fed and the primary bond dealers.

2.1 Treasury bond dealer's portfolio allocation

The bond dealers are market makers who have been tasked by the Fed to provide liquidity and continuity to the market. They hold bonds in their inventory in order to meet clients' orders. The risk of having an unfavorable position, which these dealers assume, is partly compensated with the bid-ask spread they earn on the order flow. However, anecdotal evidence (Stigum, 1990) suggests that servicing customers and bid-ask spread earnings will hardly even pay the dealers' utility bills. Empirical research by Fleming (2003) confirms that treasury bonds spreads are very narrow, ranging from 0.21 to 0.52 of 32s. In fact, the dealers earn most of their profits by taking risky positions in the bonds they trade.

The typical portfolio allocation decision of the bond dealer involves taking a short-term leveraged position in security and financing it through a repo agreement[4]. Unlike banks, dealers do not hold bonds till maturity and assume a capital loss risk. Given expectations regarding the future level of interest rates, bond dealers form the *Expected Holding Period Return* (EHPR) over the investment horizon of the position.

$$EHPR_0^n = \frac{E(P_n \,|\Omega_0) - P_0}{P_0} \tag{1}$$

where P_0 is the spot price of the bond at time $t = 0$ and $E(P_n \,|\Omega_0)$ is the expected price of the same bond at time $t = n$[5]. The Ω_0 denotes time $t = 0$ information set regarding the future level of the interest rates expected to prevail at time $t = n$.

In order to take a leveraged position, a dealer could borrow funds from a bank, but, this would usually be expensive since a bank loan rate is a spread above the fed funds rate f. The repo market is a cheaper way of financing the position since repo rate r is usually a spread below the fed funds rate f. The repo contracts (repurchase agreements) are normally extended overnight and the dealer will have to refinance the bond holding on a daily basis through the investment horizon n.[6]

Let me sketch the mechanism of the repurchase agreement. Having identified the trading strategy at time $t = 0$, the dealer conducts two coordinated transactions. First, he contacts the seller of a bond to lift the offering for a particular treasury at a quoted price P_0. Next, he contacts a funds surplus

[4] This is an example of the popular "riding the yield curve strategy."

[5] $n < T$, where T is the bond's time to maturity.

[6] Repos also could be extended for a term of up to 28 days.

institution to borrow P_0 amount of dollars, in an overnight loan, against the bond he just purchased. The bond is thereafter transferred from the seller to a clearing house as collateral, while the borrowed funds are transferred from the funds surplus institution to the seller of a security. As a result of this transaction, the dealer assumes an asset and becomes entitled to all bond's coupons and capital gains/losses. On the liability side, he owes funds to a lender, and must repay them the next day. Since the dealer intends to hold the bond for n days, he will need to refinance this position n times with different fund-surplus institutions. The cost of this strategy is a summation of overnight repo rates paid daily over n days to the funds surplus institution.

If we define the information set regarding the future course of the daily repo rates as Φ_0, we can formulate the *Expected Financing Cost* (EFC) of the trading strategy.

$$EFC_0^n = \sum_{t=0}^{n} E(r_t \,|\Phi_0) \tag{2}$$

The bond dealer bets that, over the investment horizon of n days, the expected capital gain on a particular bond will exceed the expected costs of rolling over the short-term repo agreements. Practitioners call it "riding the yield curve". The no-arbitrage condition[7] for the strategy is:

$$EHPR_0^n = EFC_0^n \tag{3}$$

Let us illustrate the logic of the repo transaction from the perspective of the banking system. Suppose a bond dealer initially financed its position through Bank A. The next day, he has to repay the loan by arranging a repo agreement with Bank B, which will then transfer funds to Bank A. From the dealer's standpoint, this equals reassigning collateral from one creditor to another. His portfolio allocation involves two transactions: assuming a new asset in the form of a bond position and creating a new liability in the form of a repo debt, which needs to be rolled over on a daily basis. On aggregate such transactions do not change the level of liquidity in the banking system but allow fund surplus institutions to lend overnight on a collateralized basis.

[7] The condition is a reformulation of the *Local Expectation Hypothesis* which says that given the information sets Ω_0 , Φ_0 the current bond price P_0 is revealed through the equations (1)-(3). The Φ_0 and Ω_0 will coincide if one assumes that the spread between the funds rate f and the repo rate r is zero.

2.2 The Fed's repo auctions

We focus on the mechanics of the repo transactions because temporary open market operations are conducted by the Fed through repo agreements with the primary bond dealers. Let us now examine the objectives of the Fed in conducting the defensive open market operations. Assume that the Fed projects a forthcoming reserves deficiency in the banking system, which will put an upward pressure on the fed funds rate away from the target. In this situation, the New York Fed's Trading Desk needs to inject reserves into the system. Rather than intervening on the inter-bank credit market, the Desk conducts an open market operation through temporary repo agreements. In this way, the Fed substitutes the private fund surplus agents in the chain of refinancing the bond dealer's positions by transferring funds to the account of the dealer's previous creditor.

Suppose that, on day t, the bond dealer needs to return funds to Bank A, which previously financed his position through a private repo. In the absence of intervention by the Fed, the dealer would arrange so that Bank B would credit Bank A and reassign the bond as collateral to Bank B. However, instead, the Fed intervenes and transfers funds to Bank A. As a result of this transaction, the dealer owes funds to the Fed, which holds the bond as collateral. From the view point of the banking system, the difference is that Bank B now has extra overnight funds to supply to the fed funds market since the demand for the private repo transaction was satisfied by the Fed. This creates a downward pressure on the fed funds rate *f,* which is exactly what the Fed was trying to achieve in the given situation.

By conducting open market operations, the Fed acts not as a buyer on the bond market, but as a big creditor financing the leveraged positions of bond dealers. In Fed's absence private sector redistributed the given amount of the monetary base between the funds deficient and the funds surplus agents. An important feature of the US monetary system is that the Fed changes the monetary base through a system of multiple primary bond dealers. The Fed's repos are organized as an auction among primary bond dealer, which takes place at a fixed time interval called *Fed time*[8].

For a primary dealer one of the advantages of participation in the Fed's repo auction is the opportunity to finance their positions at a lower cost than at the private repo market. (See figure 7 in Appendix B, which plots fed funds and weighted-average Fed's repo rates in the year 2000). When the

[8] As of April 1999, Fed time is scheduled between 9:30 and 10:00 am.

Fed intends to intervene on a particular day, it makes an announcement at *Fed time* and invites refinancing bids from primary dealers. Dealers indicate both the bond issue they want to refinance and the repo rate they are willing to pay to the Fed for the provided funds. The Fed ranks dealers' offers and chooses the most attractive ones within the amount of reserves it wants to inject into the system. This is a discriminatory (pay-your-bid) pricing rule auction, under which, the market is cleared from the highest submitted bid (the repo rate a dealer is willing to pay) downward until the desired supply is exhausted. All winning bidders pay the repo rates they quoted. The lowest winning bid is called the stop-out rate. Table 5 in Appendix C presents a summary statistics of outcomes of the repo auctions organized by the Fed. It shows that the amount of collateral offered for refinancing by primary dealers was on avearge $ 9.802 billion, the amount that was refinanced was $ 2.182 billion (the size of the open market operation). The highest and lowest repo rates offered by dealers indicate the range of rates they were willing to pay. The stop-out rate is the lowest rate at which Fed exhausted its defensive open market operation on average. The key results of the auctions are the weighted-average Fed's repo rate and the total propositions accepted.

The possibility of securing favorable rates at the Fed's repo auctions creates an incentive for primary dealers to offer considerable collateral to the Fed, and overbidding frequently occurs. In order to clear up their bond inventories following the Fed's auction dealers seek additional sources of financing with the private sector. This creates a so-called *collateral reassignment uncertainty*, which may cause a higher volatility of bond returns at *Fed time*.

