ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ
ВЫСШАЯ ШКОЛА ЭКОНОМИКИ

Международный институт экономики и финансов

Vladimir Sokolov

OPEN MARKET OPERATIONS AND VOLATILITY OF BOND RETURNS: MICROSTRUCTURE EVIDENCE

Препринт WP9/2007/03

Серия WP9

Исследования по экономике и финансам
Research of economics and finance

Москва
ГУ ВШЭ
2007

УДК 336.763.3
ББК 65.262.2
S 70

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
S 70 Evidence: Working paper WP9/2007/03. – Moscow: State University – Higher School of Economics, 2007. – 44 p.

I study the impact of the open market operations conducted by the Fed on the volatility of bond returns during the Fed time. I use the high-frequency GovPX transaction data and find evidence that the Fed's day-to-day monetary policy is not neutral with respect to the instrument employed and Fed has a pronounced impact on the bond market. The Fed's presence is significant on days when overnight open market operations are conducted and is not significant for the term open market operations. Through the detailed analyses of the repo, fed funds, and bond markets, I demonstrate that the observed volatility pattern can be attributed to a collateral reassignment problem faced by the primary dealers. Since the Fed's open market operations are pay-your-bid auctions primary dealers can choose the extent to which they participate in the auction. It appears that the incentive to get a cheaper source of financing causes them to submit more orders for refinancing with the Fed than it satisfies. The unfulfilled orders have to be financed on the private repo market later during the day. I find that the volatility of bond returns during the Fed time is positively associated with the bond dealer's repo book imbalance and negatively with the width of the operations coverage. This analysis serves as a measure of the efficiency of the day-to-day monetary policy implementation and suggests importance of the more competitive primary dealers structure.

УДК 336.763.3
ББК 65.262.2

Vladimir Sokolov – ICEF, 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 the relationship between outcomes of the temporary open market operations and the volatility of the government bond returns. The contribution of this paper is twofold. First, I extend the Harvey and Huang (2001) microstructure study covering the 1982-88 period to a more recent history of 2000-2001 and document the bond returns volatility patterns during the Fed's interventions. In the 80th Fed was operating under the Borrowed Reserves Targeting regime and at that time open market operations were informative for the private sector about the stance of the monetary policy which resulted in a higher volatility during the *Fed time*. On the contrary, under the current Fed Funds Targeting regime the operations are not supposed to carry any pay-off relevant information and are solely intended to adjust the level of liquidity in the banking system. Thus, one expects to have no discernible pattern of bond returns volatility during the conduct of open market operations. This brings us to the second issue addressed in this paper - evaluation of the day-to-day monetary policy *implementation efficiency.* While trying to achieve the main monetary policy objective, keeping the fed funds rate on target, Fed intends to have a minimal impact on the instruments it uses - the government bond market. It is well documented that the Trading Desk at the New York Fed is quite successful in predicting the reserves deficiency in the banking system as multiple studies (Bartolinni et. al. (2001, 2002) and Hamilton (1996, 1997)) demonstrate that the daily volatility of the fed funds rate is low and during

the incidents of target changes the fed funds rate adjusts to a new level smoothly. These studies provide evidence that Fed effectively fulfils the chief objective of the monetary policy. However, remarkably little attention has been paid to examining the efficiency of the policy implementation. My study is an attempt to cover this gap and verify whether the temporary open market operations have a non-negligible impact on the bond market.

The important institutional feature of the US monetary system is that the monetary authority does not intervene directly on the inter-bank market for overnight reserves but injects or drains reserves through the system of multiple primary bond dealers. While conducting open market operations Fed acts as a large creditor who refinances the previously established leveraged bond positions of the primary dealers. Format of such operations is the temporary repurchase agreements. Under this framework Fed does not purchase or sell securities on the bond market at the time of interventions but only facilitates the primary bond dealers in rolling over their debt with the private banks. Adjusting the level of reserves in the banking system Fed intends to be a price effect minimizer with respect to the instrument it employs and the repurchase agreements which are organized as auctions among primary dealers for Fed's refinancing should fit this objective.

In my study I find that in the year 2000 the bond return volatility increased significantly during the official *Fed time* on days when Fed conducted the overnight repurchase agreements and did not change on days when Fed conducted the term repurchase agreements, indicating that Fed's presence has a non-negligible impact on the bond market. This finding is somewhat puzzling as refinancing of the existing position in

a security should not affect the price formation process of that security. Given the huge size of the US government debt market the fact that Fed's overnight refinancing stirs the market up and is only available to a few primary bond dealers raises the issue of policy implementation efficiency.

In the second stage of my analysis I proceed with investigating how the outcomes of the Fed's repo auctions are related to the higher bond returns volatility during the Fed's interventions. Since Fed's repurchase agreements are organized as pay-your-bid auctions the primary dealers have an opportunity to refinance their leveraged positions at a lower cost than using a private repo market. It might give them an incentive to submit a larger portion of their securities for refinancing with the Fed. Since the size of the open market operations is unknown a lot of submitted securities are not financed and primary dealers have to reassign this collateral to the private banks. This is called a collateral reassignment uncertainty. I attribute the spike in bond returns volatility during the *Fed time* on days with overnight operations to the imbalance in the dealers' repo book caused by this uncertainty.

For the empirical analysis I construct two measures of the aggregate imbalance in the primary dealers' repo book which are: the difference between submitted and fulfilled orders for Fed's refinancing and the spread between the highest submitted repo rate and the stop out repo rate. I find that both these measures are significantly associated with the volatility of bond returns during the *Fed time*. These results demonstrate that the system of the primary bond dealers might require further improvements in order to smooth out the day-to-day monetary policy implementation.

The remainder of the paper proceeds as follows. Section

2 overviews the institutional set-up of the bond and money markets. It provides an overview of the open market operations by the Fed and the primary dealer's collateral reassignment problem. Section 3 reports the half-hour bond returns volatility patterns during the *Fed Time*. Section 4 further empirically investigates the linkage between the outcome of the open market operations and the bond market volatility. Section 5 looks into the degree of the bond dealers' repo book imbalance. Section 6 compares the way of conducting the open market operations by the European Central Bank and the Fed. Section 7 concludes.

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

Fed conducts open market operations for two reasons. First, is to accommodate the temporary exogenous shocks to the level of reserves in the banking system. It tries to remove 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 (See Appendix A for the discussion on the monetary regimes). This type of open market operations is called *defensive.* Second reason for intervention is to enforce a new level of the interest rate target and consequently a broader spectrum of interest rates in the economy. This type of operations is called *dynamic.*

Defensive operations are the authority of the Trading Desk at the New York Fed. The Desk needs to estimate the exogenous shocks, formulate the size of operations, and project its further impact on the money market. The Desk routinely

conducts this defensive operations on a daily basis. On the opposite, the fed rate target and the dynamic open market operations are a "higher-level policy decisions" and are the authority of the Federal Open Market Committee.

