Liquidity and Leverage*

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Abstract

In a financial system where balance sheets are continuously marked to market, asset price changes show up immediately as 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 dealer repos – the primary margin of adjustment for the aggregate balance sheets of intermediaries – forecast changes in financial market risk 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.

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1. Introduction

In a financial system where balance sheets are continuously marked to market, changes in asset prices show up immediately on balance sheets, and have an instant 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 financial intermediaries were passive and did 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 institution, 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 might not be taken into consideration by individual institutions. We exhibit evidence that procyclical leverage effects aggregate volatility and particularly the price of risk of volatility.

Our paper has two main objectives. Our first objective is to document the relationship between 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 risk 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 asset pricing consequences through shifts in financial market volatility. In particular, we show that changes in collateralized borrowing and lending on intermediary's balance sheet are significant forecasting variables for innovations in market-wide risk as measured by the VIX index of implied volatility in the stock market. We also decompose VIX innovations into changes of stock market volatility and changes of the difference between implied volatility and actual volatility (the volatility risk premium). We find that dealer balance sheet changes primarily forecast changes in the volatility risk premium, which has a natural interpretation as the price of risk of aggregate volatility. Previous work in asset pricing has shown that innovations in market volatility are important cross sectional asset pricing factors (see Ang, Hodrick, Xing, and Zhang (2006), and Adrian, and Rosenberg (2008)), and that the volatility risk premium forecasts future equity returns (Bollerslev and Zhou (2007)). Our finding that expansions and contractions of the balance sheets of security dealers forecast volatility innovations shows that intermediary balance sheets matter for the aggregate pricing of risk. Consistent with the conjectures of Gromb and Vayanos (2002), Brunnermeier and Pedersen (2007) and He and Krishnamurthy (2008), we thus document that funding liquidity of financial intermediaries has aggregate pricing implications.

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 financial market liquidity can be understood as the rate of growth of aggregate balance sheets. In response to increases in prices on the asset side of intermediaries' balance sheets, leverage falls, and intermediaries hold surplus capital. They will then search for uses of 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. Financial market 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. We argue that the behavior of financial intermediaries thus uncovered shed much light on several aspects of the credit crisis of 2007/8, and in particular why the distress has been most focused on the interbank credit market. 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 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,

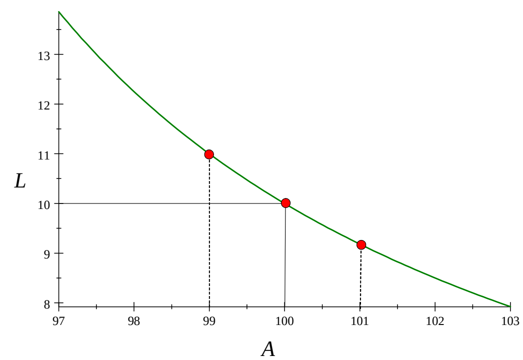

Figure 2.1: Leverage for passive investor

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

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).

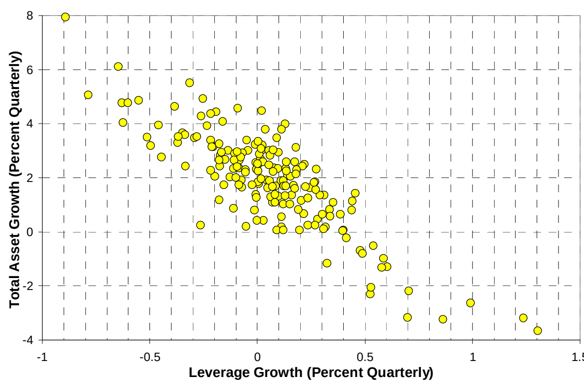

Figure 2.2: Total Assets and Leverage of Household

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.

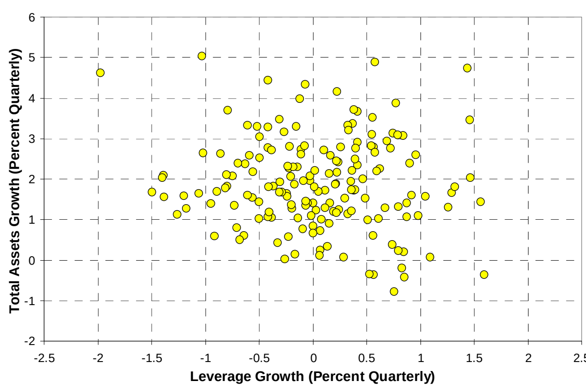

Figure 2.3: Total Assets and Leverage of Non-financial, Non-farm Corporates

Figure 2.3 is a scatter chart of the change in 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 somewhat to changes in asset prices by shifting their stance on leverage.[1]

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

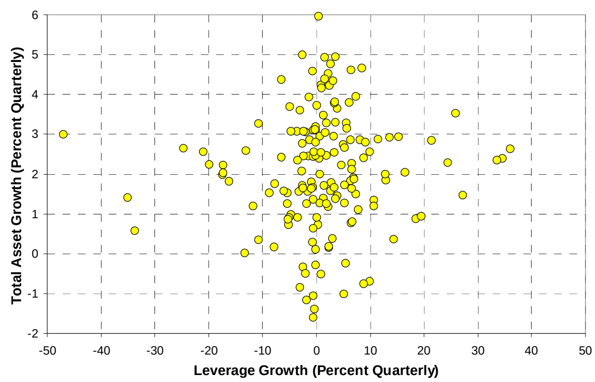

Figure 2.4: Total Assets and Leverage of Commercial Banks

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.

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

[1] This finding is consistent with Welch's (2004) analysis of non-financial leverage which demonstrates that 40 percent of leverage changes are (passively) explained by shocks to equity prices, and 60 percent by the net issuing activity.

