

Deciphering the 2007-08 Liquidity and Credit Crunch*

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1 Introduction

Financial markets experienced extraordinary events in 2007 and 2008. The increase in delinquency rates of subprime mortgages, coupled with the mismatch in the maturity structures of off-balance-sheet conduits and structured investment vehicles (SIVs), led to a sudden drying up of asset-backed commercial paper and the failure of several banks, including a classic bank run in the United Kingdom. The eruptions in credit and money markets ultimately led to a run on one of the leading investment banks in the United States. Besides banks, “quant hedge funds,” whose trading follows statistical models, were hit.

While the estimated losses in subprime mortgages of between US\$ 400 and 500 billion may appear large at first sight, they are relatively modest in terms of wealth destruction when put into perspective. For example, they roughly correspond to a not-so-uncommon drop of between 2 and 3 percent of the U.S. stock market. Nevertheless, a distinguishing feature of the present crisis is that these losses directly affected the highly leveraged financial sector. Banks’ total write-downs on mortgage products up to February were roughly US\$ 120 billion, while the market cap of the major banks declined roughly two and a half times that amount.

In this light, it seems important to understand the amplification mechanisms that explain why the mortgage crisis has caused such large dislocations and turmoil in the financial markets. The first mechanism involves liquidity spirals that arise from deterioration in borrowers’ balance sheets. When asset prices and market liquidity drop during times of crisis, funding requirements for financial institutions increase. This happens because the collateral value of the assets on borrowers’ balance sheets erodes and margins rise or investors are unable to roll over their short-term liabilities. Higher margins force financial institutions to cut back on leverage, exacerbating the initial price decline. A key problem is the maturity mismatch caused by leveraged financing.

A second amplification mechanism works through the lending channel. Uncertainty about future funding needs, combined with potentially limited access to the lending market at that time, can lead to hoarding and interest rate surges in the interbank market. A third mechanism is runs on financial institutions. Runs occur when each individual financier has an incentive to curtail funding before others do so. Finally, when financial institutions are lenders and borrowers at the same time, network and gridlock risk might emerge. In a

gridlock situation, each individual institution is unable to pay its obligation only because the others are not paying theirs. While coordination might resolve this, it is difficult in today's complex and interwoven financial system.

The next section explains how new structured financial products, off-balance-sheet vehicles, and, more generally, the transformation from a classical banking model to an “originate and distribute” model led to a deterioration of lending standards, contributed to the recent boom in house prices, and fueled the credit expansion behind the recent bonanza in leveraged buyout markets. Section 3 provides an event logbook on the market turmoil in 2007-08 and summarizes the hedge fund quant crisis of August 2007. The core of the article, Section 4, illustrates the different mechanisms at work. Finally, the paper concludes with a brief summary and outlook for the future.

2 The Trend Leading Up to the Liquidity Squeeze

The financial architecture has undergone a dramatic transformation in the last two decades. Previously banks that granted mortgages or loans traditionally kept them on their books, but now they transfer the credit risk to other financial institutions in innovative ways. The traditional banking model was replaced by an “originate and distribute” banking model in which banks grant mortgages and loans, repackage them, and pass them on to various financial investors. A continuing process of financial innovation led to an array of new structured products, to the securitization of many risk categories, and to the emergence of a shadow banking system in the form of off-balance-sheet vehicles.

2.1 Securitization: Insuring, Pooling and Tranching Risk - CDSs and CDOs

After making a loan or buying a corporate bond, a bank can either sell it outright, or insure itself by buying a credit default swap (CDS). The CDS buyer pays a periodic fixed insurance fee to a protection seller in exchange for a payment by the seller contingent upon a credit event or default. CDSs are fairly liquid. Banks can also directly trade liquid indices that consist of portfolios of CDSs, such as CDX in the U.S. or iTraxx in Europe.

Instead of selling or protecting individual loans directly, banks typically first create structured products. These consist of forming portfolios of mortgages, loans, corporate

bonds, or other assets like credit card receivables, and then slicing them into different tranches before selling them in the market. Legally, the portfolio is usually transferred to a special-purpose vehicle (SPV), a financial entity whose sole purpose is to collect principal and interest cash flows from the underlying assets and pass them on to the owners of the various tranches.

Forming a portfolio exploits the power of diversification, while tranching allows the firm to market different parts of the product to investor groups with different risk appetites. The safest tranche (often known as the “super senior” tranche) offers investors a relatively low interest rate, but it is the first to be paid out of the cash flows to the SPV. In contrast, the owners of the most junior tranche—often referred as to “toxic waste” or the equity tranche—will be paid only after all other tranches have been paid. The mezzanine tranches are in between.

The exact cutoffs between the tranches for structured products are typically chosen in such a way as to ensure a specific rating for each (e.g., AAA for the upper tranches). The tranches are then separately sold to pension funds, hedge funds, structured investment vehicles (SIVs), etc., while the toxic waste is usually (but not always) held by the issuing bank to ensure adequate monitoring of the loans by the bank. Junior tranches of these structured products embed leverage: Since the senior tranches get paid first, they resemble a leveraged position in the underlying cash flows. Note that the top tranche is safer when the underlying assets are less correlated.

Structured products and asset-backed securities (ABSs) go by many names. Collateralized debt obligations (CDOs) are the most common form. Each CDO consists of a collection of tranches and of an underlying portfolio of debt, such as corporate bonds.¹ If the tranches are derived from a portfolio of loans, they are also referred to as collateralized loan obligations (CLOs) and for mortgages they are known as collateralized mortgage obligations (CMOs). CDOs of a pool of CDOs are referred to as “CDO squared.”

