Liquidity and financial contagion

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There is an apparent puzzle at the heart of the 2007 credit crisis. The subprime mortgage sector is small relative to the financial system as a whole and the exposure was widely dispersed through securitization. Yet the crisis in the credit market has been potent. Traditionally, financial contagion has been viewed through the lens of defaults, where if A *has borrowed from* B *and* B *has borrowed from* C*, then the default of* A *impacts* B*, which then impacts* C*, etc. However, in a modern market-based financial system, the channel of contagion is through price changes and the measured risks and marked-to-market capital of financial institutions. When balance sheets are marked to market, asset price changes show up immediately on balance sheets and elicit response from financial market participants. Even if exposures are dispersed widely throughout the financial system, the potential impact of a shock can be amplified many-fold through market price changes.*

NB: The views expressed in this paper are those of the authors and not necessarily those of the Federal Reserve Bank of New York, or the Federal Reserve System.

The credit crisis of 2007 began with the deterioration in the credit quality of subprime mortgages in the United States. However, by most measures the total size of credit exposures could be argued to be small. The ferocity with which the crisis has unfolded raises important questions on the nature of financial contagion. The question is well posed in a recent speech by William Dudley, Executive Vice President of the Federal Reserve Bank of New York.[1]

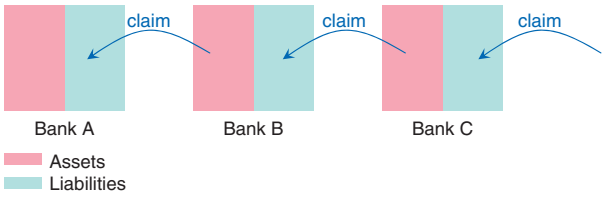
Total outstanding adjustable-rate subprime mortgages are less than USD 1 trillion. Moreover, those mortgages originated during 2006 and early 2007 represent only a fraction of that total. Thus, even if subprime delinquency rates keep climbing to unprecedented levels, it seems likely that total losses will be roughly in a range of USD 100-200 billion. Although this is a lot of money, it pales next to the USD 58 trillion of net worth of US households or the USD 16 trillion market capitalization of the US equity market.

To put these losses in perspective, a 1 percent gain or loss in the US stock market –which often occurs on a daily basis– is about the same order of magnitude of the likely subprime mortgage losses that will be gradually realized over the next few years.

So why have these losses –which are the root cause of recent market problems– led to so much market turbulence?

This is a good question. On the surface, the capital of financial institutions appeared large enough to absorb such losses without difficulty. Moreover, securitization had spread the exposures across diverse claimholders, minimizing the concentration of credit risk in the hands of financial intermediaries. A widespread opinion before the summer of 2007 was that securitization had increased the resilience of the financial system to shocks, by spreading the impact of defaults across a large number of diverse parties. So for both reasons (the small size of exposure and its wide dispersion) the conventional wisdom in policy circles up to the summer of 2007 was that the subprime exposure was too small to lead to widespread problems in the financial system.

Chart 1
The domino model of contagion



Yet, the credit crisis developed with a ferocity that appeared to sweep aside these considerations. There are important lessons here on the mechanisms of financial contagion.

It is worth drawing out the implicit assumptions that may lie behind the presumption that subprime exposures did *not* pose a serious threat to the financial system. The credit crisis of 2007 would, indeed, have been a surprise if financial contagion works primarily through defaults. A naive version of such a view could be depicted in Chart 1.

Here, bank A has borrowed from bank B, and bank B has borrowed from bank C, etc. Then, if A takes a hit and defaults, then bank B will suffer a loss. If the loss is large enough to wipe out B's capital, then B defaults. Bank C then takes a hit. In turn, if the loss is big enough, bank C defaults, etc. We could dub this the "domino" model of financial contagion.

If the domino model of financial contagion is the relevant one for our world, then defaults on subprime mortgages would have had limited impact. This is because the exposure to the subprime sector is small relative to the total size of the balance sheet, and to the capital held by the financial institutions themselves. Any defaults by subprime borrowers could easily be absorbed by the total capital of the financial sector. What is more, the widespread use of securitization will have further spread the exposures, so that any default risk is spread thinly throughout the financial system. There are no weak links in the chain, and therefore any shocks would be absorbed through small losses spread evenly across many institutions.

