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An Empirical Analysis of Stock and Bond Market Liquidity

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Abstract

An Empirical Analysis of Stock and Bond Market Liquidity

We study the joint time-series of daily liquidity in bond and stock markets over the period, 1991 to 1998. We find that spreads and depths in the stock and bond markets are predictable using lagged spreads and lagged order imbalances. Unexpected liquidity shocks are positively and significantly correlated across stock and bond markets, suggesting that liquidity shortages and replenishments are often systemic in nature. During periods of financial crises, the correlation in stock and bond spread innovations increases. Monetary policy appears to have an ameliorative effect on stock market liquidity during crises. U.S. government bond funds see higher inflows and equity funds see higher outflows during financial crises, suggesting a flight to quality during periods of stress.

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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,[1] 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.[2] 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.[3]

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 equity market liquidity by show-

[1] See Stoll (2000).

[2] "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.

[3] See also Brennan and Subrahmanyam (1996) and Brennan, Chordia and Subrahmanyam (1998).

ing that spreads and depths of individual stocks co-move with market- and industry-wide liquidity. Chordia, Roll, and Subrahmanyam (2001) study daily aggregate equity market spreads, depths and trading activity over an extended period to document weekly regularities in liquidity and the influence of market returns, volatility and interest rates on liquidity, while Jones (2001) studies annual equity liquidity over more than 100 years. Fleming (1997, 2001), and Brandt, Edelen, and Kavajecz (2001) study liquidity in the US government bond market while Fleming and Remolona (1997, 1999), Balducci, Elton and Green (2001) analyze returns, spreads, and trading volume in bond markets around economic announcements.

So far the literature on stock and bond liquidities has developed in separate strands. In practice, however, a number of asset allocation strategies shift wealth between stock and bond markets.[4] The question naturally arises as to the optimal way of executing these strategies so as to minimize trading costs. In particular, it is of interest to consider whether timing these allocations or sequencing them in a particular way can reduce trading costs associated with these strategies. For example, if the nature of calendar regularities across stock and bond markets is different, then staggering allocation strategies may lead to lower trading costs. Addressing this issue requires the analysis of the joint time-series of stock and bond liquidity, and in particular, the question of whether these series have common determinants assumes importance.

Motivated in part by the above observation, in this paper, we jointly study the time-series of liquidity in stock and the U.S. Government bond markets. Stocks and bonds are important for resource allocation, as they are the main vehicles by which funds are raised for long-term investments by firms and governments. Since liquidity has been shown to

[4] See, for example, Amman and Zimmerman (2001) and Fox (1999) for practical considerations, and Barberis (2000) or Xia (2001) for more academic studies.

be related to asset returns and, in turn, costs of capital, analyzing how stock and bond liquidities move and co-move over time is also important for enhancing the efficacy of resource allocation.

Our consideration of the joint time-series of stock and bond market liquidity sheds light on specific research questions that have not yet been addressed in the literature:

- What is the extent of co-movement between stock and bond liquidity and how does the nature of this co-movement change during financial crises?
- Are there spillover effects from bond liquidity to stock liquidity or vice versa?
- Is financial market liquidity predictable using publicly available information? If so, what variables help forecast future stock and bond market liquidity?
- What are the time-series properties of unexpected liquidity shocks? Are they cross-correlated?
- How does Federal Reserve monetary policy affect financial market liquidity during crises?
- What happens to money flows in and out of stock and bond mutual funds during financial crises and how does this impact stock and bond market liquidity?

Our goal in this paper is to address these questions by considering the joint time-series of bond and stock market liquidity over a fairly long time-period of over 1700 trading days.

The results indicate that the time series properties of stock and bond liquidity possess similarities. In particular, results from forecasting regressions indicate that bond and stock spreads are predictable to a considerable degree, though stock spreads are more predictable than bond spreads within our sample. Lagged spreads and order imbalances are all predictors of the bid-ask spreads and depth. Further, weekly regularities in bond market liquidity mimic those in stock market liquidity, except that spreads for bonds appear to be lowest on Mondays, whereas those for stocks appear to be lowest on Tuesdays.