¹There are also other forms of CDOs in addition to the “funded cash CDOs” described above. Funded CDOs are backed by a portfolio of assets that are held by a SPV. If they backed by a portfolio of corporate bonds, they are cash funded. Synthetic CDOs are funding, i.e. backed by CDS contracts and Treasury bonds. Unfunded CDOs are not backed by a portfolio of assets. The most liquid CDOs whose value is derived from CDS indexes like CDX or iTraxx are unfunded.

2.2 Shortening the Maturity Structure

Since most investors prefer assets with short maturities,² commercial banks have created off-balance-sheet vehicles that shorten the maturity of long-term structured products. Moreover, investment banks increasingly relied on the overnight repo market to finance their balance sheet.

Off-Balance-Sheet Vehicles: Conduits, SIVs, and ABCPs

Off-balance-sheet vehicles—most of them in the form of conduits or structured investment vehicles (SIVs)—invest in illiquid long-maturity assets and issue short-maturity paper in the form of asset-backed commercial paper (ABCP), which has an average maturity of 90 days, and medium-term notes (MTN), which have an average maturity of just over one year. ABCP is backed by the underlying assets, allowing the owner to seize and sell the collateral asset in case of default. ABCP became so popular in recent years that it was the dominant form of outstanding commercial paper at the start of 2006.

The off-balance-sheet vehicles' strategy of investing in long-term assets and borrowing using short-term paper exposes them to funding liquidity risk, since the commercial paper market might suddenly dry up. To ensure funding liquidity, the sponsoring bank grants a credit line, or a so-called liquidity backstop.³ Thus, the banking system still bears the liquidity risk from the maturity transformation—like in the traditional banking model of banks, in which commercial banks take on short-term deposits and invest in long-term projects.

Financing the Balance Sheets of Investment Banks: The Overnight Repo Market

Over the years, investment banks financed an increasing part of their balance sheets with short-term collateralized lending in the form of repurchase agreements, or “repos.” In a repo contract, a firm borrows funds by selling a collateral asset today and promising to repurchase it at a later date. Importantly, the growth in repo financing as a fraction of

²This allows lenders to withdraw funds at short notice to either accommodate their own funding needs (as in Diamond & Dybvig (1983), Allen & Gale (2007)) or to serve as a commitment device to discipline banks (as in Calomiris & Kahn (1991), Diamond & Rajan (2001)). Stein (2005) argues that short-maturity financing may serve as a signaling device. In his model mutual funds allow early withdrawals (i.e. are open ended), in an attempt to signal their managers' skill. However, signaling is unsuccessful, since in equilibrium bad fund managers mimic good ones resulting in a pooling equilibrium with an inefficiently short-term maturity structure.

³According to Fitch, the major U.S. ABCP sponsor banks are Citibank (US\$ 100 billion, or 25 percent of SIV), JPMorgan Chase (US\$ 77 billion), and Bank of America (US\$ 60 billion); in the European Union, the major ABCP banks are HBOS (US\$ 42 billion), ABN Amro (US\$ 40 billion), and HSBC (US\$ 32 billion).

investment banks' total assets is mostly due to an increase in overnight repos. Almost 25 percent of total assets were financed by overnight repos in 2007, an increase from about 12.5 percent in the year 2000. Term repos with a maturity of up to three months have stayed roughly constant at 12.5 percent as a fraction of total assets. So has the equity/debt leverage ratio since 2001. In short, repo financing became much more short term. The increase in investment banks' reliance on overnight financing requires them to roll over a large part of their funding on a daily basis—a trend that makes investment banks subject to funding liquidity risk.

2.3 Attractiveness of Securitized and Structured Products

The structuring of financial products is very appealing since it allows issuers to *cater* to the specific needs of different investor groups. Risk can be shifted to those who can bear it, and it can be widely spread among many market participants, allowing for lower mortgage rates and lower interest rates on corporate and other loans. Securitization allows certain institutional investors to hold assets (indirectly) that they were previously prevented from holding for regulatory reasons. For example, certain pension funds that were allowed to invest only in AAA-rated fixed-income securities could suddenly invest in an AAA-rated senior tranche of a portfolio of single A-rated securities.

Paradoxically, however, a large part of the credit risk never left the banking system, since banks, including sophisticated investment banks and hedge funds, were among the most active buyers of structured products.⁴ This suggests that other motives were also at work.

One distortionary force that led to the popularity of SIV structures is *regulatory and ratings arbitrage*. Moving loans into off-balance-sheet vehicles and granting a credit line to ensure a AAA rating allowed banks to save on regulatory capital. The Basel I accord imposes on banks an 8 percent capital charge for holding loans on their balance sheets, while the capital charge for contractual credit lines is much lower. Moreover, there is no capital charge at all for so-called reputational credit lines, non-contractual liquidity backstops that the SIV-sponsoring banks provide purely to maintain their reputation. The subsequent Basel II accord corrects the preferential treatment of contractual credit lines.