Staring from 1994 the Fed became transparent about its fed fund target and communicates the target to the public through speeches and testimonies. For private agents this shift means that *all* Fed's open market operations are *defensive* in their nature and do not carry the information about the future stance of the monetary policy. This change in the conduct of the policy removed the whole profession called the "Fed watchers" who routinely observed the balances in the banking system and the amount of Fed's interventions in order to forecast the direction of interest rates. Under the current policy, which is sometimes called the "open mouth operations" the private sector forecasts the future fed target based on the macroeconomic fundamentals rather than on the amount of reserves in the banking system.

The purpose of my study is to research the neutrality of the defensive open market operations with respect to the government bond market. Let me first narrow down the asset classes considered in this paper. For the bond market analysis I use only the government 2-years and 5-years maturity *treasury notes*. On the money market I focus on two instruments: *repurchase agreements* (repo) which are an overnight 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 problem

The bond dealers are market makers and have to keep bonds in their inventory in order to meet the clients' orders. They are assigned to provide liquidity and continuity to the market. The risk of having an unfavorable position is partly compensated with the bid-ask spread the dealer earns on the order flow. However, the anecdotal evidence (Stigum, 1990) suggests that servicing customers and the bid-ask spread will hardly even pay the dealer's utility bill. Empirical research by Fleming (2003) confirms that treasury bonds spreads are very narrow ranging from 0.21 to 0.52 of 32s basis points. The largest portion of the bond dealer's profits are earned by assuming the risky positions in the bonds they trade.

The typical portfolio allocation decision of the bond dealer involves taking the short-term leveraged position in a security and financing it through the repo agreement. Unlike banks, dealers do not hold bonds till maturity and assume a capital loss risk. Given the expectations regarding the future level of the interest rates the bond dealer forms 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 $t = n$[1]. The Ω_0 denotes time $t = 0$ information set regarding the

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

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 which is usually 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.[2]

Let me sketch the mechanism of the repurchase agreement. Having identified the trading strategy at time $t = 0$ dealer simultaneously conducts two transactions. He will contact the seller of a bond to lift the offering for a particular treasury at a quoted price P_0. At the same time a dealer contacts the funds surplus institution to borrow the P_0 amount of dollars overnight against a bond that he just purchased. Physically the bond goes from a seller to clearing house as a collateral and funds are transferred from the funds surplus institution to a seller of a security. As a result of this transaction a dealer assumes an asset and is now entitled to all its coupons and capital gains/losses. On the liability side he owes funds to a lender which must be repaid the next day. Since dealer intends to hold 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.

If we define the information set regarding the future course of the daily repo rates as Φ_0 we can formulate the *Expected*

[2]Repos also could be extended for a term of few days.

Financing Cost (EFC) of the trading strategy.

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

A bond dealer bets that over the investment horizon of n days the expected capital gain on a bond will exceed expected overnight cost of rolling over the repo agreements. The no-arbitrage condition[3] for the strategy is:

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

Let us illustrate the logic of the repo transaction with the example. Suppose a bond dealer initially financed its position through Bank A. The next day it has to repay the loan by arranging the repo agreement with Bank B that will transfer funds to Bank A (credit Bank's A account). From a dealer's standpoint this is a reassignment of collateral from one creditor to another. Bond dealer's portfolio allocation involves two transactions: assuming a new asset - a bond position and creating a new liability - a repo debt which has to be rolled over on a daily basis.

2.2 The Fed's repo auctions

Let us examine the mechanism and the objective of the defensive open market operations. Assume that the Fed projects

[3]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.

the 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 Trading Desk at the New York Fed needs to conduct the injection of the reserves into the system. Rather than intervening on the inter-bank credit market the Desk conducts open market operation in the format of the temporary repo agreements. In the mechanism of the repo market described in the previous subsection Fed substitutes the private fund surplus agents in the chain of refinancing the bond dealer's positions. This is implemented by transferring funds to the account of the dealer's previous creditor.

Suppose on a day t the bond dealer needs to return funds to the Bank A who previously financed the dealer's position through the private repo. In the absence of Fed's intervention dealer would arrange the Bank B crediting the Bank A account and reassign the bond as a collateral to Bank B. Now Fed intervenes and transfers funds to the Bank A instead. As a result of the transaction dealer owes funds to the Fed which holds bonds as a collateral. From the view point of a banking system the difference is that the Bank B which was supposed to refinance the dealer's position now has extra overnight funds. Since the demand for the private repo transaction was satisfied by the Fed the Bank B supplies its extra funds on the fed funds market. This puts a downward pressure on fed funds rate f which is exactly what Fed is trying to achieve in a given situation.

By conducting open market operations Fed acts not as a buyer on a bond market but rather as a big creditor who finances the previously established bond dealer's leveraged positions. In the absence of the operations 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 varies the monetary base through the system of multiple primary bond dealers. The Fed's repos are organized as an auction among primary bond dealer that takes place at a fixed time interval called the *Fed time*[4].

The advantage of participation in the Fed's repo auction for a primary dealer is a cheaper cost of financing their positions comparing with the private repo market. The defensive open market operations are conducted approximately every second trading day. If Fed intends to inject funds on a certain day it indicates during the *Fed time* that it offers refinancing and seeks bids from the primary dealers to be refinanced. Dealers choose both the bond issue they want to refinance and the repo rate they are willing to pay to the Fed for the provided funds. Fed ranks dealers offers and chooses the most attractive within the amount of reserves it wants to inject into the system. This is called a discriminatory (pay-your-bid) pricing rule auction. Under this rule, the market is cleared from the highest submitted bid (repo rate dealer are willing to pay) downward until the desired supply is exhausted. All winning bidders pay repo rate they quoted. The lowest winning bid is called a stop-out rate. Here is an example of the typical Fed's repo auction.

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

Table 1.
Example of outcomes of the Fed's repo auction

Treasury Open Market Operations for August 17, 2000	
Weighted Average Rate	6.436
Stop Out Rate r_S	6.43
Highest Rate Submitted	6.44
Lowest Rate Submitted	6.33
Total Propositions Submitted (in $bil.)	8.89
Total Propositions Accepted (in $bil.)	1.15

This example shows the amount of collateral offered by primary dealers for refinancing was 8.89 billion $ and the amount that was actually refinanced 1.15 billion $ (the size of the open market operation). The highest and the lowest repo rates offered by the dealers indicate the range of the rates that they were willing to pay for the funds. The stop-out rate r_S is the lowest rate at which Fed exhausted its defensive open market operation on that date. The key results of the auctions are the stop out rate and the total propositions accepted.

