Liquidity and Leverage

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Paper presented at the Financial Cycles, Liquidity, and Securitization Conference
Hosted by the International Monetary Fund
Washington, DC─April 18, 2008

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September 2007

Abstract

In a financial system where balance sheets are continuously marked to market, asset price changes show up immediately in changes in net worth, and elicit responses from financial intermediaries who adjust the size of their balance sheets. We document evidence that marked-to-market leverage is strongly procyclical. Such behavior has aggregate consequences. Changes in aggregate balance sheets for intermediaries forecast changes in risk appetite in financial markets, as measured by the innovations in the VIX index. Aggregate liquidity can be seen as the rate of change of the aggregate balance sheet of the financial intermediaries.

*A previous version of this paper was presented at the 6th BIS Annual Conference, "Financial System and Macroeconomic Resilience", 18-19 June 2007 under its former title "Liquidity and Financial Cycles". We thank conference participants at the BIS conference, and seminar participants at the Federal Reserve Bank of New York, the Federal Reserve Bank of Chicago, and Princeton University for their comments. The views expressed in this paper are those of the authors and do not necessarily represent those of the Federal Reserve Bank of New York or the Federal Reserve System.

1. Introduction

In a financial system where balance sheets are continuously marked to market, changes in asset prices show up immediately on the balance sheet, and so have an immediate impact on the net worth of all constituents of the financial system. The net worth of financial intermediaries are especially sensitive to fluctuations in asset prices given the highly leveraged nature of such intermediaries' balance sheets.

Our focus in this paper is on the reactions of the financial intermediaries to changes in their net worth, and the market-wide consequences of such reactions. If the financial intermediaries were passive and do not adjust their balance sheets to changes in net worth, then leverage would fall when total assets rise. Change in leverage and change in balance sheet size would then be negatively related.

However, as we will see below, the evidence points to a strongly *positive* relationship between changes in leverage and changes in balance sheet size. Far from being passive, the evidence points to financial intermediaries adjusting their balance sheets actively, and doing so in such a way that leverage is high during booms and low during busts. That is, leverage is procyclical.

Procyclical leverage can be seen as a consequence of the active management of balance sheets by financial intermediaries who respond to changes in prices and measured risk. For financial intermediaries, their models of risk and economic capital dictate active management of their overall value at risk (VaR) through adjustments of their balance sheets.

From the point of view of each financial intermediary, decision rules that result in procyclical leverage are readily understandable. However, there are aggregate consequences of such behavior for the financial system as a whole that are not taken into consideration by an individual financial institution. We exhibit evidence that procyclical leverage has spillover effects at the aggregate level through shifts in risk appetite and funding liquidity. In particular, balance sheet fluctuations forecast shifts in risk appetite, as measured by the VIX index.

Our paper has two main objectives. Our first objective is to document the determinants of balance sheet size and leverage for the group of financial intermediaries (including the major Wall Street investment banks) that operate primarily through the capital markets. We show that leverage is strongly procyclical for these intermediaries, and that the margin of adjustment on the balance sheet is through repos and reverse repos (and other collateralized borrowing and lending). In turn, procyclical leverage can be attributed to the bank's capital allocation decision that rests on measured risks ruling at the time. We find that the value-at-risk (VaR) disclosed by the banks is an important determinant of balance sheet stance, but we also find evidence of an additional procyclical element in leverage that operates over and above that implied by their disclosed value-at-risk.

Our second objective is to pursue the aggregate consequences of such procyclical leverage, and document evidence that expansions and contractions of balance sheets have important asset pricing consequences through shifts in market-wide risk appetite. In particular, we show that changes in aggregate intermediary balance sheet size can forecast innovations in market-wide risk premiums as measured by the VIX index of implied volatility in the stock market. We see this as an important empirical finding. Previous work in asset pricing has shown that innovations in the VIX index capture key components of asset pricing that conventional empirical models have been unable to address fully. By being able to forecast shifts in risk appetite, we hope to inject a new element in thinking about risk appetite and asset prices. The shift in risk appetite is closely related to other notions of liquidity, such as the notion of "funding liquidity" used by

Brunnermeier and Pedersen (2005b)[1]. One of our contributions is to explain the origins of funding liquidity in terms of financial intermediary behavior.

Our findings also shed light on the concept of "liquidity" as used in common discourse about financial market conditions. In the financial press and other market commentary, asset price booms are sometimes attributed to "excess liquidity" in the financial system. Financial commentators are fond of using the associated metaphors, such as the financial markets being "awash with liquidity", or liquidity "sloshing around". However, the precise sense in which "liquidity" is being used in such contexts is often left unspecified.

Our empirical findings suggest that funding liquidity can be understood as the rate of growth of aggregate balance sheets. When financial intermediaries' balance sheets are generally strong, their leverage is too low. The financial intermediaries hold surplus capital, and they will attempt to find ways in which they can employ their surplus capital. In a loose analogy with manufacturing firms, we may see the financial system as having "surplus capacity". For such surplus capacity to be utilized, the intermediaries must expand their balance sheets. On the liabilities side, they take on more short-term debt. On the asset side, they search for potential borrowers that they can lend to. Funding liquidity is intimately tied to how hard the financial intermediaries search for borrowers.

The outline of our paper is as follows. We begin with a review of some very basic balance sheet arithmetic on the relationship between leverage and total assets. The purpose of this initial exercise is to motivate our empirical investigation of the balance sheet changes of financial intermediaries in section 3. Having outlined the facts, in section 4, we show that changes in aggregate repo positions of the major financial intermediaries can forecast innovations in the volatility risk-premium, where the volatility risk premium is defined as the difference between the VIX

[1] See also Gromb and Vayanos (2002).

index and realized volatility. We conclude with discussions of the implications of our findings for funding liquidity.

2. Some Basic Balance Sheet Arithmetic

What is the relationship between *leverage* and *balance sheet size*? We begin with some very elementary balance sheet arithmetic, so as to focus ideas. Before looking at the evidence for financial intermediaries, let us think about the relationship between balance sheet size and leverage for a household. The household owns a house financed with a mortgage. For concreteness, suppose the house is worth 100, the mortgage value is 90, and so the household has net worth (equity) of 10. The initial balance sheet then is given by:

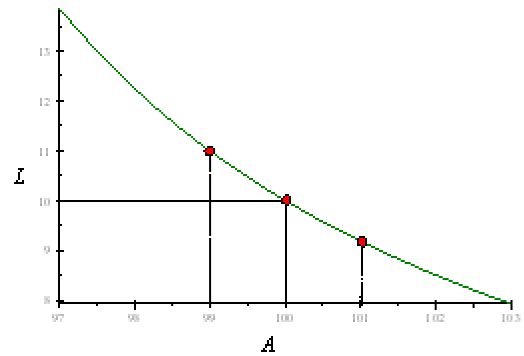
Assets	Liabilities
100	10
	90

Leverage is defined as the ratio of total assets to equity, hence is $100/10 = 10$. What happens to leverage as total assets fluctuate? Denote by A the market value of total assets and E is the market value of equity. We make the simplifying assumption that the market value of debt stays roughly constant at 90 for small shifts in the value of total assets. Total leverage is then

$$L \simeq \frac{A}{A-90}$$

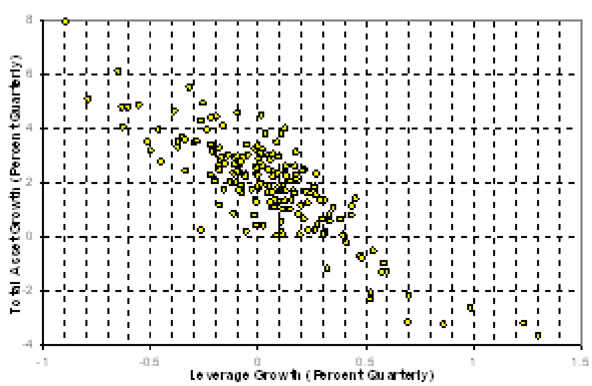
Leverage is inversely related to total assets. When the price of my house goes up, my net worth increases, and so my leverage goes down. Figure 2.1 illustrates the negative relationship between total assets and leverage. Indeed, for households, the negative relationship between total assets and leverage is clearly borne out in the aggregate data. Figure 2.2 plots the quarterly changes in total assets to quarterly changes in leverage as given in the Flow of Funds account for the United

Figure 2.1: Leverage for passive investor



States. The data are from 1963 to 2006. The scatter chart shows a strongly negative relationship, as suggested by Figure 2.1.

Figure 2.2: Total Assets and Leverage of Household.