Nevertheless, “SIV securitization” failed to slow after the Basel II accord, which went

⁴See, e.g., Duffie (2007).

into effect on January 1, 2007, in Europe and is still to be fully implemented in the U.S. Note that Basel II regulations could also be outmaneuvered since they imposed lower capital charges on assets that were highly rated by credit agencies. For example, a bank rated A- or lower could repackage its loans and buy some of them (or similar assets) back as AAA-rated assets and thereby save on regulatory capital charges. Even more importantly, SIV securitization allowed banks to raise capital at a lower AAA interest rate instead of the interest rate they would have had to pay based on the bank's own significantly lower rating. Rating arbitrage was optimal since rating agencies did not (fully) adjust the banks' own ratings for extending credit lines to the sponsored off-balance-sheet vehicles.⁵

Structured products seemed relatively attractive to investors who took credit ratings at face value and ignored the fact that structured products receive a more favorable rating compared to corporate bonds. This discrepancy is less surprising once one learns that rating agencies collect the highest fees for structured products up front. "Rating at the edge" might have contributed to this difference in standards. While a AAA-rated bond might have a zero default risk or might have just made it into the AAA-rated group, tranches were always sliced in such a way that they just made the AAA rating. Indeed, issuers of CDOs worked very closely in conjunction with rating agencies to determine the "tranching attachment points" of the tranches. It is also interesting to note that municipal bonds received the least favorable rating—a fact monoline insurers are not opposed to since this allows them to charge municipalities a higher insurance premium.

Many professional investors' statistical models provided overly optimistic forecasts about structured mortgage products for a couple of reasons: 1) they were based on historically low mortgage default and delinquency rates that arose in a credit environment with tighter credit standards, and 2) past data suggested that housing downturns are primarily regional phenomena—the U.S. had never experienced a nation-wide housing slowdown. The seemingly low cross-regional correlation of house prices generated a perceived diversification benefit that especially boosted the evaluations of AAA-rated tranches.

Finally, structured products enjoyed popularity among many fund managers and sub-

⁵This practice of raising capital indirectly through highly rated SIVs was especially pronounced for partially state-owned German banks. These banks were accustomed to AAA ratings since they used to have a form of state guarantee. When this privilege was lost as part of an EU decision from July 18, 2005, onward, the banks found that securitization could be used as an alternative way to continue financing at AAA interest rates.

division⁶ managers within large firms. They saw structured products as a creative way to (seemingly) enhance their portfolio returns and build up a good track record. Note that structured products' tail-risk exposure is not revealed immediately. On rare occasions, they may lead to a catastrophic loss, but then the track record is destroyed anyway. Managers' incentives are especially distorted in a low-interest-rate environment in which many portfolio managers were "searching for yield."⁷ Moreover, investing in junior CDOs (or even CDO squared) allows hedge funds to take on leveraged positions without being forced to explicitly state a high leverage ratio.⁸

Last but not least, the illiquidity of many junior CDOs might not have been seen as a drawback by many managers. Illiquid assets typically carry a liquidity premium. In addition, they grant investors some discretion over how to value them. Since a reliable market price does not exist for many junior CDOs, a mark-to-market valuation has to give way to a mark-to-model approach. If managers can mark-to-model, they can smooth their monthly returns over time, which makes them appear to be less risky and boosts their Sharpe ratio (a key performance metric).⁹

2.4 Consequences: Cheap Credit, the Housing Boom, and the Private Equity Bonanza

Ultimately, the emergence and popularity of these structured products led to the run-up of the current liquidity crisis by making credit extremely cheap and causing credit spreads¹⁰ to shrink to historically low levels.

⁶The Shareholder Report on UBS's Write-Downs (2008) provides a striking example of distortionary behavior by a small division within a financial institution. Two-thirds of UBS's 2007 subprime losses (totaling US \$ 18.7 billion) were attributable to the CDO desk in the investment banking division, a group of no more than 40 employees.

⁷Note that fund managers' personal compensation structure gives them more of an incentive to take on risk when interest rates are low. This is because they usually receive a percentage share of the upside while bearing less of the downside. Therefore, in an environment with a high risk-free rate, the fund manager can essentially guarantee a positive payoff just by investing in the risk-free asset. By following a riskier strategy, he puts this payoff at risk. When the interest rate is close to zero, this "guaranteed payoff" is very small, so the manager has less to lose from taking on the additional risk.

⁸For example, Bear Stearns's Asset Management Fund reportedly had a leverage ratio of 2:1 for its High Grade Structured Credit Strategies Fund (or 3:1 for its highly leveraged High Grade Structured Credit Strategies Enhanced Leverage Fund), but investing in CDOs allowed it to obtain a much higher effective leverage ratio.

⁹Marking-to-model frameworks often underemphasize the liquidity aspect and often rely simply on liquid tranches on major CDS indices, such as CDX and iTraxx. They also give the manager significant leeway in estimating the correlation structure of underlying assets, a crucial parameter in determining the value of CDOs.

¹⁰The credit spread is the difference in interest rates between risky corporate bonds and risk-free government bonds.

The main disadvantage of securitization is that the transfer of credit risk distances the borrowers from the lenders. First, it makes it unclear who holds what risk. In the end, it might very well be that the risk comes back to the issuing bank, even though it thought it had transferred the risk on to, say, a hedge fund. Second, the banks' incentive to carefully approve loan applications, and their incentive to monitor (and even to collect) these loans, is drastically reduced. Since a big part of the risk is now borne by other financial institutions, banks essentially hold the full risk only for some months before it is passed on to others. Put differently, nowadays a bank faces only a "pipeline risk." That is, only risks that are not yet passed on and are still in the bank's pipeline are the bank's concern.¹¹

Securitization allowed almost everyone to become a mortgage broker. It led to an erosion of lending standards and to excesses in lending. Mortgage brokers offered teaser rates, no-documentation mortgages, piggyback mortgages (a combination of two mortgages that eliminates the need for a down payment), and NINJA ("no income, no job or assets") loans. All these mortgages were granted under the premise that house prices could only rise, making any background check unnecessary since the lender could always refinance using the value of the house. Of course, lower mortgage rates resulted in a housing frenzy, boosting the price-to-rent ratio to levels never seen before. Lending standards eroded, particularly for subprime mortgages, which account for about 14 percent of all mortgages. Mortgages are categorized into four categories in the U.S.: prime mortgages that can either be conforming or non-conforming (jumbo), depending on whether the mortgage can be passed on to one of the federal mortgage agencies (Fannie Mae or Freddie Mac); subprime mortgages of lower quality; and Alternative-A mortgages that are granted to borrowers who are not quite prime but have better credit than subprime borrowers.