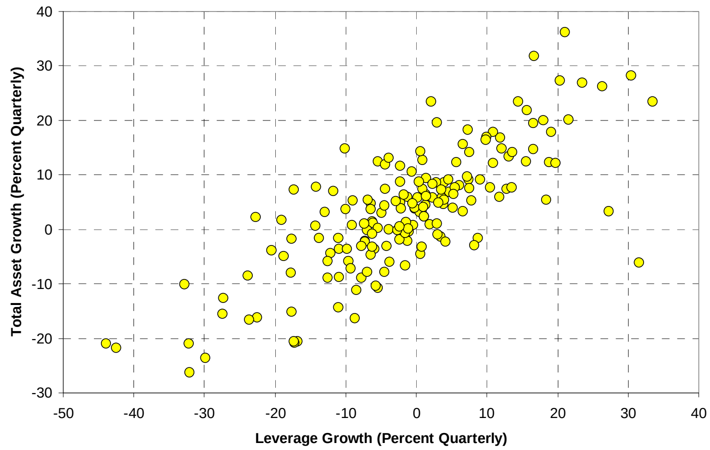

Figure 2.5: Total Assets and Leverage of Security Brokers and Dealers

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

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

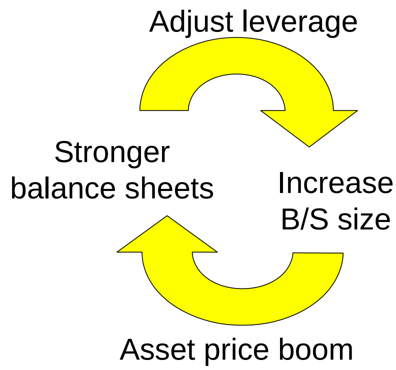

Figure 2.6: Leverage Adjustment in Upturn

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 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 financial markets are not perfectly liquid so that greater demand for the

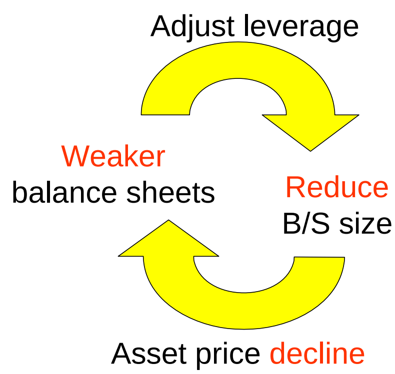

Figure 2.7: Leverage Adjustment in Downturn

asset tends to put upward pressure on its price, 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 financial markets are not perfectly liquid so 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 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 from 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 – 2008 Q1
Goldman Sachs	1999 Q2 – 2008 Q1
Lehman Brothers	1993 Q2 – 2008 Q1
Merrill Lynch	1991 Q1 – 2008 Q1
Morgan Stanley	1997 Q2 – 2008 Q1

Our choice of these five banks is motivated by our concern to examine "pure play" investment banks that are not part of bank holding companies 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. 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

[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.

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 small fraction of the balance sheet for investment banks.[3] For these reasons, investment banks provide a good 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.

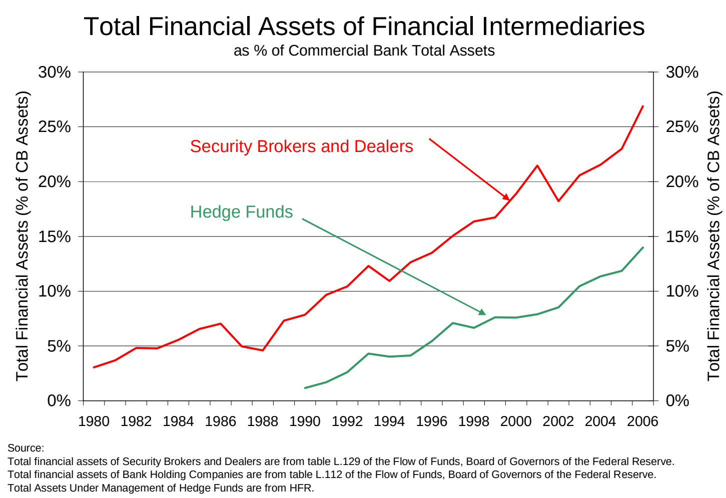

Figure 3.1: Total Financial Intermediary Assets

[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 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.

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 investor equity, rather than the size of the balance sheet. To obtain total balance sheet size, we should multiply by hedge fund leverage (which is not readily available). 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 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 2007/2008 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 3.2. 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

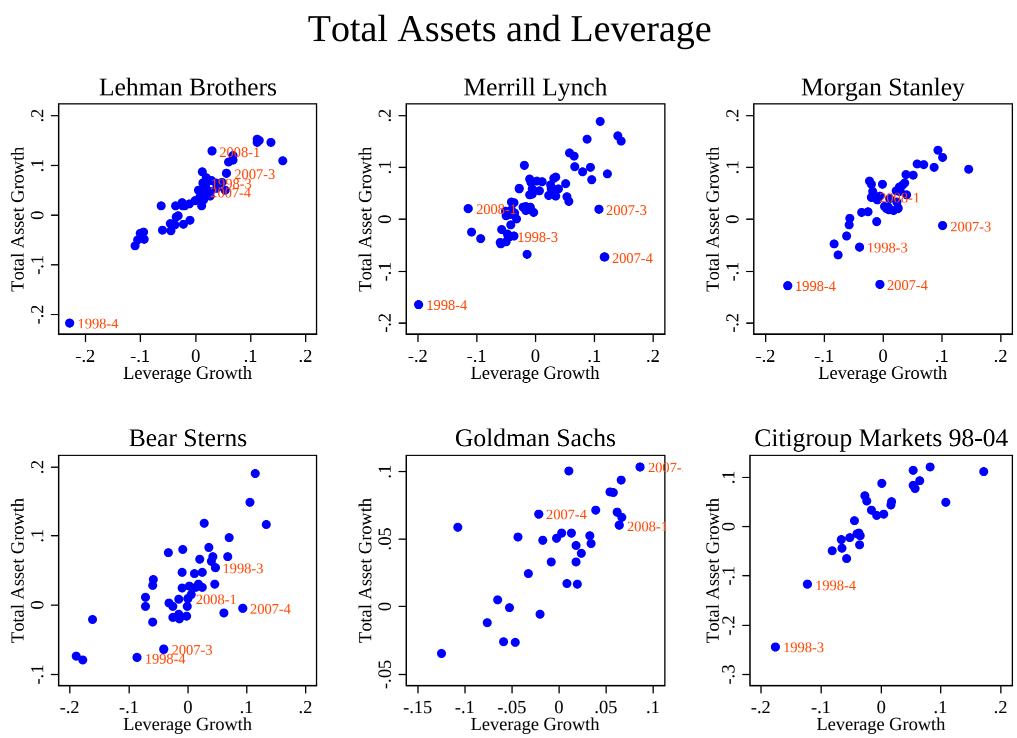

Figure 3.2: Total Assets and Leverage

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 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]

Figure 3.3 aggregates the individual scatter charts by taking the asset-weighted average of changes in balance sheet size and leverage. The upward-sloping relationship between changes in assets and changes in leverage is clearer. The 45-degree line in the scatter chart corresponds to the combination of points where the total equity value remains constant. This is because leverage growth is defined as the log difference in assets minus log difference in equity. Hence, the 45 degree line corresponds to the points where the log difference in equity is zero. The set of points below the 45 degree line corresponds to the observations in which equity fell. This explains why the observations for the third and fourth quarters of 2007 appear below the 45 degree line, as banks announced credit losses on their mortgage portfolios. More interestingly, there is a striking contrast between what happened in 1998 following the LTCM crisis and the credit crisis of 2007/8. As of the first quarter of 2008, there has not been the same type of contraction of balance sheets as was observed in the 1998 crisis. This difference holds the key to

[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.