3 Volatility of Bond Returns and Fed's Presence on the Market

3.1 GovPX data and filtering procedures

The key data set used in my study is GovPX inter-dealer bond market transaction data for the period January 1, 2000 - December 29, 2000[9]. This data set is widely used in applied microstructure studies that investigate intra-day bond market developments.

[9] I focus on the 2000 time period because prior to that open market operations data is unavailable and after 2000 the GovPX data set started to reduce coverage of the bond market transaction.

I focus on 2-years T-Notes and 5-years T-Notes since they represent the most liquid segments of the treasury market [see Fleming (2003)]. In line with other empirical GovPX studies, such as Fleming (1997, 2003) and Huang *et al.* (2002), I use only the most recently auctioned on-the-run securities.

The high-frequency GovPX data contains series that include all changes in quotes such as bid-ask prices, quote sizes, and trading volume. There are two major problems with it. The first one is specific to the GovPX series as it retains the work-up process of negotiating the traded price. The second is general and refers to the fact that the transaction data is not regularly spaced, i.e. is not homogeneous in time. The first problem is relatively easy to solve by converting the *quoted* series into *transaction* series. This is done by dropping the quotes without change in the traded volume as described in Fleming (2003). I also filter out the abnormal transactions such as the yield spreads out of -2.5 and 10 basis points range, quote sizes larger than $ 1,250 million, and returns more then 10 standard deviation from the average return throughout the whole sample.

In order to handle the non-homogeneity problem I apply the *linear interpolation* technique described in Dacorogna *et al.* (2001) and used in Huang *et al.* (2002). First, I take a natural log of all filtered quotes on bid and ask prices and obtain the middle of the log bid-ask spread. Then I construct the half-hour bond returns within each day for the year 2000. This is done by taking the mid transaction prices immediately preceding the beginning of a 30 minute interval within a day and immediately after it starts.[10] The advantage of using this interpolation technique rather than the last tick interpolation is that it generates less zero returns.

I restrict the data to the 8:30 a.m. - 16:00 p.m. time interval, and using the constructed regularly spaced data, I calculate the half-hour bond returns. This gives us 16 observations of returns for each trading day in a sample. As suggested in Dacorogna *et al.* (2001), I use the absolute deviation of returns as a measure of the *realized volatility.* Using the same 30-minutes intervals within each day I obtain two other useful series from the GovPX data: the

[10] Let me illustrate how the price is derived. Suppose that two transactions occur at 10:14 and 10:18 with bid at 10:14 being at 100 and ask being at 102 and bid and ask at 10:18 being 106 and 109. The transaction price for 10:15 is interpolated as follows. First we get $P_{10:14}$ and $P_{10:18}$ prices as follows: $P_{10:14}$ = [log(100) + log(102)]/2 = 4.615 $P_{10:18}$ = [log(106) + log(109)]/2 = 4.677 Then we take the weighed average: 4.615*(180/180+60)+4.677*(60/180+60)=4.631 where 180 and 60 are the number of seconds before and after the constructed time interval at which the trades occurred. This algorithm is applied to obtain the transaction prices at other regularly spaced intervals.

trade volume growth between time intervals and the bid-ask spreads for each interval. Table 1A presents the descriptive statistics on these series.

[Table 1A approximately here]

3.2 The half-hour volatility patterns and open market operations

In this section, I estimate the volatility of half-hour bond returns under the assumption that a different data generating process (DGP) is at work during each interval. The estimation relies on the variability of returns across trading days and is based on the Huang *et al.* (2002) specification:

$$Vol_{t,n} = \sum_{n=1}^{N} \delta_n interval_{t,n} + \theta trend_{t,n} + \varepsilon_{t,n} \tag{4}$$

where $Vol_{t,n}$ denotes return volatility during half-hour interval n on day t. The $interval_{t,n}$ is the indicator variable that takes on the value 1 during interval n on day t, and 0 otherwise. The variable $trend_{t,n}$ takes on the value of ((t-1)*16+n)/4216, t=1,...,251; n=1,...,16. It captures the time-series trend in the dependent variable.

Figure 1 plots the estimates δ_n of the intra-day half-hour bond return volatility for the 2-years and 5-years T-Notes. We can observe that in the first half of the trading day both bonds exhibit two spikes in volatility of returns at 8:30 and 10:00 am, which are the time intervals when major macroeconomic announcements are scheduled. These information releases have been the subject of several extensive studies by Ederington and Lee (1993, 1995), Huang *et al.* (2002), Fleming and Remolona (1997), Balduzzi *et al.* (2001), Faust *et al.* (2007). Figure 1 is consistent with the results of Fleming (1997), who conducts intra-day analysis of the GovPX data and reports estimates of half-hour volatility for 2-year and 5-year T-Notes of similar magnitude.

[Figure 1 approximately here]

Short-term Fed's repos and volatility of bond returns

The focus of my study is the time interval between 9:30 and 10:00 am, which is the official *Fed Time* when the Fed conducts temporary open market operations. Appendix ??? provides the descriptive statistics of the Fed's repo by term to maturity. Using the NY Fed data I create three sub-samples. First sample includes days when only overnight (O/N) repo operations were conducted, second sample includes days when only *term* repos under 15-days to maturity were conducted and the third sample, which is the reference category, includes days without any open market operations. (there were only three incidents when both overnight and term-repos under 15 days were conducted on the same day[11]). In the next step, I estimate the specification (4) separately for each of these three samples. The estimates of the coefficients are plotted in Figure 2. One can observe that relative to days with no open market operations days when Fed was present on the market have a much higher average volatility at *Fed Time.* This increase in volatility during the Fed's interventions is in line with previous results of Harvey and Huang (2001) for 1982-1988 samples[12]. However, under the current Fed Funds Targeting operating procedure such pattern is puzzling since open market operations do not carry any pay-off relevant information for government bonds.

[Figure 2 approximately here]

Another interesting observation is the apparent relationship between the 8:30 and 10:20 am macroeconomic announcements and the Fed's presence on the bond market. On days with the longer dated term repo operations, volatility at 8:30 am and 10:00 am is higher than on days without operations. This could be due to the fact most macroeconomic announcements moving the bond market happened to be on days when the Fed conducted its open market operations. Another possible explanation, which is consistent with the Harvey and Huang (2001) conclusions, is that the Fed chooses to

[11] Table 3A in appendix reports the frequency of different types of operations by days of the week.

[12] Hartmann *et al.* (2001) report that time intervals when ECB conducts open market operations are associated with higher volatility of the European money market interest rates. It should be pointed out that the ECB doesn't use the bond market for liquidity management in the banking system but solicits bids for refinancing directly from the commercial banks.

inject liquidity on days with major announcements in order to smooth out fluctuations on the financial markets.

Long-term Fed's repos and volatility of bond returns

In 2000 the Fed introduced long 28-days term temporary repo operations spanning beyond the reserves maintenance period. These operations were scheduled prior to *Fed time* at around 8:20 am on Mondays and Thursdays, and were intended to address the seasonality in the reserves level in the banking system. On most occasions, the Fed combined such operations with shorter repos scheduled at regular *Fed time* at 9:30 am[13].

I proceed with the intra-day volatility analysis by creating three sub-samples. The first sub-sample includes days when newly introduced 28-days repos were conducted. The second sub-sample bundles together days with overnight and term repos under 15 days to maturity that we distinguished in the previous subsection. Finally the reference sub-sample is the same as in the previous section - days without any open market operations.

[Figure 3 approximately here]

Figure 3 plots estimates of the half-hour volatility for these three sub-samples. There is a noticeable pattern. Days with only traditional short-term 9:30 am operations exhibit an increase in the volatility at *Fed time,* however, estimates for the sample with both long-term and traditional short-term operations, the *Fed time* bond returns volatility is as low as for the sample without any open market operations. One possible explanation for this pattern is that, on those days when long-term 28 days repos are conducted at 8:20 am, the bond market accommodates the liquidity injections, and as a result the short-term repos at the 9:30 am *Fed time* do not cause any increase in volatility of bond returns. Another possible explanation is that the collateral reassignment problem faced by primary bond dealers at *Fed time* is alleviated on days with 28-days repo auctions as dealers secure financing earlier during the day. These points will be the subject of the conditional analysis in the next section.