The domino model of contagion has been examined in many simulation studies conducted at several central banks, but the universal conclusion has been that

1 *Remarks at the Federal Reserve Bank of Philadelphia, October 17th 2007. The link to the text of the speech and charts is at* http://www.ny.frb.org/newsevents/speeches/2007/dud071017.html. *Subprime exposures are small relative to other measures, too. Total US chartered commercial bank assets are 7.74 trillion dollars as of June 2007, while total outstanding mortgages are almost 14 trillion dollars according to the Federal Reserve Board's flow of funds. Asset-backed security (ABS) issuers held 2.8 trillion dollars, commercial banks and savings and credit unions held 4.9 trillion dollars, and Agency and Government Sponsored Enterprise (GSE) backed mortgage pools held 4.1 trillion dollars.*

the impact of the domino model of contagion is very small. It is only with implausibly large shocks that the simulations generate any meaningful contagion.

However, the domino model is flawed. For a start, the domino model paints a picture of passive financial institutions who stand by and do nothing as the sequence of defaults unfold. In practice, however, they will take actions in reaction to unfolding events, and in anticipation of impending defaults. Second, the domino model does not take sufficient account of how prices and measured risks change. In the simplest scenario of the domino model, asset prices are fixed at their book values, and balance sheets take a hit only with default. Such a view is obsolete in the market-based financial system that we have today. Instead, the impact of price changes on balance sheets is likely to be much more potent in generating distress than outright defaults.

Indeed, defaults need not even be *necessary* to generate contagion. Price changes themselves may be enough. Take the episode of the distress suffered by European life insurance companies in the summer of 2002. By the nature of insurers' balance sheets, they have not borrowed from each other as banks do. However, when stock prices plumbed new lows in the summer of 2002, the European life insurers found that their regulatory constraints were beginning to bind. In the United Kingdom, for instance, the usual 'resilience test' applied to life insurance companies in which the firm has to demonstrate solvency in the face of a further 25% stock market decline was beginning to bind. German and Swiss insurers were even more constrained. The remedy for these insurers was to sell stocks, so as to reduce their exposures to them. However, large scale sales merely served to depress prices further, making the constraints bind harder. This generated a further round of selling, and so on. The regulators in the affected countries suspended the solvency tests for several weeks until the crisis abated. For instance, the UK Financial Services Authority diluted the resilience test so as to preempt the destabilizing forced sales of stocks by the major market players.[2]

The domino model of contagion is flawed, and is not useful for understanding financial contagion in a modern, market-based financial system. Instead, the key to understanding the events of 2007 is to follow the reactions of the financial institutions themselves to price changes, and to shifts in the measured risks.

Financial institutions manage their balance sheets actively in response to price changes and to changes in measured risk. Since market-wide events are felt simultaneously by all market participants, the reactions to such events are synchronized. If such synchronized reactions lead to declines in asset prices and higher levels of measured risk, there is the potential for a further round of synchronized reactions. The key players are the financial intermediaries –the broker dealers and commercial banks– whose balance sheets are highly leveraged and hence whose net worth is most sensitive to price changes and shifts in measured risk.

Elsewhere,[3] we have shown that financial intermediaries react in a very different way as compared to households to shifts in prices and risk. Households tend not to adjust their balance sheets drastically to changes in asset prices. In aggregate flow of funds data for the household sector in the United States, leverage falls when total assets rise (see the paper by Adrian and Shin referred below). In other words, for households, the change in leverage and change in balance sheet size are negatively related. However, for security dealers and brokers (including the major investment banks), there is a *positive* relationship between changes in leverage and changes in balance sheet size. Far from being passive, financial intermediaries adjust their balance sheets actively and do so in such a way that leverage is high during booms and low during busts. Leverage is procyclical in this sense.