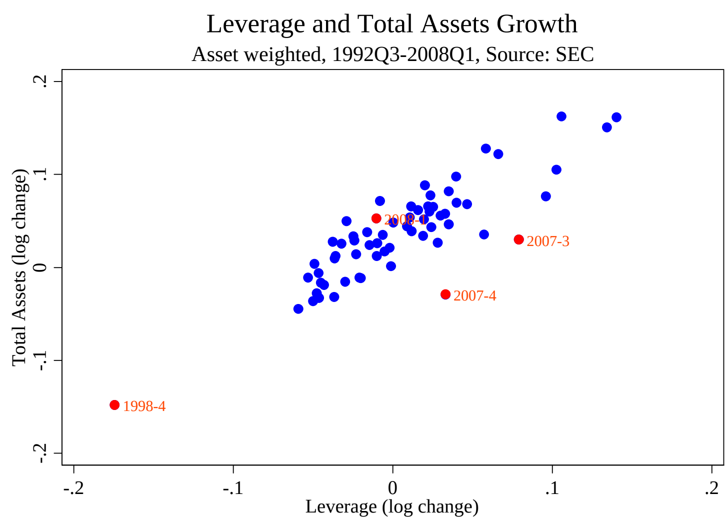

Figure 3.3: Aggregate Leverage and Total Asset Growth

several distinctive characteristics of the crisis of 2007/8. We return to this issue in section 3.3.

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 (v) of Table 3. The coefficient on lagged leverage (i.e. previous quarter's leverage) is negative, showing that leverage is mean-reverting (column i). Leverage is positively related Value-at-Risk (column ii), as increases in leverage generally increase the Value-at-Risk of total assets.

[Table 3]

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

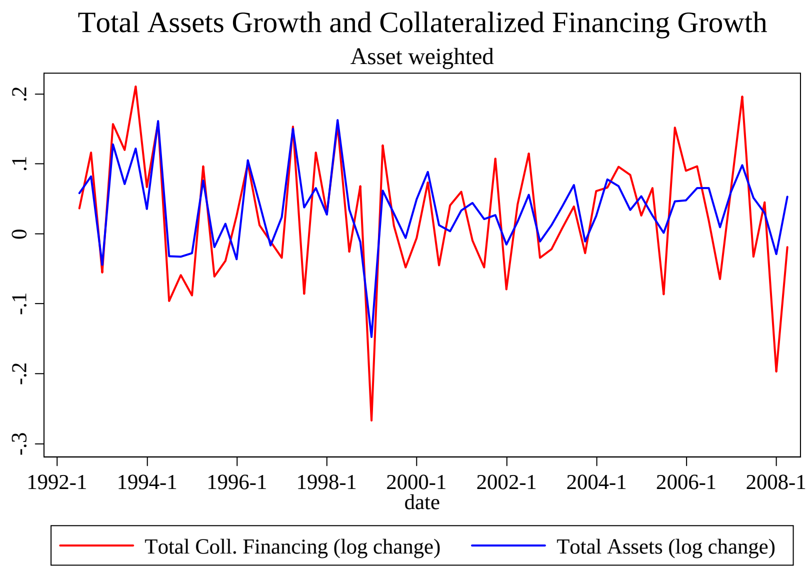

Figure 3.4: Total Asset and Total Repo Growth

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 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. Column (iv) of Table 3 shows that repo growth explains 43% of the variation of leverage growth. In addition, Table 3 shows that repos are the largest form of debt on investment banks balance sheets. Adjustments in total assets and hence leverage are primarily done via repos, as is visible in chart 3.4.

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. The expansion and contraction of total assets via repos is plotted in Figure 3.5.

Figure 3.5 plots the change in assets against change in collateralized borrowing for each of the investment banks. 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 3.6 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 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 3.6 suggests that repos and reverse repos play such a role as counterparts in the balance sheet.