[13] Table 4A in Appendix A reports the frequency of these operations.

4 Bond Market Volatility, Bid-Ask Spreads, Trading Volume surrounding Open Market Operations

In this section, I conduct a conditional regression analysis of different volatility, bid-ask spread and trading volume patterns at *Fed time* which is common for the event studies. Similarly to the event studies such as Ederington and Lee (1995) for the bond market or Pasquariello (2007) for the foreign exchange market, who isolate the bond returns around the macroeconomic announcements and central bank currency interventions, I create a sample of half-hour bond returns (9:30-10:00 am *Fed time*) for each trading day in the year 2000. This produces 251 observations of daily *Fed time* volatility. The key aspect of my study is to establish how the Fed's presence on the market impacts the bond market volatility at *Fed time*. In order to do this, I regress the *Fed time* volatility of bond returns on binary dummy variables representing different types of open market operations. Focusing on the sample at the daily frequency allows me to include the control variables that are associated with the bond market volatility. The regression specification is:

$$Y_t^{FedTime} = \delta Short\_termOMO_t + \gamma Long\_termOMO_t + \beta' \mathbf{X}_t + \varepsilon_t \quad (5)$$

where $Y_t^{FedTime}$ is either a realized half-hour bond return volatility or bid-ask spread or trading volume during the *Fed time* on day t. *Short termOMO*$_t$ and *Long termOMO*$_t$ are dummy variable indicating the Fed's presence on day t with short-term and long-term repos respectively. The case when Fed did not intervene at all on a given day is reserved as a reference category. $\mathbf{X}_t$ is a vector of control variables. The graphs 4, 5 for the *Fed time* volatility from Appendix C indicate volatility clustering in the bond data series suggesting the presence of ARCH effects. The results reported in this study are obtained using the specification with the conditional heteroskedastisity assumptions of the error term ε_t. The coefficients δ and γ form our principle interest.

Let me provide an intuition for the control variables included in the vector $\mathbf{X}_t$[14]. I use the Lagged Spread between the Effective Federal Funds rate and

[14] I experimented with adding the so-called calendar effects to the original specification which I do not present here. Following Carpenter and Demiralp (2006) and Moschitz (2004) I created dummy variables for each day of the week and dummy variables for the beginning of the month. Hamilton (1996, 1997) demonstrates that the fed funds market

the Target Rate, the Daily Slope of the Yield Curve [The yield slope is the difference between the yield to maturity on the 5-year T-Note and the 3-month T-Bill], and the 8:30 and 10:00 am macroeconomic announcement dummies.

Taylor (2001) defines the supply of reserves by the Fed as a function of the gap between the effective federal funds rate and the target. Demiralp and Jorda (2002) use this variable in their Tobit regressions for explaining different types of open market operations. I include this variable into the specification since information about the *previous* day's deviation of the fed funds rate from the target is available to private market participants and allows them to better accommodate the volume of liquidity injection by the Fed. One would expect that a larger spread will increase probability that the Fed would conduct an open market operation on the following day, which would decrease the bond dealers' uncertainty regarding the source of refinancing.

The inclusion of the current day Yield Curve Slope into the volatility analysis is motivated by Fleming and Piazzesi (2005), who argue that this measure is correlated with market participants' time-varying concerns about inflation. This variable is expected to be positively associated with the bond market volatility at *Fed time* since it reflects the market perception of the Fed's grip of monetary policy implementation. As pointed out by Fleming and Piazzesi (2005) a steeper slope reflects concern about Fed's falling behind the curve on restraining inflation.

Figures 2 and 3 from the previous section suggest that scheduled macroeconomic announcements and the Fed's interventions may be related as Fed injects liquidity in order to smooth market fluctuations. To control for this effect, I collected the daily data on all major macroeconomic announcements scheduled in the year 2000 at 8:30 and 10:00 am and created dummy variables corresponding to the types of economic announcements, which take value 1 if they fall on a day with announcement release and the value 0 otherwise[15].

volatility is the highest at the end of the maintenance period. I also controlled for this effect. I should note that the estimates for the calendar effects and the maintenance period dummies are largely insignificant and did not affect the estimates of the open market operation dummies.

[15] Tables 5A and 6A in Appendix list all 8:30 am and 10:00 am macroeconomic announcements used in the study.

The table 2A reports descriptive statistics of the variables employed. Appendix B presents a graphical account for the variables used in the study.

[Table 2A approximately here]

4.1 The impact of short-term Fed's repos

For the analysis of the regular open market operations the first dummy in the specification (4) represents the case when Fed was present on a given day with overnight (O/N) repos and the second dummy represents the case when Fed employed the term repos with under 15 days to maturity.

Table 1in appendix C reports estimation results for the volatility of 2-year and 5-year Treasury Notes returns. The coefficients on the Overnight and Term Fed's repo dummies are positive and are significant for Overnight repos at 5%. This suggests that the Fed's presence on the market results in a higher volatility of bond returns at *Fed time* relative to days without Fed's interventions. The result demonstrates that the Fed's repo dummy estimates are robust to the inclusion of a set of control variables thought to be related to the *Fed time* volatility and open market operations. As expected, Lagged Fed Funds Spread and Yield Curve Slope are respectively negatively and positively associated with the bond market volatility at *Fed time.* The larger Lagged Fed Funds Spread creates less uncertainty regarding the probability and size of the Fed's intervention, and thus reduces the volatility of bond returns. The steeper Yield Curve Slope, on the contrary, increases the uncertainty regarding the Fed's grip on monetary policy implementation and increases the volatility of returns. The estimates on the macroeconomic announcement dummies indicate that, only on days with 8:30 am announcements, the volatility during the 9:30 am *Fed time* is significantly higher than on days without the 8:30 am announcements. This may be due to the fact that following the macroeconomic announcements the bond market volatility at the announcement interval spills over to the later time periods. The fact that the 10:00 am announcements do not increase *Fed time* volatility suggests that market does not react to information releases ahead of time. Both results are consistent with macro announcement literature [Ederington and Lee (1995), Balduzzi *et al.* (2001)].

[Table 1 approximately here]

The vast literature on volatility-volume relation [Daigler and Wiley (1999) and references therein] attributes the positive association between the two variables to *dispersion of beliefs*. According to the theory, the arrival of public information generates difference in opinions that results in increased volume and volatility. The IDB markets literature, again, attributes the positive relationship between volatility and bid-ask spreads to market makers' reaction to the increase in uncertainty. Dealers widen their spreads in order to reduce the risk of an unfavorable position.

The estimates of the relationship between bid-ask spread and trading volume, on the one hand, and open market operations dummies, on the other hand, are reported in Table 2. They are largely statistically insignificant except for the bid-ask spread for the 5-year T-Note. The signs on the coefficients in columns (2) and (4) indicate that *Fed time* spreads are wider on days with open market operations relative to days without operations. This result is consistent with the notion that primary dealers face higher uncertainty when Fed intervenes. At the same time, as can be seen in columns (3) and (5), the trading volume is less on days with the Fed's repos than on days without operations. This could be due to the fact that dealers refinance their existing bond positions at the Fed's repo auctions and reduce their outright trading on the open market.

[Table 2 approximately here]

4.2 The impact of long-term Fed's repos

The most interesting result from the previous unconditional analysis section was the low volatility of bond returns at *Fed time* on days when long-term 28-days to maturity repos scheduled at 8:20 am were conducted together with short-term repos scheduled at 9:30 am. For my analysis, I bundle overnight and repos under 15-days to maturity into one binary dummy variable. I also create another binary variable for days with the long-term 28-days repos. I then interact the two and get an indicator variable for days when only one type of operations was conducted, versus for days when both types of Fed's reps were conducted. Then I run the specification (4) using these two dummy variables, having the days without operations as a reference

category. (I drop 8 observations when 28-day repos were conducted without accompanying traditional short-term repos on the same day.)