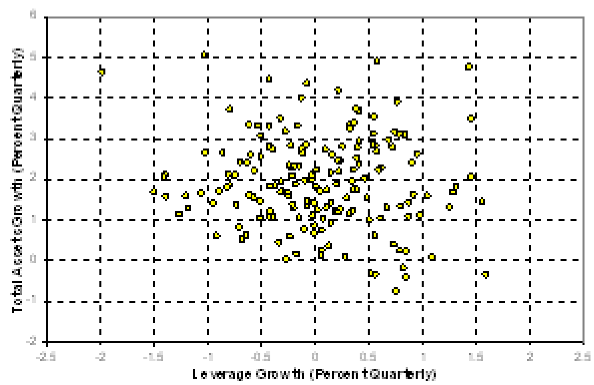
We can ask the same question for firms, and we will address this question for three different types of firms.

- Non-financial firms

- Commercial banks
- Security brokers and dealers (including investment banks).

If a firm were passive in the face of fluctuating asset prices, then leverage would vary inversely with total assets. However, the evidence points to a more active management of balance sheets. Figure 2.3 is a scatter chart of the change in

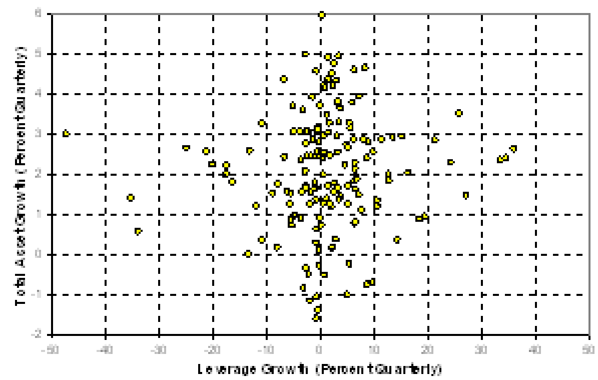
Figure 2.3: Total Assets and Leverage of Non-financial, Non-farm Corporates



leverage and change in total assets of non-financial, non-farm corporations drawn from the U.S. flow of funds data (1963 to 2006). The scatter chart shows much less of a negative pattern, suggesting that companies react to changes in assets by shifting their stance on leverage.

More notable still is the analogous chart for U.S. commercial banks, again drawn from the U.S. Flow of Funds accounts. Figure 2.4 is the scatter chart plotting changes in leverage against changes in total assets for U.S. commercial banks. A large number of the observations line up along the vertical line that passes through zero change in leverage. In other words, the data show the outward signs of commercial banks targeting a fixed leverage ratio.

Figure 2.4: Total Assets and Leverage of Commercial Banks

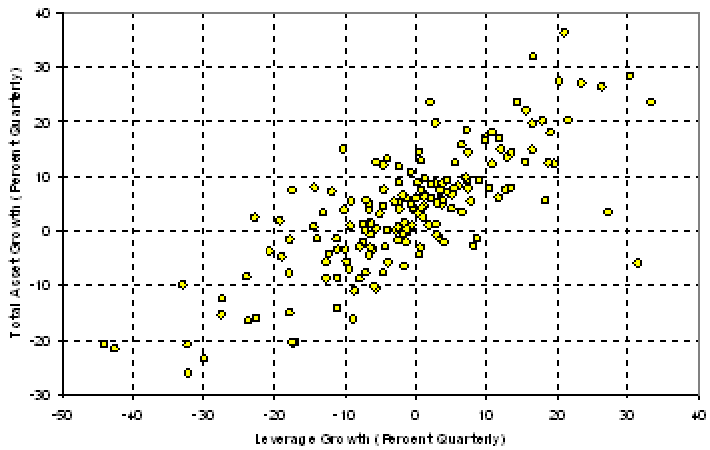


However, even more striking than the scatter chart for commercial banks is that for security dealers and brokers, that include the major Wall Street investment banks. Figure 2.5 is the scatter chart for U.S. security dealers and brokers, again drawn from the Flow of Funds accounts (1963 - 2006). The alignment of the observations is now the reverse of that for households. There is a strongly *positive* relationship between changes in total assets and changes in leverage. In this sense, leverage is pro-cyclical.

In order to appreciate the aggregate consequences of pro-cyclical leverage, let us first consider the behavior of a financial intermediary that manages its balance sheet actively to as to maintain a *constant* leverage ratio of 10. Suppose the initial balance sheet is as follows. The financial intermediary holds 100 worth of securities, and has funded this holding with debt worth 90.

Assets	Liabilities
Securities, 100	Equity, 10
	Debt, 90

Figure 2.5: Total Assets and Leverage of Security Brokers and Dealers



Assume that the price of debt is approximately constant for small changes in total assets. Suppose the price of securities increases by 1% to 101.

Assets	Liabilities
Securities, 101	Equity, 11
	Debt, 90

Leverage then falls to $101/11 = 9.18$. If the bank targets leverage of 10, then it must take on additional debt of D to purchase D worth of securities on the asset side so that

$$\frac{\text{assets}}{\text{equity}} = \frac{101 + D}{11} = 10$$

The solution is $D = 9$. The bank takes on additional debt worth 9, and with this money purchases securities worth 9. Thus, an increase in the price of the security of 1 leads to an increased holding worth 9. The demand curve is *upward-sloping*. After the purchase, leverage is now back up to 10.

Assets	Liabilities
Securities, 110	Equity, 11
	Debt, 99

The mechanism works in reverse, too. Suppose there is shock to the securities price so that the value of security holdings falls to 109. On the liabilities side, it is equity that bears the burden of adjustment, since the value of debt stays approximately constant.

Assets	Liabilities
Securities, 109	Equity, 10
	Debt, 99

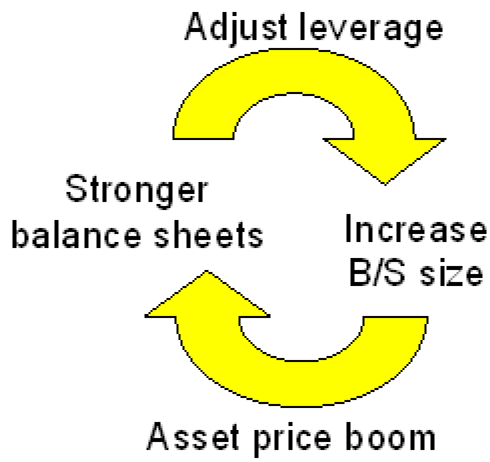
Leverage is now too high (109/10 = 10.9). The bank can adjust down its leverage by selling securities worth 9, and paying down 9 worth of debt. Thus, a *fall* in the price of securities of leads to *sales* of securities. The supply curve is *downward*-sloping. The new balance sheet then looks as follows.

Assets	Liabilities
Securities, 100	Equity, 10
	Debt, 90

The balance sheet is now back to where it started before the price changes. Leverage is back down to the target level of 10.

Leverage targeting entails upward-sloping demands and downward-sloping supplies. The perverse nature of the demand and supply curves are even stronger when the leverage of the financial intermediary is pro-cyclical - that is, when leverage is high during booms and low during busts. When the securities price

Figure 2.6: Adjustment of Leverage in Booms

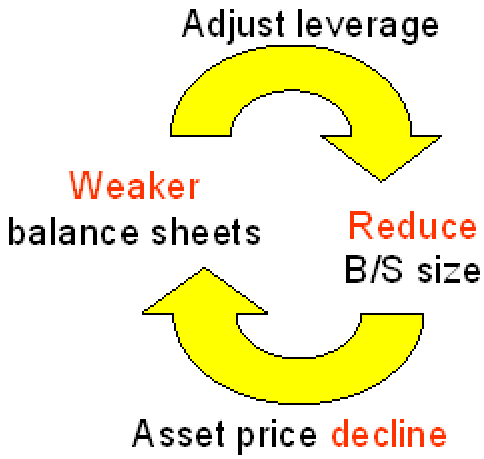


goes up, the upward adjustment of leverage entails purchases of securities that are even larger than that for the case of constant leverage. If, in addition, there is the possibility of feedback, then the adjustment of leverage and price changes will reinforce each other in an amplification of the financial cycle.

If we hypothesize that greater demand for the asset tends to put upward pressure on its price (a plausible hypothesis, it would seem), then there is the potential for a feedback effect in which stronger balance sheets feed greater demand for the asset, which in turn raises the asset's price and lead to stronger balance sheets. Figure 2.6 illustrates the feedback during a boom. The mechanism works exactly in reverse in downturns. If we hypothesize that greater supply of the asset tends to put downward pressure on its price, then there is the potential for a feedback effect in which weaker balance sheets lead to greater sales of the asset, which depresses the asset's price and lead to even weaker balance sheets. Figure 2.7 illustrates the feedback during a downturn.

