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## **An Empirical Analysis of Stock and Bond Market Liquidity**

Tarun Chordia, Asani Sarkar, and Avanidhar Subrahmanyam

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### **Abstract**

This paper explores liquidity movements in stock and Treasury bond markets over a period of more than 1800 trading days. Cross-market dynamics in liquidity are documented by estimating a vector autoregressive model for liquidity (that is, bid-ask spreads and depth), returns, volatility, and order flow in the stock and bond markets. We find that a shock to quoted spreads in one market affects the spreads in both markets, and that return volatility is an important driver of liquidity. Innovations to stock and bond market liquidity and volatility prove to be significantly correlated, suggesting that common factors drive liquidity and volatility in both markets. Monetary expansion increases equity market liquidity during periods of financial crises, and unexpected increases (decreases) in the federal funds rate lead to decreases (increases) in liquidity and increases (decreases) in stock and bond volatility. Finally, we find that flows to the stock and government bond sectors play an important role in forecasting stock and bond liquidity. The results establish a link between “macro” liquidity, or money flows, and “micro” or transactions liquidity.

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# 1 Introduction

A number of important theorems in finance rely on the ability of investors to trade any amount of a security without affecting the price. However, there exist several frictions,<sup>1</sup> such as trading costs, short sale restrictions, circuit breakers, etc. that impact price formation. The influence of market imperfections on security pricing has long been recognized. Liquidity, in particular, has attracted a lot of attention from traders, regulators, exchange officials as well as academics.

Liquidity, a fundamental concept in finance, can be defined as the ability to buy or sell large quantities of an asset quickly and at low cost. The vast majority of equilibrium asset pricing models do not consider trading and thus ignore the time and cost of transforming cash into financial assets or vice versa. Recent financial crises, however, suggest that, at times, market conditions can be severe and liquidity can decline or even disappear.<sup>2</sup> Such liquidity shocks are a potential channel through which asset prices are influenced by liquidity. Amihud and Mendelson (1986) and Jacoby, Fowler, and Gottesman (2000) provide theoretical arguments to show how liquidity impacts financial market prices. Jones (2001) and Amihud (2002) show that liquidity predicts expected returns in the time-series. Pastor and Stambaugh (2001) find that expected stock returns are cross-sectionally related to liquidity risk.<sup>3</sup>

Until recently, studies on liquidity were focused principally on its cross-sectional determinants, and were restricted to equity markets (e.g., Benston and Hagerman, 1974, and Stoll, 1978). As more data has become available, recent work has shifted focus on studying time-series properties of liquidity in equity markets as well as in fixed-income markets. Hasbrouck and Seppi (2001), Huberman and Halka (2001), and Chordia, Roll and Subrahmanyam (2000) document commonality in trading activity and liquidity in the equity markets. Chordia, Roll, and Subrahmanyam (2001) study daily aggregate

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<sup>1</sup>See Stoll (2000).

<sup>2</sup>“One after another, LTCM’s partners, calling in from Tokyo and London, reported that their markets had dried up. There were no buyers, no sellers. It was all but impossible to maneuver out of large trading bets.” – *Wall Street Journal*, November 16, 1998.

<sup>3</sup>Note that Amihud and Mendelson (1986), Brennan and Subrahmanyam (1996), Brennan, Chordia and Subrahmanyam (1998), Jones (2001), and Amihud (2002) view liquidity in a transaction costs context, while Pastor and Stambaugh (2001) relate liquidity risk to expected stock returns.

equity market spreads, depths and trading activity over an extended period to document weekly regularities in equity liquidity and the influence of market returns, volatility and interest rates on liquidity. For U.S. Treasury Bond markets, Fleming (2001) examines the time-series of a set of liquidity measures, Huang, Cai, and Song (2001) relate liquidity to return volatility, while Brandt and Kavajecz (2002) study the relationship between liquidity, order flow and the yield curve. Fleming and Remolona (1999) and Balduzzi, Elton, and Green (2001) analyze returns, spreads, and trading volume in bond markets around economic announcements.

So far, the literature on stock and bond market liquidity has developed in separate strands. There is good reason, however, to believe that liquidity in the stock and bond markets covaries. Although the unconditional correlation between stock and bond returns is low (Campbell and Ammer, 1993), there are strong volatility linkages between the two markets (Fleming, Kirby and Ostdiek, 1998), which can affect liquidity in both markets by altering the inventory risk borne by market making agents (Ho and Stoll, 1983, and O’Hara and Oldfield, 1986). Second, stock and bond market liquidity may interact via trading activity. In practice, a number of asset allocation strategies shift wealth between stock and bond markets.<sup>4</sup> A negative information shock in stocks often causes a “flight to quality” as investors substitute safe assets for risky assets.<sup>5</sup> The resulting outflow from stocks into Treasury bonds may cause price pressures and also impact stock and bond liquidity. Overall, the preceding discussion implies that liquidity can exhibit co-movement across asset classes and also can be driven by common influences such as systemic shocks to volatility, returns, and trading activity.

Motivated by these observations, in this paper we study the joint dynamics of liquidity, trading activity, returns, and volatility in stock and U.S. Treasury bond markets. While the extant literature has examined the dynamic interaction of liquidity and returns in stock markets (Hasbrouck, 1991) and time-varying liquidity in Treasury bond markets (Krishnamurthy, 2002), the intertemporal interactions of liquidity proxies with returns

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<sup>4</sup>See, for example, Amman and Zimmerman (2001) and Fox (1999) for practical considerations, and Barberis (2000) or Xia (2001) for more academic studies.

<sup>5</sup>“When stocks are expected to show weakness, investment funds often flow to the perceived haven of the bond market, with that shift usually going into reverse when, as yesterday, equities start to strengthen.” John Parry, *The Wall Street Journal*, August 1 2001, page C1.

and volatility across these asset classes have not been examined. Our structural model allows us to distinguish the relative importance of order flow and return variability in affecting liquidity as well as price formation in the stock and Treasury bond markets.

We also seek to identify primitive factors that generate order flow in stock and bond markets and, possibly, induce correlated movements in liquidity. We examine the notion (Garcia, 1989) that the monetary stance of the Fed can affect liquidity by altering the terms of margin borrowing and alleviating borrowing constraints of dealers, and also consider the idea that fund flows into stock and bond markets can affect trading activity, and thereby influence liquidity. Earlier work has analyzed the effects of monetary policy and fund flows on financial markets, but has not directly addressed their impact on liquidity. For example, Fleming and Remolona (1997) and Fair (2002) document that monetary shocks are associated with large changes in bond and stock prices. For fund flows, Edelen and Warner(2001) and Boyer and Zheng (2002) show a positive association between aggregate flow and concurrent market returns, while Goetzmann and Massa (2002) document that fund flows affect price formation in equity markets. These findings indicate that fund flows and monetary factors can affect returns and volatility in addition to liquidity. Therefore, we explore the interaction of monetary factors and fund flows with liquidity, returns, volatility and order flow. Our analysis thus allows us to link microstructure liquidity (in the sense of transaction costs) and “macro liquidity” (in the sense of fund flows between sectors of the economy).

The results indicate that the time series properties of stock and bond liquidity possess similarities, such as common calendar regularities. Shocks to spreads in one market increase spreads in both markets. There are significant cross-market dynamics flowing from volatility to liquidity. Further, we find that the correlation between innovations in bond and stock liquidity and volatility is positive and significantly different from zero, pointing to the presence of a common underlying factor that drives both liquidity and volatility.

Monetary loosening, as measured by a decrease in net borrowed reserves, enhances stock market liquidity during periods of crises. In addition, unexpected decreases (increases) in the Federal Fund rate have an ameliorative (adverse) effect on liquidity as well as volatility. We also find that flows to the stock and government bond sectors play an

important role in forecasting both stock and bond liquidity. Overall, our results support the notion that money flows (in the form of bank reserves and mutual fund investments) account for part of the commonality in stock and bond market liquidity.

The rest of the paper is organized as follows. Section 2 describes how the liquidity data is generated, while Section 3 presents basic time-series properties of the data, and describes the adjustment process to stationarize the series. Section 4 performs daily vector autoregressions. Section 5 presents the analysis of monetary policy and mutual fund flows. Section 6 concludes.

## 2 Liquidity and Trading Activity Data

Bond and stock liquidity data were obtained for the period June 17, 1991 to December 31 1998. The sample period reflects the availability of tick-by-tick Treasury bond data, obtained from GovPX Inc., which covers trading activity among primary dealers in the interdealer broker market. The stock data sources are the Institute for the Study of Securities Markets (ISSM) and the New York Stock Exchange TAQ (trades and automated quotations). The ISSM data cover 1991-1992 inclusive while the TAQ data are for 1993-1998. We use only NYSE stocks to avoid any possibility of the results being influenced by differences in trading protocols between NYSE and Nasdaq.

Our principal focus in this paper is on analyzing the drivers of stock and bond liquidity measures that have been the focus of attention in the previous literature, viz., quoted spreads and market depth. Based on earlier literature (e.g., Amihud and Mendelson, 1986, Benston and Hagerman, 1974, and Hasbrouck 1991), we take these drivers to be returns, return volatility, and trading activity. We use order imbalances as measures of trading activity, rather than volume, because our view is that imbalances bear a stronger relation to trading costs as they represent aggregate pressure on the inventories of market makers.<sup>6</sup> Below we describe how we extract liquidity measures from transactions data. Since imbalance measures are from transactions databases as well, they also are described in the following subsection.

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<sup>6</sup>See Chordia, Roll, and Subrahmanyam (2002).

## 2.1 Measures of Bond Liquidity and Order Imbalance

GovPX, Inc. consolidates data from the primary brokers and transmits the data in real-time to subscribers through on-line vendors. The service reports the best bid and offer quotes, the associated quote sizes, the price and amount (in million dollars) of each trade, and whether the trade is buyer or seller-initiated. The time of each trade is also reported to the second.<sup>7</sup> The GovPX data pertains to inter-dealer trades only.

We use trading data for on-the-run Treasury notes with 10 years to maturity since we want to capture liquidity in relatively long-term fixed income markets.<sup>8</sup> Further, although on-the-run securities are a small fraction of Treasury securities, they account for 71% of activity in the interdealer market (Fabozzi and Fleming, 2000). In addition, we do not analyze the 30-year Treasury bond, since the GovPX data captures a smaller and variable fraction of aggregate market activity for this bond, and because a major broker, Cantor Fitzgerald/eSpeed, does not report its data.<sup>9</sup>

The bond liquidity measures are based on data from New York trading hours (7:30 AM to 5:00 PM Eastern Time). We construct the following measures of bond liquidity: QSPRB: the daily average quoted bid-ask spread, calculated as the difference between the best bid and best ask for each posted quote.

DEPTHB: The posted bid and ask depth in notional terms, averaged over the trading day. DEPTHB is only available starting from 1995.

OIBB: Defined as the notional value of buys less the notional value of sells each day, divided by the total value of buys and sells (recall that GovPX data indicates whether a trade is buyer or seller initiated; hence, trades can be signed directly). Note that since bond data is from the inter-dealer market, the imbalance measures represent inter-dealer order imbalances. It is highly likely, however, that inter-dealer order imbalances arise in response to customer imbalances as dealers lay off customer orders in the dealer market. Inter-dealer imbalances thus are likely to represent an estimate, albeit a noisy one, of customer imbalances.

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<sup>7</sup>Fleming (2001) provides a detailed account of the format of GovPX data.

<sup>8</sup>We repeat the analysis with two and five-year notes and find that the main results are unchanged. Details are available from the authors.

<sup>9</sup>Boni and Leach (2001) document the share of GovPX in aggregate bond market volume.

In order to obtain reliable estimates of the bid-ask spread and imbalance, the following filters are used:

1. Bid or offer quotes with a zero value are deleted.
2. Trade prices that deviate more than 20 percent from par value (\$100) are deleted. These prices are grossly out of line with surrounding trade prices, and are most likely to be reporting errors.
3. A quoted bid-ask spread that is negative or more than 50 cents per trade (a multiple of about 12 to 15 times the sample average) is deleted.

## **2.2 Stock Liquidity and Order Imbalance Data**

Stocks are included or excluded during a calendar year depending on the following criteria:

1. To be included, a stock had to be present at the beginning and at the end of the year in both the CRSP and the intraday databases.
2. If the firm changed exchanges from Nasdaq to NYSE during the year (no firms switched from the NYSE to the Nasdaq during our sample period), it was dropped from the sample for that year.
3. Because their trading characteristics might differ from ordinary equities, assets in the following categories were also expunged: certificates, ADRs, shares of beneficial interest, units, companies incorporated outside the U.S., Americus Trust components, closed-end funds, preferred stocks and REITs.
4. To avoid the influence of unduly high-priced stocks, if the price at any month-end during the year was greater than \$999, the stock was deleted from the sample for the year.

Intraday data were purged for one of the following reasons: trades out of sequence, trades recorded before the open or after the closing time, and trades with special settlement conditions (because they might be subject to distinct liquidity considerations). Our



preliminary investigation revealed that auto-quotes (passive quotes by secondary market dealers) have been eliminated in the ISSM database but not in TAQ. This caused the quoted spread to be artificially inflated in TAQ. Since there is no reliable way to filter out auto-quotes in TAQ, only BBO (best bid or offer)-eligible primary market (NYSE) quotes are used. Quotes established before the opening of the market or after the close were discarded. Negative bid-ask spread quotations, transaction prices, and quoted depths were discarded. Following Lee and Ready (1991), any quote less than five seconds prior to the trade is ignored and the first one at least five seconds prior to the trade is retained.

For each stock we define the following variables:

QSPRS: the daily average quoted spread, i.e., the difference between the ask and the bid quote, averaged over the trading day.

DEPTHS: Average of the posted bid and ask depths in shares, averaged over the trading day

OIBS: the daily order imbalance (the number of shares bought less the number of shares sold each day, as a proportion of the total number of shares traded).<sup>10</sup>

Our initial scanning of the intraday data revealed a number of anomalous records that appeared to be keypunching errors. We thus applied filters to the transaction data by deleting records that satisfied the following conditions:<sup>11</sup>

1. Quoted spread > \$5
2. Effective spread / Quoted spread > 4.0
3. Proportional effective spread / Proportional quoted spread > 4.0
4. Quoted spread / Mid-point of bid-ask quote > 0.4

These filters removed less than 0.02% of all stock transaction records. The above variables are averaged across the day to obtain stock liquidity measures for each day. To avoid excessive variation in the sample size, we required stocks to have traded for a minimum

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<sup>10</sup>The Lee and Ready (1991) method was used to sign trades. Of course, there is inevitably some assignment error, so the resulting order imbalances are estimates. Yet, as shown in Lee and Radhakrishna (2000), and Odders-White (2000), the Lee/Ready algorithm is accurate enough as to not pose serious problems in our large sample study.

<sup>11</sup>The proportional spreads in condition 3 are obtained by dividing the unscaled spreads by the mid-point of the prevailing bid-ask quote. Further, the effective spread is defined as twice the absolute distance between the transaction price and the mid-point of the prevailing quote. While the results using effective stock spreads are qualitatively similar to those for quoted spreads, we do not report these, both for reasons of brevity and because effective spreads are not defined in the bond market.

of 100 days in an year to be included in the sample for that year. Days for which stock return data was not available from CRSP were dropped from the sample. The daily dollar trading volume is obtained from CRSP. The daily spread measures are first averaged within the day for each stock, then averaged equal-weighted across stocks to obtain the aggregate market liquidity measures that we use in this study (for convenience we use the same variable names for the aggregate liquidity and volume measures).