In this environment the attraction of getting a favorable rate at the Fed's repo auction creates an incentive for primary dealers to offer a lot of collateral to the Fed. In order to clear up the bond inventory after the open market operations are already implemented primary dealers seek the additional sources of financing with the private sector. This creates the so-called collateral reassignment uncertainty that could cause a higher volatility of bond returns during the *Fed time*. The described situation might not entirely fit the Fed's mandate of causing the minimal disturbance on the financial markets.

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

3.1 The GovPX data and filtering procedures

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

I focus on a 2-years T-Note since it is the most frequently used instrument for Fed's repos and the 5-years T-Note since it is the most liquid segment of the treasury market. 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 which include all changes in quotes such as bid-ask prices, quote sizes, and trading volume. There are two major problems with the high-frequency data. The first 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 or is not homogeneous in time. The first problem is relatively easy to solve by converting the *quoted* series into the *transaction* series. This is done by dropping quotes without the change in the traded volume as described in Fleming (2003). I also filter out the abnormal transactions such as the yield spreads that are out of -2.5 and 10 basis points range, quote sizes larger than 1,250 million $, and returns that are 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.[5]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 intervals and using the constructed regularly spaced data 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 trade volume growth between time intervals and the bid-ask spreads for each interval. Table 2 presents the descriptive statistics on these series.

[5]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.

Table 2.
Descriptive statistics of 30-minutes bond returns for year 2000

	Obs.	Mean	St. Dev.	Min	Max
A. Inra-day statistics for the 2-year bond					
Volatility[a]	3959	14.7	16.6	0	171.5
Bid-ask spread	3959	9.6	7.7	-15.6	85.8
Trade volume[b]	3959	202.6	164.8	0	1610
B. Inra-day statistics for the 5-year bond					
Volatility	3953	36.7	39.2	0	442.2
Bid-Ask spread	3953	24.7	19.1	-76.657	193.4
Trade volume	3953	94.1	84.5	0	1043

[a] The overnight return is dropped

[b] The trade volume is reported per 30 minute interval through each day for the whole year

3.2 The half-hour volatility patterns and open market operations

Under the assumption that during each half hour interval a different data generating process (DGP) is at work I estimate the volatility of half-hour bond returns separately for each of the intervals throughout the year. The estimation relies on the variability of the returns data across the trading days and is based on the Huang et. al. (2002) specification:

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

where $Vol_{t,n}$ denotes return volatility during half-hour interval n on day t. The first term on the right-hand side $interval_{t,n}$ is the indicator variable that takes on the value of 1 during in-

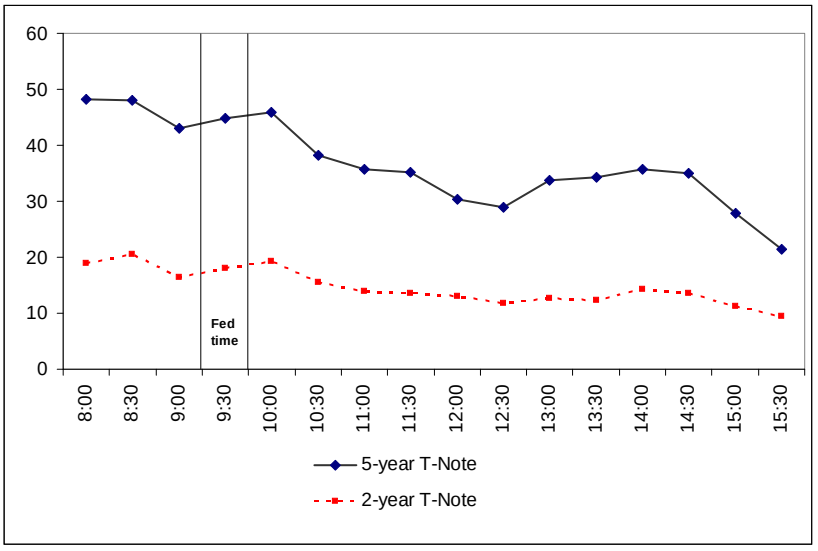
terval n on day t, and 0 otherwise. The variable $trend_{t,n}$ takes on the value of ((t-1)*16+n)/4216, t=1,...,251; n=1,...,16. It captures the time-series trend in the dependent variable. Figure 1 plots the estimates δ_n of the intra-day half-hour bond return volatility for the 2-years and 5-years T-Notes.

We observe that both bonds exhibited two spikes in volatility at 8:30 and 10:00 am. These are fixed time intervals when the major macroeconomic announcements are scheduled. These information releases are a subject of a few extensive studies by Ederington and Lee (1993, 1995), Huang et. al. (2002), Fleming (1997), Balduzzi et. al. (2001). My study focuses on the interval between 9:30 and 10:00 the *Fed Time*.

The plots demonstrates that the volatility subsides after the 8:30 am announcements but starts to increase at the *Fed time* and peaks right after the 10:00 am announcements. The increase in volatility during the *Fed Time* is in line with estimation results of Harvey and Huang (2001) for the 1982-1988 samples. As I mentioned in the introduction Fed followed a Borrowed Reserves Targeting procedure in the 80th which made the open market operations informative about the monetary policy stance. This is not the case in the year 2000 under the Fed Funds Targeting and the higher volatility during the Fed's interventions requires a further investigation.

I proceed with the analysis by estimating the intra-day volatility separately for days when Fed was present on the market conducting open market operations and for the days when Fed was absent. I also distinguish types of Fed's repos according to their maturity: overnight or term repo contracts.

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



Figures 2a,b plot half-hour volatility estimates for days with overnight open market operation against the days without overnight operations. A noticeable pattern emerges. For both bonds on days when Fed volatility was higher during the *Fed time* relative to days without the operations. Another interesting fact is the apparent relation between the 8:30 am announcements and the Fed's presence on the bond market. On days with operations, volatility at 8:30 am is much lower than on days without operations. This could be due to the fact that Fed chooses to conduct the overnight operations on days without scheduled 8:30 am announcements. Apparently this keeps volatility low at the time of the release but results in a considerable volatility increase during the *Fed time*.