In section 4, we return to the issue of feedback by exhibiting evidence that is consistent with the amplification effects sketched above. We will see that

Figure 2.7: Leverage Adjustment in Downturn



changes in key balance sheet components forecast changes in the VIX index of implied volatility in the stock market.

3. A First Look at the Evidence

3.1. Investment Bank Balance Sheets

To set the stage for our empirical study, we begin by examining the quarterly changes in the balance sheets of five large investment banks, as listed below in Table 1. The data are drawn from the Mergent database, which in turn are based on the regulatory filings with the U.S. Securities and Exchange Commission (SEC) on their 10-K and 10-Q forms.

Table 1: Investment Banks

Name	Sample
Bear Stearns	1997 Q1 – 2007 Q1
Goldman Sachs	1999 Q2 – 2007 Q1
Lehman Brothers	1993 Q2 – 2007 Q1
Merrill Lynch	1991 Q1 – 2007 Q1
Morgan Stanley	1997 Q2 – 2007 Q1

Our choice of these five banks is motivated by our concern to examine "pure play" investment banks that are not part of a larger commercial banking group so as to focus attention on their behavior with respect to the capital markets[2]. Citigroup reported its investment banking operations separately from its commercial banking operations until 2004 as "Citigroup Global Markets", and we have data for the period 1998Q1 to 2004Q4. In some of our charts below, we will report Citigroup Global Markets for comparison for reference. The stylized balance sheet of an investment bank is as follows.

Assets	Liabilities
Trading assets	Short positions
Reverse repos	Repos
Other assets	Long term debt
	Shareholder equity

On the asset side, traded assets are valued at market prices or are short term collateralized loans (such as reverse repos) for which the discrepancy between face value and market value are very small due to the very short term nature of the loans. On the liabilities side, short positions are at market values, and repos are very short term borrowing. We will return to a more detailed descriptions of repos and reverse repos below. Long-term debt is typically a very small fraction of the balance sheet.[3] For these reasons, investment banks provide a good

[2]Hence, we do not include JP Morgan Chase, Credit Suisse, Deutsche Bank, and other brokerage operations that are part of a larger commercial bank.

[3]The balance sheet of Lehman Brothers as of November 2005 shows that short positions are around a quarter of total assets, and long term debt is an even smaller fraction. Shareholder

approximation of the balance sheet that is continuously marked to market, and hence provide insights into how leverage changes with balance sheet size.

The second reason for our study of investment banks lies in their continuously increasing significance for the financial system.

Figure 3.1:

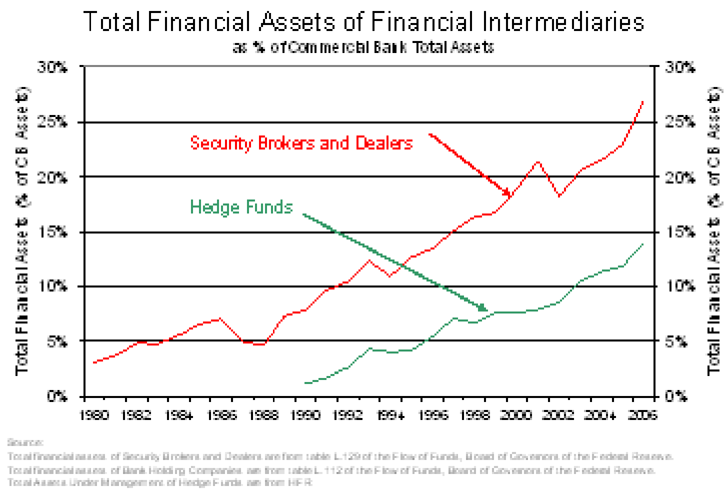


Figure 3.1 plots the size of securities firms' balance sheets relative to that of commercial banks. We also plot the assets under management for hedge funds, although we should be mindful that "assets under management" refers to total shareholder equity, rather than the size of the balance sheet. To obtain total balance sheet size, we should multiply by leverage. Figure 3.1 shows that when expressed as a proportion of commercial banks' balance sheets, securities firms have been increasing their balance sheets at a very rapid rate. Note that when hedge funds' assets under management is converted to balance sheet size by multiplying by a conservative leverage factor of 2, the combined balance sheets

equity is around 4% of total assets (implying leverage of around 25). Short-term borrowing in terms of repurchase agreements and other collateralized borrowing takes up the remainder.

of investment banks and hedge funds is over 50% of commercial banks balance sheets.

Size is not the only issue. When balance sheets are marked to market, the responses to price changes may entail responses that may be disproportionately large. LTCM's balance sheet was small relative to the total financial sector, but its impact would have been underestimated if only size had been taken into account. Similarly, the size of the sub-prime mortgage exposures was small relative to the liabilities of the financial system as a whole, but the credit crisis of 2007 demonstrates that its impact can be large. Table 2 gives the summary statistics of the investment banks over the sample period.

[Table 2]

We begin with the key question left hanging from the previous section. What is the relationship between leverage and total assets? The answer is provided in the scatter charts in figure 3.3. We have included the scatter chart for Citigroup Global Markets (1998Q1 - 2004Q4) for comparison, although Citigroup does not figure in the panel regressions reported below. The scatter chart shows the growth in assets and leverage at a quarterly frequency. In all cases, leverage is large when total assets are large. Leverage is pro-cyclical.

There are some notable common patterns in the scatter charts, but also some notable differences. The events of 1998 are clearly evident in the scatter charts. The early part of the year saw strong growth in total assets, with the attendant increase in leverage. However, the third and fourth quarters of 1998 shows all the hallmarks of financial distress and the attendant retrenchment in the balance sheet. For most banks, there were very large contractions in balance sheet size in 1998Q4, accompanied by large falls in leverage. These points are on the bottom left hand corners of the respective scatter charts, showing large contractions in

Figure 3.2:

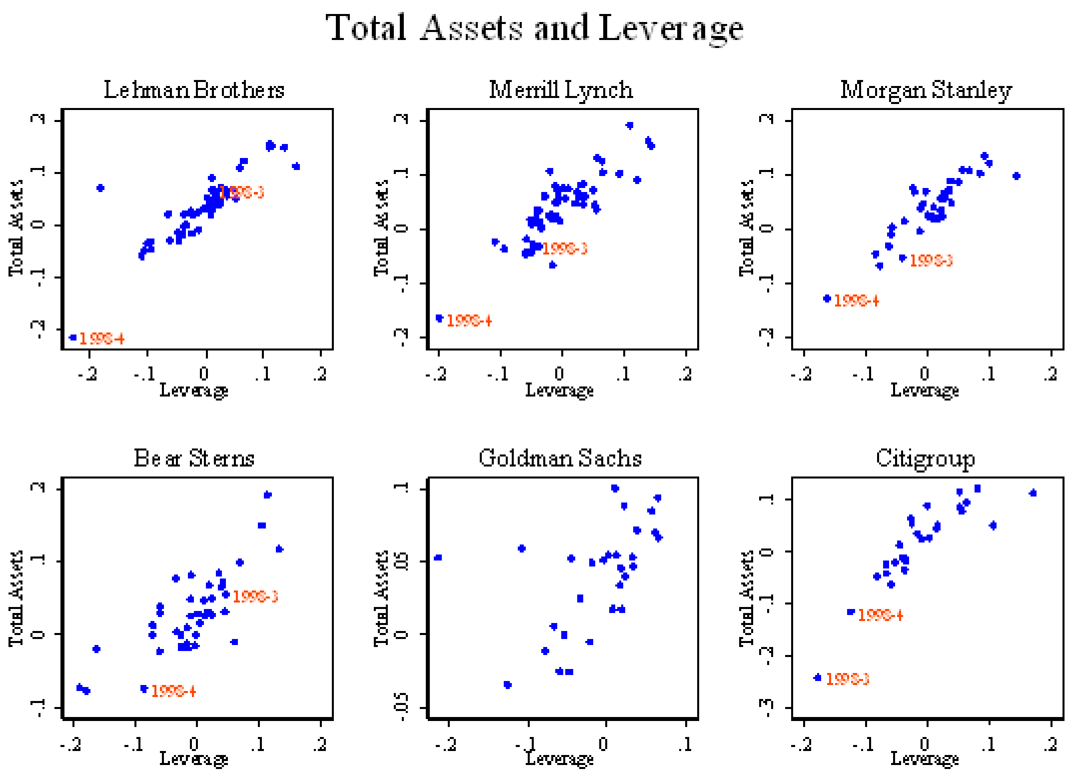


Figure 3.3:

the balance sheet and decrease in leverage. Lehman Brothers and Merrill Lynch seem especially hard hit in 1998Q4.