## 3 Basic Properties of the Data

### 3.1 Summary Statistics

We now present summary statistics associated with liquidity measures for stock and bond markets. Table 1 presents the levels of quoted spreads and absolute values of proportional order imbalances for stocks and bonds. Since the reduction in tick sizes of U.S. stocks on June 24, 1997 had a major impact on bid-ask spreads (see, Chordia, Roll, and Subrahmanyam, 2001), we provide separate statistics for the periods before and after the change. The average quoted spread is \$0.032 for bonds, but \$0.20 for stocks. The median spread measures are almost the same as the means suggesting little skewness in the daily distribution of liquidity. The daily absolute imbalance in percentage terms is 13% for bonds and about 5% for stocks. Consistent with previous results, stock spreads are lower after the tick size change. In addition, the absolute order imbalance is also lower for stocks. As expected, bond spreads and order imbalance are unaffected by the change in the stock tick size. Bond spreads are lower than those for stocks even though the absolute order imbalances and the transaction sizes in bond markets are larger.<sup>12</sup> This is possibly due to the fact that the minimum tick size is smaller in the bond market. More fundamental information-based reasons can also account for smaller bond spreads. U.S. Treasury bond prices are impacted by broad macro-economic information shocks such as inflation, monetary policy, unemployment, and adverse selection is unlikely to be a major issue in bond markets. Adverse selection is likely to be far more important

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<sup>12</sup>The minimum lot size in the U.S. Treasury bond market is \$1,000,000 whereas the lot size in the stock market is 100 shares.

in individual stocks due to private information about idiosyncratic shocks.<sup>13</sup> Also, recall that the bond data pertains to the inter-dealer trades only. Thus, the bond spreads that we see are those for the wholesale market.

Figure 1 plots the time-series for bond and stock quoted spreads. As can be seen, the bond spread series shows a structural shift in late 1998, probably due to the crisis period. Stock quoted spreads show a steady decline through the sample period, with a substantial drop around the time of the tick size change. In the next subsection, we adjust our raw data for these and other regularities that could cause non-stationarities in our series.

Panel B presents summary statistics for depth for the subperiod for which bond depth is available (1995-1998). Stock depth is lower after the tick size change, as also documented in Chordia, Roll, and Subrahmanyam (2001). Note that in the bond inter-dealer market the size of the trades are negotiated and thus the posted depth may be smaller than the actual depth. As long as the quoted depth is an unbiased estimate of the actual depth, however, all our inferences for depth will retain their validity.

### **3.2 Adjustment of Time-Series Data on Liquidity, Imbalances Returns, and Volatility**

Both Panels A and B of Table 1 indicate that bond liquidity exhibits more variability than stock liquidity, as indicated by higher coefficients of variation for the bond liquidity measures. This is consistent with our finding that the absolute order imbalance is, on average, greater in the bond market. By exploring the dynamic relationships between liquidity, price formation, and trading activity, across stock and bond markets, we seek to ascertain the extent to which day-to-day movements in liquidity are caused by returns, order imbalances, and return volatility.

Returns and return volatility in both markets are obtained as the residual and the absolute value of the residual, respectively, from the following regression (see Schwert,

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<sup>13</sup>The stock market spread is an average of the individual stock spreads and is thus likely to be affected by adverse selection.

1990, Jones, Kaul, and Lipson, 1994, and Chan and Fong, 2000):

$$R_{it} = a_1 + \sum_{j=1}^4 a_{2j} D_j + \sum_{j=1}^{12} a_{3j} R_{it-j} + e_{it}, \quad (1)$$

where  $D_j$  is a dummy variable for the day of the week and  $R_{it}$  represents the daily return on the Lehmann Brothers' bond index or on the CRSP value-weighted index.

We now adjust the raw data for known regularities. All the series, returns, order imbalance, spreads, depths, and volatility in both markets are transformed as follows. Following Gallant, Rossi, Tauchen (1992) (henceforth GRT), we regress the series on a set of adjustment variables:

$$w = x'\beta + u \quad (\text{mean equation}). \quad (2)$$

In equation (2),  $w$  is the series to be adjusted and  $x$  contains the adjustment variables. The residuals are used to construct the following variance equation:

$$\log(u^2) = x'\gamma + v \quad (\text{variance equation}). \quad (3)$$

The variance equation is used to standardize the residuals from the mean equation and the adjusted  $w$  is calculated in the following equation,

$$w_{adj} = a + b(\hat{u}/\exp(x'\gamma/2)), \quad (4)$$

where  $a$  and  $b$  are chosen so the sample means and variances of the adjusted and the unadjusted series are the same.

The following adjustment variables are used (i) 4 day of the week dummies for Monday through Thursday; since there may be day of the week effects in liquidity, returns and volatility, (ii) 11 month of the year dummies for February through December, (iii) a dummy for holidays set such that if a holiday falls on a Friday then the preceding Thursday is set to 1, if the holiday is on a Monday then the following Tuesday is set to 1, if the holiday is on any other weekday then the day preceding and following the holiday is set to 1; this is intended to capture the fact that trading activity declines substantially around holidays, (iv) a time trend and the square of the time trend to remove any long-term trends that we are not seeking to explain, (v) 3 crisis dummies, where the

crises are: the Bond Market crisis (March 1 1994 to May 31 1994), the Asian financial crisis (July 2 to December 31, 1997) and the Russian default crisis (July 6 to December 31, 1998). The dates for the bond market crisis are from Borio and McCauley (1996). The starting date for the Asian crisis is the day that the Thai baht was devalued; dates for the Russian default crisis are from the Bank for International Settlements.<sup>14</sup> , (vi) a dummy for the period 4/01/95-12/31/98 in the bond market where the liquidity in the unadjusted series seems to be low for reasons that are not readily identifiable.<sup>15</sup> (vii) dummies for the day of and the two days prior to macroeconomic announcements about GDP, employment and inflation in the bond market; this is intended to capture portfolio balancing around public information releases, (viii) a dummy for the period after the tick size change in the stock market and (ix) a dummy for 9/16/91 where for some reason, ostensibly a recording error, only 248 firms were recorded as having been traded on the ISSM dataset whereas the number of NYSE-listed firms trading on a typical day in the sample is over 1,100.

Table 2 presents the regressions coefficients from the mean equation (2). For the sake of brevity, we do not present results for the variance equation (3); however, these are available upon request. Consider the bond and stock quoted spreads in Panel A. During our sample period, both the bond and stock quoted spreads are highest on Fridays and around holidays. The bond spread is lower from July to September and higher in March and October relative to January. The stock spread is lower from May to December relative to the early part of the year. As expected, spreads are higher during the three crisis periods, and during the Russian default crisis in particular. The bond spread decreases over the sample period and the same is true for the stock spread over the pre-tick size change period. Interestingly, the stock spread decreases before the tick size change but displays an increasing trend since that time. The bond spread is higher on the day of the employment announcement but lower during the two days preceding the announcement. The bond spread is also higher during the period 4/1/95 - 12/31/98. Finally, the stock spread is significantly lower on 9/16/91, when, as mentioned previously, only 248 firms are recorded as having traded. These 248 firms are large firms that have

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<sup>14</sup>“A Review of Financial Market Events in Autumn 1998”, CGFS Reports No. 12, October 1999, available at <http://www.bis.org/publ/cgfspubl.htm>.

<sup>15</sup>We thank Joel Hasbrouck for pointing this out.

the lowest spreads.

The results for bond and stock depths are in Panel B. Bond and stock depths are lower around holidays, higher from Tuesday to Thursday relative to Friday and higher in August and September relative to January. In addition, bond depth is relatively high in February, May and July whereas the stock depth is relatively low on Monday and relatively high in March. In both markets, depth decreases during the Russian and the Asian crises, suggesting that liquidity providers step back during periods when the market is under stress; the stock depth also decreases during the bond market crisis (when bond depth data is not available). Depth has increased over time for bonds and during the pre-tick-size-change period for stocks. However, stock depth decreases after the tick size change and has been on a downward trend since. Bond depth is lower over the period 4/1/95-12/31/98.

In summary, there are distinct seasonal patterns in stock and bond liquidities. Liquidity is higher at the beginning of the week compared to Friday, and higher in the summer months of July and August compared to the rest of the year, and sharply lower in crisis periods. Liquidity shows an increasing trend over the entire sample for bonds and before the change in the tick size for stocks.

Figure 2 shows the adjusted series for bond and stock quoted spreads. These series appear to be free of long-term trends. To formally test for stationarity, we perform augmented Dickey-Fuller and Phillips-Perron tests on the adjusted series. We allow for an intercept under the alternative hypothesis, and use information criteria to guide selection of the augmentation lags. We easily reject the unit-root hypothesis for every series (including those for return, volatility, and imbalances), generally with p-value less than 0.01. Thus, the evidence indicates that all of the adjusted series are stationary.

Next, we briefly discuss the results for returns and volatility. Since day-of-the-week effects were incorporated when computing returns and volatility in equation (1), these effects are omitted from the adjustment regressions. Panel C shows that bond and stock returns display little systematic time-series variation. Bond returns are lower in March, lower during the bond market crisis, and higher following the employment report. The stock return is lower during the Russian crisis, and shows a decreasing trend following

the tick size change. Panel D presents the results for bond and stock volatility. Bond volatility is lower in July, August, November and December relative to January. Stock and bond volatility are generally higher during crisis periods. Bond volatility shows an increasing trend over the sample period whereas the stock volatility shows a decreasing trend during the pre-tick-size-change period. Bond volatility increases during the day of the employment and CPI reports, and decreases prior to the employment report.

Table 3 presents the correlations between the adjusted bond and stock liquidity and imbalance series. The time-series correlation between stock and bond quoted spreads is about 28%. Quoted depths in each market are also positively correlated with the other (about 20%) and are significantly negatively correlated with the quoted spreads. Depth in the bond market is negatively related to the quoted spreads in the stock market. While stock order imbalance is highly correlated with stock returns, there is little correlation with liquidity or volatility. The correlations between the imbalance measures and the liquidity variables are less than 0.1 in magnitude. However, volatility in either market is strongly correlated with liquidity in both markets. The correlation between volatility in the bond market (VOLB) and the quoted spread in the bond market (QSPRB) is a significant 0.26 and between volatility in the stock market (VOLS) and the quoted spread in the stock market (QSPRS) is 0.18. The cross market correlations though lower than the within-market correlations are also high. The correlation between VOLB (VOLS) and QSPRS (QSPRB) is 0.12 (0.14). Thus, volatility seems to be an important avenue through which aggregate bond and stock market liquidity are impacted.

## 4 Vector Autoregression

Our goal is to explore intertemporal associations between market liquidity, returns, volatility, and order imbalances.<sup>16</sup> While univariate relations between liquidity and the latter three variables have been partially explored in earlier literature, there is good reason to expect bi-directional causality in each case. For example, the familiar notion

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<sup>16</sup>We use signed and not absolute imbalances in our study because our view is that unsigned imbalances could be collinear with volatility and thereby obscure the volatility-liquidity relation. We find, however, that our main results are not sensitive to whether absolute order imbalance is excluded or included in the system; details are available from the authors.

that liquidity may impact returns through a premium for greater trading costs was first discussed in Amihud and Mendelson (1986). However, returns may also influence future trading behavior, which may, in turn, affect liquidity. For instance, the psychological bias of loss aversion implies return-dependent investing behavior (Odean, 1998) and a wave of trading in one direction sparked by a price change may strain liquidity.

Next, the impact of volatility on liquidity has been addressed in Benston and Hagerman (1974), the idea being that increased volatility implies increased inventory risk and hence, a higher bid-ask spread. In the reverse direction, decreased liquidity could increase asset price fluctuations (see, e.g., Subrahmanyam, 1994). Further, the predictive relation between imbalances and liquidity has been addressed in Chordia, Roll, and Subrahmanyam (2002), who find that high negative imbalance, high negative return days are followed by return reversals, ostensibly because of strained market maker inventories or investor overreaction and correction.<sup>17</sup> However, if increased liquidity makes assets more attractive and induces agents to buy these assets, then this may, in turn, influence order imbalances.

There is also reason to believe that cross-market effects across stocks and bonds may be significant. For example, if there are leads and lags in asset allocational trades across these markets, then trading activity in one market may predict trading activity, and, in turn, liquidity in another. Similarly, leads and lags in volatility and liquidity shocks may have cross-effects. For example, if systemic (macro) shocks to liquidity and volatility get reflected in one market before another, then liquidity in one market could influence future liquidity in another. Thus, insofar as the above variables in one market forecast the corresponding variables in the other, the preceding arguments carry over to cross-market effects as well.

Given that there are reasons to expect cross-market effects and bi-directional causalities, in this section we adopt an eight-equation vector auto-regression that incorporates eight variables, four each (i.e., measures of liquidity, returns, volatility, and order imbal-

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<sup>17</sup>See Chordia and Subrahmanyam (1995) for a simple model of how spread levels depend on inventory.



ances) from stock and bond markets.<sup>18</sup> Thus, consider the following system:

$$X_t = \sum_{j=1}^K a_{1j} X_{t-j} + \sum_{j=1}^K b_{1j} Y_{t-j} + u_t, \quad (5)$$

$$Y_t = \sum_{j=1}^K a_{2j} X_{t-j} + \sum_{j=1}^K b_{2j} Y_{t-j} + v_t, \quad (6)$$

where  $X$  ( $Y$ ) is a vector that represents liquidity, returns, order imbalance and volatility in the bond (stock) market. In the empirical estimation, we choose  $K$ , the number of lags in equations (5) and (6) on the basis of the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC). Where these two criteria indicate different lag lengths, we choose the lesser lag length for the sake of parsimony. Typically, the slope of the information criterion (as a function of lags) is quite flat for larger lag lengths, so the choice of smaller lag lengths is justified. We now provide estimates from the VAR model that captures time-series movements in stock and bond liquidity. We are also interested in examining whether unexpected liquidity shocks are systemic in nature, and an examination of the VAR disturbances allows us to address this issue.

## 4.1 VAR Estimation Results

Table 4 presents results from two separate tests: one for ascertaining whether the sum of the coefficients for each regressor significantly differ from zero, and another for whether a regressor Granger-causes the dependent variable. Thus, each cell in Panel A of Table 4 presents the sum of the coefficients for each regressor in the VAR, as well as p-values from Granger causality tests. Initially, we focus on the interaction of the quoted spreads with the endogenous variables. The own lags of spreads are significant. In both markets, there is two-way causation between quoted spreads and volatility. Most interesting, there are extensive cross-market causalities. At the 10% level, there is two-way causation between stock and bond quoted spreads. Also, stock returns and volatility directly impact the bond spread, while bond returns and volatility affect the stock spread indirectly. For example, bond returns impact stock volatility which, in turn, Granger-causes the stock spread.

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<sup>18</sup>Hasbrouck (1991), in the latter part of his paper, also performs a vector autoregression comprised of stock spreads and trades. However, he uses intraday horizons, whereas we use a daily horizon to look for longer-term causalities.

To understand the dynamic properties of liquidity, we compute impulse response functions (IRFs) for the quoted spreads. The IRF traces the impact of a one-time, unit standard deviation, positive shock to one variable on the current and future values of the endogenous variables. Since the innovations are correlated (as we shall show), they are orthogonalized.<sup>19</sup> When computing the IRF, we need to choose a specific ordering of the endogenous variables since different orderings may result in different responses.<sup>20</sup> Our focus is on liquidity, and in microstructure theory, information or endowment shocks generally affect prices and liquidity through trading. This suggests that the order imbalance is likely to have the greatest tendency to be “exogenous” and therefore should be first in the ordering and liquidity last, with returns and volatility in the middle. We have no clear theoretical guidance regarding the relative ordering of returns and volatility and, in any case, the empirical results are not sensitive to it. Given these considerations, we fix the following ordering for the endogenous variables: OIBB, OIBS, VOLB, VOLS, RETB, RETS, QSPRB, QSPRS. As a further check, we also compute generalized impulse responses (Pesaran and Shin, 1998) that do not depend on the VAR ordering. All responses that were statistically significant previously remain so under the alternative approach.