Fig. 2a Volatility of 2-year bond returns on days with Fed's overnight repos and days without

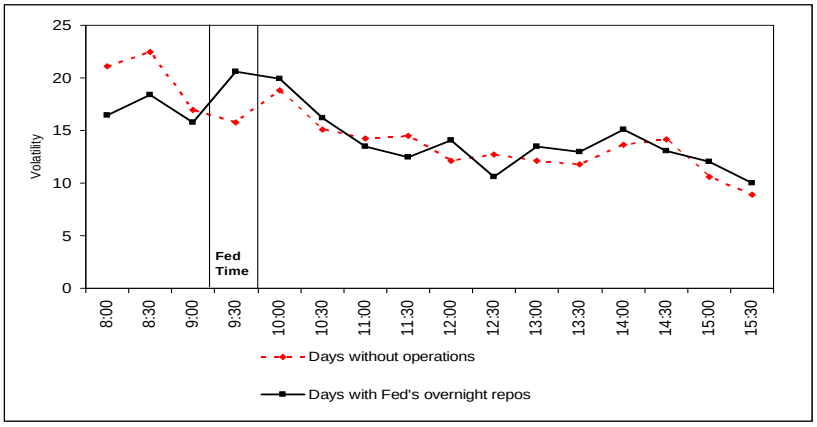
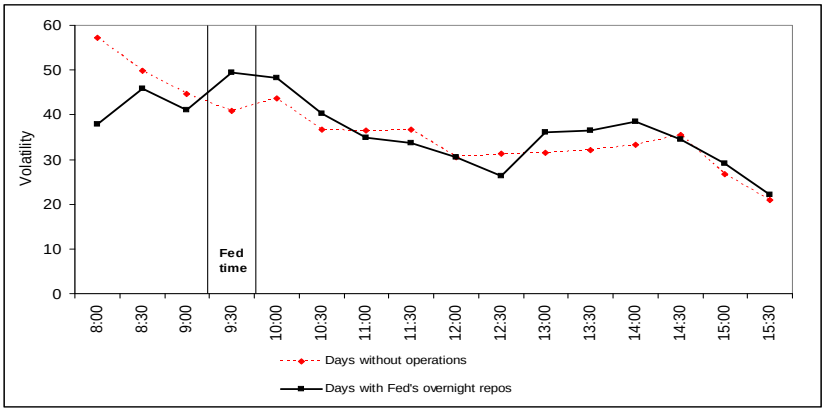


Fig. 2b Volatility of 5-year bond returns on days with Fed's overnight repos and days without



Figures 3a,b plot half-hour volatility estimates for days when Fed was conducting term repos and for days without term operations. There is no significant difference in volatility during *Fed time* between those days. Contrary to the results

for overnight repos the Fed's presence is positively associated with returns volatility during the 8:30 am announcements. The patterns suggest that Fed uses term operations on days with the major macro news releases.

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

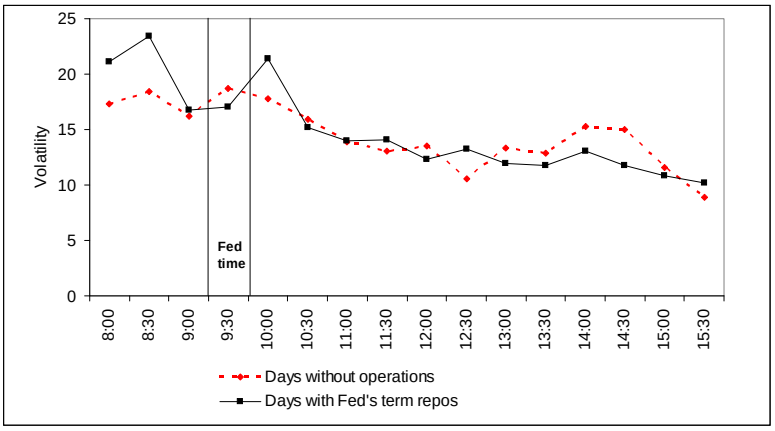
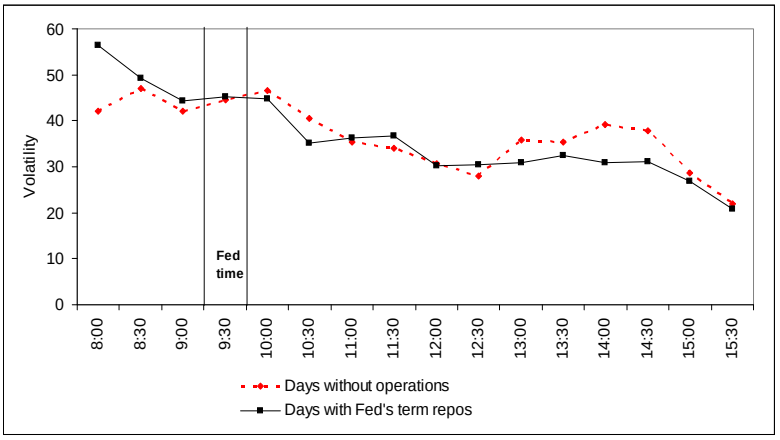


Fig. 3a Volatility of 5-year bond returns on days with Fed's term repos and days without



4 *Fed Time* Volatility and Open Market Operations

4.1 Variables and descriptive statistics

In this subsection I conduct the conditional regression analysis on testing the significance of different volatility patterns during the *Fed time* and check robustness of the results to the inclusion of the control variables associated with volatility. Similarly to the Ederington and Lee (1995) who isolate the bond returns around the 8:30 am announcements I isolate the bond returns during the *Fed time* for each trading day in the 2000 sample. This produces 251 observations of the daily *Fed time* volatility. The key aspect of the study is to establish if the Fed's presence on the market has an impact on the bond market. In order to do this I regress the *Fed time* volatility on two binary dummy variables that take values 1 if Fed was present on a given day with the overnight or term repos and 0 otherwise. The regression specification is as follows:

$$FedTimeVol_t = \delta Overnigt_t + \gamma Term_t + \beta' \mathbf{X}_t + \varepsilon_t \qquad (5)$$

where $FedTimeVol_t$ is a realized half-hour bond return volatility during the *Fed time* on day t. $Overrnigt_t$ and $Term_t$ are dummy variable indicating the Fed's presence on day t with overnight and term repos respectively. $\mathbf{X}_t$ is a vector of control variables. The disturbance term ε_t has the usual distributional assumptions. The coefficients δ and γ form our principle interest.

Let me provide an intuition for the control variables included in the vector $\mathbf{X}_t$. One variable refers to the so-called

calendar effect that is known to create a higher uncertainty in the beginning of the new month. To control for this effect I create a binary dummy variable called the *Month Effect* that takes values 1 on the first day of the calendar month and value 0 on all other days.

Another control variable is the 8:30 am macroeconomic announcement dummy. I collected the daily data on all major macroeconomic announcement that were scheduled in the year 2000 and the variable *Announcement 8:30* takes the value 1 if it falls on the day with announcement release and 0 otherwise[6]. Figures 2 and 3 suggest that the 8:30 am macroeconomic announcements and the Fed's interventions are related and we need to control for that.