However, there are also some notable differences. It is notable, for instance, that for Citigroup Global Markets, the large retrenchment seems to have happened in the third quarter of 1998, rather than in the final quarter of 1998. Such a retrenchment would be consistent with the closing down of the former Salomon Brothers fixed income arbitrage desk on July 6th 1998 following the acquisition of the operation by Travelers Group (later, Citigroup). Many commentators see this event as the catalyst for the sequence of events that eventually led to the demise of Long Term Capital Management (LTCM) and the associated financial distress in the summer and early autumn of 1998.[4]

[Table 3]

Table 3 shows the results of a panel regression for change in leverage. The negative relationship between the change in leverage and change in total assets is confirmed in the final column (column (v)) of Table 3. The coefficient on lagged leverage (i.e. previous quarter's leverage) is negative, suggesting that there is mean-reversion in the leverage ratio for the banks. Leverage is positively related to repos.

More interestingly, the regressions reveal which items on the balance sheet are adjusting when balance sheets expand and contract. In particular, the regressions show that the margin of adjustment in the expansion and contraction of balance sheets is through repos. In a repurchase agreement (repo), an institution sells a security while simultaneously agreeing to buy it back at a pre-agreed price on a fixed future date. Such an agreement is tantamount to a collateralized loan, with

[4]The official account (BIS, 1999) is given in the report of the CGFS of the Bank for International Settlements (the so-called "Johnson Report"). Popular accounts, such as Lowenstein (2000) give a description of the background and personalities.

the interest on the loan being the excess of the repurchase price over the sale price. From the perspective of the funds lender – the party who buys the security with the undertaking to re-sell it later – such agreements are called reverse repos. For the buyer, the transaction is equivalent to granting a loan, secured on collateral.

Repos and reverse repos are important financing activities that provide the funds and securities needed by investment banks to take positions in financial markets. For example, a bank taking a long position by buying a security needs to deliver funds to the seller when the security is received on settlement day. If the dealer does not fully finance the security out of its own capital, then it needs to borrow funds. The purchased security is typically used as collateral for the cash borrowing. When the bank sells the security, the sale proceeds can be used to repay the lender.

Reverse repos are loans made by the investment bank against collateral. The bank's prime brokerage business vis-à-vis hedge funds will figure prominently in the reverse repo numbers. The scatter chart gives a glimpse into the way in which changes in leverage are achieved through expansions and contractions in the collateralized borrowing and lending. We saw in our illustrative section on the elementary balance sheet arithmetic that when a bank wishes to expand its balance sheet, it takes on additional debt, and with the proceeds of this borrowing takes on more assets.

Figure 3.4 plots the change in assets against change in collateralized borrowing. The positive relationship in the scatter plot confirms our panel regression finding that balance sheet changes are accompanied by changes in short term borrowing.

Figure 3.5 plots the change in repos against the change in reverse repos. A dealer taking a short position by selling a security it does not own needs to deliver the security to the buyer on the settlement date. This can be done by borrowing

Figure 3.4:

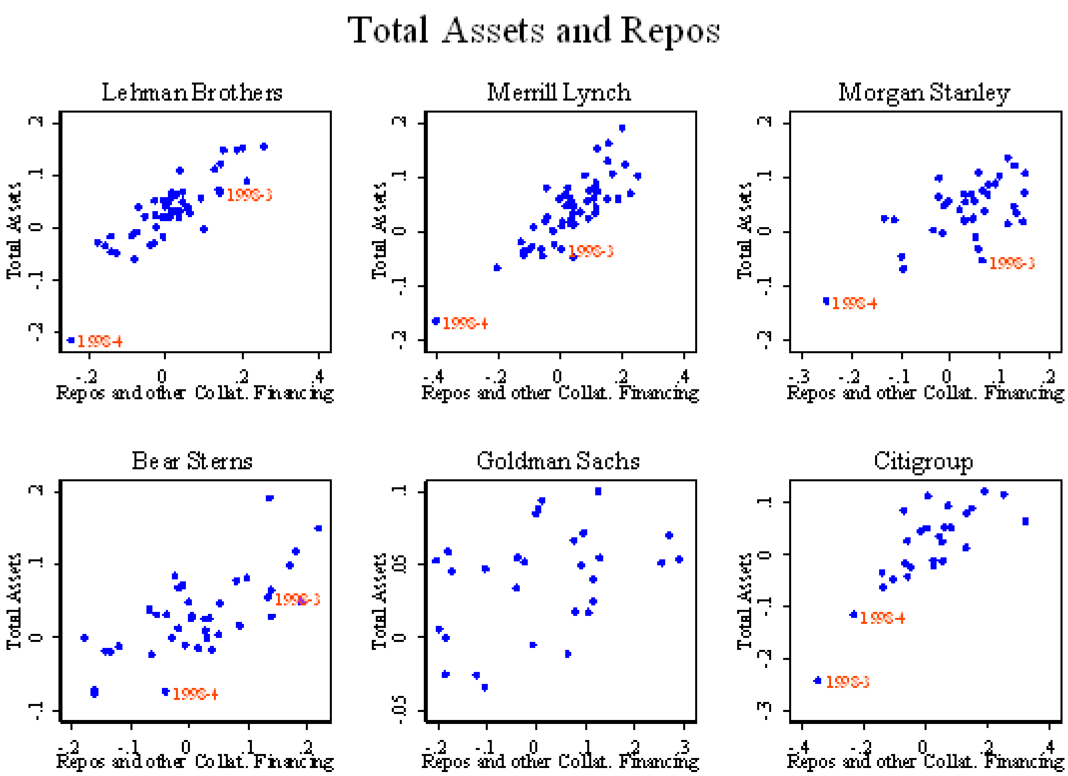
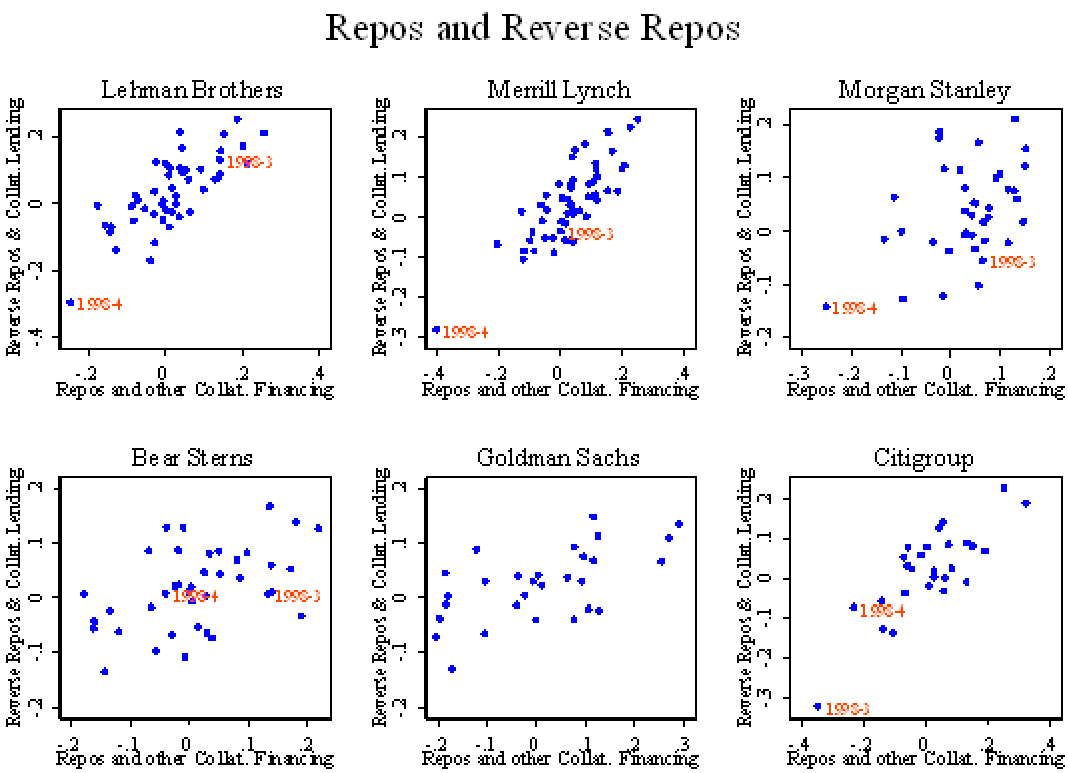

Total Assets and Repos
Lehman Brothers
Merrill Lynch
Morgan Stanley
Bear Sterns
Goldman Sachs
Citigroup
Total Assets
Repos and other Collat. Financing
1998-3
1998-4

Figure 3.5:



Repos and Reverse Repos
Lehman Brothers
Merrill Lynch
Morgan Stanley
Bear Sterns
Goldman Sachs
Citigroup
Reverse Repos & Collat. Lending
Repos and other Collat. Financing
1998-3
1998-4

the needed security, and providing cash or other securities as collateral. When the dealer closes out the short position by buying the security, the borrowed security can be returned to the securities lender. The scatter plot in figure 3.5 suggests that repos and reverse repos play such a role as counterparts in the balance sheet.