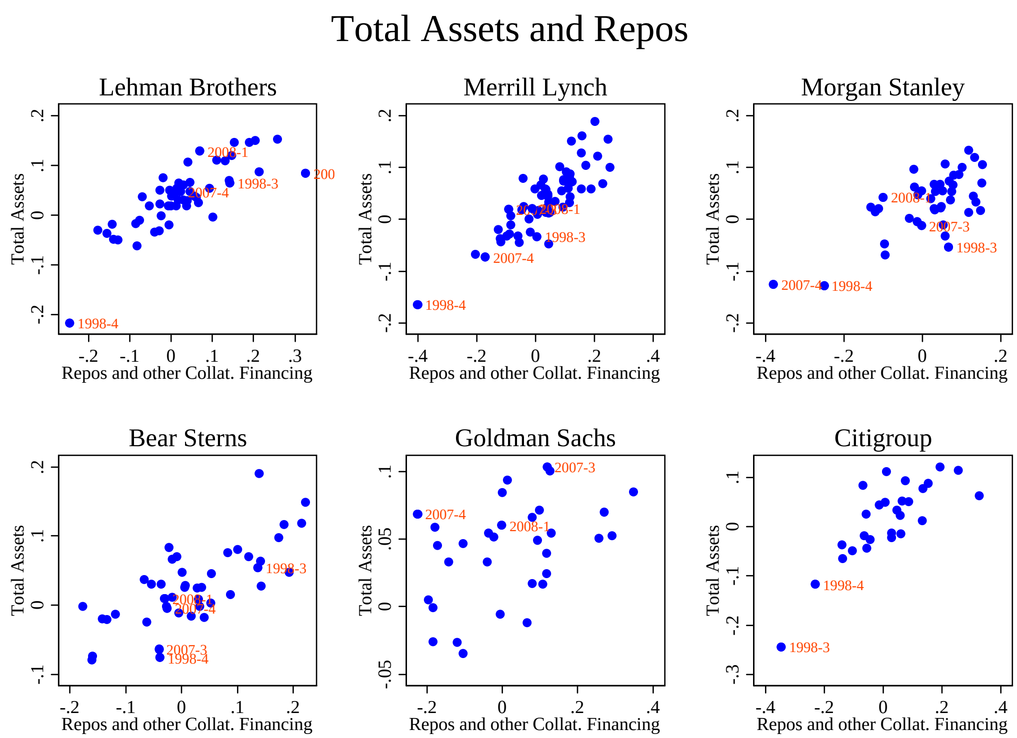

Figure 3.5: Total Assets and Repos

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

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

For instance, A could be the total marked-to-market assets of the firm at some

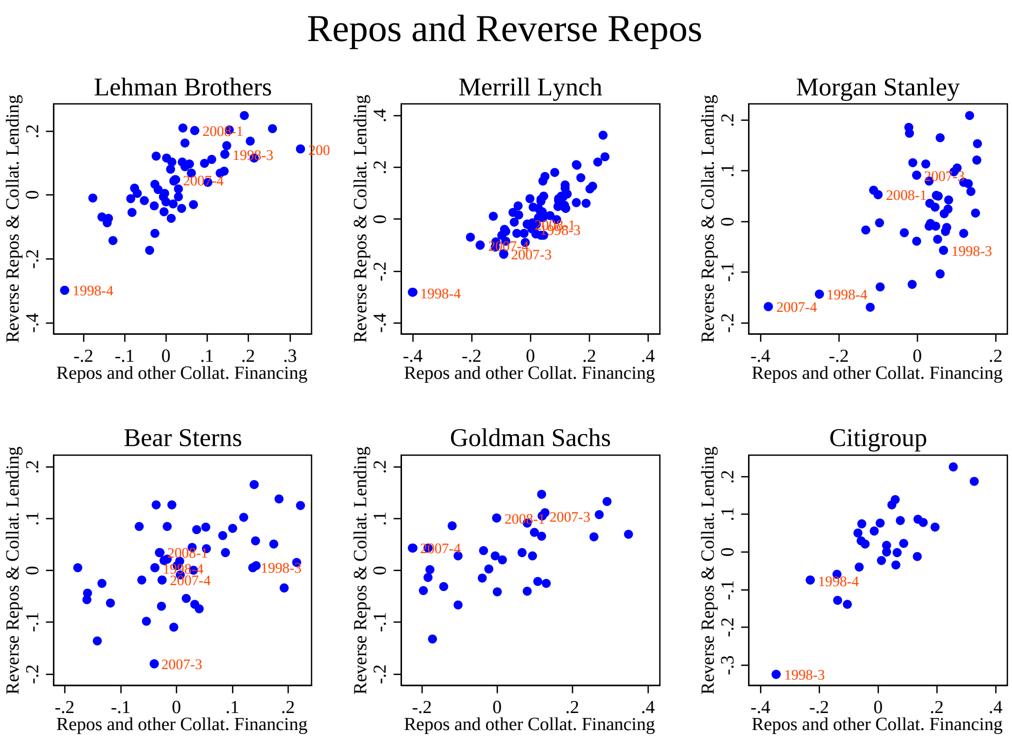

Figure 3.6: Repos and Reverse Repos

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

$$\begin{aligned} L &= \frac{A}{K} \\ &= \frac{1}{\lambda} \times \frac{A}{VaR} \\ &= \frac{1}{\lambda} \times \frac{1}{V} \end{aligned}$$

where V is the *unit value-at-risk*, defined as the value-at-risk per dollar of assets. Procyclical leverage then follows directly from the *counter*-cyclical nature of unit value-at-risk. Measured risk is low during booms and high during busts.

We can indeed see this counter-cyclical relationship in the data. In figure 3.7, we plot the unit value-at-risk against total assets, having removed the fixed effects for individual banks. We see that the relationship is downward sloping. We highlight 2007Q4 and 2008Q1 for Bear Stearns and Lehman Brothers, as they are clear outliers in the plot. The high levels of unit value-at-risk for these two investment banks at the height of the credit crisis is suggestive of balance sheets that are under considerable stress. Shortly after filing its 10-Q form for the first quarter of 2008, Bear Stearns suffered its run, and was acquired by J.P. Morgan Chase with the assistance of the Federal Reserve. We will return to a more detailed description of the 2007/8 credit crisis below, in section 3.3.

In Figure 3.8 we plot the evolution of the average unit value-at-risk over time. We see again that the average unit value-at-risk increased sharply in 2007Q4 and 2008Q1.

Equation (3.1) also suggests that the ratio of Value-at-Risk to shareholder equity may be an informative series to track over time. The naive hypothesis would

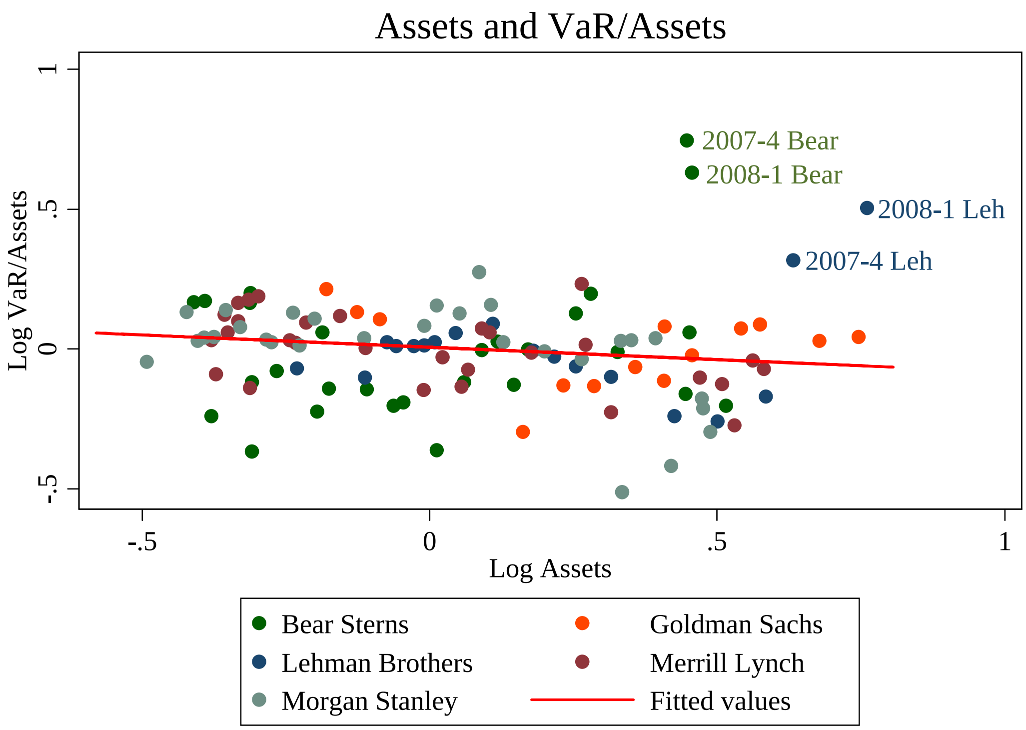

Figure 3.7: VaR and Total Assets

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.