The bond returns volatility during the *Fed time* could be associated with the overall daily volatility on the bond and money markets. The last set of control variables nets out these daily effects. Let me explain how I construct these measures. To capture the daily bond market situation I obtain the daily volatility of the yield curve slope[7]. I call this variable the *Yield Slope Spread Volatility.* To capture the money market situation I use the daily volatility of spread between the effective federal funds rate and the fed funds target rate, which I call the *Fed Funds Spread Volatility.* Both measures are obtained by applying the moving standard deviation with a 5 days window to their original daily series. Inclusion of these variables allows to control for the overall bond market

[6] Appendix B lists all 8:30 am macroeconomic announcements used in the study.

[7] 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 federal funds market volatility[8]. The next table reports the descriptive statistics of the variables employed.

Table 3.
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	17.98	17.15	0	98.32
Fed Time 5-year bonds returns volatility	251	44.79	43.06	0	225.59
B. Fed's repos					
Overnight open market operations (frequency)	251	116			
Term open market operations (frequency)	251	108			
C. Control variables					
Month effect dummy (frequency)	251	12			
Announcement 8:30 dummy (frequency)	251	132			
Log Yield Slope Spread Volatility	247	-2.99	0.56	-4.31	-1.34
Log Fed Funds Spread Volatility	247	-2.80	0.61	-4.21	-0.69

Table 4 reports the estimation results for the 2-year and

[8]Appendix C presents a graphical account for the variables used in the study.

5-year bonds. Columns (1) and (3) provide estimates of the coefficients δ, γ without inclusion of control variables. The coefficient on the Overnight Fed's repo dummy is positive and significant at 10%. This suggests that Fed's presence on the market results in a higher volatility of bond returns during the *Fed time* relative to days without Fed's interventions. The Term Fed's repo dummy coefficient is not significant which confirms the early unconditional results from Figure 3.

The columns (2) and (4) demonstrate that the results on the Overnight Fed's repo dummy are robust to the inclusion of the set of control variables that are thought to be related to the *Fed time* volatility and open market operations. I report the Newey-West standard error estimates that assume heteroskedasticity and autocorrelations.

Interestingly the inclusion of the control variables enhances the strength of the partial correlation between the *Fed Time* Volatility and the Overnight Fed's repo dummy variables. For the 2-year T-Note all control variables are significant at 5% and have the following interpretation. The beginning of the month and the increased volatility of the Fed funds spread are negatively associated with the bond returns volatility during the *Fed time* while the macro releases at 8:30 am and the higher Yield Slope are positively associated with the *Fed time Volatility.* These results suggest that the higher uncertainty on the overall bond market spills into the higher variability of bond returns during the *Fed time* but at the same time the increased money market uncertainty results in a lower variability of bond returns. As can be seen from column (4) only the Fed Funds spread volatility is statistically significant for the 5-year bond meaning that the overall bond market volatility does not translate into the *Fed time* volatility for this

maturity segment. The 8:30 am macro releases are positively associated with the 9:30 am 2-year bond volatility and are not significantly related to the 9:30 am 5-year bond volatility.

Table 4.
Fed time volatility and open market operations in year 2000
Dependent variable: Fed Time bond returns volatility

Independent variable	2-year T-Note		5-year T-Note	
	(1)	(2)	(3)	(4)
Overnight Fed's repo[a]	4.68* (2.55)[b]	5.96** (2.61)	9.327* (5.563)	11.56** (5.66)
Term Fed's repo[a]	-0.57 (2.05)	0.14 (2.10)	2.988 (5.218)	4.51 (5.37)
Month effect dummy		-10.61** (2.92)		-3.61 (11.35)
8:30 Announc. dummy		3.27** (1.94)		7.58 (5.13)
Yield slope volatility		3.06** (1.87)		5.64 (4.67)
Fed funds spread volatility		-0.02** (0.01)		-0.04** (0.01)

[a] Takes value 1 if Fed was present on the day and 0 otherwise
[b] Newey-West heteroskedasticity robust standard errors

What we get from this exercise is that the presence of the Fed conducting the overnight repos is not neutral with respect

to the bond market. After netting out the effect of control variables the partial correlation between the Fed's presence dummy and the bond returns volatility gets stronger. This suggests that the result is robust and could be interpreted that the day-to-day monetary policy has a significant impact on the bond market.

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

The purpose of the analysis in the previous section was to document the intra-day bond market volatility patterns. This section proposes an empirical model of the impact of the outcomes of the Fed's repo auctions on the bond market. Presumably the impact of open market operations should not be significant as the defensive operations do not carry the payoff relevant information regarding the stance of the monetary policy and should not affect the bond price formation. This fits the Fed's mandate of causing minimum disturbance on the instrument it uses for conduct of the monetary policy. On the other hand, we know that 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. In this environment dealers face the collateral reassignment problem and might be forced to readjust their bond positions as a result of inadequate financing. This represents an indirect form of the liquidity effect when the change in the monetary base affects the bonds market.

For this part of my study I employ an additional data provided by the New York Fed which covers the outcomes of

the open market operations[9] in the year 2000 and has a daily frequency. Let me present the summary statistics on these data in Table 5.

Table 5.
Descriptive statistics on outcomes of open market operations

	Obs.	Mean	St. Dev.	Min	Max
Total Propositions Submitted (in $bil.)	190	9.80	4.12	2.2	21.9
Total Propositions Accepted (in $bil.)	190	2.18	1.57	0	6.68
Weighted Average Rate	190	5.92	1.29	0	6.625
Highest Rate Submitted	190	6.20	0.35	5.46	6.66
Lowest Rate Submitted	190	6.07	0.38	5	6.55
Stop Out Rate	190	5.91	1.29	0	6.61

This statistics tells us that in the year 2000 there were 190 incidents when Fed intervened on the bond market with temporary open market operations and on average the propositions submitted for refinancing exceeded those accepted by 7.62 billion dollars.

[9]I use only temporary repurchase agreements that add reserves and ignore the reverse repos that drain reserves.

5.1 Outcomes of the repo auctions and the bond market

In this subsection I move to identifying the "liquidity effect" of the change in the monetary base on the bonds market. I put forward the hypothesis that the open market operations create imbalances in the dealer's refinancing of the bond's portfolio. Intuitively, this is due to the fact that the size of the operations are unknown to the dealer and the amount of the position proposed but not financed by the Fed has to be readjusted. This creates the collateral reassignment uncertainty that the dealer has to resolve. I employ two measures for the degree of imbalances in the dealer's repo book after open market operations are carried out.