3.2. Value at Risk

Procyclical leverage is not a term that the banks themselves are likely to use in describing what they do, although this is in fact what they are doing. To get a better handle on what motivates the banks in their actions, we explore the role of value at risk (VaR) in explaining the banks' balance sheet decisions.

For a random variable A, the *value at risk* at confidence level c relative to some base level A_0 is defined as the smallest non-negative number VaR such that

$$\text{Prob}\,(A < A_0 - VaR) \leq 1 - c$$

For instance, A could be the total marked-to-market assets of the firm at some given time horizon. Then the value at risk is the equity capital that the firm must hold in order to stay solvent with probability c. Financial intermediaries publish their value at risk numbers as part of their regulatory filings, and also regularly disclose such numbers through their annual reports. Their *economic capital* is tied to the overall value at risk of the whole firm, where the confidence level is set at a level high enough to target a given credit rating (typically A or AA).

If financial intermediaries adjust their balance sheets to target a ratio of Value-at-Risk to economic capital, then we may conjecture that their disclosed Value-at-Risk figures would be informative in reconstructing their actions. If the bank maintains capital K to meet total value at risk, then we have

$$K = \lambda \times VaR \tag{3.1}$$

where λ is the proportion of capital that the intermediary holds per unit of VaR. The proportionality λ is potentially time varying. Hence, leverage L satisfies

$$L = \frac{A}{K} = \frac{1}{\lambda} \times \frac{A}{VaR}$$

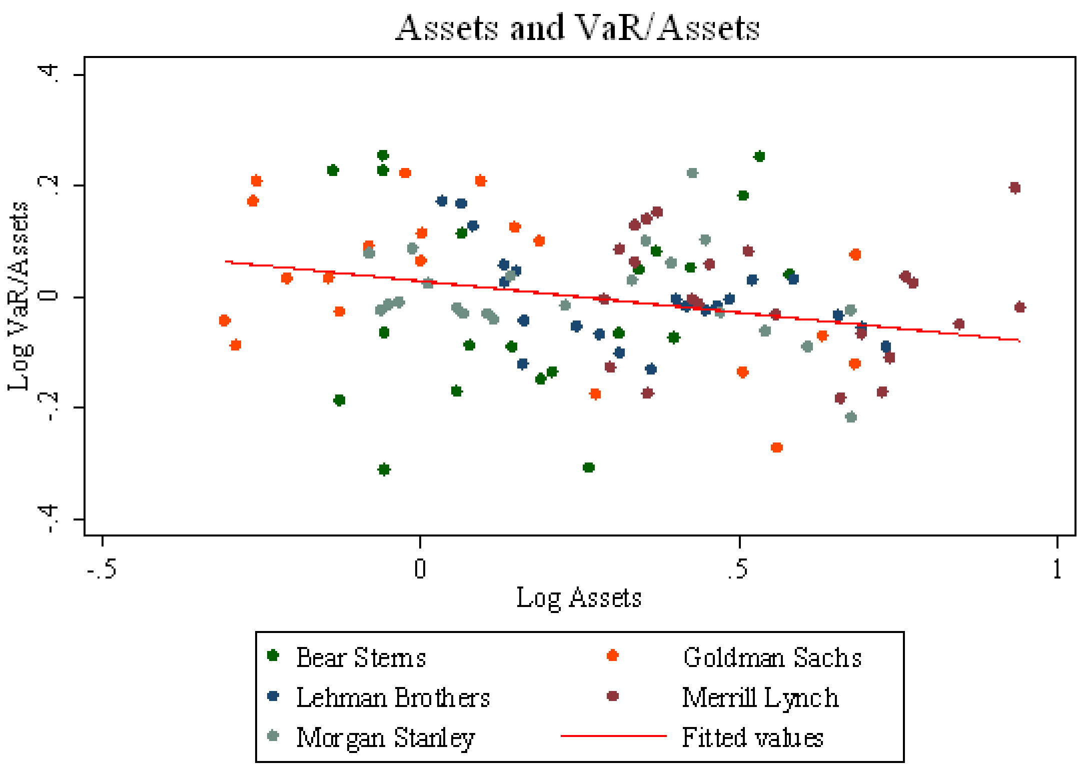
Procyclical leverage then translates directly to *counter*-cyclical nature of unit value-at-risk (i.e. value-at-risk per dollar of assets). Measured risk is low during booms and high during busts. We can indeed see this counter-cyclical relationship in the data. In Figure 3.6, we plot the VaR to total asset ratio against total assets and see that it is downwardsloping (we have removed fixed effects to produce this plot).

We explore the way in which the ratio of total value at risk to equity varies over time. Equation (3.1) suggests that it would be informative to track the ratio of value at risk to shareholder equity over time. The naive hypothesis would be that this ratio is kept constant over time by the bank. The naive hypothesis also ties in neatly the regulatory capital requirements under the 1996 Market Risk Amendment of the Basel capital accord. Under this rule, the regulatory capital is 3 times the 10 day, 99% value at risk. If total value risk is homogenous of degree 1, then (3.1) also describes the *required* capital for the bank, also.

In Figure 3.7 we plot the evolution of the VaR/equity ratio and leverage over time. We can see that both ratio are fairly constant. Only Goldman Sachs exhibits a marked increase in leverage (and a corresponding increase in VaR/Equity) over time. On average, both leverage and VaR/equity appear stationary, which is in accordance with the risk management and regulatory constraints.

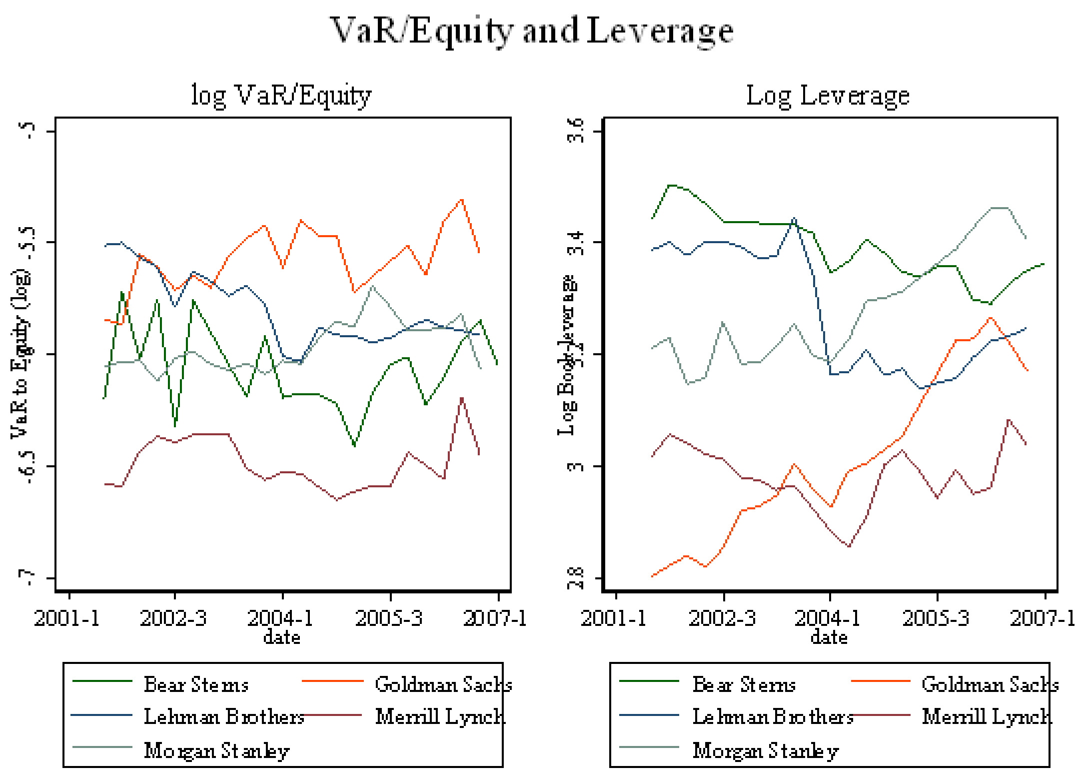
Table 4 presents the regressions for the quarterly change in the ratio of value at risk to equity. Value at risk numbers are those numbers that the banks themselves have reported in their 10-K and 10-Q filings. For the reasons outlined already, the firm's self-assessed value at risk is closely tied to its assessment of economic