Low credit spreads also made leveraged buyouts very attractive by making the cost of funds very low, causing an acquisition spree by private equity funds. Sizable public companies were delisted, and "going private" was the motto of the time. Since private equity funds primarily took over "value firms," i.e., firms with high book-to-market ratios, leveraged buyouts boosted value stocks.

For several months, many informed observers were seriously concerned about how low credit spreads had gone. Some even spoke of a "liquidity bubble" or "credit bubble."¹²

¹¹See Keys et al. (2008) for empirical evidence that increased securitization led to a decline in credit quality.

¹²See, for example, the *Wall Street Journal* article by Dennis K. Berman, "Sketchy Loans Abound with

However, they were reluctant to invest on that view. Why? Citigroup's former CEO, Chuck Prince, provided a succinct answer by referring to Keynes's analogy between bubbles and musical chairs:

“When the music stops, in terms of liquidity, things will be complicated. But as long as the music is playing, you've got to get up and dance. We're still dancing”.¹³

In other words, no single player had an incentive to derail the system, since investors' willingness to buy structured products made it more profitable to ride the wave than to lean against it, and it was not clear when other sophisticated players would stop playing the game. In academic terms, the lack of synchronization among the sophisticated players enabled the credit/liquidity bubble to persist and made it difficult to predict when the tide would turn. Nevertheless, there was a widespread feeling that the day of reckoning would eventually come, at which point everybody would rush to sell high-risk bonds and reverse their positions in credit derivatives.

3 The Unfolding of the Crisis - Event Logbook

3.1 Subprime Mortgage Crisis, Money Markets, and the Banking Crisis

Given the erosion in lending standards, it is not surprising that more and more mortgages (especially in the subprime category) became delinquent and that home foreclosures subsequently skyrocketed. An increase in subprime mortgage defaults was first noted in February 2007, as can be seen by looking at the ABX (home equity) index, which reflects the cost of insuring a basket of mortgages of a certain rating against default. The situation calmed in March, but events worsened again in May. On May 4, UBS shut down its internal hedge fund Dillon Read, after suffering about US\$ 125 million of subprime-related losses. Later in May, Moody's put 62 tranches across 21 U.S. subprime deals on downgrade review, indicating that it was more likely that these tranches would be downgraded in the near future. This led to a further deterioration of mortgage-related products (as can be seen in Figure

Capital Plentiful, Debt Buyers Take Subprime-Type Risk,” March 27, 2007, Page C1 and Abreu & Brunnermeier (2002) for a theoretical model that explains why individual market participants are reluctant to act against the mispricing.

¹³From the front page of the *Financial Times*, July 10, 2007.

1). Then, in mid-June, the news that two hedge funds run by Bear Stearns were having trouble meeting margin calls caught the attention of the market. Bear Stearns injected US\$ 3.2 billion in loans only in the less leveraged of the two distressed funds. Note that Bear Stearns did not have any contractual obligation, but took action solely to save its reputation.¹⁴