As can be seen from Table 3, the coefficient on the short-term *only* operations is positive and highly significant confirming our previous results of a non-negligable effect of the Fed on bond market. The coefficient on the variable indicating the conduct of both short and long term Fed's repos on the same day is not statistically different from zero, which means that the volatility of bond returns on those days is as low as on days without operations. One of the regularities in the conduct of such operations is that they normally occur on Mondays and Thursdays and might be priced in by the market. Also the fact that the Fed injects liquidity earlier during the day at 8:20 am satisfies the market demand for financing, as a result of which there is less overbidding for funds at the regular *Fed time* 9:30 am.

[Table 3 approximately here]

I proceed with bid-ask spreads and trading volume regressions for the long-term repo operations in Table 4. The reported results are broadly consistent with the estimates in Table 2. The coefficient signs on open market operations dummies suggest that market makers widen their spreads at *Fed time* when the Fed is present. The only exception is in column (2) for case when the Fed conducts both types of operations on the same day. The coefficient is not significantly different from zero, which is the reference case of no interventions. This result confirms our arguments that the collateral reassignment uncertainty is alleviated when the Fed intervenes twice on the same day. The results in columns (3) and (5) of the Table suggest that, on days with open market operations, trading volume is significantly lower than on days without operations.

[Table 4 approximately here]

5 Bond Market Volatility at *Fed Time* and the Outcomes of the Fed's Repo Auctions

5.1 Variables and descriptive statistics

This section proposes an empirical model for measuring the impact of the outcomes of the Fed's repo auctions on the bond market. The objective is to explain some of the puzzling patterns of bond market volatility presented in the previous section. The operations are implemented in the format of the repo agreements and the repo rate paid for the funds by the dealers is determined through the auction. Since bond dealers do not know in advance the size of the operations they tend to overbid and, as a result, face a collateral reassignment problem after the Fed's auction.

I employ additional data provided by the New York Fed, which covers the outcomes of open market operations[16] in the year 2000 and has a daily frequency. I also incorporate daily data on the effective federal funds and federal funds target rates. Let me present the summary statistics on these data in Table 5.

[Table 5 approximately here]

This statistics tells us that in the year 2000 there were 190 incidents when the Fed intervened on the bond market through temporary open market operations. Panel B of the table indicates that there were 260 trading sessions on the federal funds market. The daily effective fed funds rate tends to be higher, on average, than the target rate and slightly more volatile. The last fact indicates that the New York Fed Funds Desk is doing a good job of conducting day-to-day monetary policy. Figure 8 in the Appendix B demonstrates that, in most cases, the weighted-average rate paid by the primary dealers to the Fed for funding was lower than the effective federal funds rate on the same day. This means that it was profitable for primary dealers to obtain funds from the Fed through collateralized borrowing then borrow funds at the unsecured federal funds market.

[16] I use only temporary repurchase agreements that add reserves and ignore the reverse repos that drain reserves (there were only 3 instances of Match Sale Purchases (MSPs) in 2000 conducted by the Fed).

5.2 Outcomes of the repo auctions and the bond market

The NY Fed data on outcomes of open market operations allows us to create two measures for the degree of aggregate imbalance in the dealer's repo book following operations by the Fed. First, I determine the difference between the value of bonds proposed by dealers to the Fed for refinancing and the value of the refinancing accepted (the size of the open market operation) for each type of operation. I call this variable: *Dealers Overbidding*. The size of the difference on any given day indicates the aggregate overbidding by primary dealers and is an indicator of the imbalance in their the repo book that needs to be refinanced in the private sector[17].

My second measure is the spread between the effective federal fund rate and the weighted-average rate paid by primary dealers for Fed's refinancing on the repo auction. I call it: *Fed Fund -Weighted Repo Rates Spread.* Because there are different types of open market operations I create this variable separately for each of those types. This spread indicates the attractiveness for primary dealers to participate in the Fed's auction. The wider the spread the more expensive is financing on the private market, hence there is a higher incentive for bond dealers to overbid during open market operations.

I regress these two measures on the Fed time bond returns volatility and add the control variables described above. Table 6 reports the estimation results for the first measure and Table 7 for the second.

[Table 6 approximately here]

As can be seen form Table 86, the size of the primary dealer's overbidding is positively associated with the bond returns volatility on days with short-term repos, while the size of overbidding is not related to bond market volatility on days when both types of operations were conducted. Similar results are evident in Table 7. On days with short-term repos, the size of the spread between the federal funds rate and the weighted-average rate at the Fed' auction is positively related to bond volatility. The larger the incentive to overbid for Fed's funding on a day when Fed is present with short-term

[17] The overbidding phenomenon was particularly strong under the fixed rate tenders conducted by the European Central Bank as demonstrated by Ayuso and Repullo (2001). The Fed practices the variable rate tender but overbidding is still present.

repos, the higher the bond market volatility on that day. On days with both long and short repos the *Fed Fund - Weighted Repo Rates Spread* spread is insignificant. This means that even in the presence of an incentive to compete for Fed's funding the demand for refinancing is satisfied by the dual operations and the volatility of bond returns is unaffected.

[Table 7 approximately here]

Tables 6 and 7 provide evidence that the collateral reassignment problem the primary dealers face due to overbidding on days with only short-term open market operations can explain the volatility patterns presented in the previous sections. On days when Fed intervenes twice, dealers overbid less at *Fed time* and the collateral reassignment problem wanes. As a result, the volatility of bond returns on days when Fed intervenes twice is not statistically different from that on days without open market operations. When Fed conducts long-term repos at 8:20 am, primary dealers solve their collateral reassignment problem and overbid less at *Fed time* at 9:30 am.

6 Conclusion

The success of open market operations conducted by central banks is traditionally measured in terms of deviations of the inter-bank interest rate from the target. My study focuses on another aspect of day-to-day monetary policy, i.e. the desire to exert minimal influence on the instruments employed for policy implementation. The large size of the US government bond market[18] makes it a convenient tool for adjusting the level of liquidity in the banking system trough temporary repos but also makes private bond market participants more sensitive to disturbances in the price formation process.

I demonstrate that regular short-term open market operations conducted by the Fed in the year 2000 had a significant impact on the volatility of bond returns at *Fed time*. However, on days when the Fed intervened twice (at 8:20 am with long-term repos, in addition to, at 9:30 am with short-term repos), the volatility of bond returns was not different from days without

[18] Mizrach and Neely (2008) estimate its daily trading volume at $ 524.7 billion in the year 2007.

interventions. These findings suggest that the introduction of the long-term repos, which was intended to smooth out the seasonal patterns in the banks' reserves, also improved the efficiency of monetary policy implementation.

My study presents evidence linking the observed patterns of bond returns volatility to the collateral reassignment problem faced by bond dealers as a result of overbidding at the Fed's repo auctions. The larger the overbidding is, the more financing dealers will have to acquire from the private market to compensate for orders that were not satisfied by the Fed. I find that two empirical measures of the volume of overbidding are positively associated with the volatility of bond returns on days when the Fed's repos were scheduled only at regular *Fed time*. However, on days with both long and short-term repos, there is no significant positive association between the size of overbidding and bond returns volatility. This means that, in order to cause minimum disturbance to the instrument used for monetary policy conduct, the Fed should extend the maturity of the term repo contracts and intervene more than once per day.