Figure 3.6:



Assets and VaR/Assets
Log VaR/Assets
-.4
-.2
0
.2
.4
-.5
0
.5
1
Log Assets
Bear Sterns
Lehman Brothers
Morgan Stanley
Goldman Sachs
Merrill Lynch
Fitted values

Figure 3.7:


VaR/Equity and Leverage
log VaR/Equity
VaR to Equity (log)
-7
-6.5
-6
-5.5
-5
2001-1
2002-3
2004-1
2005-3
2007-1
date
Log Leverage
Log Book-leverage
2.8
3
3.2
3.4
3.6
Bear Sterns
Goldman Sachs
Lehman Brothers
Merrill Lynch
Morgan Stanley

capital, and we would expect behavior to be heavily influenced by changes in value at risk.

[Table 4]

We focus on the ratio of value at risk to equity. In the panel regressions, the lagged value at risk to equity ratio is strongly negative, with coefficients in the range of -0.5 to -0.6, suggesting rapid reversion to the mean. We take this as evidence that the banks use VaR as a cue for how they adjust their balance sheets. However, the naive hypothesis that banks maintain a fixed ratio of value at risk to equity does not seem to be supported in the data. Column (ii) of Table 4 suggests that an increase in the value at risk to equity ratio coincides with periods when the bank increases its leverage. Value at risk to equity is procyclical, when measured relative to leverage. However, total assets have a negative sign in column (v). It appears that value at risk to equity is procyclical, but total assets adjust down some of the effects captured in leverage. The evidence points to an additional, procyclical risk appetite component to banks' exposures that goes beyond the simple hypothesis of targeting a normalized value at risk measure.

4. Forecasting Risk Appetite

We now present the main results of our paper. We show the asset pricing consequences of balance sheet expansion and contraction. We have already noted how the demand and supply responses to price changes can become perverse when financial intermediaries' actions result leverage that co-vary positively with the financial cycle. We exhibit empirical evidence that the waxing and waning of balance sheets have a direct impact on asset prices through the ease with which traders, hedge funds and other users of credit can obtain funding for trades.

So far, we have used quarterly data drawn either from the balance sheets of individual financial intermediaries or the aggregate balance sheet items from the Flow of Funds accounts. However, for the purpose of tracking the financial market consequences of balance sheet adjustments, data at a higher frequency is more likely to be useful. For this reason, we use the weekly data on the primary dealer repo and reverse repo positions compiled by the Federal Reserve Bank of New York.

Primary dealers are the dealers with whom the Federal Reserve has an on-going trading relationship in the course of daily business. The Federal Reserve collects data that cover transactions, positions, financing, and settlement activities in U.S. Treasury securities, agency debt securities, mortgage-backed securities (MBS), and corporate debt securities for the primary dealers. The data are used by the Fed to monitor dealer performance and market conditions, and are also consolidated and released publicly on the Federal Reserve Bank of New York website[5]. The dealers supply market information to the Fed as one of several responsibilities to maintain their primary dealer designation and hence their trading relationship with the Fed. It is worth noting that the dealers comprise an important but limited subset of the overall market. Moreover, dealer reporting entities may not reflect all positions of the larger organizations. Nevertheless, the primary dealer data provide a valuable window on the overall market, at a frequency (every week) that is much higher than the usual quarterly reporting cycle.

Dealers gather information at the close of business each Wednesday, on their transactions, positions, financing, and settlement activities over the previous week. They report on U.S. Treasury securities, agency debt securities, mortgage backed securities, and corporate debt securities. Data are then submitted on the following day (that is, Thursday) via the Federal Reserve System's Internet Electronic Sub-

[5] www.newyorkfed.org/markets/primarydealers.html

mission System. Summary data are released publicly by the Fed each Thursday, one week after they are collected. The data are aggregated across all dealers, and are only available by asset class (that is, Treasuries, agencies, etc.). Individual issue data, and individual dealer data, are not released publicly.

Repos and reverse repos are an important subset of the security financing data. The financing is reported on a gross basis, distinguishing between "securities in" and "securities out" for each asset class. "Securities in" refer to securities received by a dealer in a financing arrangement (be it against other securities or cash), whereas "securities out" refer to securities delivered by a dealer in a financing arrangement (be it against securities or cash). For example, if a dealer enters into a repo, in which it borrows funds and provides securities as collateral, it would report securities out. Repos and reverse repos are reported across all sectors. The actual financing numbers reported are the funds paid or received. In the case of a repo, for example, a dealer reports the actual funds received on the settlement of the starting leg of the repo, and not the value of the pledged securities. In cases where only securities are exchanged, the market value of the pledged securities is reported.

[Table 5]

We use the weekly repo and reverse repo data to forecast financial market conditions in the following week. Summary statistics are in Table 5. Our measure of financial market conditions is the VIX index of the weighted average of the implied volatility in the S&P500 index options. The VIX index has found widespread application in empirical work as a proxy for market risk appetite. Ang, Hodrick, Xing, and Zhang (2006) show that VIX innovations are significant pricing factors for the cross section of equity returns, and Bollerslev and Zhou (2007) show that the volatility risk premium —the difference between the VIX and realized volatility of the S&P500 index — forecasts equity returns better than other commonly used forecasting variables (such as the P/E ratio or the term spread).

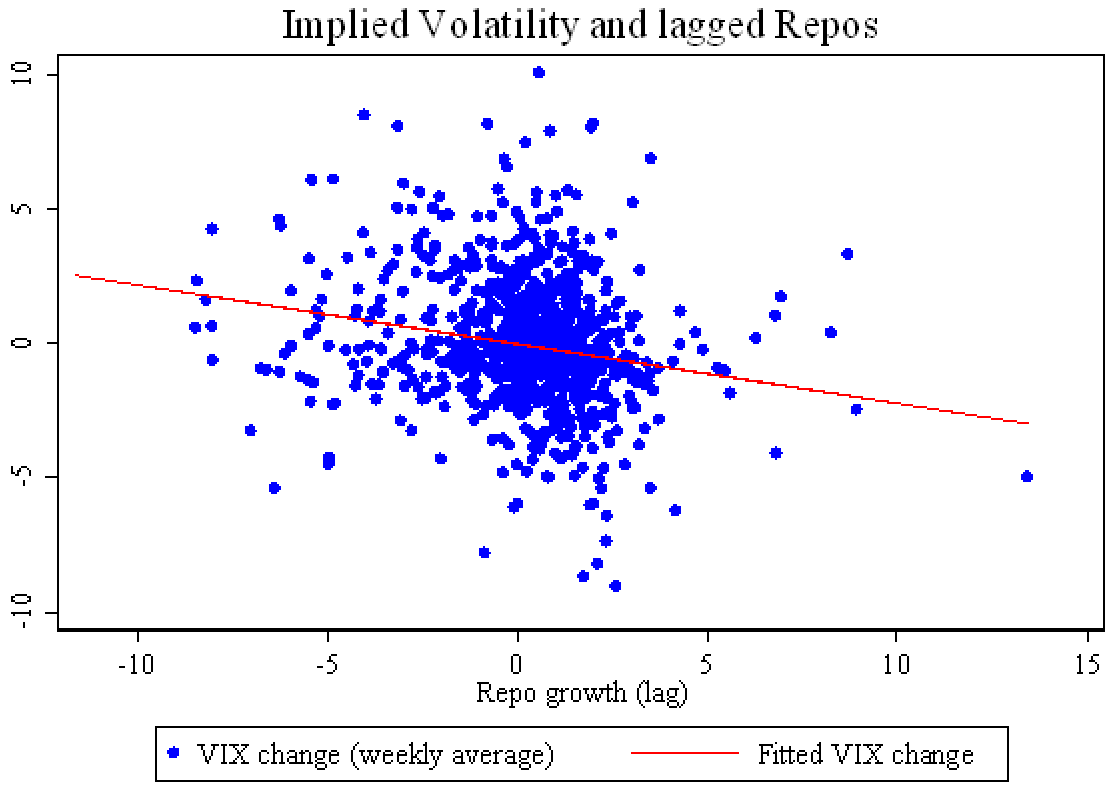
We use the daily VIX data from the website of the Chicago Board Options Exchange (www.cboe.com/micro/vix), and compute the S&P500 volatility from daily data over weekly windows. We compute the volatility risk premium as the difference between implied volatility and realized volatility. This risk premium is closely linked to the payoff to volatility swaps, which are zero investment derivatives that return the difference between realized future volatility and implied volatility over the maturity of the swap (see Carr and Wu (2007) for an analysis of variance and volatility swaps). We then compute averages of the VIX and the variance risk premium over each week (from the close of Wednesday to the close of the following Tuesday).