Markets behave differently during periods of financial crises. We consider the Asian crisis in 1997 and the Russian default crisis in 1998. Our results suggest that the correlation between unpredictable shocks to stock and bond liquidity increases dramatically during crises relative to normal times. In addition, liquidity becomes much harder to predict during periods of crises, possibly due to market turbulence during this period. We also examine the relation between liquidity and a proxy for monetary policy, namely, net borrowed reserves divided by the required reserves. The results are consistent with the notion that Federal Reserve policy has an ameliorative effect on liquidity in financial markets during financial crises.

Finally, we examine how monthly money flows in and out of stock and bond funds affect liquidity during financial crises as well as in normal periods. We find that during periods of crises, there is an increase in flows to government bond funds and a substantial reduction in the in flows to equity funds. This "flight to quality" results in decreased equity market liquidity, as well as reduced liquidity in the bond markets.

The rest of the paper is organized as follows. Section 2 describes the data. Section 3 presents summary statistics, while Section 4 performs daily predictive regressions. Section 5 analyzes liquidity around periods of financial crises: namely the Asian and the Russian crises. Section 6 presents the analysis of mutual fund flows and monetary policy. Section 7 concludes.

2 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 government 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 focus in this paper is on forecasting stock and bond liquidity measures that have been the focus of attention in the previous literature, viz., quoted and effective spreads as well as market depth. We use order imbalances as predictive determinants of liquidity, rather than volume, because our view is that imbalances bear a stronger relation to the following day's liquidity as they represent the aggregate pressure on the inventories of market makers.[5]

2.1 Measures of Bond Liquidity

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.[6] The GovPX data pertains to inter-dealer trades only.

[5]See Chordia, Roll, Subrahmanyam (2002).

[6]Fleming (2001) provides a detailed account of the format of GovPX data.

We use trading data for the 10-year, on-the-run Treasury note. 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). We choose the 10-year note for two reasons. First, it is among the most actively traded fixed-income securities. Second, GovPX data is representative of the overall market for 10-year notes during our sample period. For other long-term Treasury notes (such as the 30-year Treasury bond), the GovPX data captures a smaller and variable fraction of aggregate bond market activity since a major broker, Cantor Fitzgerald/eSpeed, does not report its data.[7]

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 the trade. Only quotes that are matched with trades are retained in the sample. The trade price is matched with the most recently available quote record on the same day.
ESPRB: the daily average effective spread, i.e., the difference between the execution price and the mid-point of the prevailing bid-ask quote.
DEPTHB: Average of each set of posted bid and ask depth in notional terms, averaged over the trading day
CLIQB: A composite measure of liquidity, defined as quoted spread divided by market depth.
The last two variables are available only starting 1995.

We also define the following terms for order imbalance in the bond market, to be used in our predictive regressions that are described in Section 4:
OIB_B: the daily buy imbalance (the total notional value of buys less sells each day).

[7] Boni and Leach (2001) document the share of GovPX in aggregate bond market volume.

OIB_B+: max(OIB_B,0).

OIB_B-: min(OIB_B,0).

Since the bond data is from the inter-dealer market, the order imbalances represents the inter-dealer order imbalances. However, it is highly likely that the inter-dealer order imbalances arise in response to customer imbalances as dealers lay off customer orders in the inter-dealer market. The inter-dealer imbalances are, thus, likely to be a noisy measure of the customer imbalances.

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 or effective 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.

4. Trades with effective spreads in the upper five percentile of its distribution for a particular calendar year are deleted. These trades are clearly outliers, since their effective spreads are several times greater than its standard deviation and, further, greatly exceed the maximum quoted spread for the calendar year.

2.2 Stock Liquidity 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) were 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.

ESPRS: the daily average effective spread, i.e., the difference between the execution price and the mid-point of the prevailing bid-ask quote.

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

CLIQS: A composite measure of liquidity, defined as quoted spread divided by market depth.

OIB_S: the daily order imbalance (the total estimated numbers of shares bought less shares sold each day).[8]

OIB_S+: max(OIB_S,0)

OIB_S-: min(OIB_S,0)

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:[9]

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. 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

[8]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.