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. Denote by V the value at risk

2 *FSA Guidance Note 4 (2002): "Resilience test for insurers". See also FSA Press Release, June 28th 2002, No. FSA/PN/071/2002: "FSA introduces new element to life insurers' resilience tests".*

3 *Adrian and Shin (2007): "Liquidity and leverage" working paper, FRB New York and Princeton University,* http://www.princeton.edu/~hsshin/working.htm

per dollar of assets held by a bank. In other words, the total value at risk of the bank is given by $V \times A$ where A is total assets. Then, if the bank maintains capital K to meet total value at risk, then we have

$$K = V \times A$$

Hence, leverage L satisfies

$$L = A/K = 1/V$$

Procyclical leverage then translates directly to the counter-cyclical nature of value at risk. Measured risk is low during booms and high during busts. 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.

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 assets (securities, for simplicity) 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

$$\text{assets/equity} = (101 + D)/11 = 10$$

The solution is $D = 9$. The bank takes on additional debt worth 9, and with the proceeds 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, on the way down. 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

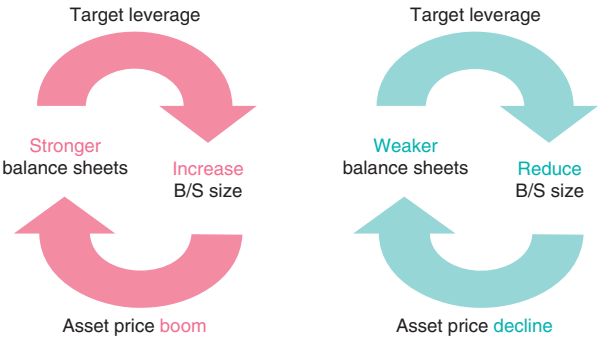
Leverage is now too high ($109/10 = 10.9$). The bank can adjust down its leverage by selling securities worth 9, and paying down 9 worth of debt. Thus, a fall in the price of securities leads to sales of securities. The supply curve is downward-sloping. The new balance sheet then looks as follows.

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.

Chart 2
Price amplification of balance sheet changes

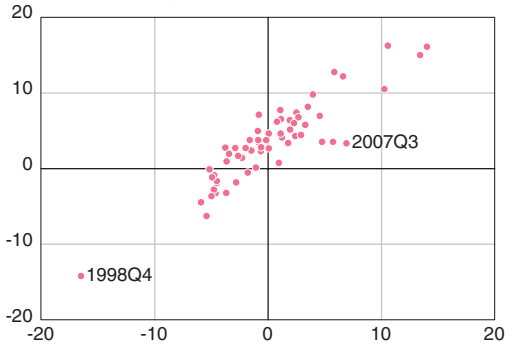


If we hypothesize that greater demand for the asset tends to put upward pressure on its price (a plausible hypothesis, it would seem), then there is the potential for a feedback effect in which stronger balance sheets feed greater demand for the asset, which in turn raises the asset's price and lead to stronger balance sheets. 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.

A striking portrait of procyclical leverage is given in the following figure, which plots the value-weighted change in leverage and change in assets for the five major US investment banks[4] (Bear Stearns, Goldman Sachs, Lehman Brothers, Morgan Stanley and Merrill Lynch), plus Citigroup Global Markets which reported separately from its parent until 2004 (1998Q1 – 2004Q4).

Name	Sample
Bear Stearns	1997Q1 – 2007Q3
Goldman Sachs	1999Q2 – 2007Q3
Lehman Brothers	1993Q2 – 2007Q3
Merrill Lynch	1991Q1 – 2007Q2
Morgan Stanley	1997Q2 – 2007Q3

Chart 3
US investment banks: asset-weighted growth rates of total assets and leverage
(Quarterly growth rates in %)