My first measure is the daily difference between value of bonds proposed to the Fed for refinancing and the value of the refinancing accepted (size of the open market operation). I call this variable: *repo book difference*. The size of the difference indicates the imbalance it the repo book of the dealers that has to be refinanced with the private sector.

My second measure is the spread between the Highest Rate Submitted by dealers on the refinancing auction and the Stop Out Rate at which the auction ended. I call it: *High-Stop Spread*. Since the market clears from the highest submitted bid downwards until all the desired supply is exhausted this measure indicates the coverage of the bids for refinancing fulfilled by the Fed. I regress these two measures on the Fed time bond returns volatility and add the control variables described above. Table 6 reports the results for 2-year T-Note and Table 7 reports the same specification for the 5-year T-Note.

Table 6.
2-year bond volatility and imbalance in the dealer's repo book
Dependent variable: Fed Time 2-year bond returns volatility

	(1)	(2)
A. Repo book imbalance		
Repo book difference on days with overnight operations	0.571*	0.575*
	(0.323)	(0.329)
Repo book difference on days with term operations	-0.107	-0.105
	(0.142)	(0.142)
Month effect dummy		-11.005**
		(2.382)
8:30 Announcement dummy		3.203*
		(1.955)
B. Repo auction spread		
High-Stop Spread	-33.655**	-30.827**
	(13.100)	(13.579)
Month effect dummy		-10.509**
		(2.392)
8:30 Announcement dummy		3.307*
		(1.957)

Table 7.
5-year bond volatility and imbalance in the dealer's repo book
Dependent variable: Fed Time 5-year bond returns volatility

	(1)	(2)
A. Repo book imbalance		
Repo book difference on days with overnight operations	1.275*	1.235*
	(0.727)	(0.738)
Repo book difference on days with term operations	0.174	0.175
	(0.385)	(0.388)
Month effect dummy		-5.385
		(9.225)
8:30 Announcement dummy		7.269
		(5.033)
B. Repo auction spread		
High-Stop Spread	-80.352**	-72.074**
	(36.361)	(38.600)
Month effect dummy		-4.426
		(8.804)
8:30 Announcement dummy		7.390
		(5.062)

Tables 6 and 7 provide evidence that the degree of the imbalance of the dealer's repo book as a result of the open market operation is positively associated with the bond market volatility. The measure of the difference of positions proposed for refinancing and actually accepted is significantly correlated with bonds return volatility under different specifications. This means that the mismatch must be financed

with the private sector which creates collateral reassignment problem and indirectly represents the 'liquidity effect'. In the Panel B of the tables I find that the spread between the highest rate submitted for refinancing and the stop out rate is negatively associated with the bond market volatility. This means that the larger the coverage of the bids satisfied by the open market operations on a particular day the lower the bond market volatility on that day. All reported results indicate that the outcomes of the Fed's repo auction have a significant effect on the realized bond market volatility during the *Fed time.* This situation does not exactly fit the Fed's mandate of causing minimal disturbances to the financial market in its conduct of the day-to day monetary policy and raises the question of the monetary policy implementation efficiency.

6 European Central Bank's Repo Auctions Versus Fed's Temporary Open Market Operations

The use of the primary dealer system for adjusting the monetary base in the U.S. has historical reasons. Prior to the 80s the private repo market was not developed and bond dealers financed their leveraged positions through the bank loans and paid rates which were spread above the fed funds rate. These loans were settled in the evening and participation in the Fed's auction for refinancing (open market operations) in the middle of the day was a chance for them to obtain cheaper funds. Regulations D and Q pushed for a rapid development of efficient private repo market. Since repo rate is a spread below the fed funds rate this innovation put dealers' cost down and

now they finance their entire inventory through the private repo agreements. This also moved timing of their financing decision to early morning since this is the time when fund surplus institutions want to invest. In this environment Fed has to compete with the private sector for the bond dealer's refinancing business. However, since conditions on the private repo market are determined by the level of reserves in the banking system Fed's temporary operations still remain a potential source of cheaper funds when the private repo market is tight. Timing of the Fed's intervention – late morning has not changed which until April 1999 presented a collateral reassignment problem I described above.

My study focuses on the interaction of the Fed with the financial markets in a recent history. I show how industry innovations and changes in the Fed's procedures altered motives and payoffs of parties involved. The bigger issue is why such particular institutional setup is in place. Let me compare the Fed's operations with the European Central Bank's (ECB) management of the reserves in the banking system.

Format of adjusting the monetary base by the ECB and the Fed is different in a sense that ECB interacts directly with the banking system while Fed adjusts the base through the refinancing of the bond dealers. There are around 2500 European banks that are authorized directly to bid for funds on the ECB auction. The bank's motive to participate in the ECB repo auction is to earn a spread on cost of funds they pay to the ECB and the rate they will earn after re-lending the funds elsewhere. Having such objective a participation in the ECB auction implies a particular bidding strategy which depends on the bank's expectation of the future value of the funds. For the detailed game-theoretic model of the ECB

repo auctions see Daripa (2001). The pay-off structure of a representative European commercial bank depends on the fact if it obtains funds from the ECB or not. If it does not win the auction at the ECB and is reserve deficient it will have to borrow funds at the inter-bank market and pay a going rate. If the bank's bid goes through then it will either finance its assets at a cheaper cost or will earn a spread by re-lending them.

In the U.S. 30-40 primary bond dealers refinance their existing bond positions and are not planning to resell funds at a profit. They simply do not get these funds as they go to pay their previous debt. In my study a address the issue of how dealers pursue the objective of minimizing their cost of funding when they decide to participate in Fed's open market operation. For the banking system the impact of the open market operations on the private repo market in the morning translates into the change of the reserves pressure on the inter-bank fed funds market in the evening.

In Europe there is still a large diversity among the fiscal authorities plus the sovereign credit rankings of the countries differ. Thus, the ECB has to directly manage the banking system. The upside of such system is the removal of the middle men and a better allocation of the funds on the inter-bank market. The volatility spikes on the settlement days of the Fed funds markets in the U.S. are a well documented fact by Hamilton (1996, 1997). However, the advantage of the U.S. system is an institutionalized support of the financial markets that transforms into a better developed bond and private repo markets and a more efficient allocation of funds among the non-banking institutions and the banking sector.

7 Conclusion

The success of the Fed's interventions is traditionally measured in terms of its main objective which is keeping the fed funds rate on target. The common measure of the Fed's success is fed funds rate volatility [Bartolini et. al. (2001, 2002), Moschitz (2004), Wurz (2003)]. My study focuses on another aspect of interventions which is the Fed's desire to cause the minimal disturbance on the bond market which is employed as a transmission channel in adjusting the monetary base. This minimum disturbance serves as a measure of the *efficiency* of the monetary policy *implementation* and is particularly interesting from the microstructure perspective.