[9]The proportional spreads in condition 3 are obtained by dividing the unscaled spreads by the mid-point of the prevailing bid-ask quote.

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 Summary Statistics

Table 1 presents the levels of quoted and effective spreads and absolute order imbalances for stocks and bonds.

Please insert Table 1 here.

The average quoted and effective spreads are $0.032 and $0.030, respectively for bonds, but $0.20 and $0.13, respectively, for stocks. The daily absolute imbalance in percentage terms is 13% for bonds and about 5% for stocks. Bond spreads are lower than those for stocks even though the absolute order imbalances and the transaction sizes in bond markets are larger.[10] This is possibly due to the fact that the minimum tick size is smaller in the bond market. However, the tick size is endogeneous suggesting that there may be more fundamental informational-based reasons for the smaller spreads in the bond market. US government 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. However, adverse selection is likely to be far more important in stock prices due to private information about idiosyncratic shocks. 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 with large transaction sizes. The median spread measures are almost the same as the means suggesting little skewness in the daily distribution of liquidity.

[10]The minimum lot size in the US government bond market is $1,000,000 whereas the lot size in the stock market is 100 shares.

Panel B presents summary statistics for depth and the composite liquidity measures for the subperiod for which we have data on bond depth available (1995-1998), and both panels indicate that 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 absolute order imbalance is, on average, greater in the bond market.

Table 2 presents the correlations between the contemporaneous bond and stock liquidity and imbalance variables. The stock market data for Table 2 (and Table 3) ends on June 24, 1997 because of the change in the tick size from 1/8 to 1/16 after this date.

Please insert Table 2 here.

While the time-series correlation between stock and bond quoted spreads is high (about 21%), that between effective spreads is insignificantly different from zero. Depth in each market is also positively correlated with the other (about 10%) giving rise to the strong correlation between the composite liquidity measures (quoted spread divided by depth) for stocks and bonds (31%). Depth in each market is significantly negatively correlated with the quoted and the effective spreads. Depth in the bond market is negatively related to the quoted and effective spreads in the stock market while depth in the stock market is negatively related only to quoted spreads in the bond market.

Recall that the order imbalance measures in both markets have been divided into the two components, $OIB+$ and $OIB-$ in order to capture differences in the impact on liquidity of positive and negative order imbalances. The correlation between $OIB+S$ and the quoted or effective spread in the stock market is significantly positive and the correlation between $OIB-S$ and the two spread measures is significantly negative suggesting that stock market liquidity declines (spreads increase) strongly with order flow in or out of the stock market. The correlation between the quoted as well as effective bond spread and $OIB+B$ is negative suggesting that the bond market liquidity improves with order flow into the bond market.

The buy imbalance in the stock market, $OIB+S$ is positively correlated with sell imbalance in the bond market, $OIB-B$, and with the bond quoted and effective spreads. Further, the sell imbalance in the bond market ($OIB-B$) is positively correlated with a buy imbalance in the stock market ($OIB+S$) and with quoted and effective spreads in the stock market. This is consistent with positive information shocks in the stock market resulting in money flowing out of bonds into stocks and causing higher bond and stock spreads. Thus, order flow seems to be a venue through which both bond and stock market liquidity are impacted. We now study the impact of own and cross-market order flow on liquidity within the context of a predictive regression framework.

4 Predictive Regressions

In this section, we attempt to provide a parsimonious model that captures time-series predictability in stock and bond liquidity. The ability to predict liquidity would be very valuable to traders. We choose to adopt a pure forecasting specification for stock and bond quoted and effective spreads, depths, and the composite liquidity variable and we will use the forecasting regressions to discuss the impact of lagged stock market liquidity on bond market liquidity and vice versa.[11]

Our principal predictors of liquidity are lagged imbalances and lagged values of liquidity. Lagged imbalances on a given day could signal, for example, heavy selling pressure

[11] Our results are qualitatively similar when we use proportional quoted and effective spreads instead of the unscaled spreads. We use unscaled spreads to avoid any apprehension that our results are driven by the use of price levels in the dependent variables.