7 Appendix A

Table 1A.
Descriptive statistics of 30-minutes bond returns for year 2000

	Obs.	Mean	St. Dev.	Min	Max
A. Intra-day statistics for the 2-year bond					
Return volatility [a]	3959	14.709	16.609	0	171.518
Bid-ask spread	3959	9.646	7.756	-15.62	85.895
Trade volume[b]	3959	202.624	164.827	0	1610
B. Intra-day statistics for the 5-year bond					
Return volatility	3953	36.769	39.292	0	442.266
Bid-Ask spread	3953	24.756	19.062	-76.65	193.424
Trade volume	3953	94.169	84.577	0	1043

Notes:
[a] The overnight return is dropped
[b] The trade volume is reported per 30 minute interval through each day for the whole year

Table 2A.
Descriptive statistics of daily series for year 2000

	Obs.	Mean	St. Dev.	Min	Max
A. Dependent variable					
Fed Time 2-year bonds Returns volatility	251	17.986	17.154	0	98.324
Fed Time 5-year bonds Returns volatility	251	44.794	43.061	0	225.592
B. Control variables					
Yield Curve Slope	251	0.158	0.615	-0.93	1.2
Fed Funds Spread	251	0.017	0.117	-1.09	0.530

Table 3A
Frequency of open market operations by maturity type

	Mon	Tues	Wed	Thrs	Fri	Total
Overnight repos only	32	21	37	31	20	141
Term repos under 15 days only	8	9	2	8	8	35
Overnight repos AND Term repos under 15 days	1	0	0	2	0	3
Total	41	30	39	41	28	179

Source: New York Fed

Table 4A
Frequency of open market operations by maturity type

	Mon	Tues	Wedn	Thrs	Fri	Total
9:30 am short maturity repos only	16	27	37	23	27	130
8:20 am 28-days Term repos only	5	0	0	3	0	8
Both 8:20 and 9:30 operations present	25	3	2	18	1	49
Total	46	30	39	44	28	187

Source: New York Fed

Table 5A
List of the 8:30 am macroeconomic announcements

Announcement	Units
Auto and Truck Sales	Millions
Initial jobless claims	Thousands
Nonfarm Payrolls/Hourly Earnings	$
Unemployment Rate	Per cent change
Export/Import Prices	Per cent change
PPI	Per cent change
CPI	Per cent change
Housing Starts	Millions
Trade Balance	$
Durable Orders	Per cent change
Employment Cost Index	Per cent change
GDP/GDP Chain Deflator	Per cent change
Productivity	Per cent change

Source: Briefing.com

Table 6A
List of the 10:00 am macroeconomic announcements

Announcement	Units
Factory Orders	Per cent change
New/Existing Home Sales	Thousands
Initial Claims	Thousands
Consumer Confidence	Index
Construction Spending	Per cent change
Leading Indicators	Per cent change
Wholesale Inventories	Per cent change
Help-Wanted Index	Millions
Chicago PMI	Per cent change

Source: Briefing.com

8 Appendix B

Fig. 1 Intra-day volatility of half-hour bond returns during the year 2000

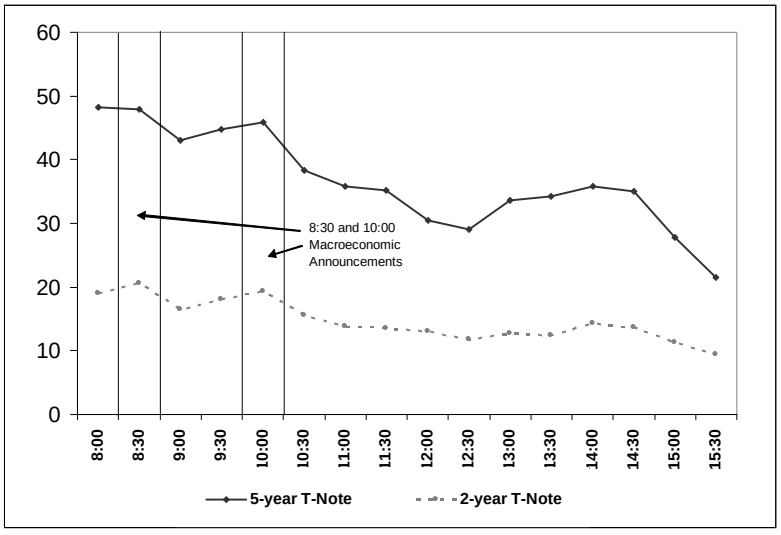


Fig. 2a Volatility of 2-year bond returns on days with Fed's repos

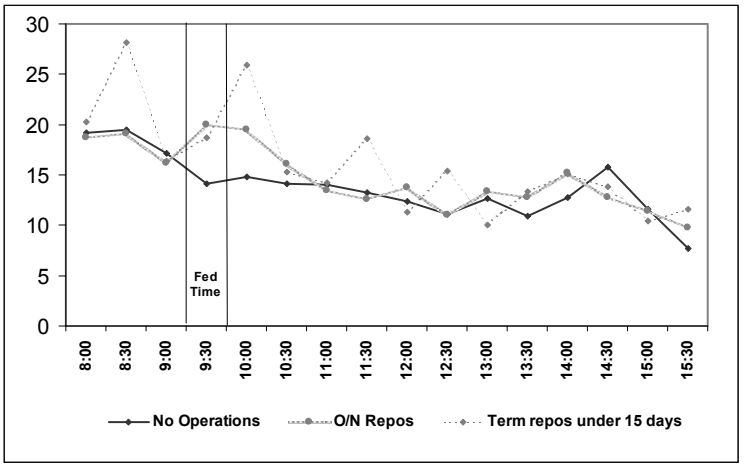


Fig. 2b Volatility of 5-year bond returns on days with Fed's repos

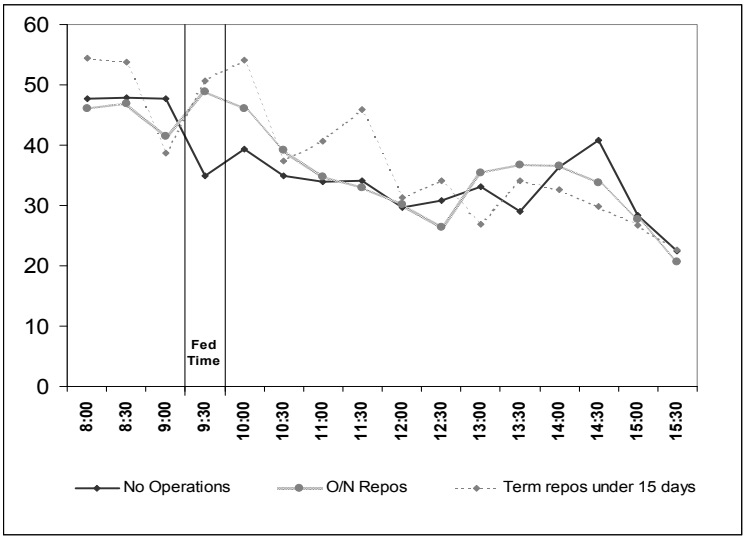


Fig. 3a Volatility of 2-year bond returns on days with Fed's long-term repos and days without such repos

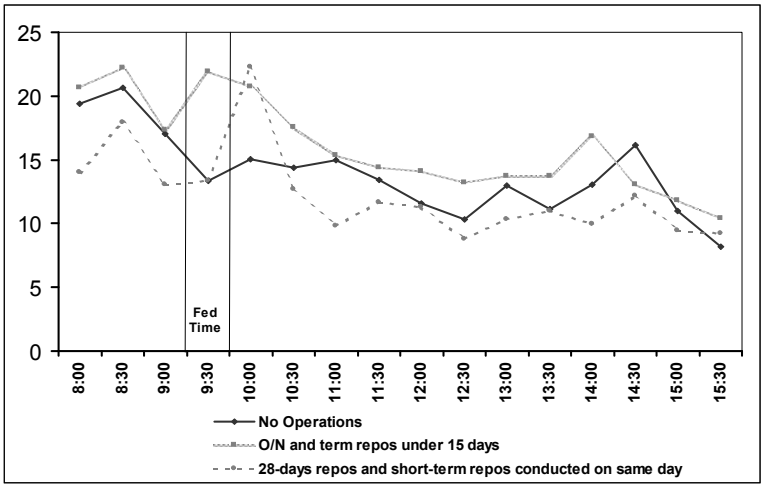


Fig. 3b Volatility of 5-year bond returns on days with Fed's long-term repos and days without such repos