The contemporaneous correlations in the VAR innovations, reported in Table 5, show that order imbalances mostly have low correlations with the other variables with the exception of OIBS and returns. However, returns and volatility are significantly correlated with liquidity. Since OIB generally has relatively weak effects on liquidity and volatility, we omit its IRFs for brevity; these are available upon request from the authors.

Figure 3 (Panel A) illustrates the response of the stock quoted spread to a unit standard deviation shock in the endogenous variables for a period of 10 days. Monte Carlo two-standard-error bands are provided to gauge the statistical significance of the responses. The figure indicates that the stock quoted spread increases by 0.02 standard deviation units on the first day in response to its own shock, with the response decaying rapidly from day one to day two and more gradually after that. A shock to stock returns

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<sup>19</sup>Specifically, the inverse of the Cholesky decomposition factor of the residual covariance matrix is used to orthogonalize the impulses.

<sup>20</sup>However, the VAR coefficient estimates and the Granger causality results are unaffected by the ordering of variables.

reduces the stock quoted spread while a shock to the stock volatility increases the stock spread, with the response peaking on the second day. These results are consistent with the results of Chordia, Roll, and Subrahmanyam (2001) who show that up-market moves have a positive effect on the spread, and with models of microstructure which argue that increased volatility, by increasing inventory risk, tends to decrease liquidity.

There is evidence of cross-market dynamics. In particular, the stock spread increases with a shock to the bond spread, and the magnitude is about a quarter of the response of the stock spread to its own shock. A shock to bond volatility also increases the stock spread. Panel B of Figure 3 illustrates the response of endogenous variables to a unit shock in the stock quoted spread. A shock to the stock quoted spread increases stock volatility, and the effect is statistically significant after two days. The bond quoted spread increases in response to a shock to the stock quoted spread, and the response lasts for up to two days.

The first panel of Figure 4 shows the response of the bond quoted spread to unit shocks in the endogenous variables. The responses are qualitatively similar to those for the stock spread. The bond spread decreases with a shock to bond returns, and increases when there is a shock to bond volatility and the bond spread. Again, there are significant cross-market effects as bond spreads decreases with a shock to the stock return, and increase in response to shocks to the stock volatility and the stock spread. Panel B of Figure 4 shows that a shock to the bond spread increases bond volatility.

As an alternative way of characterizing liquidity dynamics, Panel B of Table 4 shows the variance decompositions of bond and stock spreads. The fraction of the error variance in forecasting the bond spread, due to innovations in the bond spread, is more than 90 percent at short horizons and declines steadily to reach 85 percent after 10 days. Bond volatility explains about 7 percent of the forecast error variance at short horizons, increasing to almost 10 percent after 10 days. For forecasting the stock spread, innovations in the own-spread is again the most important variable by far, followed by the bond spread. The importance of stock volatility increases with time. These results show that innovations in own-market liquidity explain most of the liquidity dynamics, especially at shorter horizons. Own-market volatility and cross-market liquidity are the other important variables, with the impact of volatility increasing with time. The remaining variables

are relatively unimportant in explaining the liquidity dynamics at the daily level.

Next, we briefly discuss the interactions of returns and volatility. The IRFs (not reported) show that volatility in each market is positively related to its own shock and to shocks in volatility in the other market. In addition, stock returns react positively to shocks in bond returns and negatively to shocks in stock volatility. Stock volatility also decreases in response to a shock in stock returns. The results generally are consistent with the well-known notions that volatility is persistent and that down-markets are associated with increased volatility (e.g., Schwert, 1990), and also point to significant cross-market effects. Finally, the order imbalance in each market is positively related to its own shock and to shocks in the order imbalance in the other market.

We now repeat the previous analysis using quoted depths instead of quoted spreads in the VAR. Due to unavailability of data, the sample period is from January 1, 1995 to December 31, 1998. Since the results are broadly similar to those for spreads, we describe the results briefly without reporting them. The IRFs show that, within each market, depth increases in response to a shock in returns, and decreases after a shock to volatility. With respect to cross-market responses, bond depth responds positively to a shock in stock depth, but the reverse is not true. While stock depth responds positively to bond returns and negatively to bond volatility, the response of bond depth to stock market variables is not statistically significant. The variance decomposition results confirm that, other than the stock depth, stock market variables are relatively unimportant in explaining the forecast error variance of the bond depth.

## 4.2 Liquidity shocks

The VAR results in Table 4 indicate that liquidity is quite predictable. Yet unexpected arrival of information, as well as unexpected shocks to investors' liquidity, can cause unanticipated trading needs, and, in turn, unanticipated fluctuations in liquidity. It is of interest to examine whether such fluctuations are correlated across stock and bond markets, both from an academic and a practical standpoint. From an academic standpoint, we would like to know whether liquidity shocks are systemic in nature or unique to a particular market. From a practical standpoint, asset allocation strategies could

be designed to take advantage of increased liquidity, e.g., if shocks are positively correlated, it suggests contemporaneous execution of orders in both markets on unusually high liquidity days in one market.

Table 5, which reports the correlations in the VAR innovations, shows that shocks to spreads are negatively associated with returns. This is consistent with the results of Chordia, Roll, and Subrahmanyam (2001). The table also shows that cross-market liquidities are positively and significantly correlated. Innovations in stock and bond spreads have a correlation of 0.22 and this number is statistically different from zero. Innovations in stock and bond depths have a correlation of 0.13 (not shown), which is also statistically significant. These results indicate that there are contemporaneous commonalities in stock and bond liquidity. Either the two markets respond to similar macroeconomic shocks or that the trading behavior of investors simultaneously impacts both markets.

### 4.3 Summary of Daily Results

Our most significant results can be summarized as follows. Liquidity in one market impacts liquidity in the other market both directly as well as indirectly via its effect on other financial variables. For example, a shock to the bond quoted spread increases the stock spread directly; in addition, a shock to the bond spread increases bond volatility which, in turn, increases stock quoted spreads. Own-market liquidity and volatility and cross-market liquidity are the most important variables in explaining the dynamics of liquidity at the daily level. In particular, shocks to volatility explain a significant fraction of the error variance in forecasting liquidity. This result is consistent with standard microstructure models such as Ho and Stoll (1983), in which volatility, by increasing inventory risk, has an adverse effect on liquidity.

Volatility in each market is also related to lagged own market volatility as well as the volatility in the other market. Thus, as in the case of liquidity, there are significant cross-market effects in volatility. Volatility persistence is observed in both markets. Also, the standard result that volatility decreases in up-markets and increases in down-markets obtains in both the stock and bond markets.

The impact of volatility on spreads is economically significant; for example, we find that the effect of a one-standard deviation shock to stock volatility on stock spreads aggregates to an annualized amount of \$210,000 on a daily round-trip trade of 1 million shares in the basket of NYSE-listed common stocks, whereas the effect of bond volatility on stock spreads is about half this amount, and the effect of bond spreads on stock spreads is about one-third this amount.<sup>21</sup>

We also find that spread innovations are negatively associated with return innovations, suggesting that liquidity in both stock and bond markets is lower in down-markets, possibly because of heavily selling pressure that strains market making capacities. There are significant cross-correlations in liquidity innovations even after accounting for the effect of returns and volatility, suggesting the existence of other sources of commonality. The next section seeks to explore such systematic influences.

## 5 Long-Horizon Variations in Liquidity: The Role of Monetary Policy and Mutual Fund Flows

Thus far we have studied the dynamics of liquidity at the daily level and found evidence of significant cross-market dynamics and commonalities in stock and bond market liquidities. What are these common factors? Possibly, systemic shocks that affect portfolio rebalancing needs of investors and market makers' ability to provide liquidity. Motivated by this observation, we now add, in turn, two plausible macro drivers of liquidity to the VAR system.

First, we consider measures of the Federal monetary policy stance. A loose monetary policy may increase liquidity and encourage more trading by making margin loan requirements less costly, and by enhancing the ability of dealers to finance their positions. Along these lines, while several studies have informally discussed the notion that the Federal Reserve steps in to enhance financial market liquidity by loosening credit constraints

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<sup>21</sup>Our assessments of economic significance in this paper are based on the ten-day cumulative impulse response of the spread to a one-standard deviation shock in another variable, and on assuming 250 trading days in an year. Taking the total incremental trading cost per million shares traded and multiplying by the number of trading days in an year yields the dollar amount we report.

during periods of market turbulence,<sup>22</sup> to date there has been no empirical study on the impact of changes in monetary policy on aggregate liquidity in financial markets.<sup>23</sup> Monetary conditions may also affect asset prices through their effect on volatility (Harvey and Huang, 2002), interest rates, equity cost of capital or expected corporate profitability. Indeed, Smirlok and Yawitz (1985) and Cook and Hahn (1988) show that an expansionary monetary policy increases stock prices in the short-run and thus lowers expected return. Again, however, there could be reverse causality because reduced liquidity and increased volatility, could, in turn, spur the Federal Reserve to soften its monetary stance. For these reason, we add monetary policy as an endogenous variable to our VAR system.

Second, we examine aggregate mutual fund flows into equity and bond markets. Greater buying or selling by these institutions could lead to decreased liquidity by causing inventory imbalances, especially during periods of financial turbulence (see, for example, Edelen, 1999). At the same time, in the reverse direction, increased liquidity or decreased volatility of these asset markets could make the assets more attractive and spur mutual fund buying, again justifying the use of fund flows as endogenous variables. In essence, the fund flows analysis examines the impact of a primitive source of order imbalances, namely, buying and selling by financial intermediaries who manage money for individual investors, on price formation and liquidity.

A caveat is that, unlike the daily liquidity data, the data on mutual funds and borrowed reserves (our primary indicator of monetary tightness) are not available at the daily frequency. Mutual fund flow data is available only monthly while net borrowed reserves are available at a fortnightly frequency. We use bi-weekly borrowed reserves data from the Federal Reserve and monthly equity and government bond net flows from the Investment Company Institute for our analysis in this subsection.<sup>24</sup>

Net borrowed reserves are defined as total borrowings minus extended credit minus

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<sup>22</sup>See Garcia (1989) and “Monetary Policy Report to Congress,” *Federal Reserve Bulletin*, March 1995, pp. 219-243.

<sup>23</sup>At 9am on the day following the 1987 stock market crash, the following statement hit the wires, “The Federal Reserve, consistent with its responsibilities as the nation’s central bank, affirmed today its readiness to serve as a source of liquidity to support the economic and financial system.”

<sup>24</sup>In this section, returns are computed by compounding the residuals from equation (1) over the relevant period and volatility is the absolute value of the compounded returns (adjusted for month-of-the-year regularities and trends). Liquidity and imbalance measures are computed by simply averaging the adjusted daily time-series over the relevant time span.

excess reserves. Thus, net borrowed reserves represent the difference between the amount of reserves banks need to have to satisfy their reserve requirements and the amount which the Fed is willing to supply. Following Strongin and Tarhan (1990), Strongin (1995) and Christiano et al. (1999), we divide the net borrowed reserves by total reserves, and associate higher values of this ratio (which we term NBOR) with increased monetary tightness. These authors argue that innovations to NBOR primarily reflect exogenous shocks to monetary policy. Market participants also use net borrowed reserves as a measure of the Fed’s monetary stance.<sup>25</sup> For example, Melton (1985) notes that “...since late 1979, the key link between the Fed and the federal funds rate is the amount of reserves that the banks must borrow from the Fed’s discount window. Consequently, the best single indicator of the degree of pressure the Fed is putting on the reserves market is the amount of borrowed reserves.”

Another popular monetary policy variable is the surprise in the Fed Funds target changes. Cochrane and Piazzesi (2002) argue that these monetary shocks are ideal measures of unexpected movements in monetary policy. The Federal Reserve periodically changes its target funds rate to signal changes in monetary policy. Since the timing of the target rate changes is typically known, the market forms expectations regarding the target rate change. These expectations can, in principle, be recovered from the prices of the federal funds futures contracts.<sup>26</sup> We compute FFSUR as the difference between the target funds rate and its market expectation on days when the Fed changes the target rate.<sup>27</sup> FFSUR is zero on days when the target rate remains the same. FFSUR is further decomposed into negative surprises (NFFSUR) and positive surprises (PFFSUR). NFFSUR indicates a greater-than-expected cut or below-expected increase in the target rate

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<sup>25</sup>“In the aftermath of the [September 11] crisis, the Fed pumped tens of billions of dollars into the economy. As a result, the banks excess reserves soared. But as the financial markets returned to some semblance of normality, the Fed gradually began mopping up much of that excess money. Bank reserves have now fallen back significantly, and in the process, short-term interest rates have moved back up to their intended target level.” Why the Fed Should Stick to Rate Cutting, by Rich Miller, *Business Week*, October 15 2001.

<sup>26</sup>We are grateful to Ken Kuttner (2001) for providing us with his expectations data.

<sup>27</sup>The target rate changes are dated according to the day on which they became known to the market. As discussed in Kuttner (2001), this corresponded to the day after the decision to change rates until 1994, and to the decision day from February 1994, when the Fed started communicating its intention to change the target on the decision day. The target change on October 15, 1998 occurred between FOMC meetings, and announced after close of the futures markets; hence, the surprise is equal to the new target on the 16th minus the expectations implied by the closing futures rate on the 15th.



while the reverse is true for PFFSUR.

## 5.1 Summary Statistics

Table 6 presents the biweekly net borrowed reserves, NFFSUR, PFFSUR as well as money flows (in billions of dollars) into equity and bond funds each month. Bond funds experience outflows during our sample period, the reverse is true for equity funds. As with the daily variables, we adjust NBOR, EFLOW and BFLOW for monthly variations, time trends and crisis effects. We do not report the coefficients for brevity, but discuss the qualitative results. NBOR is lower from January to March, relative to the rest of the year, and it is increasing over time at a decreasing rate. The crisis coefficients are negative, suggesting a looser monetary policy during crises. EFLOW and BFLOW are both lower in December compared to the rest of the year. EFLOW is also relatively low in the summer months (June to August) and in October. BFLOW decreased during the bond crisis, while EFLOW decreased during the Russian crisis. Finally, BFLOW has been decreasing while EFLOW has been increasing over the sample period.

## 5.2 Monetary Policy

We estimate a VAR with NBOR, our monetary policy variable, and the quoted bid-ask spread, OIB, volatility, and returns in the stock and bond markets.<sup>28</sup> The information criteria suggest a VAR of order one. NBOR is first in the ordering of the endogenous variables, with the ordering of the other endogenous variables kept the same as before. The assumption is that a shock to NBOR is relatively exogenous to the financial system. An examination of the correlations in the VAR innovations, reported in Panel A of Table 7, indicates that shocks to NBOR mostly have low contemporaneous correlations with shocks to the financial variables.

There has been considerable debate as to what extent the Federal Reserve does, or should, take into account the financial market when formulating monetary policy. For example, Rigobon and Sacks (2001) argue that stock returns predict changes in the Fed funds rate. In unreported impulse response analyses, we find that NBOR responds

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<sup>28</sup>Unit root tests performed for all of the lower-frequency series did not reject stationarity.

positively to its own shocks, suggesting that monetary policy is generally persistent. In addition, monetary policy appears to ease following a decline in bond market liquidity – i.e., NBOR decreases in response to a shock in the bond spread. Further, the easing continues for a period of six weeks. The response of endogenous variables to NBOR (also omitted for brevity) illustrates that bond volatility and spreads increase in response to a unit shock to NBOR, but the response is not statistically significant. The variance decompositions, shown in Table 7, are consistent with these observations. Over 90 percent of the forecast error variance of NBOR is explained by innovations in NBOR for up to 2 months (or 8 biweekly periods), with the bond bid-ask spread explaining up to 4 percent of the error variance. Less than 1 percent of the error variances in forecasting bond and stock spreads are due to shocks in NBOR. In contrast, more than 13 percent of the error variance in stock spreads is explained by shocks to the bond spread after one period. Consistent with the daily analysis, volatility and returns explain an increasing fraction of the error variance in forecasting liquidity.