being carried over to the next day, which could affect market maker inventories and consequently the bid-ask spread on the following day.[12] It is possible that a negative imbalance could induce relatively more pronounced changes in liquidity to the extent that market makers find it more difficult to adjust inventory to order flows out of the market. We, thus, split up lagged imbalances into positive and negative components in our forecasting regressions.[13]

Also, asset allocation strategies that require shifting of wealth between stock and bond markets on a periodic basis may be spread out over time across both markets, for the purposes of minimizing price impact. This implies that imbalances in the stock market on a given day could be predictors of future bond market liquidity, and vice versa. We therefore include cross-market imbalances as well as cross-market liquidity measures in our regressions.

Liquidity may also be influenced by the opportunity cost of devoting time to trading decisions, which could vary across days of the week. To investigate such regularities, we include indicator variables for days of the week as well as for days preceding and following holiday closures. Further, to capture portfolio rebalancing around major public information releases, we include dummy variables for macroeconomic announcements about GDP, the employment rate, and the Consumer Price Index. Separate dummies are provided for the day of the announcement and for the two days preceding the announcement.

Our explanatory variables are as follows:

[12] See Chordia and Subrahmanyam (1995) for a simple model of how spread levels depend on inventory.

[13] The direction of market movements could also trigger asymmetric effects on liquidity. However, the market movements in the value weighted stock market return and the Lehman aggregate bond index return are significantly positively correlated with order flow. We have run our forecasting regressions with and without the market variables and find that these variables do not have any impact when included along with the order flow variables. The results with the market variables are not presented in the tables.

OIB_B+: max(OIB,0)

OIB_B-: min(OIB,0)

OIB_S+: max(OIB,0)

OIB_S-: min(OIB,0)

Holiday: a dummy variable that equals one if a trading day satisfies the following conditions. (1) Independence day, Veterans' Day, Christmas or New Year's Day falls on a Friday, then the preceding Thursday, (2) a holiday falls on a weekend or on a Monday then the following Tuesday, (3) a holiday falls on a weekday then the preceding and the following days. Otherwise the dummy variable is zero.

Monday-Thursday: equals one if the trading day is Monday, Tuesday, Wednesday, or Thursday, 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, and CPI12: corresponding dummy variables for employment and CPI announcements respectively.

We include five lagged values of the dependent liquidity variable for stocks as well as for bonds. We also include lags of the imbalance variables.[14] To mitigate the impact of outliers, we have eliminated the top 0.5% and the bottom 0.5% of the sample. In order to correct for heteroskedasticity and any remaining serial correlation in the residuals, for estimation we use the Generalized Method of Moments with the Newey-West correction.

[14]Our exploratory analysis indicated that longer lags were largely irrelevant in predicting liquidity.

4.1 Regression Results

The regression results are presented in Table 3.

Please insert Table 3 here.

We present results in turn for quoted spreads (Panel A), effective spreads (Panel B), depths (Panel C) and the composite liquidity measure (Panel D).

Quoted bond spreads are lowest on Monday and highest on Friday. Further, consistent with previous research (Fleming and Remolona, 1999), bond spreads increase on days of CPI and Employment announcements. In addition, bond spreads decrease over the two days leading up to the Employment announcements. Bond spreads do not respond to the GDP announcement. This is probably due to the fact that, as Fleming and Remolona (1999) document, the increase in the bid-ask spread is limited to a 10-minute window surrounding the announcement. Since the magnitude of the spread increase from a GDP announcement is much smaller than that from CPI and Employment announcements (Fleming and Remolona, 1997), these effects may not be statistically discernible with daily data. Overall, our variables explain about 55% of the daily variation in bond quoted spreads.

Our variables explain a much greater fraction of the daily variation in stock spreads (about 95%). Stock spreads also exhibit stronger lagged dependence than bond spreads. This could be an artefact of the feature of our data that aggregate stock spreads are those on a portfolio of stocks and are therefore less noisy, whereas the bond spreads are those on a single bond. Interestingly, while bond spreads are lowest Monday, stock spreads appear to be lowest Tuesday. Friday is the lowest-liquidity day for both markets. Unlike bond spreads, stock spreads are not significantly related to the macroeconomic announcements.