In Figures 3.9 we plot the evolution of the VaR/equity ratio and leverage over time. The Value-at-Risk numbers are reported in the 10-K and 10-Q filings since 2001. We can see that both ratios—VaR/Equity and Leverage—are fairly constant before 2007, with the exception of Goldman Sachs, which exhibits a marked increase in leverage. In 2007, both leverage and the VaR/equity ratio

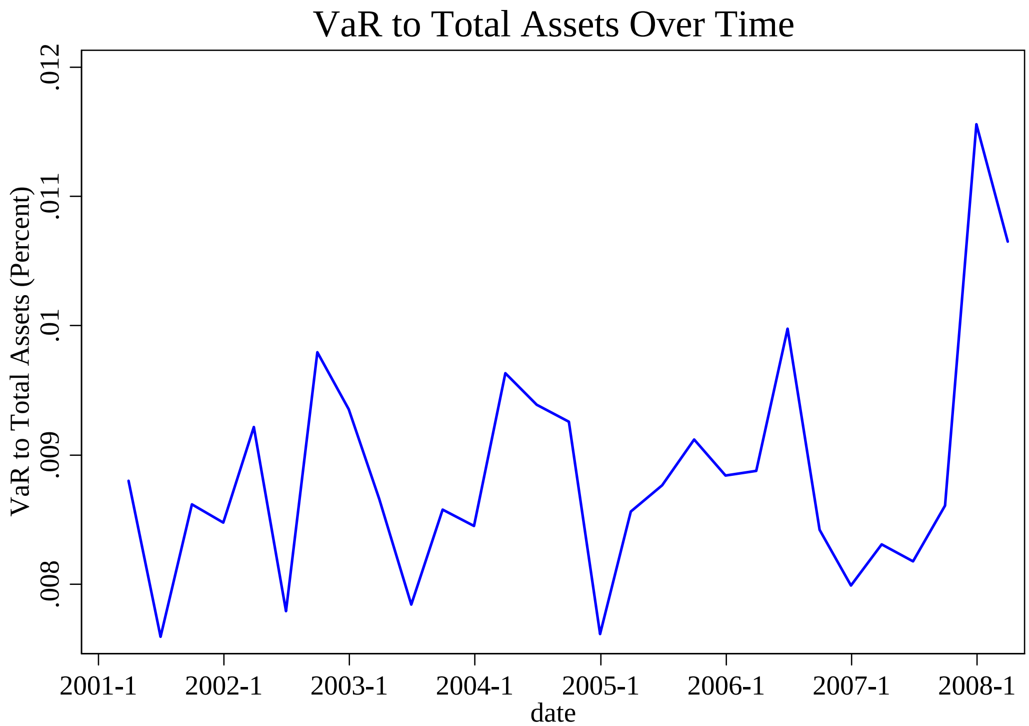

Figure 3.8: VaR to Total Assets (Percent)

increased markedly for most banks. In Figure 3.10 we plot average leverage for all banks since 1992. There are two peaks in the evolution of leverage over time, one prior to the LTCM crisis of 1998, and a second peak during the 2007/2008 mortgage crisis.

Table 4 presents the regressions for the quarterly change in the ratio of Value-at-Risk to equity. For the reasons outlined already, the firm's self-assessed Value-at-Risk is closely tied to its assessment of economic capital, and we would expect behavior to be heavily influenced by changes in Value-at-Risk.

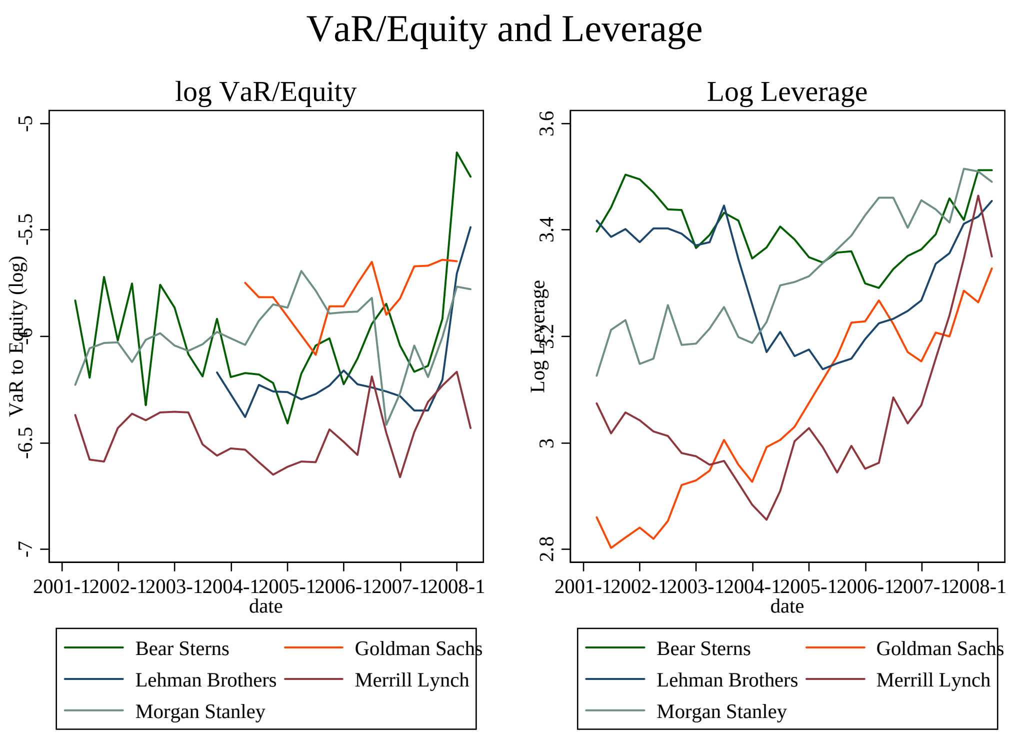

Figure 3.9: VaR/Equity and Leverage

[Table 4]