I demonstrate that in the year 2000 the overnight open market operations by the Fed had a significant impact on the volatility of bond returns during the *Fed time*. This suggests that the Fed's day-to-day monetary policy is not neutral with respect to the instrument employed and Fed has a pronounced impact on the bond market.

My study also presents evidence that the collateral reassignment problem faced by the bond dealers is the factor related to the increased volatility of bond returns. The size of the mismatch of the dealers' repo book as a result of the open market operations is positively associated to the volatility of bond returns while the size of the coverage of the primary dealers' bids fulfilled by the operations is negatively associated with the bond market volatility. This result indicate that in order to smooth out the frictions caused by the interventions some further institutional improvements such as increasing competition among the primary dealers might be necessary.

8 Appendix A

Classification of the monetary regimes depends on the operating procedures of the Fed and its targets. Fed can target various measures of the monetary reserves, interest or inflation rates. The monetary theory recognizes the Non-Borrowed Reserves, the Borrowed Reserves, and the Funds rate targeting regimes. In the US the Non-Borrowed Reserves procedure was pursued during the brief episode of Paul Volcker's tenure 1979-1982 at the Fed. The Borrowed Reserves procedure was introduced between 1982 and 1990. Cosimano and Sheehan (1994) estimate that actual policy of the Fed under Borrowed Reserves operating procedure and find that it is similar to what would occur under a Funds Rate procedure. Through the 90s and currently the operating procedure followed by the Fed is the Funds rate targeting.

9 Appendix B

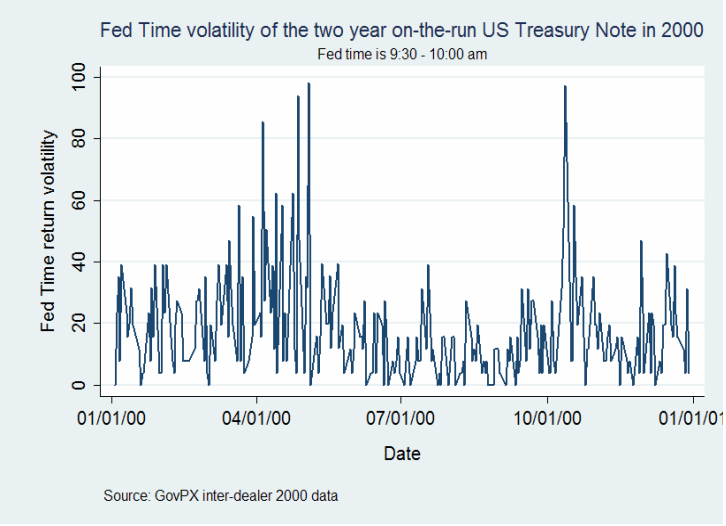
List of the 8:30 am macroeconomic announcements employed in the paper.

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

Source: Briefing.com

10 Appendix C

Fig. C1



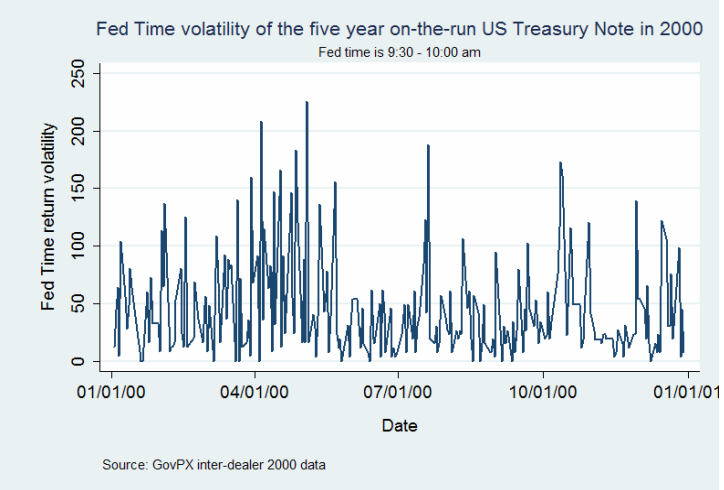


Fig. C2


Daily Slope of the US Treasury Yield Curve in 2000
Difference between 5 year T-Note and 3 month T-Bill
Yield Curve Slope (in %)
-1
-.5
0
.5
1
01/01/00
04/01/00
07/01/00
10/01/00
01/01/01
Date
Source: St.Louis Fed 2000 data

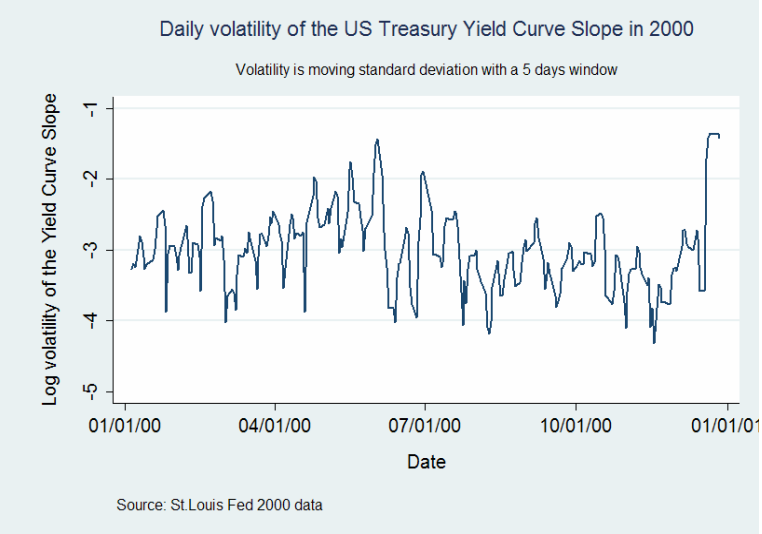
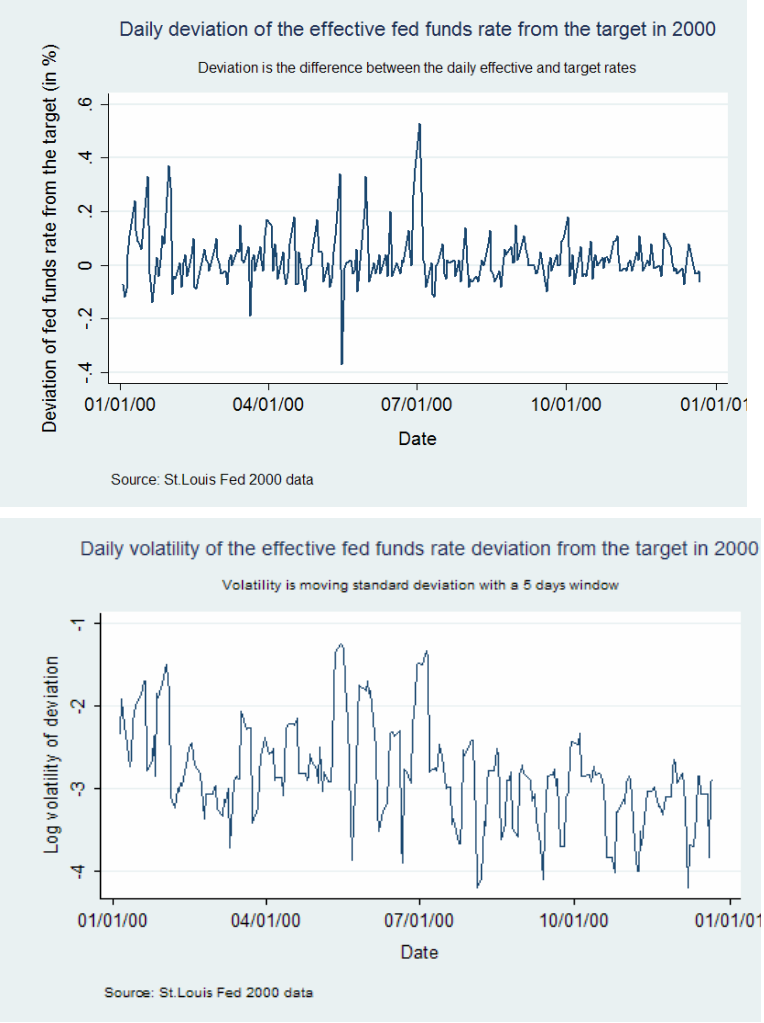