While the lagged spreads on the bond or the stock market have no impact on the spreads in the other market, the impact of order flow, as measured by the order imbalance, is discernible on the quoted spread. Stock and bond quoted spreads increase with order flows out of the stock market, $OIB-S$. The cross effect of order flow out of the stock market on bond quoted spreads seems initially surprising because order flow out of the stock market should be related to order flow into the bond market which should lead to lower spreads in the bond market. However, note that the bond order imbalances are included in the regression and the negative impact of stock order flow is over and above that of the bond order flow. This suggests that there may be some underlying economic factor that drives the impact of stock order flow on both bond and stock liquidity. We will examine the money supply posture of the Federal reserve as one such underlying factor.

The effective spread results in Panel B are essentially the same as those for the quoted spreads. The only exception is that bond effective spreads are higher on days when the GDP, CPI as well as the unemployment statistics are announced. The stock effective spreads are higher on the days of the CPI and the employment announcements.

Panel C presents the results for depth in the stock and the bond market. Depth in both the bond and the stock market seems to be highest on Tuesdays and Wednesdays as compared to other days. Bond market depth decreases substantially on the day unemployment numbers are announced while stock market depth increases in the one to two days prior to the unemployment announcement. While the contemporeneous univariate correlations in Table 2 indicate that bond and stock depths are positively correlated, an increase in the lagged stock market depth results in lower bond market depth. Order flow out of the stock market results in significantly higher depths in the stock market. The composite liquidity results in Panel D are similar to those for the spreads.

Overall, the results suggest that the in-sample predictability is driven mainly by the lagged values of the dependent variables, and the day of the week seasonalities. The lagged liquidity has stronger predictive power in the stock market than in the bond market because as shown in Table 1, the bond market liquidity has higher variability. Lagged negative imbalances in the stock market have an impact on both the bond and the stock market liquidity.

4.2 Liquidity shocks

The regression results in Table 3 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 know nothing about the time-series properties of aggregate liquidity innovations. For example, are liquidity shocks systemwide 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.

We define liquidity shocks to be the residuals from the regressions in Table 3 (which include own- and cross-market variables). The correlations in these liquidity shocks across the two markets are documented in Table 4.

Please insert Table 4 here.

Panel A of Table 4 presents the results for the full sample. Liquidity shocks show a reasonably high degree of correlation across markets. Quoted (effective) spread innovations across markets have a correlation of 0.13 (0.08), while the correlation for the composite liquidity innovations in stock and bond markets is 0.15. All these correlations are statistically different from zero.

This evidence suggests strongly that liquidity shocks have a systemic component. We plot liquidity innovations for quoted and effective spreads, and the composite measure of liquidity in Figures 1 through 3. These figures show the frequent intertemporal coincidence of unexpected shocks to stock and bond market liquidity. The figures also show that shocks to liquidity appear to have become larger in magnitude towards the end of the sample period, when the Russian and Asian crises took place. We will return to this issue in Section 5.

4.3 Out-of-sample Predictions

We use the model Table 3 to predict daily liquidity one step ahead one day at a time. We employ rolling regressions which use the preceding 250 days of data to make one-day ahead forecasts to compare the mean-squared error (MSE) from this approach to a naïve model which predicts tomorrow's spread to be equal to today's spread. We also used a different naive model that predicted tomorrow's spread to be equal to the average of the previous five days' spread. The results (not reported here) are very similar.

The MSE's from these rolling regressions are listed in Table 5.

Please insert Table 5 here.

Panel A shows the result for the entire sample. Interestingly, our model is much more useful in predicting bond market liquidity than stock market liquidity in that the MSE reductions relative to the naïve model are far greater for the bond regressions. Specifically, the MSE reduction relative to the naïve model for bond spreads is about 37% while that for stock spreads is about 2%.