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

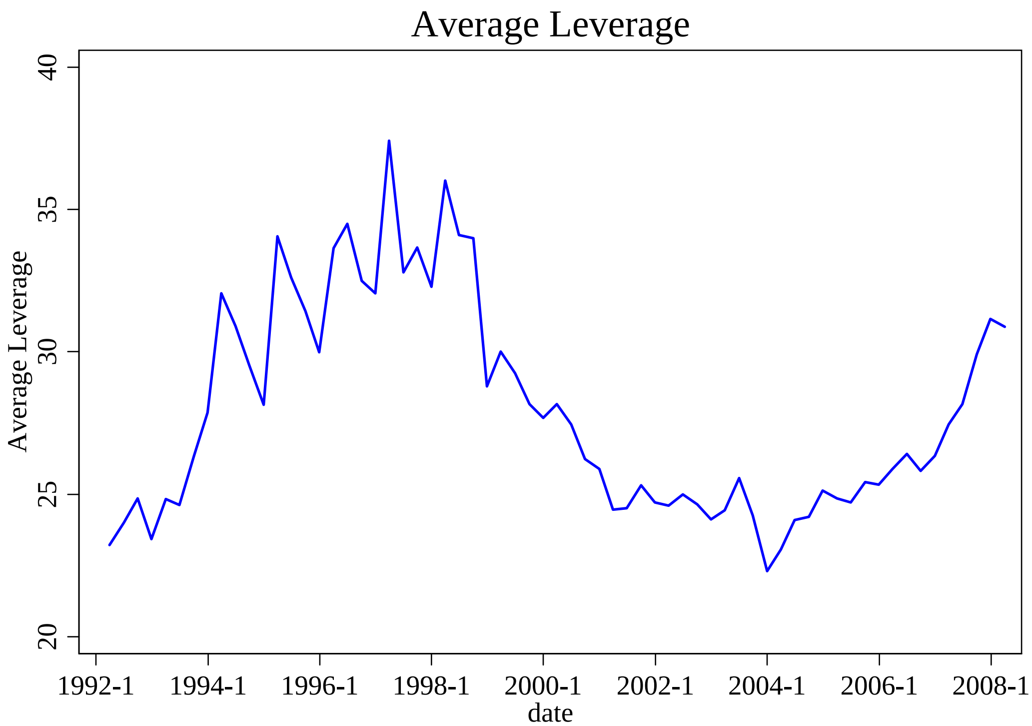

Figure 3.10: Average Leverage over Time

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.

3.3. Credit Crisis of 2007/8

The scatter chart given by figure 3.3 also gives clues on some peculiar features of the credit crisis of 2007/8. Note the contrast between the drastic shrinking of assets and leverage 1998Q4 associated with the LTCM crisis and the course so far of the credit crisis that began in the summer of 2007. While balance sheets contracted sharply in 1998, there has not (yet) been a comparable contraction of balance sheets in the crisis of 2007/8. Understanding the reasons for the difference between 1998 and 2007 holds the key to unlocking some of the mysteries surrounding the drying up of the interbank credit market in the summer of 2007. One of those mysteries is the fact that some financial markets (notably the stock market, and the market for high grade corporate debt) have held up relatively well throughout the crisis, while the interbank credit markets have suffered unusually severe stresses.

For instance, the LIBOR spread has been consistently high during the whole crisis - even as the acute distress at around the time of the Bear Stearns demise began to dissipate in April 2008. Figure 3.11 shows that while the dollar LIBOR rate has generally tracked the Fed Funds rate down as the Federal Reserve has cut interest rates aggressively, the spreads have been volatile and very large.

One conjecture for why bank balance sheets did not contract sharply in 2007Q3 and Q4 as they did in 1998 is that the banks were not at liberty to do so due to the liquidity lines they offered to their off-balance sheet vehicles. The beginnings of the credit problems of 2007 were first manifested by falling prices of securities that are associated with the subprime mortgage sector. The falls in the prices of securities proceeded into July of 2007, and were accompanied by increases in measured risks. In particular, the off balance sheet SIVs (structured investment vehicles) and conduits that had been set up to buy large quantities of subprime mortgage related assets began to experience difficulties in rolling over their asset-

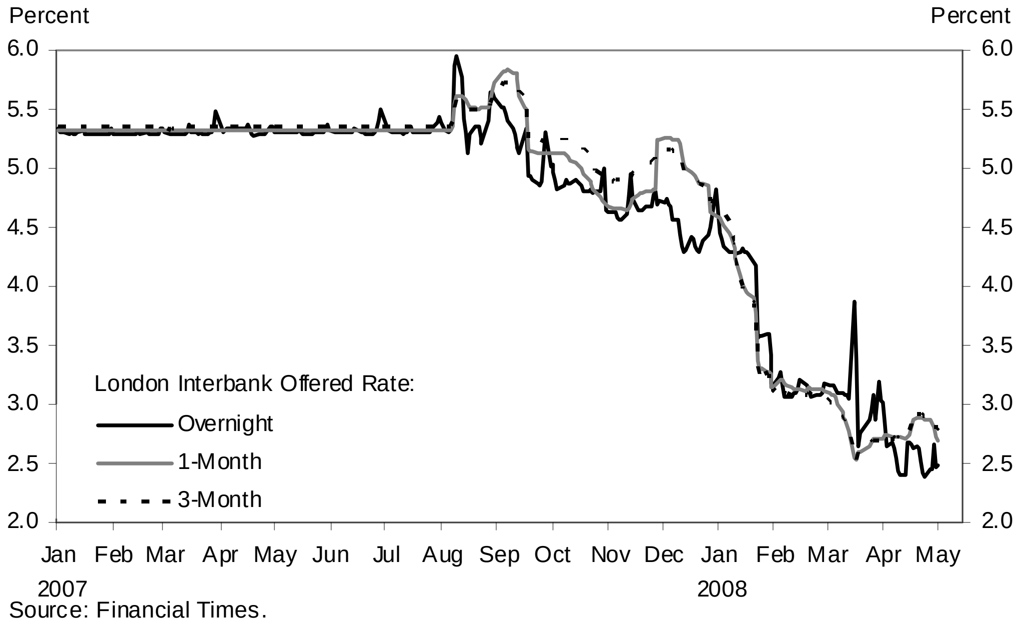

Figure 3.11: LIBOR rates

backed commercial paper liabilities. Many of the conduits and SIVs had been set up with back-up liquidity lines from banks, and such liquidity lines were beginning to be tapped by the end of July and early August.

The tapping of the credit lines were happening at precisely the moment that the risk constraints were binding harder for the banking sector. Tighter value at risk constraints translated to higher shadow value of capital and hence to the desired contraction of balance sheets. Contracting balance sheets of hedge funds and other holders of asset backed commercial paper (ABCPs) led to a fall in the demand for the liabilities issued by SIVs and conduits. In late July and early August 2007, SIVs and conduits began to experience difficulties in rolling over their short term liabilities.