The previous results indicate that monetary policy does not have statistically significant effects on the stock and bond bid-ask spread. One reason may be that substantive changes in monetary policy variables occur primarily in times of financial crises and, in turn, financial markets respond to monetary policy mainly during crises periods. We find that net borrowed reserves declined significantly (by about 33%) in the crisis period relative to the non-crisis period, suggesting a loose monetary stance of the Federal Reserve during periods of financial crises. Several recent articles have suggested that financial crises affect liquidity.<sup>29</sup> For Treasury bonds, Fleming (2001) finds that price impacts and quoted bid-ask spreads are higher during crisis periods. To test crisis period effects, we replace NBOR with NBORCR in the VAR, where NBORCR is simply NBOR multiplied by a crisis dummy. The crisis dummy is one during the three crisis periods identified earlier, and is zero otherwise. In Figure 5, we present the response of endogenous variables to crisis period shocks in net borrowed reserves. As conjectured, we find that stock and bond spreads increase in response to a shock in NBORCR; though only the former effect is statistically significant.

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<sup>29</sup>See, for example, Greenspan, 1999, and “Finance and Economics: Alan Greenspan’s miracle cure,” *Economist*, October 24, 1998, pp.75-76 and “A Review of Financial Market Events in Autumn 1998,” CGFS Reports No. 12, October 1999, available at <http://www.bis.org/publ/cgfspubl.htm>.

In Panel C of Table 7, we compute the variance decompositions of the stock and bond spreads during the crisis periods. In contrast to the normal period variance decompositions, NBOR explains a greater fraction of the error variance of the spreads. For the bond spread, NBOR explains more than 4.5 percent of the variation in the bond spread after 2 months, about the same fraction explained by bond volatility. For the stock spread, NBOR explains about 3.5 percent of the variation in the stock spread after 2 weeks, lower in magnitude only to the spreads and the stock return. These results are consistent with the view that monetary shocks explain an important part of the common variation in the stock and bond liquidity during crises.

We repeat the analysis after replacing stock and bond spreads with depths in the VAR. The results (not shown) are similar to those found with the quoted spread. In particular, an expansion of monetary policy during crisis periods increases the stock and bond depth and increases the bond return. However, due to the limited number (104) of observations, the effects are not statistically significant.

We saw above that monetary policy is in part predictable. In particular, a loosening (tightening) of monetary policy is likely to be followed by further loosening (tightening). This implies that financial market investors are likely to react only to the surprise component in monetary policy. Unfortunately, data on expectations of borrowed reserves is not readily available. As an alternative, and as a robustness check, we use the previously-described negative surprises (NFFSUR) and positive surprises (PFFSUR) in the federal funds rate. We estimate a VAR of order one with NFFSUR and the financial market variables. Figure 6 (Panel A) shows the response of endogenous variables to a unit orthogonalized shock to NFFSUR. Stock and bond volatility and stock spreads are lower following a shock to NFFSUR, consistent with earlier results. Stock and bond returns also decrease after a shock to NFFSUR, perhaps because the market views the higher-than-expected rate cut as a signal of worse-than-expected economic conditions.

Panel B of Figure 6 shows the response of endogenous variables to a shock in PFFSUR, computed from a VAR of order one with PFFSUR and the financial variables. A unit shock to PFFSUR increases stock and bond market volatility as well as the bond spread. Overall, the results are consistent with the notion that a monetary expansion increases liquidity and decreases volatility, while monetary tightening has the opposite

result. Negative Federal Fund surprises have a larger impact than positive surprises. In addition, surprises to the Federal Funds rate appear to have a stronger effect on liquidity than net borrowed reserves.

### 5.3 Fund flows

We now examine the interaction of mutual fund flows with financial market variables. We estimate a VAR of order one (again suggested by the information criteria) with EFLOW, BFLOW and the financial market variables. In ordering the endogenous variables, we place BFLOW and EFLOW first and second in the ordering, with the remaining variables ordered as before. Panel A of Table 8 shows that innovations to EFLOW and BFLOW are negatively correlated with each other, but generally have low correlations with the other variables (except the stock spread and stock returns).

The response of fund flows to endogenous variables shows (not reported) that equity (bond) flows decline (increase) in response to a shock in bond returns, but otherwise fund flows do not respond to the financial variables. Figure 7 illustrates the impulse response of endogenous variables to a shock in EFLOW. There is little evidence that innovations to equity flows independently affect spreads. The main result here is that following a shock to stock flows, stock returns increase. Warther (1995) finds a similar result for weekly data, but finds that returns are uncorrelated with past flows at the monthly level. Figure 8 presents the impulse responses of endogenous variables to bond flows. We find that equity flows decrease in response to a shock in bond flows. This is in contrast to Warther (1995), who finds that current bond flows are positively related to expected and unexpected stock flows contemporaneously and with a lag of one. With regard to liquidity, we find that the bond spread increases in response to a shock in bond flows, with the response peaking in the third month, at which time the effect becomes statistically significant. Bond flows also significantly impact stock spreads at the first lag.

The variance decompositions, shown in Panel B of Table 8, are consistent with these results. Innovations in BFLOW account for almost all of the forecast error variance in BFLOW, with stock imbalances being the only other variable of importance. BFLOW

explains up to 18 percent while bond returns explain up to 6 percent of the error variance in forecasting EFLOW. BFLOW and EFLOW together explain up to 17 percent of the forecast variance of the bond spread and up to 7 percent of the error variance of the stock spread. These results are consistent with our claim that fund flows cause common variations in stock and bond flows, and also affect liquidity. Similar to the earlier results, volatility is important in explaining variations in spreads. In particular, the stock volatility explains between 16 percent and 21 percent of the error variance in the stock spread.

## **5.4 Summary of Monetary Policy and Fund Flow Results**

Our results on monetary policy and fund flows are as follows. Monetary easing (in the form of a decrease in net borrowed reserves) has a positive impact on stock and bond market liquidity during crisis periods; though only the former effect is significant. For the whole sample period, unanticipated shocks to the Federal Funds rate affect liquidity as conjectured: unexpected increases in the Federal funds rate increase spreads and vice versa; though, for positive federal funds surprises, bond market liquidity responds more strongly, whereas for negative Federal funds surprises, it is stock liquidity that is affected more. While volatility in both bond and stock markets increases (decreases) with positive (negative) federal funds surprises, the impact on stock market volatility is larger. Equity fund flows have a negligible impact on liquidity, but an increase in bond fund flows tends to increase both bond and stock market spreads. We propose that the insignificant impact of equity fund flows may be due to the fact that our measure encompasses only mutual fund flows, whereas individual investors who directly trade securities form a relatively larger share of the equity market than the bond market. Hence, our measure of equity flows (which ignore trades done by individuals for their own account) may be less accurate than that of bond flows.

From the standpoint of economic significance, we find that a one-standard deviation shock to net borrowed reserves has an annualized impact of about \$20,000 on trading costs for a daily trade of one million shares in the basket of NYSE-listed common stocks, while the corresponding impact of a one-standard deviation negative Federal Funds rate

surprise is \$15,000. These numbers appear reasonably substantial. The economic significance of bond fund flows on liquidity is small: A one-standard deviation shock to bond flows has an annualized effect of only \$2250 on the cost of trading a million dollars worth of Treasury Bonds per day; the effect of stock flows on trading costs is even smaller. However, stock and bond flows explain a significant fraction of the error variance in forecasting liquidity in both stock and bond markets. We also find that substantial commonality between stock and bond market liquidity continues to exist even at longer horizons; unexpected shocks to these variables are significantly and positively cross-correlated even at bi-weekly and monthly frequencies.

## 6 Concluding Remarks

We examine common determinants of stock and bond liquidity over the period 1991 through 1998, and study the effect of money flows (bank reserves and mutual fund investments) on transactions liquidity. Thus, our study promotes a better understanding of the dynamics of liquidity by analyzing liquidity co-movements across different asset classes. We also take a step towards linking microstructure liquidity with macro-level liquidity as embodied in money flows, which, in turn, helps enhance our understanding of the factors that drive liquidity across different markets. Our analysis takes on particular significance given the association between variations in liquidity and the cost of capital (Pastor and Stambaugh, 2001), and also has direct implications for predicting and controlling trading costs associated with asset allocation strategies.

Some of our principal findings are as follows:

- Weekly regularities in stock and bond market liquidities closely mimic. Tuesdays and Friday are respectively the highest- and lowest-liquidity days of the week for both markets. Further, liquidity in both stock and bond markets tends to be higher during the summer/early fall months of July to September and lower in October.
- At both daily, bi-weekly, and monthly horizons, shocks to volatility or spreads in either market have a persistent effect on spreads in both markets. Therefore, volatility is an important driver of both stock and bond market liquidity.

- Unexpected liquidity and volatility shocks are positively and significantly correlated across stock and bond markets, suggesting that liquidity and volatility shocks are often systemic in nature.
- A loosening of monetary policy, as measured by a decrease in net borrowed reserves, appears to have an ameliorative effect on stock liquidity during crises.
- Unexpected decreases (increases) in the Federal Funds rate have a positive (negative) impact on liquidity. Both stock and bond volatility increase (decrease) upon an unexpected increase (decrease) in the Federal funds rate.

Our work suggests a fertile research agenda. Little theoretical work has been done on time-series movements in liquidity, and there is no theory on linking movements in liquidity across equity and fixed-income markets. A model of market equilibrium with endogenous trading across stock and bond markets would seem to be desirable. Further, the theoretical link between monetary policy, fund flows, and stock and bond market liquidity also represents a research issue that has largely remained unexplored. We hope our work serves to stimulate research in these areas.

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**Table 1: Levels of stock and bond market liquidity**

Bond liquidity estimates are based on the daily mean of the best bid and ask offer quotes by dealers on the 10-year Treasury note, as reported in the GovPX data set. The stock liquidity series are constructed by first averaging all transactions for each individual stock on a given trading day and then cross-sectionally averaging all individual stock daily means that satisfy the data filters described in the text. QSPR stands for quoted spread, OIB for the order imbalance, and DEP for depth. OIB is measured as the number of buy trades minus the number of sale trades, divided by the total number of trades. The suffixes B and S refer to bond and stock variables, respectively, and ABS is notation for absolute value. The mean, median, standard deviation (S.D.) and the coefficient of variation (C.V.) is reported for each measure. The sample period spans the period June 17, 1991 to December 31, 1998 except for bond depth, data for which is from January 1, 1995 to June 24, 1997.

**Panel A: Bid-ask spread and order imbalance**

	June 17 1991- June 23 1997 (No. of observations: 1504 for bonds and 1521 for stocks)				June 24 1997- December 31 1998 (No. of observations: 380 for bonds and 385 for stocks)			
	Mean	S.D.	Median	C.V.	Mean	S.D.	Median	C.V.
QSPRB	0.032	0.005	0.031	15.52	0.033	0.009	0.030	27.41
ABS OIBB (%)	0.135	0.115	0.107	85.72	0.131	0.095	0.113	72.61
QSPRS	0.197	0.018	0.194	9.25	0.137	0.007	0.136	4.93
ABS OIBS (%)	0.054	0.040	0.047	73.87	0.048	0.033	0.043	69.12

**Panel B: Market depth**

	January 1 1995- June 23 1997 (No. of observations: 620 for bonds and 626 for stocks)				June 24 1997- December 31 1998 (No. of observations: 380 for bonds and 385 for stocks)			
	Mean	S.D.	Median	C.V.	Mean	S.D.	Median	C.V.
DEPB (\$ millions)	6.38	1.60	6.10	25.12	7.35	2.15	6.98	29.27
DEPS ('000 shares)	8.77	0.65	8.78	7.45	4.36	0.45	4.29	10.22

**Table 2: Adjustment regressions for stock and bond liquidity**

Bond liquidity estimates are based on the daily mean of the best bid and ask offer quotes by dealers on the 10-year Treasury note, as reported in the GovPX data set. The stock liquidity series are constructed by first averaging all transactions for each individual stock on a given trading day and then cross-sectionally averaging all individual stock daily means that satisfy the data filters described in the text. The sample spans the period June 17, 1991 to December 31, 1998 except for bond depth, for which the sample is January 1 1995 to December 31, 1998. QSPR stands for quoted spread and DEP for depth. The suffixes B and S refer to bond and stock variables, respectively. DEP is in 1,000 share units for stocks and \$1 million face value for bonds. RET is the market return and VOL is the return volatility. The returns used are the Lehman Brothers' aggregate daily bond index returns and the daily CRSP value-weighted index return for stocks. Holiday: a dummy variable that equals one if a trading day satisfies the following conditions, (1) if Independence day, Veterans' Day, Christmas or New Year's Day falls on a Friday, then the preceding Thursday, (2) if any holiday falls on a weekend or on a Monday then the following Tuesday, (3) if any holiday falls on a weekday then the preceding and the following days, and zero otherwise. Monday-Thursday: equals one if the trading day is Monday, Tuesday, Wednesday, or Thursday, and zero otherwise. February-December: equals one if the trading day is in one of these months, and zero otherwise. GDP: dummy variable that equals one on the day of the GDP announcement and zero otherwise. GDP12: dummy variable that equals one on two days prior to the GDP announcement and zero otherwise. Emp, Emp12, CPI, CPI12: dummy variables for employment and CPI announcements respectively. The definition of the dummy variables is the same as for GDP announcements. Estimation is done using the Ordinary Least Squares (OLS). The coefficients for spreads are multiplied by a factor of 100, whereas those for returns are multiplied by  $10^4$ . Estimates marked \*\*(\*) are significant at the five (ten) percent level or lower.