We are able to forecast innovations in the VIX. This can be seen in columns (ii)-(vi) of Table 6. We report forecasting regressions for VIX changes over the next week, as well as the Wednesday-Thursday and Wednesday-Friday changes. All of the forecasting results are significant at the 1% level. The forecasting R^2 increases from 8.9% when only the past VIX level is used, column (i) to 11.6% when Repo changes are included in the forecast. We believe the latter result (the ability to forecast the innovation in implied volatility) to be a very significant result. The forecasting result also holds for reverse repos, consistent with the notion that it is the total size of the balance sheet that matters for aggregate liquidity.

[Table 6]

In order to gain a better understanding what is determining the forecasting result, we also run the forecasting regressions for S&P500 volatility and the volatil-

Figure 4.1:



ity risk premium (columns vii-x). We see that it is the volatility risk premium that is being forecast, not actual equity volatility. Adjustments to the size of financial intermediary balance sheets via repos thus forecasts the price of risk of aggregate volatility, rather than aggregate volatility itself. We provide a graphical illustration of the forecasting power of repos in Figure 4.1.

We can put forward the following economic rationale for the forecasting regressions presented here. When balance sheets expand through the increased collateralized lending and borrowing by financial intermediaries, the newly released funding resources then chase available assets for purchase. More capital is deployed in increasing trading positions through the chasing of yield, and the selling of the "tails", as in the selling of out of the money puts. If the increased funding for asset purchases result in the generalized increase in prices and risk appetite in the financial system, then the expansion of balance sheets will eventually be reflected in the asset price changes in the financial system - hence, the ability of changes in repo positions to forecast future risk appetite.

5. Related Literature

The targeting of leverage seems closely to the bank's attempt to target a particular credit rating. To the extent that the "passive" credit rating should fluctuate with the financial cycle, the fact that a bank's credit rating remains constant through the cycle suggests that banks manage their leverage actively, so as to shed exposures during downturns. Kashyap and Stein (2003) draw implications from such behavior for the pro-cyclical impact of the Basel II bank capital requirements.

To the extent that balance sheets play a central role in our paper, our discussion here is related to the large literature on the amplification of financial shocks. The literature has distinguished two distinct channels. The first is the increased credit that operates through the *borrower's* balance sheet, where increased lending comes from the greater creditworthiness of the borrower (Bernanke and Gertler (1989), Kiyotaki and Moore (1998, 2001)). The second is the channel that operates through the *banks'* balance sheets, either through the liquidity structure of the banks' balance sheets (Bernanke and Blinder (1988), Kashyap and Stein (2000)), or the cushioning effect of the banks' capital (Van den Heuvel (2002)). Our discussion is closer to the latter group in that we also focus on the intermediaries' balance sheets. However, the added insight from our discussions is on the way that marking to market enhances the role of market prices, and the responses that price changes elicit from intermediaries.

Our results also related to the developing theoretical literature on the role of liquidity in asset pricing (Gromb and Vayanos (2002), Allen and Gale (2004), Acharya and Pedersen (2005), Brunnermeier and Pedersen (2005a, 2005b), Morris and Shin (2004), Acharya, Shin and Yorulmazer (2007a, 2007b)). The common thread is the relationship between funding conditions and the resulting market prices of assets. The theme of financial distress examined here is also closely related to the literature on liquidity drains that deal with events such as the stock market crash of 1987 and the LTCM crisis in the summer of 1998. Gennotte and Leland (1990) and Geanakoplos (2003) provide analyses that are based on competitive equilibrium.

The impact of remuneration schemes on the amplifications of the financial cycle have been addressed recently by Rajan (2005). The agency problems within a financial institution holds important clues on how we may explain procyclical behavior. Stein (1997) and Scharfstein and Stein (2000) present analyses of the capital budgeting problem within banks in the presence of agency problems.

The possibility that a market populated with value at risk (VaR) constrained traders may have more pronounced fluctuations has been examined by Danielsson, Shin and Zigrand (2004). Mark-to-market accounting may at first appear to be an esoteric question on measurement, but we have seen that it has potentially important implications for financial cycles. Plantin, Sapra and Shin (2005) present a microeconomic model that compares the performance of marking to market and historical cost accounting systems.

6. Concluding Remarks

Aggregate liquidity can be understood as the rate of growth of aggregate balance sheets. When financial intermediaries' balance sheets are generally strong, their leverage is too low. The financial intermediaries hold surplus capital, and they will attempt to find ways in which they can employ their surplus capital. In a loose analogy with manufacturing firms, we may see the financial system as having "surplus capacity". For such surplus capacity to be utilized, the intermediaries must expand their balance sheets. On the liabilities side, they take on more short-term debt. On the asset side, they search for potential borrowers that they can lend to. Aggregate liquidity is intimately tied to how hard the financial intermediaries search for borrowers. In the sub-prime mortgage market in the United States we have seen that when balance sheets are expanding fast enough, even borrowers that do not have the means to repay are granted credit - so intense is the urge to employ surplus capital. The seeds of the subsequent downturn in the credit cycle are thus sown.

References

Adrian, T. and H. S. Shin (2006) "Money, Liquidity and Financial Cycles" paper prepared for the Fourth ECB Central Banking Conference, "The Role of Money: Money and Monetary Policy in the Twenty-First Century", Frankfurt, November 9-10, 2006.

Allen, F. and D. Gale (2004) "Financial Intermediaries and Markets," *Econometrica* 72, 1023-1061.

Acharya, Viral and Lasse Pedersen (2005) "Asset Pricing with Liquidity Risk" *Journal of Financial Economics* 77, 375-410.

Ang, A., R. Hodrick, Y Xing, and X. Zhang (2006), "The Cross-Section of Volatility and Expected Returns," *Journal of Finance* 61, pp. 259-299.

Bank for International Settlements (1999): "A Review of Financial Market Events in Autumn 1998," CGFS Publication Number 12, Bank for International Settlements, http://www.bis.org/publ/cgfs12.htm.

Bernanke, B. and A. Blinder (1988) "Credit, Money and Aggregate Demand" *American Economic Review*, 78, 435-39.

Bernanke, B. and M. Gertler (1989) "Agency Costs, Net Worth, and Business Fluctuations" *American Economic Review*, 79, 14 - 31.

Bollerslev, T. and H. Zhou (2007) "Expected Stock Returns and Variance Risk Premia," *Federal Reserve Board Finance and Discussion Series* 2007-11.

Brunnermeier, Markus and Lasse Heje Pedersen (2005a) "Predatory Trading", *Journal of Finance*, 60, 1825-1863

Brunnermeier, Markus and Lasse Heje Pedersen (2005b) "Market Liquidity and Funding Liquidity", working paper, Princeton University and NYU Stern School.

Jon Danielsson, Hyun Song Shin and Jean-Pierre Zigrand, (2004) "The Impact of Risk Regulation on Price Dynamics", *Journal of Banking and Finance*, 28, 1069-1087

Diamond, Douglas and Raghuram Rajan (2005) "Liquidity Shortages and Banking Crises" *Journal of Finance*, 60, pp. 615

Geanakoplos, J. (2003) "Liquidity, Default, and Crashes: Endogenous Contracts in General Equilibrium" *Advances in Economics and Econometrics: Theory and Applications, Eighth World Conference, Volume II,* Cambridge University Press

Gennotte, Gerard and Hayne Leland (1990) "Hedging and Crashes", *American Economic Review*, 999–1021.

Gromb, Denis and Dimitri Vayanos (2002) “Equilibrium and Welfare in Markets with Financially Constrained Arbitrageurs”, *Journal of Financial Economics*, 2002, 66, 361-407

Kashyap, A. and J. Stein (2000) “What Do a Million Observations on Banks Say about the Transmission of Monetary Policy?” *American Economic Review*, 90, 407-428.