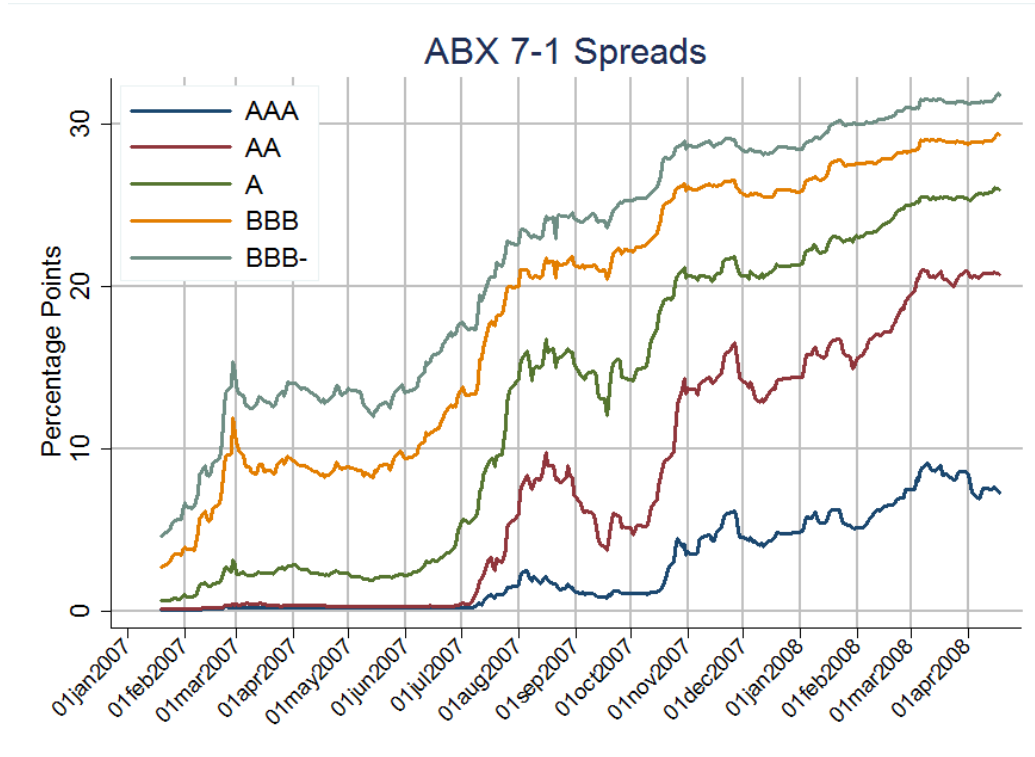


Figure 1: *ABX spreads, series 7-1* is based on credit default swaps on 20 asset-backed securities (rated, for example, BBB-) that contain subprime mortgages. To buy protection against default on a pool of underlying assets like home equity deals, one must pay a fixed spread over time (say, 5 percent). Source: LehmanLive.

Several downgrades by Moody’s, Standard & Poor’s, and Fitch unnerved credit markets in June and July. The major U.S. home loan lender, Countrywide Financial Corp., announced an earnings drop on July 24. On July 26, the NAHB index revealed that new home sales had declined by 6.6 percent year-on-year, and the largest U.S. homebuilder reported a loss in the quarter.

Starting in mid-June of 2007, corporate spreads—the difference between interest rates

¹⁴It is not clear whether Bear Stearns would have bailed out the fund had the trouble emerged later on in the crisis, after other funds and SIVs had already defaulted and thereby lowered the reputational costs of failing a fund.

on corporate bonds and government bonds—also widened.¹⁵ This occurred despite the fact that corporations were well capitalized, with cash holdings at all-time highs. The spillover effect to corporate credit may have occurred because investors became concerned about how to value structured products in general, whether for mortgage products or corporate credit products, and confidence in the reliability of rating agencies eroded. Indeed, one can argue that corporate credit spreads simply returned to their long-run historical average in the fall of 2007 after some years in which they were artificially low.

What really hurt the banking universe was the drying up of the short-term *asset-backed commercial paper market* (ABCP). Figure 2 shows the sharp drop-off in the number of outstanding ABCPs. Note that these problems were mostly confined to the ABCP market. Non-asset-backed commercial paper (be it financial or nonfinancial) was affected only slightly. Across the Atlantic, IKB, a small German Bank, was the first European victim of the subprime crisis. Its ABCP conduit suffered losses and was unable to roll over its ABCP, forcing the conduit to draw on its credit line from IKB, which IKB could not shoulder. Hectic weekend negotiations erupted and on Monday, July 30, IKB announced that its main shareholder, KfW (a government-owned bank created as part of the Marshall Plan after the Second World War), would inject liquidity. On August 1, a general Euro 3.5 billion rescue package involving public and private banks was announced.

On July 31, American Home Mortgage Investment Corp. announced its inability to fund lending obligations, and it subsequently declared Chapter 11 bankruptcy on August 6.

On August 9, the French bank BNP Paribas froze redemptions for three investment funds, citing the inability to value structured products. Following this event, banks were reluctant to lend to each other, and the interbank LIBOR rate rose.

In addition to the commercial paper market, banks finance themselves on the interbank market, fed funds market and the repo market. In the interbank market, banks borrow and lend to each other unsecured at individually agreed-upon rates, typically one to three months. The LIBOR rate, sometimes also referred to as the Eurodollar LIBOR rate, is an average indicative quote for the interbank lending market and forms the basis for many short-term interest rates. In the repurchase agreement, or “repo,” market financial institu-

¹⁵This spillover effect can be seen by overlaying the ABX spread with the CDX spreads. The CDX reflects a portfolio of CDSs for corporate bonds, while the ABX captures a portfolio of CDSs for mortgage products.