**Panel A: Bond and stock quoted spread (Number of observations: 1884 for bonds and 1906 for stocks)**

	QSPRB	t-statistic	QSPRS	t-statistic
Intercept	0.035	55.50	0.233	321.76
Day of the week				
Monday	-0.331	-8.16	-0.065	-1.42
Tuesday	-0.348	-8.84	-0.166	-3.71
Wednesday	-0.294	-7.21	-0.135	-2.91
Thursday	-0.192	-4.75	-0.081	-1.77
Holiday	0.179	2.75	0.219	3.07
Month				
February	0.097	1.57	0.008	0.12
March	0.242	4.02	-0.116	-1.69
April	0.100	1.63	-0.055	-0.80
May	0.069	1.12	-0.214	-3.04
June	0.004	0.06	-0.459	-6.85
July	-0.252	-4.26	-0.468	-7.02
August	-0.177	-2.97	-0.615	-9.16
September	-0.166	-2.79	-0.679	-10.05
October	0.148	2.50	-0.371	-5.58
November	0.038	0.63	-0.375	-5.47
December	-0.003	-0.04	-0.352	-5.15
Crisis				
Russian crisis 07/06/98-12/31/98	1.347	17.97	1.075	7.14
Asian crisis 07/02/97-12/31/97	0.129	2.24	0.326	2.74
Bond crisis 03/01/94-05/31/94	0.123	1.68	0.504	6.14
Tick size change				
Tick size change dummy	---	---	-10.038	-57.21
September 16 1991 dummy	---	---	-1.928	-3.30
Trend				
Time	0.000	-1.26	---	---
Square of Time	0.000	-4.15	---	---
Time, pre-tick size change	---	---	-0.005	-36.51
Square of time, pre-tick size change	---	---	0.000	8.73
Time, post-tick size change	---	---	0.005	3.52
Square of time, post-tick size change	---	---	0.000	-3.14
Dummy for 04/01/95-12/31/98	0.403	7.85	---	---
Macroeconomic announcements				
GDP	0.111	1.15	0.035	0.32
GDP12	0.013	0.18	-0.077	-0.95
EMP	0.247	4.04	0.129	1.85
EMP12	-0.157	-3.60	0.054	1.07
CPI	0.084	1.50	-0.022	-0.35
CPI12	-0.024	-0.58	-0.026	-0.56

**Panel B: Bond and stock depth (Number of observations 1000 for bonds and 1906 for stocks)**

	DEPB	t-statistic	DEPS	t-statistic
Intercept	5.30	17.95	5.412	76.63
Day of the week				
Monday	0.166	0.90	-0.120	-2.69
Tuesday	0.680	3.80	0.149	3.41
Wednesday	0.934	5.02	0.209	4.61
Thursday	0.555	3.04	0.133	2.96
Holiday	-0.855	-3.12	-0.334	-4.78
Month				
February	0.819	3.02	0.011	0.16
March	-0.052	-0.20	0.165	2.47
April	0.455	1.68	-0.032	-0.47
May	0.546	2.00	-0.060	-0.87
June	0.200	0.74	0.074	1.14
July	0.970	3.41	-0.033	-0.51
August	0.739	2.57	0.151	2.31
September	1.008	3.51	0.328	4.98
October	0.012	0.04	0.091	1.40
November	0.242	0.84	-0.049	-0.74
December	-0.316	-1.12	0.026	0.39
Crisis				
Russian crisis 07/06/98-12/31/98	-1.414	-4.15	-0.349	-2.38
Asian crisis 07/02/97-12/31/97	-0.733	-3.43	-0.328	-2.83
Bond crisis 03/01/94-05/31/94	---	---	-1.054	-13.15
Tick size change				
Tick size change dummy	---	---	-0.075	-0.44
September 16 1991 dummy	---	---	0.898	1.58
Trend				
Time	0.004	3.08	---	---
Square of Time	0.000	-0.03	---	---
Time, pre-tick size change	---	---	0.004	29.89
Square of time, pre-tick size change	---	---	0.000	-13.70
Time, post-tick size change	---	---	-0.009	-6.61
Square of time, post-tick size change	---	---	0.000	4.83
Dummy for 04/01/95-12/31/98	-0.996	-2.95	---	---
Macroeconomic announcements				
GDP	-0.705	-1.58	-0.104	-0.96
GDP12	0.113	0.34	-0.035	-0.44
EMP	-0.383	-1.39	-0.113	-1.65
EMP12	0.427	2.17	0.038	0.78
CPI	0.000	0.00	0.026	0.42
CPI12	0.379	2.03	0.076	1.67



**Panel C: Bond and stock returns (Number of observations: 1908 for bonds and 1907 for stocks)**

	RETB	t-statistic	RETS	t-statistic
Intercept	0.021	0.69	0.014	0.15
Holiday	-2.757	-0.83	-15.562	-1.55
Month				
February	-5.024	-1.53	-3.627	-0.37
March	-5.821	-1.82	-11.494	-1.19
April	-1.204	-0.37	-4.702	-0.48
May	1.238	0.38	-2.633	-0.27
June	1.064	0.34	-13.698	-1.45
July	1.036	0.33	0.593	0.06
August	-0.744	-0.24	-17.399	-1.84
September	1.093	0.35	-0.457	-0.05
October	-1.641	-0.53	-3.076	-0.33
November	-2.586	-0.82	-2.587	-0.27
December	0.855	0.27	0.509	0.05
Crisis				
Russian crisis 07/06/98-12/31/98	0.884	0.22	-52.110	-2.45
Asian crisis 07/02/97-12/31/97	1.299	0.42	-12.560	-0.75
Bond crisis 03/01/94-05/31/94	-7.352	-1.88	-7.210	-0.62
Tick size change				
Tick size change dummy	---	---	34.710	1.40
September 16 1991 dummy	---	---	40.985	0.50
Trend				
Time	-0.006	-1.16	---	---
Square of Time	0.000	0.79	---	---
Time, pre-tick size change	---	---	-0.007	-0.37
Square of time, pre-tick size change	---	---	0.000	0.82
Time, post-tick size change	---	---	-0.403	-2.06
Square of time, post-tick size change	---	---	0.001	2.82
Dummy for 04/01/95-12/31/98	1.670	0.61	---	---
Macroeconomic announcements				
GDP	7.697	1.49	-6.708	-0.43
GDP12	3.042	0.80	12.641	1.10
EMP	4.505	1.51	6.584	0.73
EMP12	6.173	2.84	-7.687	-1.18
CPI	3.082	1.03	14.480	1.61
CPI12	1.723	0.79	6.429	0.98

**Panel D: Bond and stock volatility (Number of observations: 1908 for bonds and 1907 for stocks)**

	VOLB	t-statistic	VOLS	t-statistic
Intercept	0.193	9.53	0.643	10.21
Holiday	0.014	0.60	-0.073	-1.07
Month				
February	-0.028	-1.27	0.041	0.62
March	-0.010	-0.49	-0.026	-0.40
April	-0.025	-1.17	0.047	0.72
May	-0.022	-0.99	-0.001	-0.02
June	-0.026	-1.25	0.017	0.26
July	-0.048	-2.29	-0.035	-0.55
August	-0.043	-2.06	-0.060	-0.94
September	-0.035	-1.67	-0.019	-0.30
October	-0.007	-0.33	0.030	0.47
November	-0.057	-2.68	-0.047	-0.71
December	-0.049	-2.34	-0.002	-0.03
Crisis				
Russian crisis 07/06/98-12/31/98	0.094	3.57	0.776	5.41
Asian crisis 07/02/97-12/31/97	0.004	0.21	0.223	1.96
Bond crisis 03/01/94-05/31/94	0.095	3.70	0.141	1.80
Tick size change				
Tick size change dummy	---	---	-0.040	-0.24
September 16 1991 dummy	---	---	-0.162	-0.29
Trend				
Time	0.000	2.73	---	---
Square of Time	0.000	-3.43	---	---
Time, pre-tick size change	---	---	-0.001	-5.71
Square of time, pre-tick size change	---	---	0.000	6.42
Time, post-tick size change	---	---	0.002	1.39
Square of time, post-tick size change	---	---	0.000	-2.24
Dummy for 04/01/95-12/31/98	0.020	1.11	---	---
Macroeconomic announcements				
GDP	0.034	1.01	0.024	0.23
GDP12	-0.004	-0.14	0.058	0.75
EMP	0.156	7.92	0.152	2.50
EMP12	-0.019	-1.33	-0.067	-1.51
CPI	0.074	3.78	0.013	0.21
CPI12	-0.015	-1.04	-0.003	-0.07

**Table 3: Correlations in stock and bond market liquidity.**

This table presents the correlation matrix for the time series of market-wide liquidity and trading activity. All variables have been adjusted for trend, seasonality and crisis effects, as described in Table 2. Bond liquidity estimates are based on the daily mean of the best bid and ask offer quotes by dealers on the 10-year Treasury note, as reported in the GovPX data set. The stock liquidity series are constructed by first averaging all transactions for each individual stock on a given trading day and then cross-sectionally averaging all individual stock daily means that satisfy the data filters described in the text. QSPR stands for quoted spread, OIB for the order imbalance, and DEP for depth. OIB is measured as the number of buy trades minus the number of sale trades, divided by the total number of trades. RET is the market return and VOL is the return volatility. The returns used are the Lehman Brothers' aggregate daily bond index returns and the daily CRSP value-weighted index return for stocks. The suffixes or subscripts B and S refer to bond and stock variables, respectively. The sample spans the period June 17, 1991 to December 31, 1998, with the exception of bond depth for which the sample period is January 1 1995 to December 31, 1998. \* denotes significance at the 5% level and + denotes significance at the 10% level.

**Returns, volatility, spread and order imbalance (Number of observations: 1882).****Depth (Number of observations: 999)**

	QSPRB	OIBB	DEPB	VOLB	RETB	QSPRS	OIBS	DEPS	VOLS	RETS
QSPRB	1.00									
OIBB	<b>-0.06*</b>	1.00								
DEPB	<b>-0.49*</b>	0.03	1.00							
VOLB	<b>0.26*</b>	-0.01	<b>-0.14*</b>	1.00						
RETB	<b>-0.10*</b>	<b>0.09*</b>	0.05	<b>-0.04<sup>+</sup></b>	1.00					
QSPRS	<b>0.28*</b>	0.01	<b>-0.21*</b>	<b>0.12*</b>	<b>-0.06*</b>	1.00				
OIBS	0.02	<b>0.07*</b>	0.04	<b>-0.07*</b>	<b>0.25*</b>	<b>-0.05*</b>	1.00			
DEPS	<b>-0.29*</b>	0.01	<b>0.19*</b>	<b>-0.09*</b>	<b>0.09*</b>	<b>-0.61*</b>	0.01	1.00		
VOLS	<b>0.14*</b>	-0.01	<b>-0.06*</b>	<b>0.21*</b>	-0.02	<b>0.18*</b>	<b>-0.06*</b>	<b>-0.09*</b>	1.00	
RETS	<b>-0.07*</b>	<b>0.04<sup>+</sup></b>	<b>0.06<sup>+</sup></b>	<b>-0.07*</b>	<b>0.32*</b>	<b>-0.12*</b>	<b>0.74*</b>	<b>0.12*</b>	<b>-0.10*</b>	1.00

Panel A presents the sum of the lagged coefficients (Csum) and the p-values of the Granger Causality tests (chi-square) that the lagged coefficients are jointly zero. Bold values of Csum represent significance of the sum of the lagged coefficients. The results were computed from a VAR with two lags and a constant term, and use 1880 observations. The endogenous variables in the VAR are ordered as OIBB, OIBS, VOLB, VOLS, RETB, RETS, QSPRB and QSPRS. Panel B presents the variance decompositions of the VAR. QSPR stands for quoted spread, OIB for the order imbalance, and DEP for depth. OIB is measured as the number of buy trades minus the number of sale trades, divided by the total number of trades. RET is the market return and VOL is the return volatility. The returns used are the Lehman Brothers' aggregate daily bond index returns and the daily CRSP value-weighted index return for stocks. The suffixes or subscripts B and S refer to bond and stock variables, respectively. The sample period is June 17, 1991 to December 31, 1998. \* denotes significance at the 5% level and + denotes significance at the 10% level.

Regressor		OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
OIBB	Csum	<b>0.192<sup>*</sup></b>	0.006	0.032	-0.186	0.108	0.133	0.000	0.005
	p-value	<b>0.000</b>	0.458	0.650	0.503	<b>0.018</b>	0.743	0.468	0.260
OIBS	Csum	0.080	<b>0.332<sup>*</sup></b>	0.000	-0.043	0.018	-0.622	<b>0.008<sup>*</sup></b>	0.017
	p-value	0.557	<b>0.000</b>	0.797	0.169	0.592	<b>0.048</b>	<b>0.086</b>	0.128
VOLB	Csum	-0.024	-0.006	<b>-0.065<sup>*</sup></b>	0.108	-0.016	-0.058	<b>0.003<sup>*</sup></b>	0.002
	p-value	0.518	<b>0.003</b>	0.157	0.629	0.177	<b>0.019</b>	<b>0.013</b>	0.682
VOLS	Csum	<b>-0.017<sup>*</sup></b>	0.001	0.013	0.033	-0.006	0.046	0.000	<b>0.006<sup>*</sup></b>
	p-value	<b>0.023</b>	0.615	0.341	0.574	0.920	0.599	<b>0.016</b>	<b>0.000</b>
RETB	Csum	<b>-0.029<sup>*</sup></b>	<b>0.017<sup>*</sup></b>	<b>-0.064<sup>*</sup></b>	<b>0.186<sup>*</sup></b>	-0.010	<b>0.219<sup>*</sup></b>	0.000	0.001
	p-value	<b>0.065</b>	<b>0.047</b>	<b>0.014</b>	<b>0.034</b>	0.678	<b>0.049</b>	0.477	0.664
RETS	Csum	-0.002	<b>-0.017<sup>*</sup></b>	0.010	<b>-0.149<sup>*</sup></b>	-0.005	0.046	<b>-0.001<sup>+</sup></b>	<b>-0.002<sup>*</sup></b>
	p-value	0.882	<b>0.000</b>	0.631	<b>0.000</b>	0.777	0.230	0.150	0.180
QSPRB	Csum	-0.196	<b>0.750<sup>*</sup></b>	<b>2.531<sup>*</sup></b>	1.848	0.369	<b>7.766<sup>*</sup></b>	<b>0.544<sup>*</sup></b>	-0.098
	p-value	0.887	<b>0.008</b>	<b>0.019</b>	0.790	0.607	0.109	<b>0.000</b>	<b>0.066</b>
QSPRS	Csum	<b>0.170<sup>+</sup></b>	0.045	0.245	<b>1.417<sup>*</sup></b>	-0.160	-0.050	<b>0.009<sup>+</sup></b>	<b>0.702<sup>*</sup></b>
	p-value	0.269	0.143	0.332	<b>0.025</b>	0.815	0.364	<b>0.036</b>	<b>0.000</b>
Akaike Information Criterion			-14.099						
Schwarz Information Criterion			-13.699						

**Table 4 (continued): Vector Autoregression of Bond and Stock Quoted Bid-Ask Spread, Order Imbalance, Volatility and Returns**

**Panel B: Variance decomposition from VAR**

**Variance Decomposition (%) of QSPRB**

Forecast Horizon	Forecast Standard Error	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.01	0.22	0.13	6.77	0.48	0.87	0.78	90.75	0.00
2	0.01	0.32	0.17	8.44	1.25	1.12	1.18	87.26	0.25
4	0.01	0.28	0.15	9.41	1.35	1.11	1.62	85.64	0.43
8	0.01	0.27	0.15	9.57	1.45	1.13	1.83	84.92	0.68
10	0.01	0.27	0.15	9.58	1.46	1.13	1.85	84.84	0.72

**Variance Decomposition (%) of QSPRS**

Forecast Horizon	Forecast Standard Error	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.02	0.00	1.54	0.96	1.86	0.13	1.27	2.73	91.52
2	0.02	0.07	2.47	1.28	4.83	0.10	1.65	3.02	86.57
4	0.03	0.06	2.41	1.58	6.06	0.12	2.20	2.59	84.99
8	0.03	0.06	2.36	1.61	6.50	0.12	2.53	2.39	84.43
10	0.03	0.06	2.35	1.61	6.54	0.12	2.56	2.37	84.39

**Table 5: Contemporaneous Correlation between Innovations.** The table presents the correlation matrix for the VAR innovations in the time series of market-wide liquidity, volatility, returns and the order imbalance. Bond liquidity estimates are based on the daily mean of the best bid and ask offer quotes by dealers on the 10-year Treasury note, as reported in the GovPX data set. The stock liquidity series are constructed by first averaging all transactions for each individual stock on a given trading day and then cross-sectionally averaging all individual stock daily means that satisfy the data filters described in the text. QSPR stands for quoted spread, OIB for the order imbalance, and DEP for depth. OIB is measured as the number of buy trades minus the number of sale trades, divided by the total number of trades. RET is the market return and VOL is the return volatility. The returns used are the Lehman Brothers' aggregate daily bond index returns and the daily CRSP value-weighted index return for stocks. The suffixes B and S refer to bond and stock variables, respectively. DEP is in 1,000 share units for stocks and \$1 million face value for bonds. The sample period spans the period June 17, 1991 to December 31, 1998 for bond and stock spreads and January 1 1995 to December 31, 1998 for bond and stock depth. \* denotes significance at the 5% level and + denotes significance at the 10% level.