5 Crisis periods

Several recent articles have suggested that financial crises affect liquidity.[15] For Treasury bonds, Fleming (2001) finds that price impacts and quoted bid-ask spreads are higher during crisis periods. Thus, it is plausible that the time-series properties of bond and stock liquidity may be different during periods of crises as compared to normal circumstances. We identified two crisis periods in our sample - the Asian financial crisis (October 1 to December 31, 1997) and the Russian default crisis (July 6 to December 31, 1998). The dates for the Asian crisis are from Choe, Kho, and Stulz (1997) and those for the Russian default crisis are from the Bank of International Settlements.[16] We define a non-crisis period as spanning the days from June 25, 1997 through the end of 1998 that did not include the crisis.[17]

In Panels B and C of Table 4, we document the cross-correlations in liquidity innovations for the crisis and non-crisis periods. The table indicates that the correlations in liquidity innovations increase during periods of crises. For instance, the correlation

[15]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.

[16]"A Review of Financial Market Events in Autumn 1998", CGFS Reports No. 12, October 1999, available at http://www.bis.org/publ/cgfspubl.htm.

[17]We commenced the non-crisis period immediately after the stock market tick size change from 1/8 to 1/16 was introduced on June 14, 1997, because this effect had an immediate and permanent impact on the stock market spread (see Chordia, Roll, and Subrahmanyam, 2001).

between stock and bond quoted (effective) spread innovations increases from 0.18 (0.17) in the non-crisis period to 0.42 (0.34) in the crisis period, and the increase is statistically significant. This indicates that shocks to spreads were more likely to be systemic in nature during crisis periods, suggesting greater investor uncertainty in aggregate during these periods. However, the correlation between depth innovations is lower during periods of crises.

Panel B of Table 5 documents MSE's of our predictive model during crisis and non-crisis periods. MSE's are sharply higher during crisis periods for all liquidity measures except stock depth. Overall, the results of this table and those of Table 4 indicate that liquidity was harder to predict and cross-market correlations in liquidity shocks increase during the crises periods, suggesting a greater propensity for systemic shocks to occur during these periods.

6 The Role of Mutual Fund Flows and Monetary Policy

Until now we have used order imbalances as proxies for order flows into the bond and stock markets. Two important sources of order flow are mutual fund flows and the money supply to the markets by the Federal reserve system. A loose monetary policy suggests that order flows into bond and stock markets are likely to be positive and this may impact liquidity.

While several studies have informally discussed the notion that the Federal Reserve steps in to enhance financial market liquidity by loosening credit constraints during periods of market turbulence,[18] to date there has been no empirical study on the impact

[18]See Garcia (1989) "Monetary Policy Report to Congress," *Federal Reserve Bulletin*, March 1995, pp. 219-243.

of changes in monetary policy on aggregate liquidity in financial markets.[19]

It has been conjectured that money flows in and out of mutual funds may have an important impact on financial market liquidity, especially during periods of financial turbulence (see, for example, Edelen, 1999), but this issue also remains to be explored. These are the issues to which we now turn.

The caveat is that, unlike the daily order imbalance data, the data on mutual funds and for the borrowed reserves (our indicator of monetary tightness) is available at a lower frequency. The mutual fund data is available only monthly while the net borrowed reserves are available at a fortnightly frequency. We use bi-weekly borrowed reserves data from the Federal Reservea and monthly equity and government bond net flows from the Investment Company Institute for our analysis in this subsection.

Please insert Table 6 here.

Table 6 presents the biweekly net borrowed reserves, as well as money flows (in millions of dollars) into equity and bond funds each month. Net borrowed reserves is defined as total borrowings minus extended credit minus excess reserves. Thus, net borrowed reserves is 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. Since reserve requirements change over time, we divide net borrowed reserves by the required reserves. Higher values of this ratio indicate increased monetary tightness. Strongin and Tarhan (1990), among others, use this measure of monetary tightness. Market participants also use net borrowed reserves as a measure of monetary tightness. For example, Melton (1985) notes that "...since late 1979, the key link between the Fed and

[19] 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."

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."