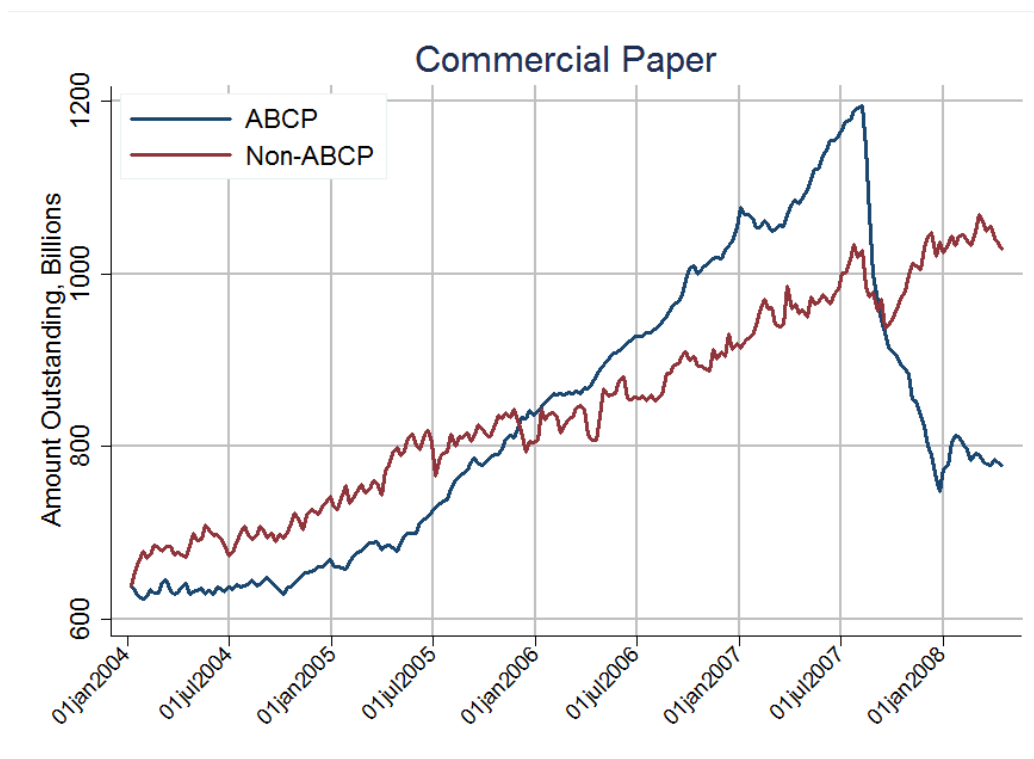


Figure 2: Outstanding asset-backed commercial paper (blue curve) and unsecured financial, nonfinancial, and other commercial paper (red curve). Source: Federal Reserve Board.

tions can obtain funding on a collateralized basis by selling securities, either theirs or their clients', and agreeing to repurchase them when the loan matures. General collateral (GC) repos use as collateral various Treasury bonds, while MBS repos use mortgage-backed securities as collateral. The U.S. Federal Funds rate is the overnight rate at which banks lend reserves to each other. Banks have to maintain reserves with the Federal Reserve to back checking account deposits. Since reserves in the U.S. (unlike in Europe) earn no interest from the Fed, banks that have excess reserves prefer to lend them to financial institutions that are short of reserves. The Fed targets this rate by injecting or withdrawing reserves via open market operations using repo contracts.

In response to the freezing up of the interbank market on August 9, the European Central Bank injected Euro 95 billion in overnight credit into the interbank market. The U.S. Federal Reserve followed suit, injecting US\$ 24 billion. While certain conduits had already experienced trouble in rolling over their ABCP in July, by early August the ABCP market as a whole was affected.¹⁶ The average quoted ABCP rate jumped from 5.39 percent

¹⁶

to 5.75 percent on August 9 and to 6.14 percent on the following day. Like the ABCP rate, the LIBOR also increased during this time (see top panel of Figure 3).¹⁷

The top panel of Figure 3 plots the three-month LIBOR minus the overnight interest swap rate (OIS) (dark-blue shaded area). The LIBOR reflects banks' default risk and liquidity risk over the next three months, while the overnight rate is essentially riskless and hence not subject to pressures associated with these risks. In order to construct the spread, the overnight rate is transformed into a fixed three-month swap rate, the same maturity as LIBOR. The graph shows that the first of three "illiquidity waves" started on August 9, 2007. At that time, the perceived default and liquidity risks of banks rose significantly, driving up the LIBOR.

Historically, many market observers focused on the so-called TED (Treasury-Eurodollar) spread, the difference between (Eurodollar) LIBOR and the Treasury bill rate. The TED spread is given by combining both shaded areas (blue and red) of the top panel of Figure 3. Compared to the LIBOR-OIS spread, the TED spread captures the additional fact that Treasury bonds—the best form of collateral—become especially valuable in times of crisis. During these times, everybody lends only against Treasury bonds as collateral, pushing down the Treasury bond rate. Graphically, this shows up as sharp downward spikes of the red shaded area.

It is not surprising that these downward spikes coincide with the spikes of the MBS-GC repo spread in the lower panel of Figure 3. The latter is the difference between the repo rate one has to pay using mortgage-backed securities as collateral and the repo rate on general collateral, i.e., various Treasury bonds. This spread is another liquidity measure and arguably more reliable than the TED spread, since the Eurodollar LIBOR rate is also influenced by the fact that European banks are systematically short U.S. dollars.

Most interestingly, the agency spread, the difference between 30-year agency bonds¹⁸ and 30-year Treasury bonds, depicted in the lower panel as a dashed line, seems to have

¹⁷Note that CPs are quoted as a discount rate to US\$100 face value and can differ from ABCP issuer to ABCP issuer. The CP rates published on <http://www.federalreserve.gov/releases/cp/> reflect only indicative quotes for an average issuer. The CP rate closely follows LIBOR, the rate at which AA-rated banks lend to each other (on an uncollateralized basis). If the CP rate were to strongly exceed LIBOR, each individual bank would have an incentive to borrow from another bank at LIBOR and buy ABCP. Similarly, the Federal Reserve's discount rate (at which 7,000 banks can borrow against collateral) should put a cap on the discount rate for CP.

¹⁸Agency bonds are issued by the quasi-governmental organizations Fannie Mae and Freddie Mac and are therefore often viewed as effectively enjoying a governmental guarantee.

anticipated the illiquidity wave that hit on August 9. The same is true for the second wave that occurred later in 2007.