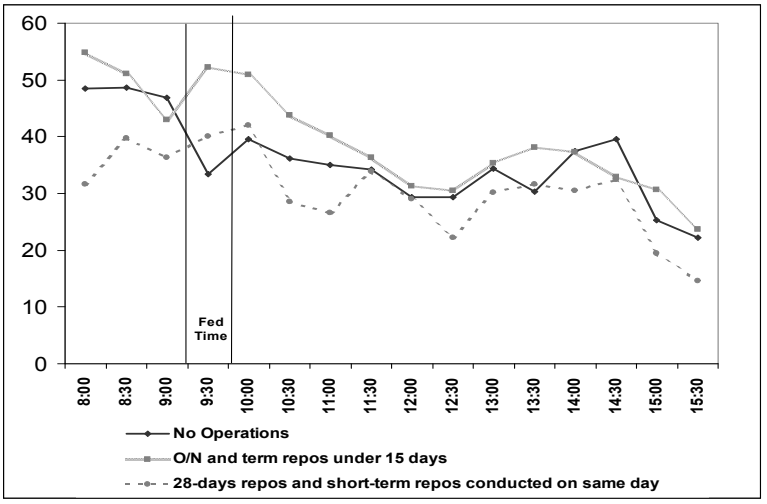


Fig. 4

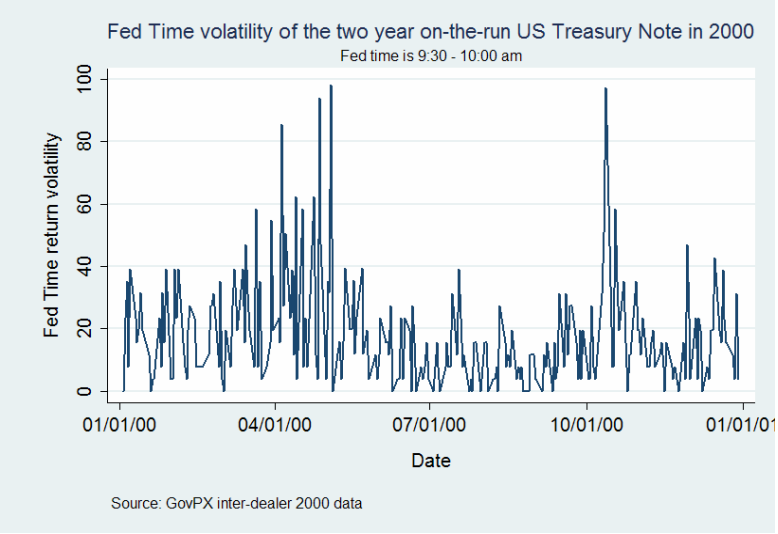

Fed Time volatility of the two year on-the-run US Treasury Note in 2000
Fed time is 9:30 - 10:00 am
Fed Time return volatility
0
20
40
60
80
100
01/01/00
04/01/00
07/01/00
10/01/00
Date
Source: GovPX inter-dealer 2000 data

Fig. 5

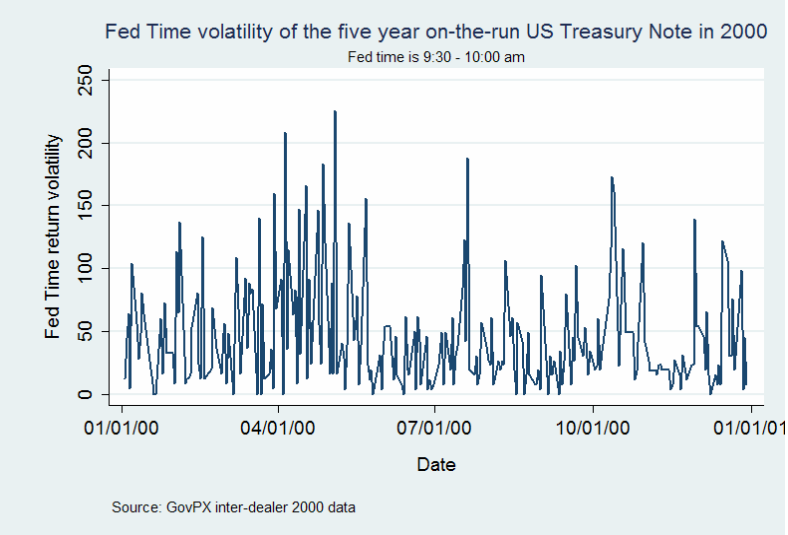

Fed Time volatility of the five year on-the-run US Treasury Note in 2000
Fed time is 9:30 - 10:00 am
Fed Time return volatility
0
50
100
150
200
250
01/01/00
04/01/00
07/01/00
10/01/00
Date
Source: GovPX inter-dealer 2000 data

Fig. 6

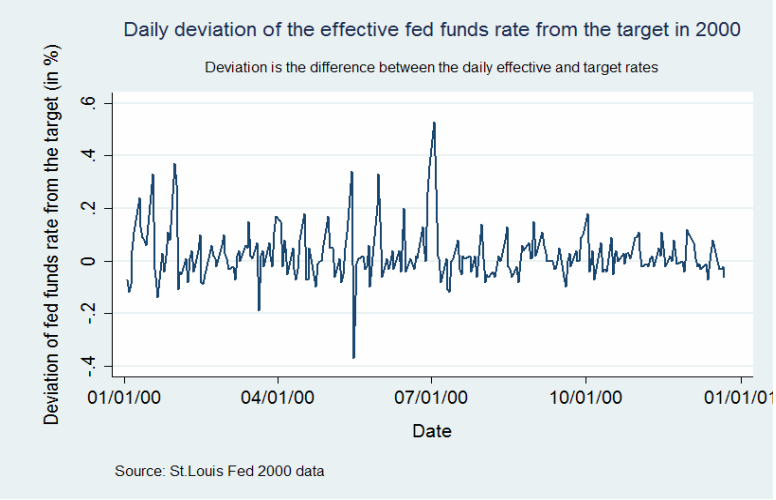
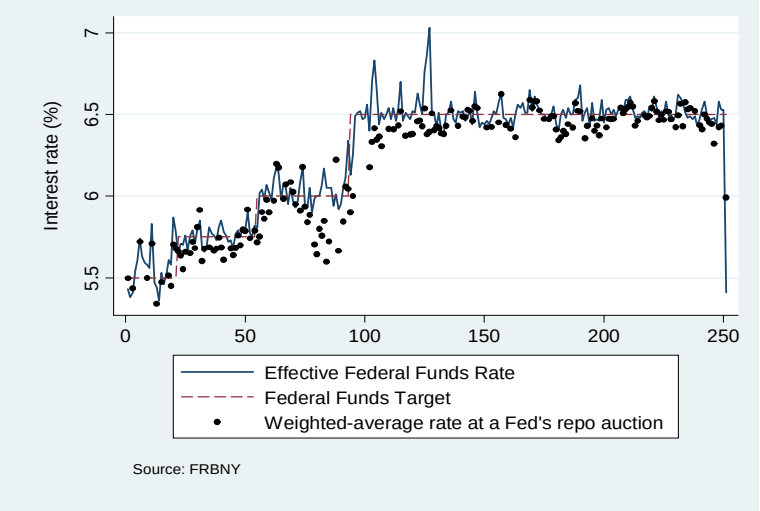


Fig. 7 Daily dynamics of the effective fed funds, fed funds target and the weighted-average rates



9 Appendix C

Table 1.
Fed time volatility and open market operations in year 2000
Dependent variable: *Fed Time* bond returns volatility (GARCH)

Independent variable	2-year T-Note	5-year T-Note
(1)	(2)	(3)
Overnight Fed's repo[a]	4.359**	14.220**
	(2.094)	(6.330)
Short-Term Fed's repo[a]	2.640	15.251*
	(3.259)	(9.021)
Lagged Fed Funds spread	-12.706	-24.122
	(10.063)	(28.865)
Yield Curve Slope	3.053**	5.853
	(1.529)	(4.217)
Announcement 8:30 am	4.058**	8.036
	(2.008)	(5.398)
Announcement 10:00 am	-0.821	-1.721
	(1.760)	(5.332)
Constant	10.241***	27.403***
	(2.441)	(7.673)
Variance Equation		
ARCH(1)	0.230***	0.117***
	(0.052)	(0.047)
GARCH(1)	0.737***	0.806***
	(0.045)	(0.060)

Notes:
[a] Takes value 1 if Fed was present on the day and 0 otherwise
** Denotes significance at 5% level. *** at 1% level.