	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
OIBB	1.00							
OIBS	<b>0.06*</b>	1.00						
VOLB	-0.02	<b>-0.07*</b>	1.00					
VOLS	-0.01	<b>-0.06*</b>	<b>0.22*</b>	1.00				
RETB	<b>0.09*</b>	<b>0.26*</b>	<b>-0.04*</b>	-0.02	1.00			
RETS	<b>0.04*</b>	<b>0.75*</b>	<b>-0.07*</b>	<b>-0.10*</b>	<b>0.32*</b>	1.00		
QSPRB	<b>-0.05*</b>	<b>-0.04*</b>	<b>0.26*</b>	<b>0.13*</b>	<b>-0.11*</b>	<b>-0.11*</b>	1.00	
QSPRS	-0.00	<b>-0.13*</b>	<b>0.11*</b>	<b>0.16*</b>	<b>-0.07*</b>	<b>-0.18*</b>	<b>0.21*</b>	1.00

**Table 6: Net borrowed reserves, fed funds surprises and mutual fund flows** The table presents monthly equity mutual fund net flows (EFLOW) and monthly government bond mutual fund net flows (BFLOW). The unit is one billions dollars. Monthly mutual fund data are from the Investment Company Institute. NBOR is equal to net borrowed reserves divided by total reserves, where net borrowed reserves equal total borrowings minus extended credit minus excess reserves. Reserves data is from the Federal Reserve. NFFSUR (PFFSUR) is the negative (positive) surprise in the target federal funds rate changes, where the surprise is the target rate minus its market expectations. The unit is in basis points (0.01 percent). The sample period spans June 17, 1991 to December 31, 1998.

	NBOR	NFFSUR	PFFSUR	EFLOW	BFLOW
Mean	-0.018	-14.069	9.625	11.952	-0.208
Median	-0.017	-10.333	10.833	10.673	-0.415
No. of observations	198	15	8	91	91

**Table 7: Vector Autoregression (VAR) of Net Borrowed reserves, Bond and Stock Quoted Bid-Ask Spread, Order Imbalance, Volatility and Returns**

This table presents results from a VAR with one lag and a constant term, and using 196 observations. The endogenous variables in the VAR are ordered as NBOR, OIBB, OIBS, VOLB, VOLS, RETB, RETS, QSPRB and QSPRS. Panel A presents the contemporaneous correlation in the VAR innovations. Panel B shows the variance decompositions of NBOR, QSPRB and QSPRS. Panel C shows the variance decompositions during crisis periods of NBOR, QSPRB and QSPRS. NBOR is the ratio of net borrowed reserves to total reserves, where net borrowed reserves equal total borrowings minus extended credit minus excess reserves. This data is from the Federal Reserve, and is at a biweekly frequency. QSPR stands for quoted spread, and OIB for the order imbalance. OIB is measured as the number of buy trades minus the number of sale trades, divided by the total number of trades. VOL is the return volatility and RET is the daily market return compounded over the biweekly period. The returns used are the Lehman Brothers' aggregate daily bond index returns and the daily CRSP value-weighted index return for stocks. The suffixes or subscripts B and S refer to bond and stock variables, respectively. The sample period is June 17, 1991 to December 31, 1998. \* denotes significance at the 5% level and + denotes significance at the 10% level.

**Panel A: Contemporaneous correlation between VAR innovations**

	NBOR	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
NBOR	1.00								
OIBB	<b>0.12<sup>+</sup></b>	1.00							
OIBS	-0.06	0.09	1.00						
VOLB	0.08	-0.05	-0.01	1.00					
VOLS	-0.02	-0.06	<b>-0.13<sup>+</sup></b>	<b>0.17<sup>*</sup></b>	1.00				
RETB	-0.06	0.09	<b>0.23<sup>*</sup></b>	<b>-0.14<sup>*</sup></b>	-0.11	1.00			
RETS	-0.04	0.06	<b>0.49<sup>*</sup></b>	-0.01	-0.06	<b>0.34<sup>*</sup></b>	1.00		
QSPRB	0.03	-0.08	0.09	<b>0.17<sup>*</sup></b>	0.11	<b>-0.14<sup>*</sup></b>	<b>-0.13<sup>+</sup></b>	1.00	
QSPRS	0.07	0.03	-0.10	<b>0.12<sup>+</sup></b>	0.11	<b>-0.14<sup>*</sup></b>	<b>-0.29<sup>*</sup></b>	<b>0.42<sup>*</sup></b>	1.00



**Panel B of Table 7 (continued): Variance decompositions**

**Variance Decomposition (%) of NBOR**

Forecast Horizon	Forecast Standard Error	NBOR	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.01	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.01	93.86	0.02	1.23	0.10	0.02	0.15	1.20	3.13	0.29
4	0.01	92.41	0.06	1.34	0.21	0.23	0.15	1.50	3.74	0.36
8	0.01	92.29	0.07	1.36	0.22	0.24	0.15	1.53	3.79	0.37

**Variance Decomposition (%) of QSPRB**

Forecast Horizon	Forecast Standard Error	NBOR	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.00	0.17	0.90	1.31	2.73	0.26	2.17	2.81	89.65	0.00
2	0.00	0.46	0.75	1.34	5.19	1.22	1.63	4.04	85.24	0.14
4	0.00	0.47	0.83	1.79	5.43	1.24	1.49	4.46	83.94	0.35
8	0.00	0.47	0.85	1.88	5.44	1.24	1.47	4.48	83.70	0.46

**Variance Decomposition (%) of QSPRS**

Forecast Horizon	Forecast Standard Error	NBOR	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.02	0.63	0.03	0.87	0.65	0.97	1.52	6.39	13.45	75.49
2	0.02	0.45	0.17	0.72	1.52	2.87	1.08	7.08	10.43	75.68
4	0.02	0.41	0.32	0.61	1.40	3.23	0.97	7.49	8.91	76.66
8	0.02	0.42	0.34	0.60	1.35	3.25	0.95	7.45	8.75	76.91

**Panel C: Crisis period variance decompositions**

**Variance Decomposition (%) of QSPRB**

Forecast Horizon	Forecast Standard Error	NBOR	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.00	1.18	0.93	1.65	1.80	0.19	1.90	2.18	90.16	0.00
2	0.00	1.21	0.78	1.77	4.02	0.98	1.45	3.11	86.54	0.13
4	0.00	3.39	0.95	2.09	4.47	1.01	1.34	3.39	83.14	0.23
8	0.00	4.54	1.00	2.13	4.50	1.02	1.33	3.42	81.81	0.25

**Variance Decomposition (%) of QSPRS**

Forecast Horizon	Forecast Standard Error	NBOR	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.02	3.53	0.00	0.74	0.33	0.86	0.99	6.09	13.11	74.34
2	0.02	2.73	0.12	0.59	1.10	2.66	0.74	6.75	10.26	75.05
4	0.02	2.32	0.27	0.51	1.04	3.03	0.69	7.19	8.75	76.20
8	0.02	2.23	0.29	0.49	1.00	3.06	0.68	7.17	8.62	76.47

**Table 8: Monthly Vector Autoregression (VAR) of Mutual fund flows, Bond and Stock Quoted Bid-Ask Spread, Order Imbalance, Volatility and Returns**

This table presents results from a VAR with one lag and a constant term, and using 90 observations. The endogenous variables in the VAR are ordered as EFLOW, BFLOW, OIBB, OIBS, VOLB, VOLS, RETB, RETS, QSPRB and QSPRS. Panel A presents the contemporaneous correlation in the VAR innovations. Panel B shows the variance decompositions of EFLOW, BFLOW, QSPRB and QSPRS. EFLOW (BFLOW) measures monthly equity (government bond) mutual fund net flows. The data is from the Investment Company Institute and is at a monthly frequency. QSPR stands for quoted spread, and OIB for the order imbalance. OIB is measured as the number of buy trades minus the number of sale trades, divided by the total number of trades. RET is the daily market return compounded over the month and VOL is the return volatility. The returns used are the Lehman Brothers' aggregate daily bond index returns and the daily CRSP value-weighted index return for stocks. The suffixes B and S refer to bond and stock variables, respectively. The sample period is June 17, 1991 to December 31, 1998.

**Panel A: Contemporaneous correlation between VAR innovations**

	BFLOW	EFLOW	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
BFLOW	1.00									
EFLOW	<b>-0.34*</b>	1.00								
OIBB	0.03	0.12	1.00							
OIBS	<b>0.28*</b>	0.06	<b>0.43*</b>	1.00						
VOLB	-0.05	0.10	-0.01	-0.00	1.00					
VOLS	-0.02	-0.09	-0.16	-0.17	<b>0.20<sup>+</sup></b>	1.00				
RETB	0.10	-0.01	<b>0.25*</b>	<b>0.33*</b>	-0.05	0.07	1.00			
RETS	-0.15	<b>0.44*</b>	<b>0.30*</b>	<b>0.26*</b>	0.02	0.09	<b>0.40*</b>	1.00		
QSPRB	0.13	0.04	0.04	<b>0.23*</b>	0.08	0.02	-0.09	-0.02	1.00	
QSPRS	<b>0.25*</b>	<b>-0.20<sup>+</sup></b>	0.11	0.11	0.08	<b>0.24*</b>	-0.06	<b>-0.24*</b>	<b>0.33*</b>	1.00

**Table 8 (continued)**  
**Panel B: Variance decompositions**

**Variance Decomposition (%) of BFLOW**

Forecast Horizon	Forecast Standard Error	BFLOW	EFLOW	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	90.95	0.02	1.17	4.45	1.36	1.17	0.08	0.04	0.62	0.12
4	0.00	87.34	0.37	1.20	6.40	1.21	1.25	0.39	0.71	1.01	0.12

**Variance Decomposition (%) of EFLOW**

Forecast Horizon	Forecast Standard Error	BFLOW	EFLOW	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.01	12.28	87.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.01	14.99	69.43	0.28	3.75	0.02	2.38	6.22	0.41	1.44	1.07
4	0.01	17.34	64.16	0.63	4.01	0.19	2.94	6.12	0.65	1.72	2.24

**Variance Decomposition (%) of QSPRB**

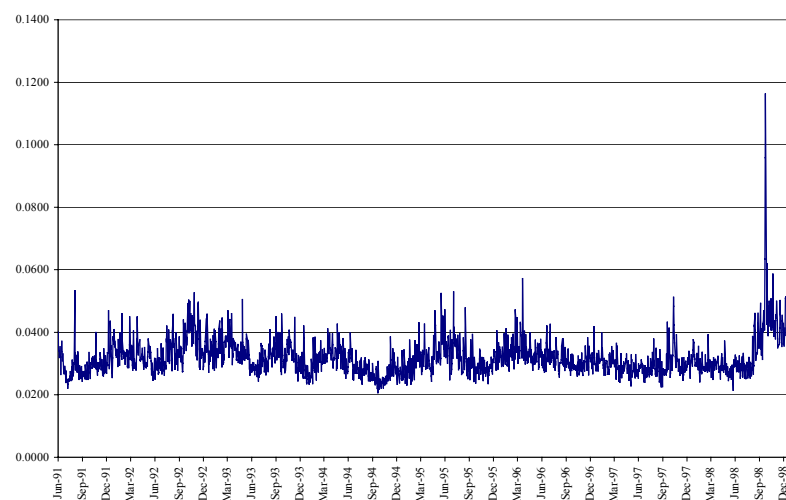
Forecast Horizon	Forecast Standard Error	BFLOW	EFLOW	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.00	1.55	0.88	0.04	4.12	0.30	4.51	3.85	0.03	84.73	0.00
2	0.00	6.39	4.74	0.19	3.59	1.12	4.41	4.38	0.02	75.15	0.02
4	0.00	12.84	4.29	0.72	5.11	1.07	3.98	3.92	0.20	67.85	0.02

**Variance Decomposition (%) of QSPRS**

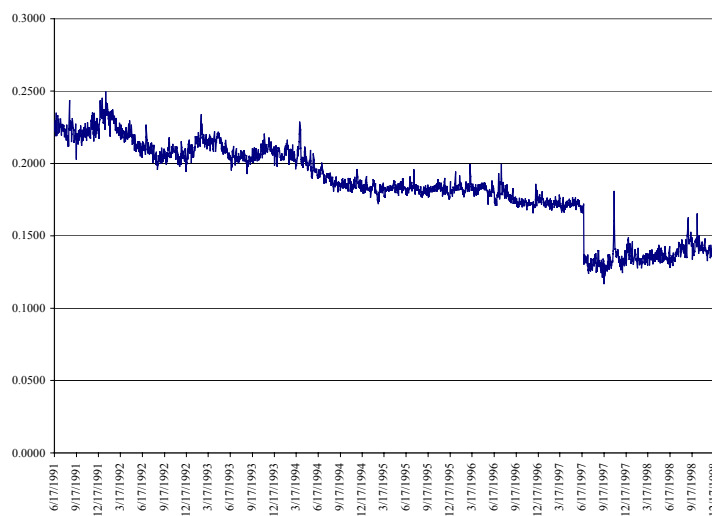
Forecast Horizon	Forecast Standard Error	BFLOW	EFLOW	OIBB	OIBS	VOLB	VOLS	RETB	RETS	QSPRB	QSPRS
1	0.01	5.74	1.28	1.31	0.07	0.19	20.52	3.95	1.76	3.33	61.85
2	0.02	4.32	2.15	1.74	0.74	0.13	18.05	4.84	1.63	2.42	63.97
4	0.02	3.69	1.78	2.21	0.76	0.27	15.76	3.86	1.88	1.97	67.83

**Figure 1. The Quoted Bid-Ask Spread: Unadjusted Series**

**Panel A. The Quoted Bid-ask Spread in the 10-year Treasury Note Market**

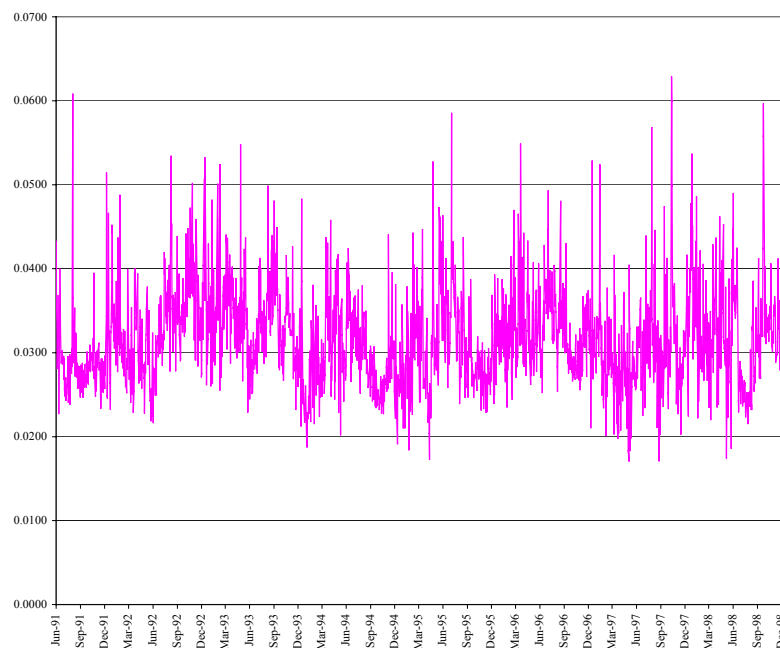


**Panel B. The Quoted Bid-ask Spread in the Stock Market**

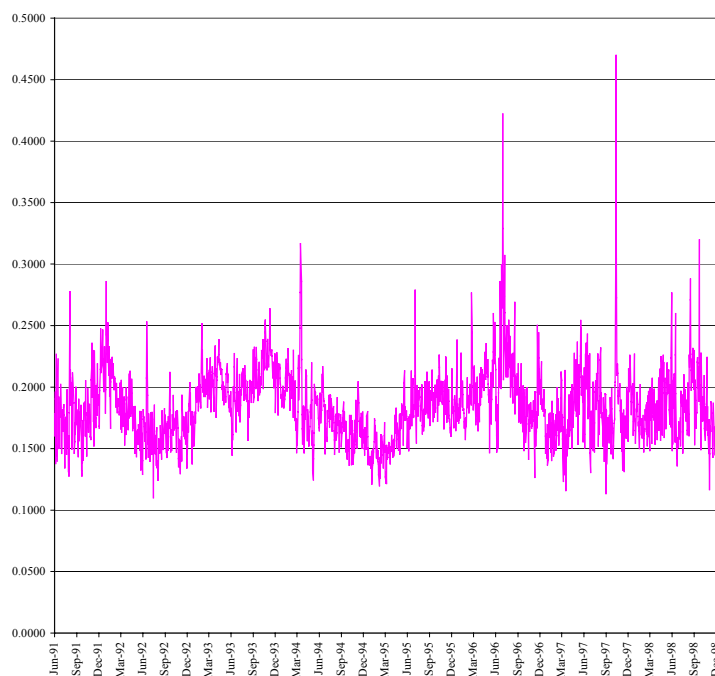


**Figure 2. The Quoted Bid-Ask Spread: Adjusted Series**

**Panel A. The Quoted Bid-ask Spread in the 10-year Treasury Note Market**



**Panel B. The Quoted Bid-ask Spread in the Stock Market**



**Figure 3**

**Panel A: Response of the stock quoted spread to endogenous variables**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.