Furthermore, as credit lines got tapped, the balance sheet constraint at the banks began to bind even harder, making them even more reluctant to lend. For some banks, their reputational concerns induced them to bring back on to the balance sheet the assets that were held previously off balance sheet in the various conduits and SIVs. In effect, the banks were "lending against their will". The fact that bank balance sheets did not contract is indicative of the involuntary expansion of the banks' balance sheets. One of the consequences of such involuntary expansion was that they sought other ways to curtail lending. Their natural response was to cut off lending that was discretionary. The seizing up of the interbank credit market can thus be seen as the conjunction of:

- Desired contraction of balance sheets
- "Involuntary" lending due to the tapping of credit lines by off balance sheet entities and return of assets back on to the banks' balance sheets.

One corroborating piece of evidence for the hypothesis that the stresses in the interbank market have been caused by the "involuntary" lending by the banks is the unusually large spreads on "jumbo" mortgages - i.e. those non-conforming mortgages that do not qualify for the guarantees offered by the government sponsored enterprises Fannie Mae and Freddie Mac. Figure 3.12 shows the jumbo spread going back to 1998. We can see that the currently very high spreads are much higher than past episodes of financial distress, including the 1998 crisis, Y2K and 9/11. Moreover, the spreads have increased since the run on Bear Stearns in March 2008. We see the behavior of the jumbo spread as evidence of the lack of credit capacity on the financial intermediaries' balance sheets, following the large scale write-downs due to credit losses. Although the banks have been successful in raising some new capital, the evidence is that the capital raised so far has not been enough to relieve the balance sheet constraints.

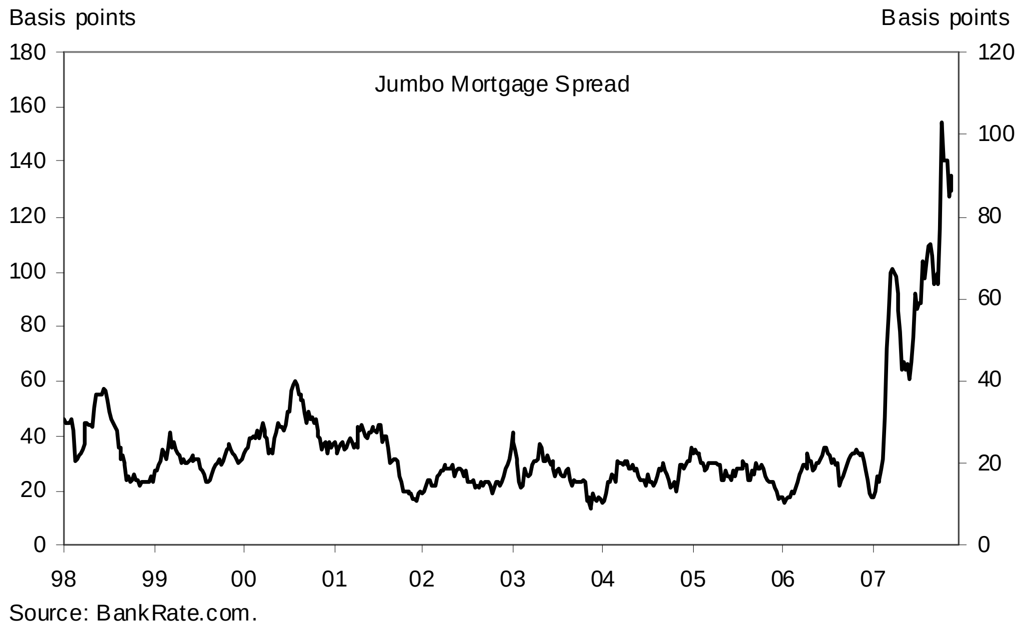

Figure 3.12: Jumbo Mortgage Spreads

4. Forecasting Risk Appetite

We now explore the asset pricing consequences of balance sheet expansion and contraction. We have already noted how the demand and supply responses to price changes can amplify asset price movements when financial intermediaries' actions result in 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 are more 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. The primary dealer data have previously been analyzed by Adrian and Fleming (2005) and Kambhu (2006).

Primary dealers are the dealers with whom the Federal Reserve has an on-going trading relationship in the course of daily business. The primary dealers comprise the five investment banks studied earlier in the paper, as well as commercial and foreign banks that own security broker and dealers. Currently 20 intermediaries are primary dealers.[5] 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[6]. 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. 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 financing activities over the previous week. Data are then submitted on the following day (that is, Thursday) to the Federal Reserve. Summary data are released publicly by the Federal Reserve each Thursday, one week after they are collected. The data are aggregated across all dealers, and are only available by asset class.

Repos and reverse repos are a subset of the security financing data. Financ-

[5] A list of current primary dealers can be found at:
http://www.newyorkfed.org/markets/pridealers_current.html.

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

ing distinguishes between "securities in" and "securities out" for each asset class. "Securities in" refer to securities received by a dealer in a financing arrangement (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. Adrian and Fleming (2005) provide more detail about the data.

[Table 5]

We use the weekly repo and reverse repo data to forecast financial market conditions in the following week. 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 reflects aggregate financial market volatility, as well as the price of risk of market volatility. 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 provide summary statistics of the primary dealer data, and the volatility data in Table 5.

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).

The growth rate of repos on dealers balance sheets significantly 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, Wednesday-Friday, and Thursday-Friday changes. The forecasting results are significant at the 1% level for volatility innovations over the next week, and at the 5% for volatility innovations over shorter time periods. 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 significant forecasting power of dealer's repo growth for innovations in implied volatility) to be important. 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 volatility 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