Table 2.
Fed time bid-ask spreads, trading volume and
open market operations in year 2000
Dependent variables: *Fed Time* bond bid-ask spread and trading volume

Independent variable	2-year T-Note		5-year T-Note	
(1)	(2)	(3)	(4)	(5)
	Bid-Ask spread	Trading Volume	Bid-Ask spread	Trading Volume
Overnight Fed's repo[a]	0.973 (0.789)[b]	-24.115 (26.179)	3.829** (2.059)	0.584 (12.108)
Short-Term Fed's repo[a]	0.343 (1.092)	-38.901 (31.114)	10.324** (5.141)	-25.265 (16.219)
Lagged Fed Funds spread	6.036* (3.480)	-235.355*** (93.913)	33.921* (20.465)	-65.793 (64.219)
Yield Slope	-1.227** (.629)	116.859*** (17.496)	2.530 (1.819)	94.752*** (7.302)
Constant	4.372*** (.575)	292.362*** (23.399)	11.076*** (1.387)	120.646*** (8.852)

Notes:
[a] Takes value 1 if Fed was present on the day and 0 otherwise
[b] Newey-West heteroskedasticity and autocorrelation robust standard errors
** Denotes significance at 5% level. *** 1% level.

Table 3.
Fed time volatility and long-term open market operations in year 2000
Dependent variable: *Fed Time* bond returns volatility (GARCH)

Independent variable	2-year T-Note	5-year T-Note
(1)	(2)	(3)
28-days Fed's repo[a]	4.536 (4.032)	17.973 (6.330)
Under 15-days Fed's repo[a]	5.696*** (2.290)	17.585*** (6.579)
Both operations present[a]	0.537 (3.032)	7.923 (7.531)
Lagged Fed Funds spread	-13.688 (10.359)	-26.355 (28.679)
Yield Curve Slope	2.522* (1.551)	4.506 (4.072)
Announcement 8:30 am	3.576* (1.982)	7.027 (5.374)
Announcement 10:00 am	-0.713 (1.842)	-1.519 (5.309)
Constant	10.280*** (2.635)	26.763*** (7.675)
Variance Equation		
ARCH(1)	0.217*** (0.051)	0.140*** (0.051)
GARCH(1)	0.749*** (0.046)	0.787*** (0.058)

Table 4.
Fed time bid-ask spreads, trading volume and open
market operations in year 2000
Dependent variables: Fed Time bond bid-ask spread and trading volume

Independent variable	2-year T-Note		5-year T-Note	
(1)	(2)	(3)	(4)	(5)
	Bid-Ask spread	Trading Volume	Bid-Ask spread	Trading Volume
28-days Fed's repo[a]	2.405 (2.196)[b]	-45.229 (81.285)	10.319*** (3.827)	-66.897*** (16.564)
Under 15-days Fed's repo[a]	2.105*** (.799)	-9.134 (27.505)	6.368*** (2.315)	-9.061 (13.151)
Both operations present[a]	-0.267 (1.023)	-92.695*** (27.573)	7.926** (3.399)	-26.809** (13.816)
Lagged Fed Funds spread	5.488* (3.363)	-275.496*** (88.899)	36.709* (21.424)	-86.461 (64.636)
Yield Slope	-1.596*** (.640)	103.398*** (17.369)	2.886* (1.758)	91.165*** (7.493)
Constant	3.923*** (.596)	300.699*** (24.752)	9.380*** (1.488)	130.514*** (9.860)

Notes:
[a] Takes value 1 if Fed was present on the day and 0 otherwise
[b] Newey-West heteroskedasticity and autocorrelation robust standard errors
** Denotes significance at 5% level. *** 1% level.

Table 5.
Descriptive statistics on open market operations and federal funds

	Obs.	Mean	St. Dev.	Min	Max
A. Outcomes of open market operations					
Total Propositions Submitted (in $bil.)	190	9.802	4.122	2.2	21.9
Total Propositions Accepted (in $bil.)	190	2.182	1.571	0	6.68
Weighted-Average Rate	190	5.927	1.294	0	6.625
Highest Rate Submitted	190	6.204	0.350	5.46	6.66
Lowest Rate Submitted	190	6.072	0.383	5	6.55
Stop Out Rate	190	5.916	1.292	0	6.61
B. Federal Funds Market					
Effective Federal Funds Rate	260	6.259	0.370	5.36	7.03
Federal Funds Target	260	6.240	0.360	5.5	6.5

Table 6.
2-year bond returns volatility and primary dealers overbidding
Dependent variable: Fed Time bond returns volatility, Daily data 2000

Independent variable	2-year	5-year
(1)	(2)	(3)
Primary dealers overbidding on days with only 28-days repos	0.078 (0.255)	1.201 (0 .890)
Primary dealers overbidding on days with repos shorter 15-days	0.301** (0.151)	1.337*** (0.475)
Primary dealers overbidding on days with both types of operations	-0.124 (0.135)	0.031 (0.407)
Lagged Fed Funds spread	-13.030 (10.479)	-27.513 (29.187)
Yield Curve Slope	2.589* (1.461)	3.238 (3.957)
Constant	13.999*** (1.415)	35.192*** (4.755)
Variance Equation		
ARCH(1)	0.228*** (0.049)	0.132*** (0.046)
GARCH(1)	0.754*** (0.040)	0.796*** (0.055)

Table 7.
2-year bond returns volatility and imbalance in the dealer's repo book
Dependent variable: Fed Time bond returns volatility, Daily data 2000

Independent variable	2-year	5-year
(1)	(2)	(3)
Fed funds-Weighted Average Spread on days with only 28-days repos	-1.244 (38.167)	-6.266 (73.797)
Fed funds-Weighted Average Spread on days with repos shorter 15-days	8.260*** (0.904)	14.076*** (2.304)
Fed funds-Weighted Average Spread on days with both types of operations	-2.610 (14.106)	-1.923 (40.650)
Lagged Fed Funds spread	-13.192 (10.135)	-28.491 (29.376)
Yield Curve Slope	2.858** (1.492)	4.160 (4.129)
Constant	14.688*** (1.059)	40.586*** (3.641)
Variance Equation		
ARCH(1)	0.214*** (0.040)	0.107*** (0.038)
GARCH(1)	0.762*** (0.028)	0.802*** (0.051)

References

[1] Akhtar, M. (1997). *Understanding open Market Operations*, Federal Reserve Bank of New York.

[2] Andersson, M. (2007). "Using Intraday Data to Gauge Financial Markets Responses to Fed and ECB monetary Policy Decisions." *International Journal of Central Banking*, forthcoming.

[3] Ayuso J., and Repullo R. (2001). "Why did the Banks Overbid? An Empirical Model of the Fixed Rate Tenders of the European Central Bank." *Journal of International Money and Finance* 20, 857-870.

[4] Balduzzi, P., Elton, E., and Green., C. (2001). "Economic News and Bond Prices: Evidence from the U.S. Treasury Market." *The Journal of Financial and Quantitative Analysis* 36, 523-543.