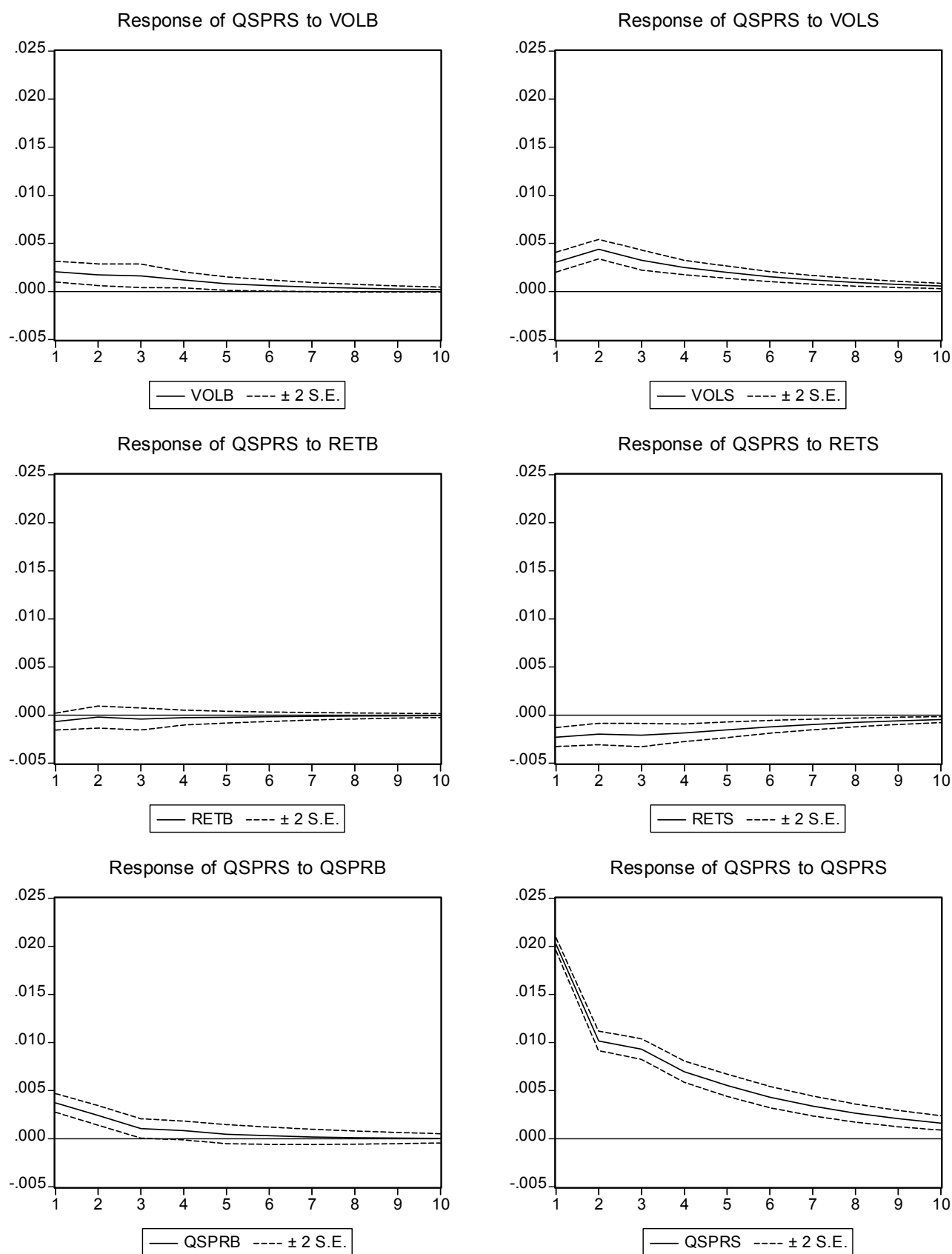
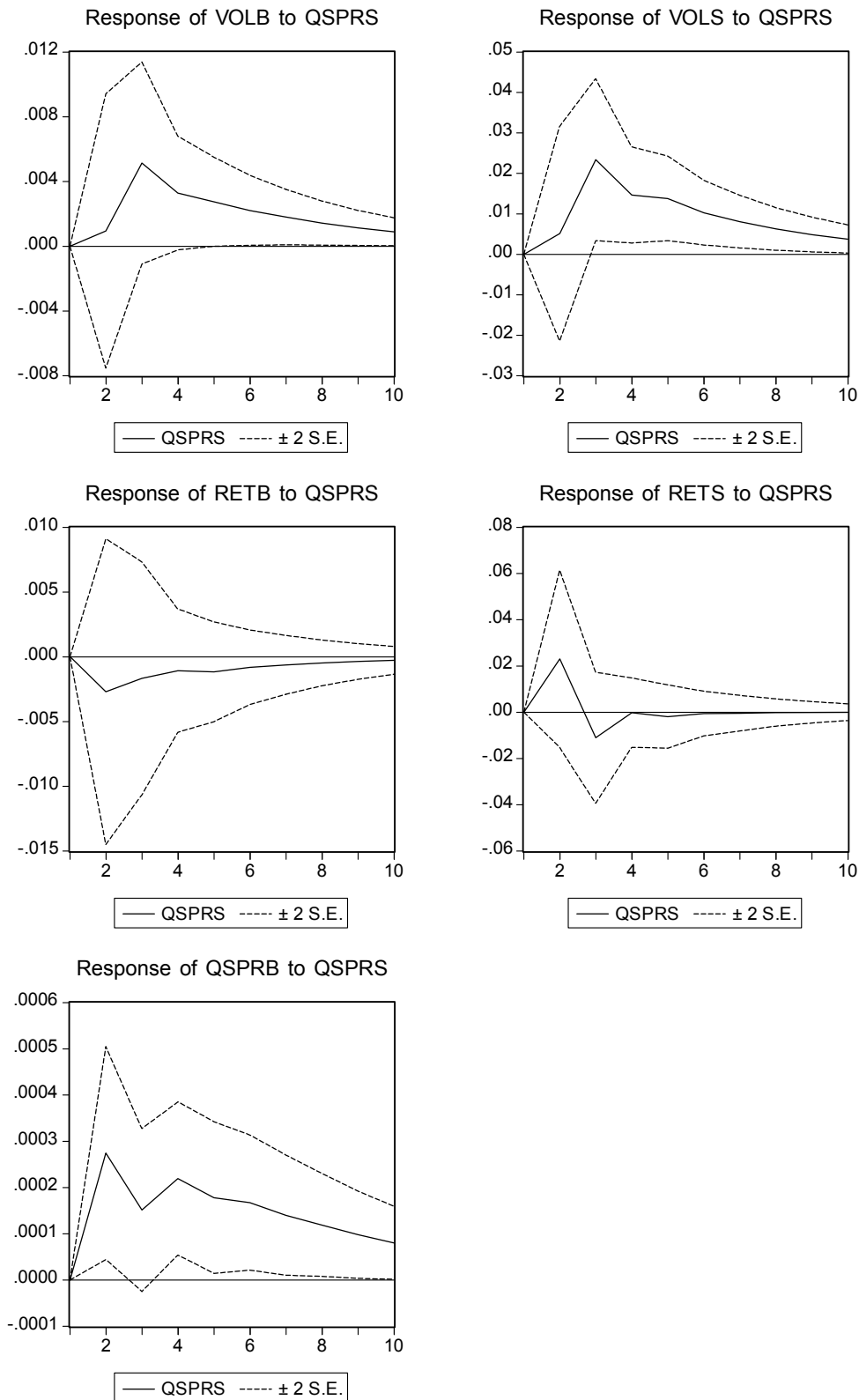


Figure 3, contd.

**Panel B: Response of endogenous variables to the stock quoted spread**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.



**Figure 4**

**Panel A: Response of the bond quoted spread to endogenous variables**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.

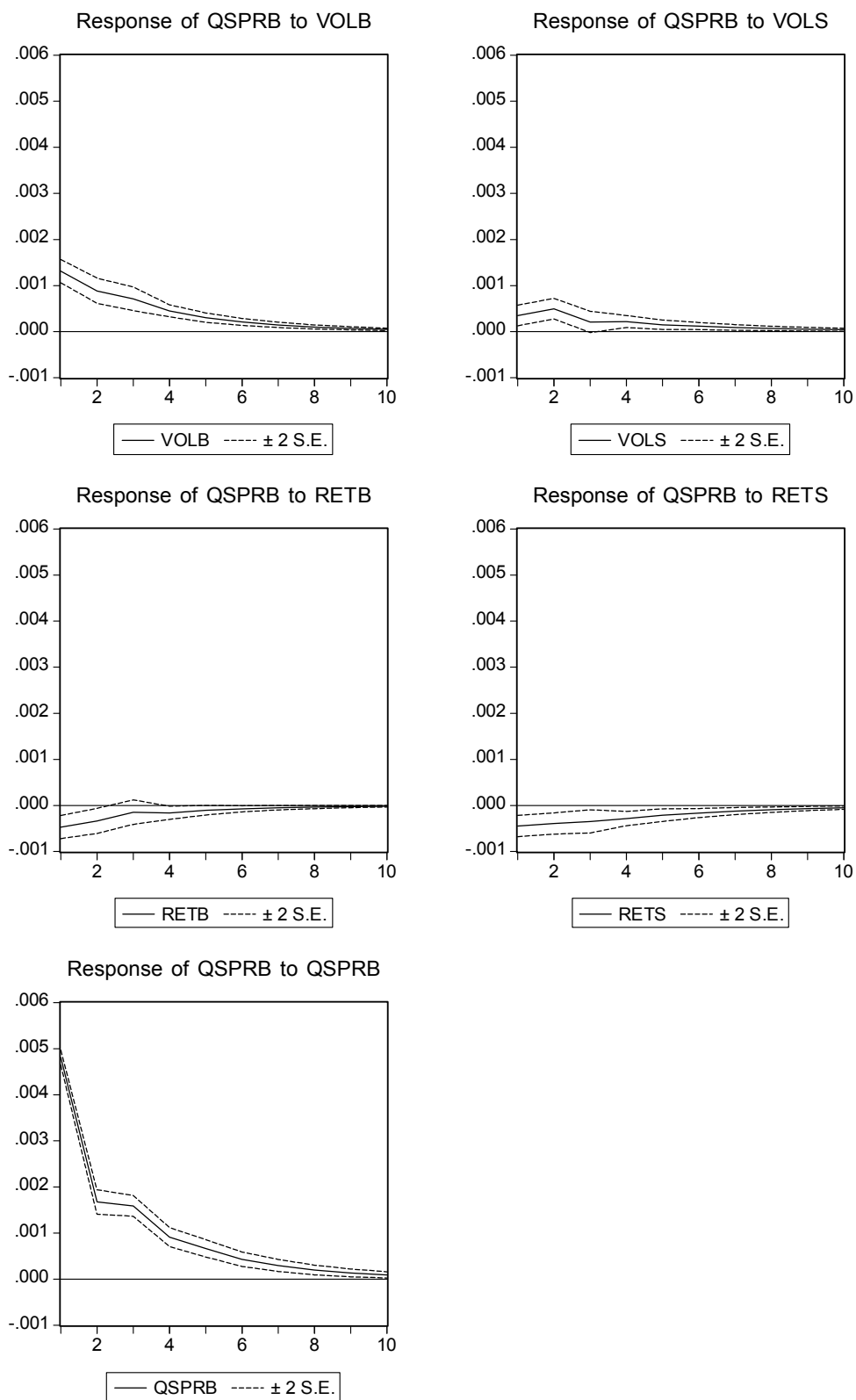
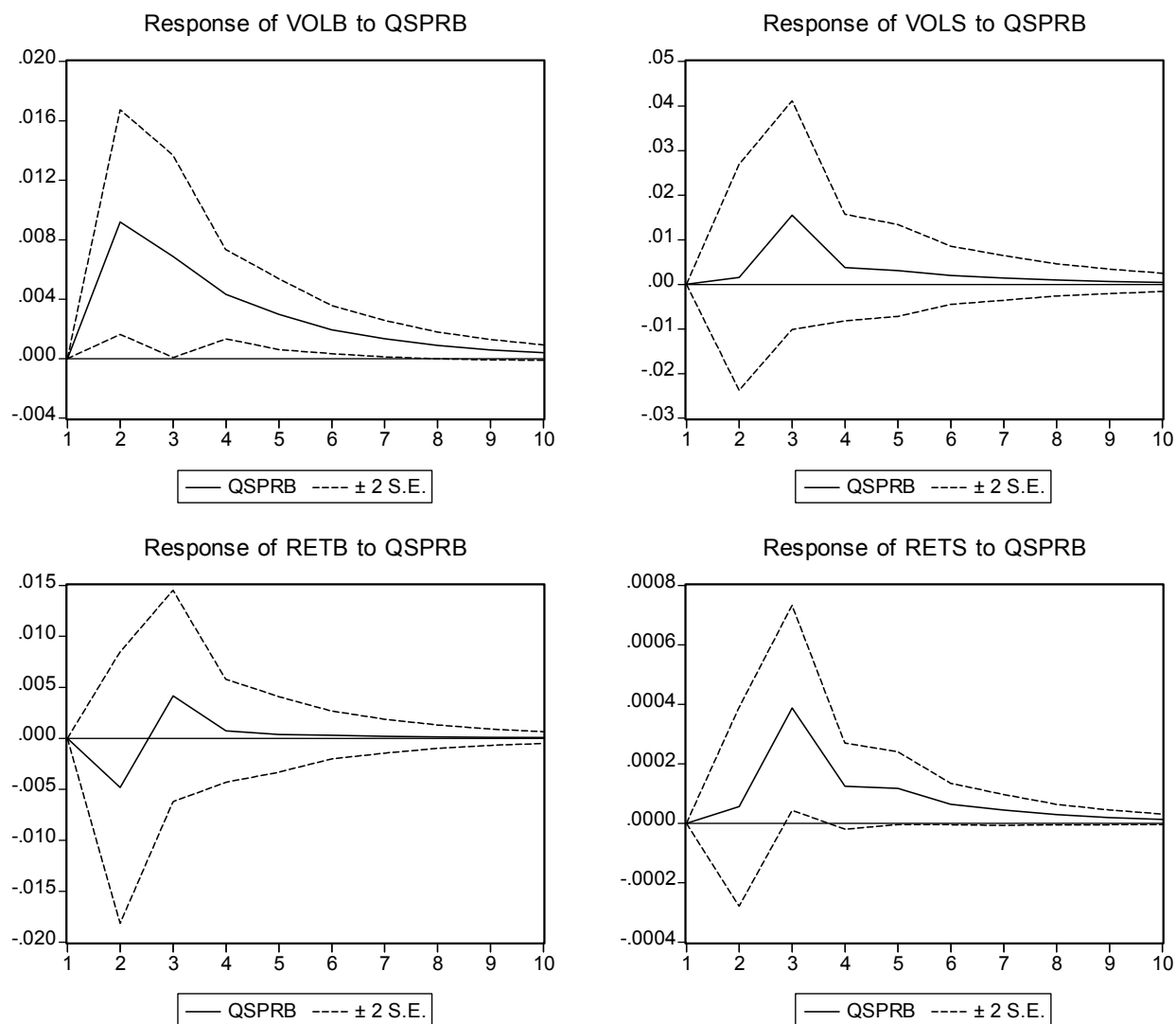




Figure 4, contd.