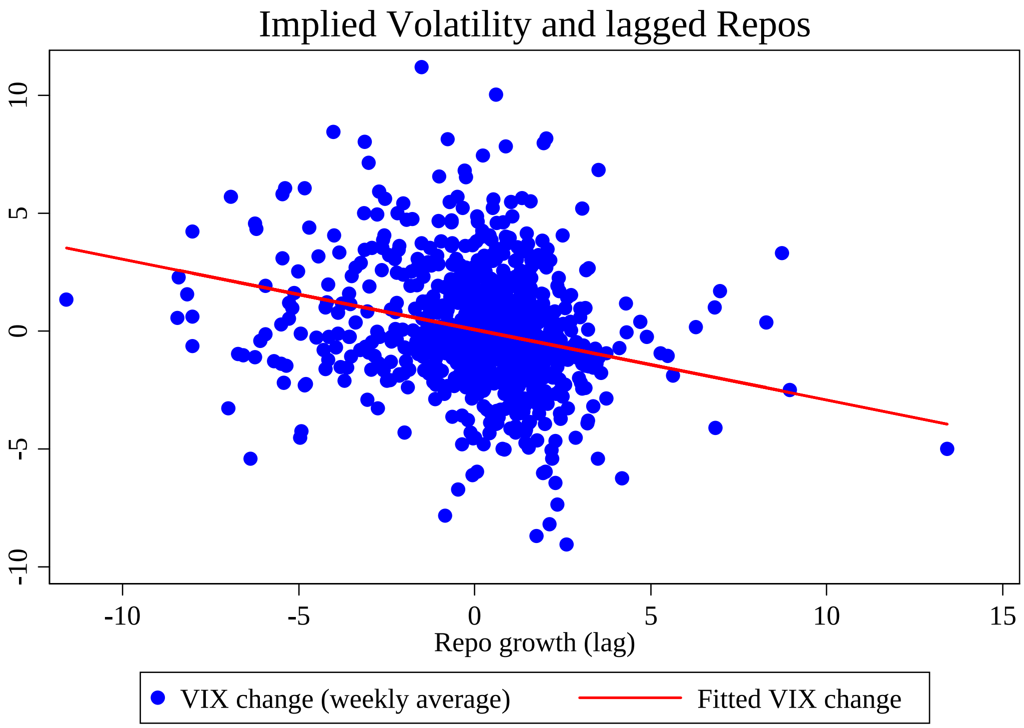

Figure 4.1: Implied Volatility and lagged Repos

aggregate volatility, rather than aggregate volatility itself. We provide a graphical illustration of the forecasting power of repos as a scatter chart 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 volatility via options. 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 volatility, and particularly the volatility risk premium.

5. Related Literature

The managing of leverage is 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 (1997, 2005)). 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 are 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 (2005, 2007), 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 (2008) 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 the aggregate financial sector balance sheet. When asset prices increase, financial intermediaries' balance sheets generally become stronger, and—without adjusting asset holdings—their leverage tends to be too low. The financial intermediaries then hold surplus capital, and they will attempt to find ways in which they can employ their surplus capital. In 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 liability side, they take on more short-term debt. On the asset side, they search for potential borrowers. 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.

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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	335899	207065	97302	278741	876881	64
Total Liabilities	322121	199467	93111	268311	847335	64
Equity	13013	8185	3426	10611	30920	64
Reverse Repos and other Collateralized Lending	131972	77747	34216	115881	314715	64
Reverse Repos	63185	29322	19097	55699	135830	64
Repos and other Collateralized Borrowing	104353	59292	29423	88510	263724	64
Repos	97099	40767	54682	82697	202372	52
Trading VaR	48	16	29	46	92	28

Panel B: Quarterly Growth	Mean	Std Dev	Min	Median	Max	Obs
Total Assets	4%	5%	-15%	4%	16%	63
Total Liabilities	4%	6%	-15%	4%	17%	63
Equity	3%	3%	-5%	3%	8%	63
Reverse Repos and other Collateralized Lending	4%	7%	-19%	3%	21%	63
Reverse Repos	3%	9%	-16%	2%	28%	63
Repos and other Collateralized Borrowing	3%	9%	-26%	4%	21%	63
Repos	2%	9%	-19%	1%	19%	52
Trading VaR	4%	9%	-25%	5%	19%	27

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.

		Leverage (quarterly growth)			
		(i)	(ii)	(iv)	(v)
Leverage (log lag)	coef	-0.08	0.01	-0.06	-0.03
	p-value	0.00	0.88	0.08	0.02
Trading VaR (quarterly growth)	coef		0.07		
	p-value		0.01		
Repos (quarterly growth)	coef			0.22	
	p-value			0.00	
Total Assets (quarterly growth)	coef				0.83
	p-value				0.00
Constant	coef	0.28	-0.02	0.12	0.08
	p-value	0.00	0.92	0.04	0.07
Observations		228	107	191	228
Number of Banks		5	5	5	5
R-squared		5%	8%	24%	63%
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.

		Trading VaR / Equity (quarterly growth)			
		(i)	(ii)	(iii)	(iv)
Trading VaR / Equity (log lag)	coef	-0.66	-0.59	-0.62	-0.65
	p-value	0.00	0.00	0.00	0.00
Leverage (quarterly growth)	coef		1.31		2.11
	p-value		0.00		0.00
Total Assets (quarterly growth)	coef			-0.04	-1.63
	p-value			0.90	0.00
Constant	coef	-4.04	-3.65	-3.68	-3.96
	p-value	0.00	0.00	0.00	0.00
Observations		106	106	106	106
Number of i		5	5	5	5
R-squared		23%	32%	24%	43%
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 - April 2, 2008.

Panel A: US$ Billions	Mean	Std Dev	Min	Max	Obs
Reverse Repos and other Collateralized Lending	1708	1026	397	4227	926
Reverse Repos	1252	702	332	2972	926
Repos and other Collateralized Borrowing	1792	1087	382	4616	926
Repos	1736	1086	369	4567	926
Net Repos	484	396	21	1600	926
Panel B: Weekly Growth	Mean	Std Dev	Min	Max	Obs
Reverse Repos and other Collateralized Lending	17%	207%	-1075%	1266%	925
Reverse Repos	19%	265%	-1410%	1471%	925
Repos and other Collateralized Borrowing	18%	215%	-1076%	1360%	925
Repos	19%	222%	-1159%	1344%	925
Net Repos	40%	437%	-2429%	5356%	925

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 - April 2, 2008. P-values are adjusted for autocorrelation and heteroskedasticity.

		Implied Volatility (Change)							Volatility (Change)		Volatility Risk Premium (Change)	
		One week average				Wed-Thur	Wed-Fri	Thur-Tues				
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vi)	(vii)	(viii)	(ix)	(x)
Implied Volatility	coef	-0.10	-0.09	-0.09	-0.10	-0.01	-0.02	-0.06	-0.45	-0.45	-0.78	-0.79
(lag)	p-value	0.00	0.00	0.00	0.00	0.31	0.01	0.01	0.00	0.00	0.00	0.00
Repos	coef		-0.28			-0.05	-0.05	-0.15		0.01		-0.14
(lagged growth)	p-value		0.00			0.02	0.06	0.00		0.87		0.04
Reverse Repos	coef			-0.24								
(lagged growth)	p-value			0.00								
Net Repos	coef				-0.06							
(lagged growth)	p-value				0.01							
Constant	coef	1.95	1.85	1.82	1.93	0.13	0.35	1.15	4.99	4.90	6.22	6.29
	p-value	0.00	0.00	0.00	0.00	0.31	0.05	0.00	0.00	0.00	0.00	0.00
R-squared (adj.)		4.9%	9.0%	9.1%	5.5%	0.5%	1.0%	4.7%	22.3%	22.0%	39.1%	39.7%