The net borrowed reserves have declined significantly from the non-crisis period to the crisis period suggesting a loose monetary stance of the Federal Reserve. Equity flows decline from an average of $21 billion during normal periods to about $10 billion during periods of crises while the bond funds change from an outflow of $155 million to an inflow of $871 million. The decrease in cash inflows to equity funds combined with the increase in cash inflows to government bond funds illustrates the "flight to quality" often alluded to by financial market commentators during periods of crises.

6.1 Monetary Policy

In this subsection, we examine the effects of monetary policy on stock and bond market liquidity during crises. The independent variables include the lag of the dependent variable (liquidity measure) in both markets, the net borrowed reserves and its lag and the lag of the stock market order imbalances (positive and negative). We include the contemporary value of the net borrowed reserves because it is unlikely that the bid-ask spread or depth determine the reserve requirements. Since the bond market imbalances in Table 3 had no impact on liquidity, they are not included in this regression. A dummy for the tick size change in the stock market is used for the period after June 24, 1997. A dummy for crises is also used and all the above variables are interacted with a crisis dummy for the time period of the two crises. The results are presented in Table 7.

Please insert Table 7 here.

Panel A presents the results for the quoted spreads. The dummy for the crises is positive and significant, pointing to an increase in the quoted spread during the crises. While, an increase in the net borrowed reserves (which represents a tightening of the money supply) during non-crises periods has no impact on liquidity, during crises it leads to an increase in stock market quoted spreads. The marginal impact of an increase in the lagged stock quoted spreads is a decrease in the stock and bond quoted spreads. The effective spread results in Panel B are similar except that the lagged order flow into and out of the stock market during crises results in higher bond effective spreads. The depth results are presented in Panel C. A tightening of the money supply during normal periods leads to increased (decreased) depth in the stock (bond) market and this effect is reversed during periods of crises.

Overall, the effect of a loose money supply during crises (Table 6) has a beneficial impact on the stock market with decreased spreads and increased depth. The loose money supply stance during crises has no impact on the bond market spreads although depth decreases.

6.2 Fund flows

We re-estimate the regression model of Table 7 using monthly data, which consists of taking monthly averages of our daily liquidity data. The difference is that net borrowed reserves are replaced by one lag each of the equity and bond mutual fund flows. The results are presented in Table 8.

Please insert Table 8 here.

Since most of the results are similar to those in Table 7, we will focus our discussion only on the mutual fund flows. During normal periods, mutual fund flows have no impact on liquidity in any of the Panels of Table 7. During crises, quoted and effective bond spreads rise and depth in the bond market decreases with inflows into government bond funds. This suggests that with the flight to quality and the large amount of cash inflows into the government bond funds during crises, liquidity in the bond market is adversely affected. In addition, increased inflows into government bond funds also increases the effective stock spread, perhaps because bond inflows are associated with outflows from stock funds in crises periods.

7 Conclusion

We examine common determinants of stock and bond liquidity over the period 1991 through 1998. Our study takes a step towards identifying publicly available variables that help predict future variations in market liquidity, and considers the effects of financial crises and mutual fund flows on aggregate liquidity. The analysis helps us enhance our understanding of the dynamic behavior of liquidity across different markets.

Our principal findings are as follows:

- Weekly regularities in stock and bond market liquidities closely mimic each other except that bond spreads are lowest Mondays while stock spreads are lowest Tuesdays. Friday is the lowest-liquidity day of the week for both markets.

- Out-of-sample predictability of bond market liquidity is substantially improved by the inclusion of lagged bid-ask spread and order imbalances. However, predictability worsens considerably during crisis periods for both stocks and bonds.

- Unexpected liquidity shocks are positively and significantly correlated across stock and bond markets, which suggests that liquidity shocks are often systemic in nature.

The cross-market correlation is significantly higher during crises. The results are consistent with increased investor uncertainty leading to frequent and correlated portfolio reallocations during financial crises.

- Analysis of the relation between a proxy for monetary policy and liquidity is consistent with the notion that monetary policy appears to have an ameliorative effect on stock market liquidity during crises.

- There is a net inflow into government bond funds (a flight to quality) and outflow from equity funds in crisis periods, reducing liquidity in both bond and stock markets.

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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