**Panel B: Response of endogenous variables to the bond quoted spread**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.



**Figure 5: Crisis Period response of endogenous variables to net borrowed reserves**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.

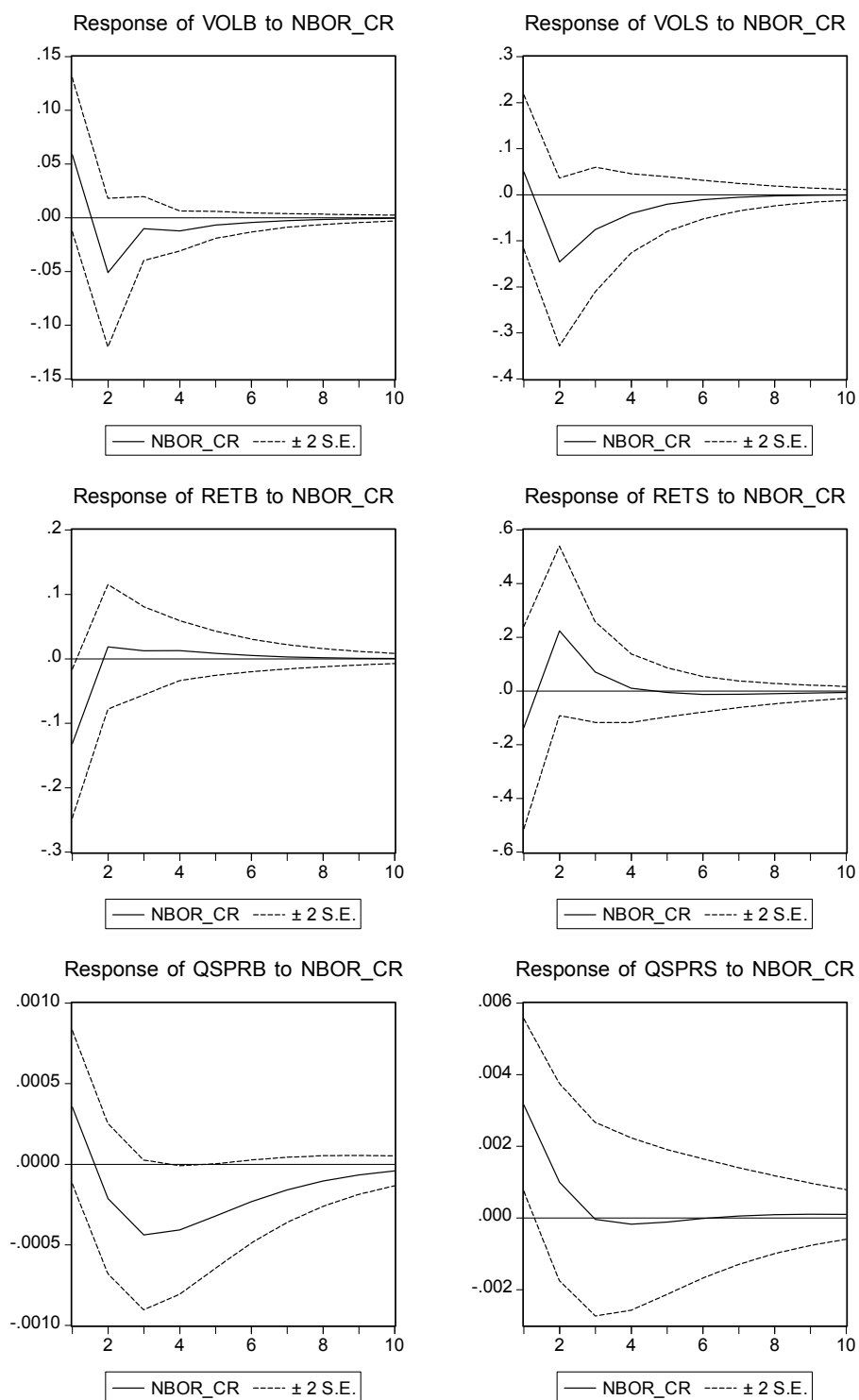


Figure 6

Panel A: Response of endogenous variables to negative federal funds surprises

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.

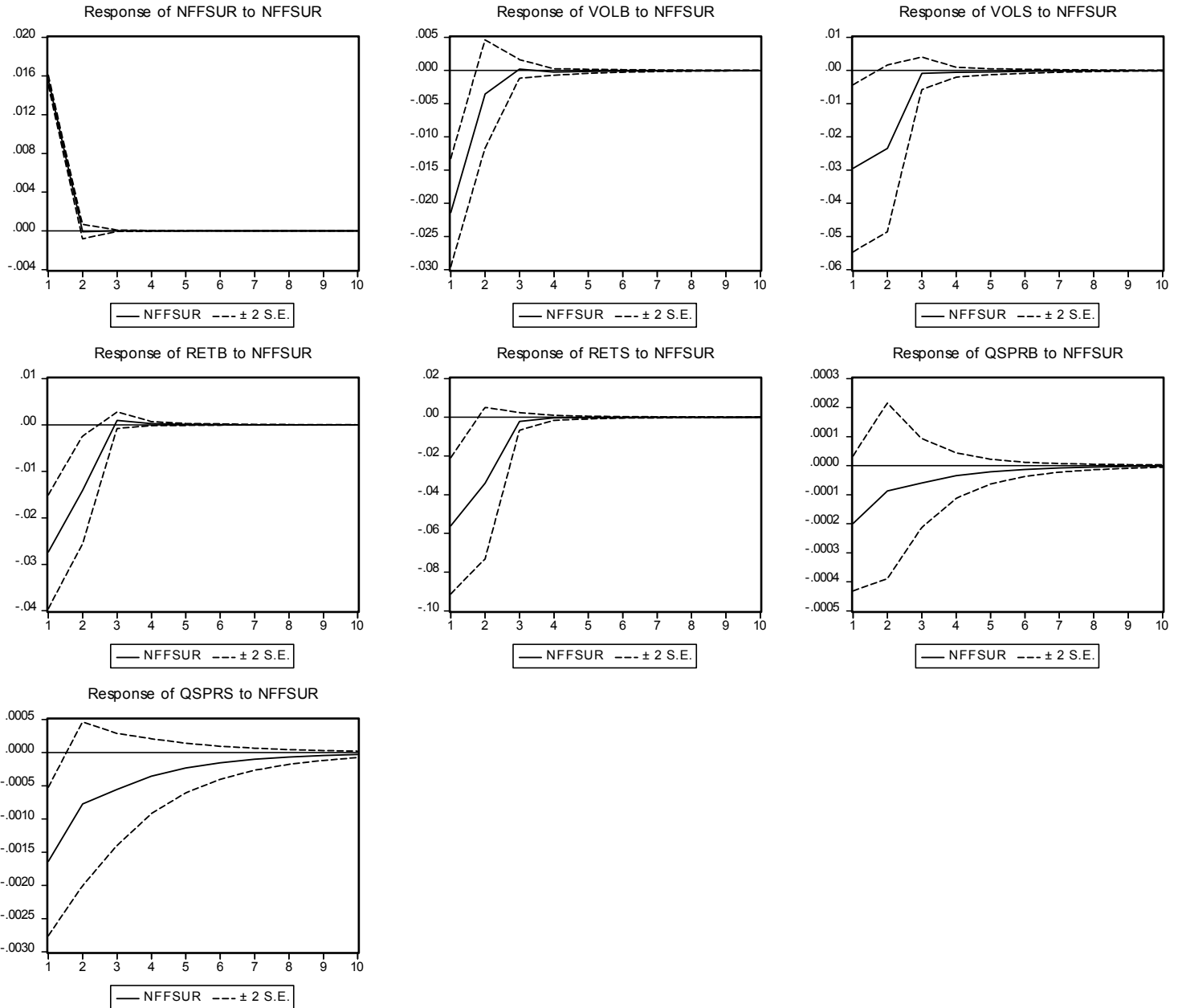
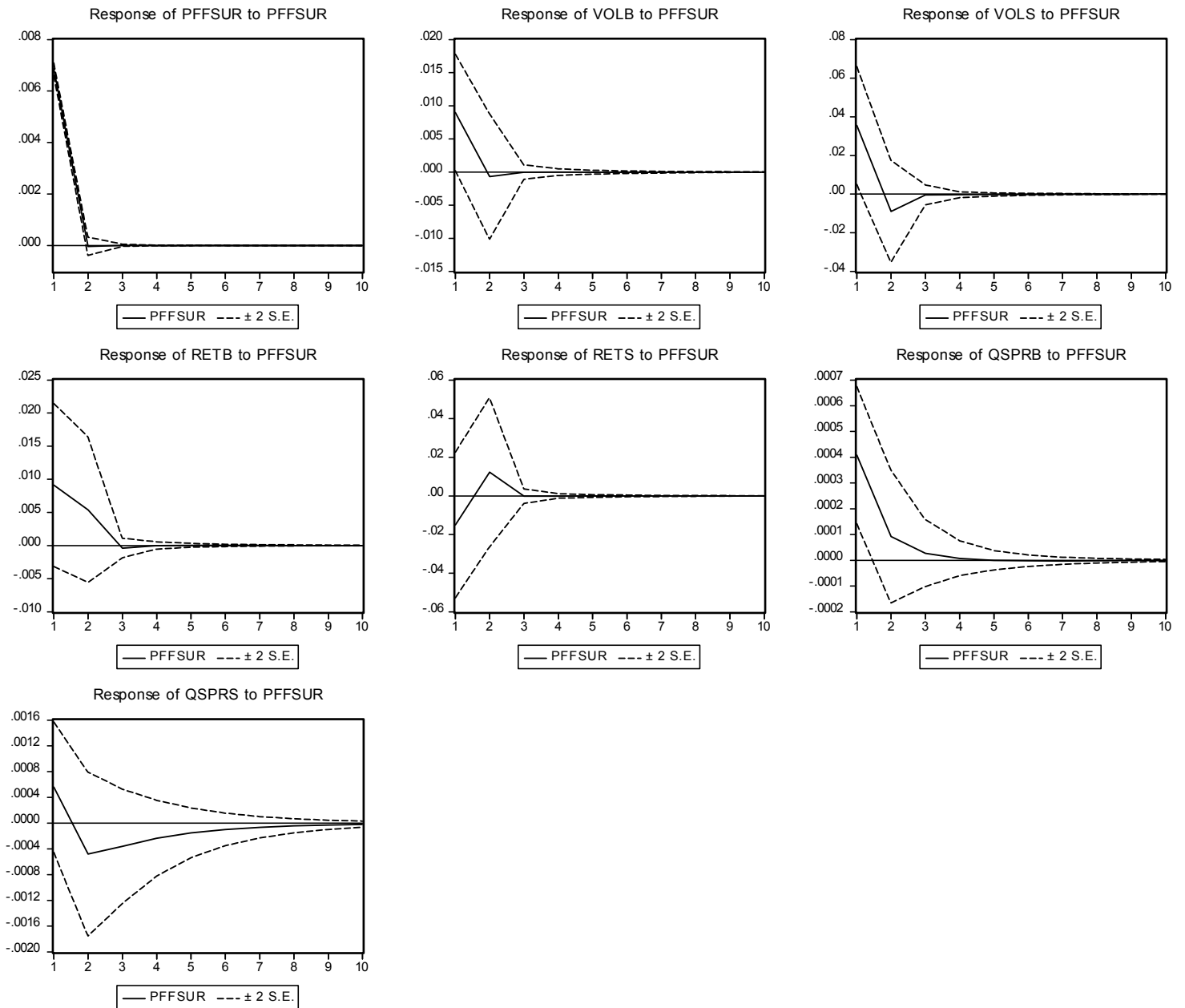


Figure 6, contd.

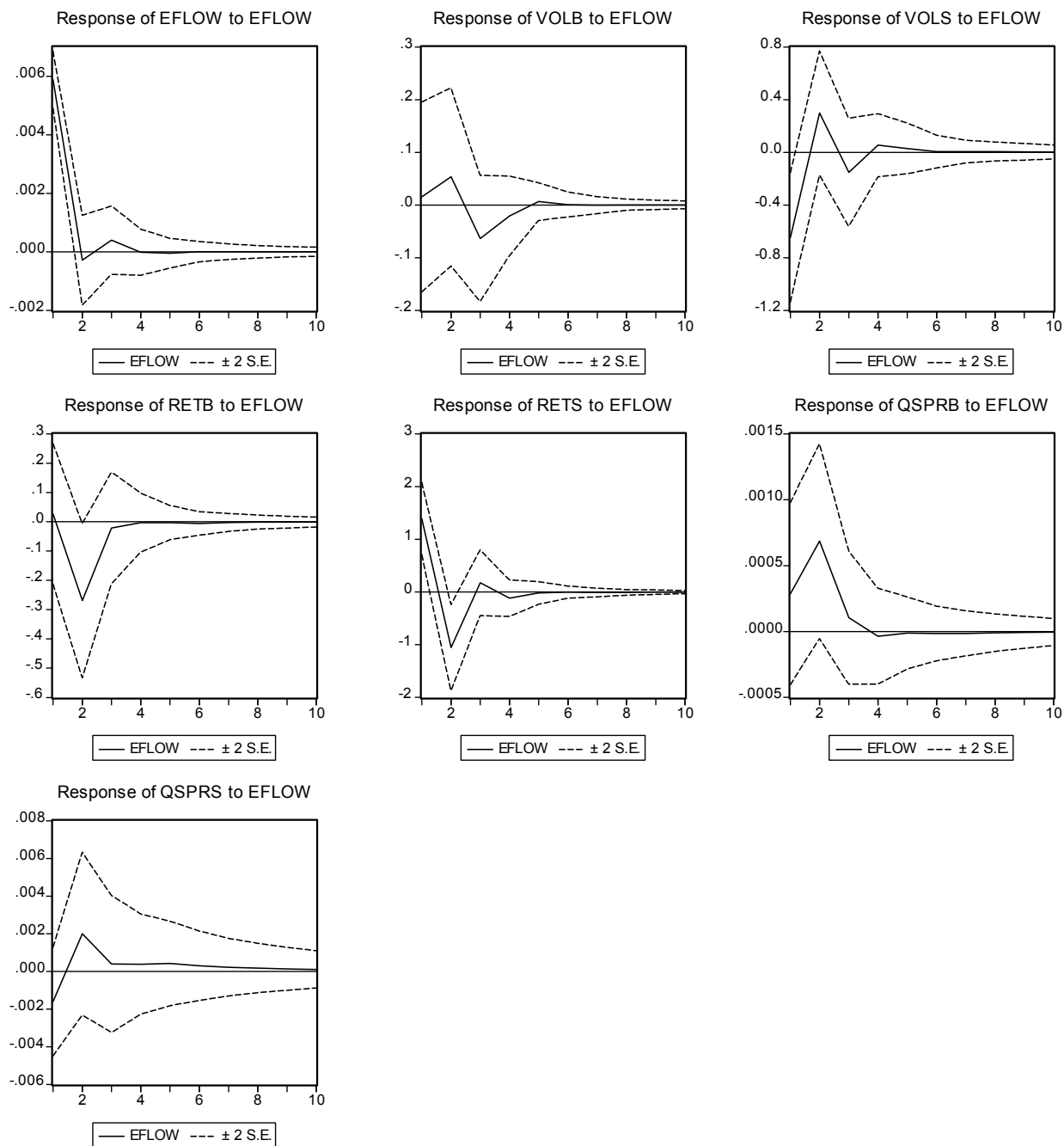
**Panel B: Response of endogenous variables to positive federal funds surprises**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.



**Figure 7: Response of endogenous variables to equity fund flows**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.



**Figure 8: Response of endogenous variables to bond fund flows**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.