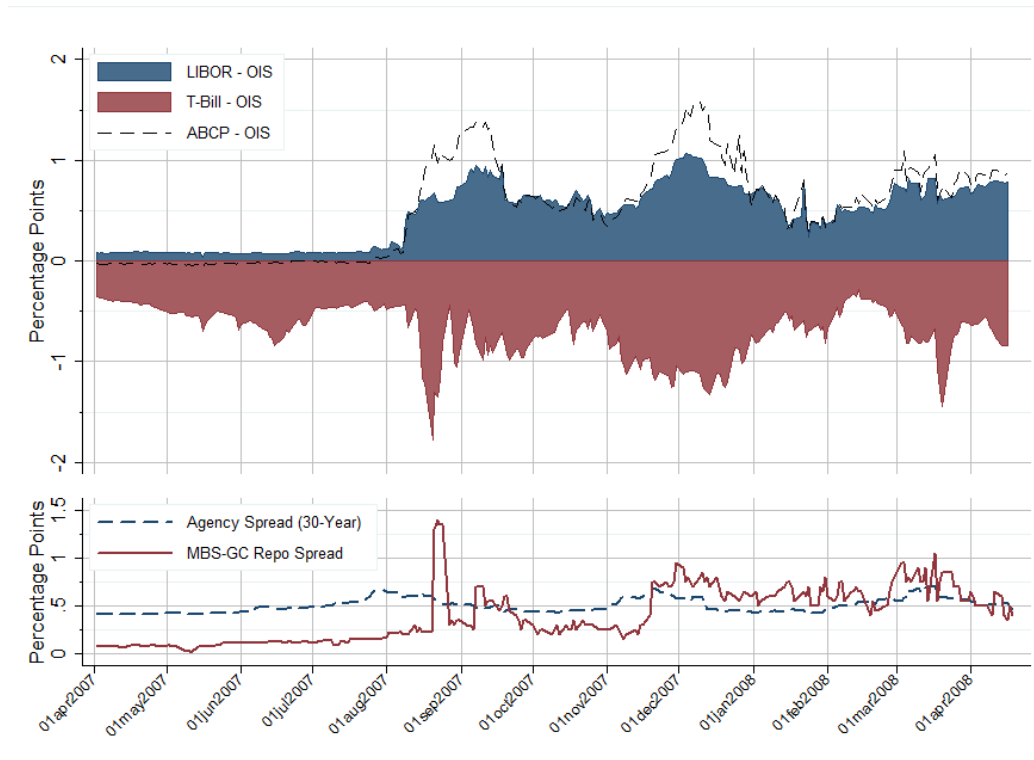


Figure 3: The top panel shows the LIBOR-OIS spread (blue shaded area). The TED spread (LIBOR minus the Treasury bill rate) is given by the sum of both shaded areas and reflects that Treasury bonds are especially sought-after collateral in times of crisis. The MBS-GC repo spread in the lower panel also reflects the special role of Treasury bonds as collateral. It is defined as the difference between the repo rate one has to pay using mortgage-backed securities as collateral and the repo rate on general collateral, i.e., various Treasury bonds. The lower panel also shows the *agency spread* (dashed line), the difference between agency bonds issued by Freddie Mae and Fannie Mac and 30-year Treasury bonds. Finally, the top panel also shows the ABCP rate minus OIS spread. Sources: Bloomberg, LehmanLive, Global Insight, and Federal Reserve Board.

All through August, rating agencies continued to downgrade several conduits and SIVs. To alleviate the liquidity crunch, the Federal Reserve reduced the discount rate by half a percentage point to 5.75 percent on August 17, broadened the type of collateral that banks could post, and lengthened the lending horizon to 30 days. Around 7,000 banks can borrow at the Fed’s discount windows.¹⁹ On the same day, it also became apparent that

¹⁹However, banks are reluctant to borrow at the Fed’s discount window since it signals that they don’t have access to the (cheaper) interbank market. The U.S. Federal Reserve and the U.S. Treasury Department actively tried to persuade banks to make use of the discount window in an effort to overcome this negative stigma.

Sachsen LB, a second German bank, could not shoulder its liquidity commitments toward its conduit Ormond Quay. A bailout was orchestrated, which resulted in a takeover of Sachsen LB by LBBW on August 26. Further downgrades, another drop in outstanding ACBP, and worsening employment numbers convinced the European Central Bank to hold off on an intended rate increase on September 6.

On September 18, the Fed lowered the federal funds rate by half a percent (50 basis points) to 4.75 percent and the discount rate to 5.25 percent. The Bank of England, on the other hand, took a strong stand and held its bank rate fixed at 5.75 percent on September 6. This hurt the U.K. bank Northern Rock, a former building society, which relied heavily on short-term financing. On Friday, September 19, the U.K. experienced its first bank run in more than a century. Northern Rock faced a funding liquidity crisis even though its loan portfolio was sound. Supposedly, it had no exposure to the U.S. subprime market, and its actual default rates did not increase compared to previous years. Still, it could not obtain the short-term liquidity necessary to sustain its long-term loans. Then, on Friday, September 28, the U.S. Internet banking pioneer NetBank went bankrupt and was taken over by ING Bank.

October 2007 was characterized by a series of write-downs by major international banks. The situation eased significantly, as banks seemed to clean their books and the Fed's liquidity injections appeared to be effective. Also, several major banks were in negotiations with sovereign wealth funds (SWFs) for an equity infusion to strengthen their balance sheets. Taken together, SWFs invested more than \$US 38 billion from November until mid-January in major U.S. banks.²⁰ Nevertheless, the Fed cut its main interest rates by another 0.25 percent on October 31.

Things worsened again starting in November, as it became clear that earlier estimates of the total loss in mortgage markets of US\$ 200 billion had to be revised upward (see the ABX indices of Figure 1). As a consequence, many banks were forced to take additional, larger write-downs, leading to a subsequent widening of the LIBOR-OIS spread (see Figure 3). The LIBOR peaked in mid-December, leading to another interest rate cut of 0.25 percentage point by the Fed on December 11. Note that banks preferred to finance themselves in the LIBOR interbank market rather than make use of the Fed's discount window, which offered significantly better terms but had a stigma attached to it. To overcome this stigma,

²⁰See IMF Global Stability Report, April 2008.

on December 12 the Fed announced the creation of the Term Auction Facility (TAF). Commercial banks could anonymously bid for 28-day loans against a broad set of collateral. This step significantly reduced the LIBOR and made Treasury bonds less special.