[5] Bartolini, L., Bertola, G., and Prati, A. (2001). "Bank's Reserve Management, Transaction Costs, and the Timing of Federal Reserve Intervention." *Journal of Banking and Finance* 25, 1287-1317.

[6] Bartolini, L., Bertola, G., and Prati, A. (2002). "Day-to-Day Monetary Policy and the Volatility of the Federal Funds Interest Rate." *Journal of Money, Credit, and Banking* 34.

[7] Becker K., Finnerty, J., and Kopecky, K. (1996). "Macroeconomic News and the Efficiency of International Bond Futures Markets." Journal of Futures Markets 16.

[8] Bindseil, U. (2004). *Monetary Policy Implementation. Theory, Past, and Present*, Oxford University Press.

[9] Campbell, J. (1987). "Money Announcements, The Demand for Bank Reserves, and the Behavior of the Federal Funds Rate within the Statement Week." *Journal of Money, Credit, and Banking* 19, 56-67.

[10] Carpenter S., and Demiralp S. (2006). "The Liquidity Effect in the Federal Funds Market: Evidence from Daily Open Market Operation." *Journal of Money, Credit, and Banking* 38, 901-920

[11] Cosimano, T., and Sheehan, R. (1994). "The Federal Reserve Operating Procedure, 1984-1990: An Empirical Analysis." *Journal of Macroeconomics* 16, 573-588.

[12] Dacorogna M., Gencay R., Muller U., Olsen R., Pictet O. (2001). *An Introduction to High-Frequency Finance*, Academic Press.

[13] Daripa, A. (2001). "A Theory of Treasury Auctions." *Journal of International Money and Finance* 20, 743-767.

[14] Demiralp, S., and Jorda, O. (2002). "The Announcement Effect: Evidence from Open Market Desk Date." *FRBNY Economic Policy Review*, May, 29-48.

[15] Daigler, R., and Wiley, M. (1999). "The Impact of Trader Type on the Futures Volatility-Volume Relation." *Journal of Finance* 54, 2297-2316.

[16] Duffie, D. (1996). "Special Repo Rates." *The Journal of Finance*, Vol. LI, No. 2, 493-526.

[17] Ederington, L., and Lee, J. (1993). "How Market Process Information: News Releases and Volatility." *Journal of Finance* 48, 1161-1191.

[18] Ederington, L., and Lee, J. (1995). "The Short-Run Dynamics of the Price Adjustment to New Information." *Journal of Financial and Quantitative Analysis* 30, 117-134.

[19] Faust, J., Rogers, J., Wang, S., Wright, J., (2007). "The High-frequency Response of Exchange Rates and Interest Rates to Macroeconomic Announcements," J*ournal of Monetary Economics* 54, 1051-1068.

[20] Fleming M. (1997). "The Round-the-Clock Market for U.S. Treasury Securities." *FRBNY Economic Policy Review* 3, July 9-32.

[21] Fleming M. (2003). "Measuring Treasury Market Liquidity." *FRBNY Economic Policy Review*, September 83-108.

[22] Fleming M., and Garbade K. (2007). "Dealer Behavior in the Specials Market for US Treasury Securities." *Journal of Financial Intermediation* 16, 204-28.

[23] Fleming M., and Piazzesi M. (2005). "Monetary Policy Tick-by-tick." mimeo

[24] Fleming M., and Remolona E. (1997). "What Moves the Bond Market?" *FRBNY Economic Policy Review*, December 31-50.

[25] Fleming M., and Remolona E. (1999). "Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information." *The Journal of Finance*," Vol. LIV, No. 5.

[26] Furfine, C. (2000). "Interbank Payments and the Daily Federal Funds Rate." *Journal of Monetary Economics* 46, 535-53.

[27] Furfine, C. (1999). "The Microstructure of the Federal Funds Market, Financial Markets." *Institutions and Instruments* 8, 24-44.

[28] Green, C., (2004). "Economic News and the Impact of Trading on Bond Prices." *Journal of Finance* 59, 1201-1233.

[29] Gurkaynak, R., Sack, B., and Swanson, E. (2005) "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements." *International Journal of Central Banking* 1,pp. 55-93.

[30] Hamilton, J. (1996). "The Daily Market for Federal Funds." *The Journal of Political Economy* 104, 26-56.

[31] Hamilton, J. (1997). "Measuring the Liquidity Effect." *The American Economic Review* 87, 80-97.

[32] Hartmann P., Manna M., and Manzanares A. (2001), "The Microstructure of the Euro Money Market." *Journal of International Money and Finance* 20, 895-948.

[33] Harvey, C., and Huang, R. (2002). "The Impact of the Federal Reserve Bank's Open Market Operations." *Journal of Financial Markets* 5, 223-257.

[34] Hilton S., and Hrung W. (2007). "Reserves Levels and Intraday Federal Funds Rate Behavior." FRNB Staff Report no. 284.

[35] Huang, R., Jun Cai, and Xiaozu Wang. (2002). "Information Based Trading in the Treasury Note Interdealer Broker Market." *Journal of Financial Intermediation* 11, 269-96.

[36] Lumpkin S. (1998). *Repurchase and Reverse Repurchase Agreements*, in Cook, T., and Rowe, T., *Instruments of the Money Market*, 6th edition, Federal Reserve Bank of Richmond.

[37] Meulendyke, A. (2002). *U.S. Monetary Policy and Financial Markets.* Federal Reserve Bank of New York.

[38] Mizrach, B., and Neely, C., (2008). "The Microstructure of the U.S. Treasury Market." In *Encyclopedia of Complexity*, NY: Springer-Verlag.

[39] Moschitz, J. (2004). "The Determinants of the Overnight Interest Rate in the Euro Area." European Central Bank Working Paper No. 393

[40] O'Hara, M. (1995). *Market Microstructure Theory*, Blackwell.

[41] *Open Market Operation in the 2000*. Federal Reserve Bank of New York.

[42] Pasquariello, P., (2007). "Informative Trading or Just Costly Noise? An Analysis of Central Bank Interventions." *Journal of Financial Markets* 10, p. 107-143.

[43] Stigum, M. (1989). *The Repo and Reverse Markets*, Dow Jones/Irwin.

[44] Stigum, M. (1990). *The Money Market*, Dow Jones/Irwin.

[45] Taylor, J. (2001). "Expectations, Open Market Operations, and Changes in the Federal Funds Rate." *Federal Reserve Bank of St. Louis Review*, July/August, 33-47.

[46] Thornton, D. (2001). "Identifying the Liquidity Effect at the Daily Frequency." *Federal Reserve Bank of St. Louis Review*, July/August, 59-78.

[47] Urich T., and Wachter, P. (2001). "Financial Markets Responses to Monetary Policy Changes in the 1990s." *Contemporary Policy* 19, Issue 3, 254-67

[48] Woodford, M. (2003). *Interest and Prices*. Princeton University Press.

[49] Wurz, F. (2003). "A Comprehensive Model on the Euro Overnight Rate." European Central Bank Working Paper No. 207.

Препринт WP9/2008/01
Серия WP9
Исследования по экономике и финансам
Research of economics and finance

Владимир Соколов

Операции на открытом рынке и волатильность доходности облигаций: микроструктурное исследование

(на английском языке)

Публикуется в авторской редакции

Выпускающий редактор *А.В. Заиченко*
Технический редактор *Ю.Н. Петрина*

ЛР № 020832 от 15 октября 1993 г.
Отпечатано в типографии ГУ ВШЭ с представленного оригинал-макета.
Формат 60×84 $^{1}/_{16}$. Бумага офсетная. Тираж 150 экз. Уч.-изд. л. 2,7.
Усл. печ. л. 2,56. Заказ № . Изд. № 876.

ГУ ВШЭ. 125319, Москва, Кочновский проезд, 3
Типография ГУ ВШЭ. 125319, Москва, Кочновский проезд, 3

Тел.: (495) 772-95-71; 772-95-73