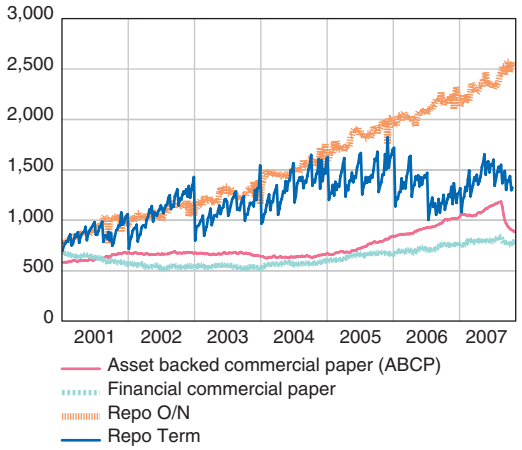
Two features stand out. First, leverage is procyclical. Leverage increases when balance sheets expand. Conversely, leverage falls when balance sheets contract. Thus, leverage tracks the waxing and waning of balance sheets in a way that amplifies the financial cycle. Although "procyclical leverage" is not a term that the banks themselves would use in describing how they behave, this is in fact what they are doing.

Second, there is a striking contrast between the distress in 1998Q4 associated with the LTCM crisis and the credit crisis of 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. 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.

To begin with, let us see the aggregate stock of repos (both term repos and overnight repos), as well as the stock of commercial paper. The commercial paper category is itself sub-divided into the asset backed commercial paper (ABCP) and ordinary financial CP. The four series are given in the chart below, that track the stocks going back to 2001.

4 *At the time of writing, we do not have access to the 2007 3rd quarter figures for Merrill Lynch. Otherwise, the list is complete up to 2007Q3.*

Chart 4
Short-term borrowing of the financial sector
Commercial paper and repurchase agreements (Repos)
(USD millions)

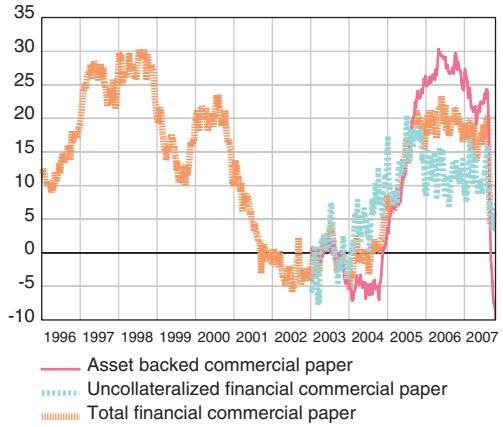


Source: Federal Reserve Bank of New York, Board of Governors of the Federal Reserve

It is noticeable how the stock of asset backed commercial paper has contracted sharply since late June of 2007, even as the overnight repos have not seen any diminution. The drop in ABCP stocks is even clearer in Chart 5 that gives the growth rates of the series.

The drop in ABCP issuance is very sharp indeed after the end of June 2007. The red line (ABCP) goes off a cliff, so to speak.

Chart 5
Commercial paper outstanding
(Annual growth rates in %)



Source: Board of Governors of the Federal Reserve

The contraction of the ABCP market suggests an explanation for why bank balance sheets have not (so far) contracted as sharply as they did in 1998. The beginnings of the credit problems of 2007 were first manifested by falling prices of securities that are associated with the subprime sector. For instance, the ABX indices started to fall in June of 2007. The ABX indices track the credit default swaps (CDS) associated with various rated tranches of collateralized debt obligations (CDOs) written on subprime mortgages, and are compiled by the London firm Markit.[5]

The falls in the prices of securities proceeded into July. By late July, measured risks increased to uncomfortable levels. In particular, the off balance sheet structured investment vehicles (SIVs) 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-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 ABCPs led to a fall in the demand for the liabilities issued by SIVs and conduits. In late July and early August, 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. 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 for other ways to curtail lending. Their natural response was to cut off lending that was discretionary. The seizing

5 www.markit.com

up of the interbank credit market can be seen as the conjunction of:

- Desired contraction of balance sheets
- "Involuntary" lending due to the tapping of credit lines by distressed entities.

The question is how far the contraction of balance sheets have to run in the current crisis. Given the recent disclosed losses at the major banks arising from the subprime crisis, it would be reasonable to conjecture that the contraction of balance sheets still has some way to go.

The balance sheet perspective gives new insights into the nature of financial contagion in the modern, market-based financial system. 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 subprime 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.