Daily volatility of the US Treasury Yield Curve Slope in 2000
Volatility is moving standard deviation with a 5 days window
Log volatility of the Yield Curve Slope
-5
-4
-3
-2
-1
01/01/00
04/01/00
07/01/00
10/01/00
01/01/01
Date
Source: St.Louis Fed 2000 data

Fig. C3


Daily deviation of the effective fed funds rate from the target in 2000
Deviation is the difference between the daily effective and target rates
Deviation of fed funds rate from the target (in %)
-.4
-.2
0
.2
.4
.6
01/01/00
04/01/00
07/01/00
10/01/00
01/01/01
Date
Source: St.Louis Fed 2000 data
Daily volatility of the effective fed funds rate deviation from the target in 2000
Volatility is moving standard deviation with a 5 days window
Log volatility of deviation
-4
-3
-2
-1
01/01/00
04/01/00
07/01/00
10/01/00
01/01/01
Date
Source: St.Louis Fed 2000 data

References

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

[2] Balduzzi, P., Elton, E., Green., C. (2001) "Economic News and Bond Prices: Evidence from the U.S. Treasury Market," *The Journal of Financial and Quanitative Analysis*, Vol. 36, No. 4 p. 523-543.

[3] 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 Fianace*, Vol.25, p. 1287-1317.

[4] 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*, Vol.34.

[5] Becker K., Finnerty, J., and Kopecky, K., (1996). "Macroeconomic News and the Efficiency of International Bond Futures Markets," Journal of Futures Markets, Vol. 16, 2, p.131.

[6] 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*, Vol.19, No.1, p. 56-67.

[7] Cosimano, T., Sheehan, R., (1994). "The Federal Reserve Operating Procedure, 1984-1990: An Empirical Analysis," *Journal of Macroeconomics*, Vol.16, No. 4, p. 573-588.

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

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

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

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

[12] Ederington, L., Lee, J., (1993). "How Market Process Information: News Releases and Volatility," *The Journal of Financ*e, Vol. 48, No. 4, p1161-1191.

[13] Ederington, L., Lee, J., (1995). "The Short-Run Dynamics of the Price Adjustment to New Information," *Journal of Financial and Quantitative Analysis*, Vol. 30, No. 1, p.117-134.

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

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

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

[17] Fleming M., 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.

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

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

[20] Hamilton, J., (1996). "The Daily Market for Federal Funds," *The Journal of Political Economy*, Vol 104, Issue 1, 26-56.

[21] Hamilton, J., (1997). "Measuring the Liquidity Effect," *The American Economic Review*, Vol. 87, Issue 1, 80-97.

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

[23] Huang, R., Jun Cai, and Xiaozu Wang (2002). "Information Based Trading in the Treasury Note Interdealer Broker Market," *Journal of Financial Intermediation* 11, no, 3, p. 269-96.

[24] Lumpkin S., (1998). *Repurchase and Reverse Repurchase Agreements*, Federal Reserve Bank of Richmond.

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

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

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

[28] *Open Market Operation in the 1990s*. Federal Reserve Bank of New York.

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

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

[31] 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.

[32] Tabellini, G. (1987). "Secrecy of Monetary Policy and the Variability of Interest Rates," *Journal of Money, Credit, and Banking*, Vol.19., No.4, p. 425-436.

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

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

[35] Walsh, C., (1998). *Monetary Theory and Policy*, MIT press.

[36] Wong (1993). *Fixed-Income Arbitrage*, Wiley press.

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

Публикуемые в серии работы были представлены на научных семинарах, организованных в МИЭФ в рамках научной программы МИЭФ – ГУ ВШЭ, координируемой Международным академическим комитетом МИЭФ. Программа реализуется с 2003 г. при участии Директора проекта МИЭФ со стороны Лондонской школы экономики и политических наук профессора Ричарда Джекмана и старшего академического советника Амоса Витцума.

Papers published in this series were presented at the ICEF research seminars within the frame of its research programme coordinated by the International Academic Committee of ICEF. The programme has been implemented since 2003 and supervized by ICEF Project Director at LSE Professor Richard Jackman and Senior Academic Advisor Dr. Amos Witztum.

Препринт WP9/2007/03
Серия WP9
Исследования по экономике и финансам
Research of economics and finance

Соколов Владимир Николаевич

Операции на открытом рынке и волатильность доходности облигаций: результаты микроструктурного исследования

(на английском языке)

Публикуется в авторской редакции

Зав. редакцией оперативного выпуска *А.В. Заиченко*

ЛР № 020832 от 15 октября 1993 г.
Формат $60\times84^{1}/_{16}$. Бумага офсетная. Печать трафаретная.
Тираж 150 экз. Уч.-изд. л. 3. Усл. печ. л. 2,55
Заказ № . Изд. № 677

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