Anil Kashyap and Jeremy Stein, 2003, “Cyclical Implications of the Basel II Capital Standard”, University of Chicago, Graduate School of Business and Harvard University, http://faculty.chicagogsb.edu/anil.kashyap/research/basel-final.pdf

Kiyotaki, N. and J. Moore (1998) “Credit Chains” LSE working paper, http://econ.lse.ac.uk/staff/kiyotaki/creditchains.pdf.

Kiyotaki, N. and J. Moore (2001) “Liquidity and Asset Prices” LSE working paper, http://econ.lse.ac.uk/staff/kiyotaki/ liquidityandassetprices.pdf.

Carr, P. and Wu, L., (2007) ”Variance Risk Premia,” *Review of Financial Studies*, forthcoming.

Lowenstein, R. (2000) *When Genius Failed*, Random House, New York.

Plantin, G., H. Sapra and H. S. Shin (2005) “Marking to Market: Panacea or Pandora’s Box” working paper, Princeton University

Rajan, R. (2005) “Has Financial Development Made the World Riskier?” paper presented at the Federal Reserve Bank of Kansas City Economic Symposium at Jackson Hole,
http://www.kc.frb.org/publicat/sympos/2005/sym05prg.htm

Scharfstein, David and Jeremy Stein (2000) "The Dark Side of Internal Capital Markets: Divisional Rent-Seeking and Inefficient Investment" *Journal of Finance*, 55, 2537-2564.

Stein, Jeremy (1997) "Internal Capital Markets and the Competition for Corporate Resources" *Journal of Finance*, 52, 111-133.

Van den Heuvel, S. (2002) "The Bank Capital Channel of Monetary Policy," working paper, Wharton School, University of Pennsylvania, http://finance.wharton.upenn.edu/~vdheuvel/BCC.pdf

Table 2: Investment Bank Summary Statistics

This Table reports aggregate balance sheet items for the five investment banks of Table 1. In Panel A, we report time series summary statistics for the cross sectional average of the balance sheet items. In Panel B, we report the summary statistics of quarterly grwoth rates which are weighted by the Total Assets cross sectionally.

Panel A: US$ Millions	Mean	Std Dev	Min	Median	Max	Obs
Total Assets	301460	163696	97302	265079	730825	60
Total Liabilities	288739	157018	93111	254984	702510	60
Equity	11908	7172	3426	9246	28302	60
Reverse Repos and other Collateralized Lending	94222	46691	29423	86515	217254	60
Reverse Repos	58612	24191	19097	54028	125601	60
Repos and other Collateralized Borrowing	120139	64681	34216	114162	282272	60
Repos	88899	31491	54682	80030	169110	48
Trading VaR	49	13	29	47	82	24

Panel B: Quarterly Growth	Mean	Std Dev	Min	Median	Max	Obs
Total Assets	4%	5%	-15%	4%	16%	59
Total Liabilities	4%	6%	-15%	4%	17%	59
Equity	3%	2%	-2%	4%	10%	59
Reverse Repos and other Collateralized Lending	3%	9%	-26%	4%	21%	59
Reverse Repos	3%	9%	-16%	2%	28%	59
Repos and other Collateralized Borrowing	4%	7%	-19%	3%	21%	59
Repos	2%	9%	-19%	1%	19%	48
Trading VaR	3%	8%	-17%	3%	19%	23

Table 3: Explaining Leverage

This table reports panel regressions of quarterly leverage growth rates on the lagged level of leverage, the growth rates of trading VaRs, the growth rates of repos, and the growth rates of total assets. Leverage is computed from the balance sheets of the five investment banks from Table 1 whose summary statistics are reported in Table 2. Leverage is defined as the ratio of total assets to book equity. All of the balance sheet data is from the 10-K and 10-Q filings of the banks with the Security and Exchange Commission, and is taken from the Mergent Database.

		Leverage (quarterly growth)			
		(i)	(ii)	(iv)	(v)
Leverage (log lag)	coef	-0.09	-0.10	-0.04	-0.04
	p-value	0.00	0.01	0.03	0.00
Trading VaR (quarterly growth)	coef		0.07		
	p-value		0.02		
Repos (quarterly growth)	coef			0.37	
	p-value			0.00	
Total Assets (quarterly growth)	coef				0.90
	p-value				0.00
Constant	coef	0.28	0.32	0.12	0.10
	p-value	0.00	0.01	0.04	0.01
Observations		211	108	211	211
Number of Banks		5	5	5	5
R-squared		5%	12%	43%	66%
Fixed Effects		yes	yes	yes	yes

Table 4: Explaining the VaR/Equity Ratio

This table reports panel regressions of quarterly growth rates of the ratio of VaR to equity on the lagged level of leverage, the growth rates of trading VaRs, and the growth rates of total assets. The data is for the five investment banks from Table 1 whose summary statistics are reported in Table 2. All of the balance sheet data is from the 10-K and 10-Q filings of the banks with the Security and Exchange Commission, and is taken from the Mergent Database.

		Trading VaR / Equity (quarterly growth)			
		(i)	(ii)	(iii)	(iv)
Trading VaR / Equity (log lag)	coef	-0.61	-0.56	-0.62	-0.54
	p-value	0.00	0.00	0.00	0.00
Leverage (quarterly growth)	coef		0.91		1.65
	p-value		0.00		0.00
Total Assets (quarterly growth)	coef			-0.04	-1.29
	p-value			0.90	0.00
Constant	coef	-3.67	-3.32	-3.68	-3.20
	p-value	0.00	0.00	0.00	0.00
Observations		107	107	107	107
Number of i		5	5	5	5
R-squared		33%	39%	33%	44%
Fixed Effects		yes	yes	yes	yes

Table 5: Primary Dealer Financing Summary Statistics

This Table reports summary statistics of collateralized financing by the Federal Reserve's Primary Dealers from form FR2004 for January 3, 1990 - August 29, 2007.

Panel A: US$ Billions	Mean	Std Dev	Min	Max	Obs
Reverse Repos and other Collateralized Lending	1712	1010	382	4076	896
Reverse Repos	1655	1008	369	4040	896
Repos and other Collateralized Borrowing	1636	961	397	3896	896
Repos	1204	663	332	2636	896
Net Repos	451	357	21	1456	896

Panel B: Weekly Growth	Mean	Std Dev	Min	Max	Obs
Reverse Repos and other Collateralized Lending	18%	217%	-1092%	1360%	895
Reverse Repos	19%	223%	-1162%	1344%	895
Repos and other Collateralized Borrowing	17%	209%	-1097%	1266%	895
Repos	19%	264%	-1388%	1471%	895
Net Repos	40%	443%	-2429%	5356%	895

Table 6: Forecasting Volatility

This table reports forecasting regressions of VIX implied volatility changes, S&P500 volatility changes, and the volatility risk premium on lagged growth rates of repo, reverse repo, and net repo positions of U.S. Primary Dealers. The VIX is computed from the cross section of S&P500 index option prices by the Chicago Board of Options Exchange. We compute weekly volatility from S&P500 returns. the volatility risk premium is the difference between the average VIX over the week and S&P500 volatility for the same week. Summary statistics of the Primary Dealer financing data are given in Table 5. The data is weekly from January 3, 1990 - August 29, 2007. P-values are adjusted for autocorrelation and heteroskedasticity.

		Implied Volatility (Change)							Volatility (Change)		Volatility Risk Premium	
		One week average				Wed-Thur	Wed-Fri	Thur-Fri				
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vi)	(vii)	(viii)	(ix)	(x)
Implied Volatility	coef	-0.12	-0.11	-0.11	-0.12	-0.01	-0.03	-0.03	-0.45	-0.45	0.22	0.21
(lag)	p-value	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00
Repos	coef		-0.20			-0.05	-0.05	-0.05		0.05		-0.16
(lagged growth)	p-value		0.00			0.01	0.04	0.04		0.52		0.03
Reverse Repos	coef			-0.14								
(lagged growth)	p-value			0.00								
Net Repos	coef				-0.06							
(lagged growth)	p-value				0.00							
Constant	coef	2.16	2.09	2.09	2.14	0.16	0.38	0.38	4.93	4.90	6.23	6.30
	p-value	0.00	0.00	0.00	0.00	0.19	0.03	0.03	0.00	0.00	0.00	0.00
Observations		903	878	878	878	878	878	878	878	878	878	878
R-squared		8.9%	11.6%	10.9%	10.1%	1.1%	1.6%	1.6%	22.8%	22.0%	40.2%	40.9%