Amid continuous write-downs, the investment community's primary worry in January and early February was the potential downgrading of so-called monoline insurers. Monoline insurers' original business model was to insure municipal bonds against default, guaranteeing a AAA rating for the bonds. However, in recent years the thinly capitalized monoline insurers also extended guarantees to mortgage-backed securities and other structured products. As losses in the mortgage market mounted, the securities were on the verge of being downgraded by all three major rating agencies. This had the potential to trigger a ripple of downgrades of hundreds of municipal bonds, corporate bonds, and structured products, with a face value of US\$ 2,400 billion. And this in turn would have put money market funds under severe pressure. Money market funds pledge never to "break the buck," i.e., they promise to maintain the value of every dollar invested and hence demand that underwriters of assets agree to buy back the assets if needed. However, this buy-back guarantee holds only if the rating of the underlying asset does not change. A downgrade could therefore force a huge sell-off of a wide set of assets by money market funds.

On Saturday, January 19, Fitch, one of the rating agencies, downgraded one of the monoline insurers, Ambac, unnerving the markets on Monday, January 21. While markets in the U.S. were closed for Dr. Martin Luther King Day, share prices worldwide dropped precipitously. Emerging markets in Asia lost about 15 percent, and Japanese and European markets were down around 5 percent. The sell-off continued in the morning of Tuesday, January 22, in Asia and Europe. Dow Jones and NASDAQ futures were down 5 to 6 percent, indicating a large drop in the U.S. equity market as well. Given this environment, the Fed decided to cut the federal funds rate by 0.75 percentage point to 3.5 percent—the Fed's first "emergency cut" since 1982. It turns out that part of the downturn can be attributed to the aggressive unwinding of Société Générale's Euro 49.9 billion position that the rogue trader Jérôme Kerviel had secretly acquired in unauthorized trading. The emergency interest rate cut was subsequently justified by negative unemployment data, which led the Fed to cut the federal funds rate by another 0.5 percent at its regular FOMC meeting on January 30. In contrast, the European Central Bank took a different route and kept its interest rates fixed.

The potential downgrade of monoline insurers also created significant selling pressure on the municipal bond market. Municipal bonds are so-called auction-rated securities (ARS) that are traded in an auction at regular intervals. Since ARS brokers were reluctant to commit capital and make markets, many rate-setting auctions failed, sales were rationed, and remaining transactions occurred at a prespecified penalty interest rate. The first auctions failed on February 7. On February 13, 80 percent of the auctions failed.

In early March, the spread between agency bonds and Treasury bonds started to widen again, as shown in the lower panel of Figure 3. The wider spread hurt Carlyle Capital, an Amsterdam-listed hedge fund, which was heavily invested in agency papers. On March 2, Carlyle received margin calls. As it became clear that it could not meet the margin calls, Carlyle's collateral assets were seized and partially liquidated. This action depressed the price of agency bonds further, hurting especially the investment bank Bear Stearns. Not only did Bear Stearns hold large amounts of agency papers on its own, but it was also one of the creditors to Carlyle.

On March 11, the Federal Reserve Bank of New York announced its US\$ 200 billion Term Securities Lending Facility (TSFL). This program allows investment banks to swap agency and other mortgage-related bonds for Treasury bonds for up to 28 days. No bank could immediately take advantage of this program since the first of the weekly auctions was only held on March 27.²¹ Some market participants might have mistakenly interpreted this move as a sign that the Fed knew that some investment bank might be in difficulty. Naturally, they pointed to the smallest, most leveraged investment bank with large mortgage exposure, Bear Stearns.²²

Also on March 11, one of Goldman's derivatives group sent an e-mail to hedge fund Hayman Capital that was widely interpreted to mean that Goldman would no longer step in for clients on Bear Stearns's derivatives deals. For example, Goldman would not allow nettings that would directly expose them to Bear Stearns (see Figure 7 in Section 4.4). That news caused unease among Bear Stearns's hedge fund clients, and many of them fled. Note that Bear Stearns's clients had held about US\$ 60 billion in margin accounts. Bear Stearns's liquidity situation worsened dramatically during the subsequent day. The firm,

²¹To avoid any stigma, haircuts and the extent to which investment banks make use of this facility are kept secret.

²²Bear Stearns had about US\$ 16 billion in CMBS, US \$15 billion in prime and Alt-A mortgage products, and US\$ 2 billion in subprime mortgage products.

which had relied on refinancing much of its balance sheet on a daily basis, was suddenly also unable to secure funding on the repo market. On the repo market, lenders accepted only Treasury bonds as collateral. They did so, even though the GC repo rate was relatively low compared to the non-Treasury repo rate—a clear sign of a flight to quality. The sharp downward spike in the red shaded area (OIS-T-Bill spread) in the top panel of Figure 3 and the elevated MBS-GC repo spread in the bottom panel show this clearly.

Bear Stearns faced a modern “investment bank run.” With about 150 million trades spread across various counterparties on the books, the firm’s potential bankruptcy also posed a significant systemic risk. On Thursday, March 13, Bear Stearns’s management contacted officials from the Federal Reserve Bank of New York. By early morning on Friday, March 14, the New York Fed had agreed to provide emergency financing to Bear Stearns via JPMorgan Chase for up to 28 days. JPMorgan Chase was used as a conduit, since as a commercial bank it is under the Fed’s supervisory authority. It also has access to the Fed’s discount window and, as Bear Stearns’s clearing bank, has good knowledge about Bear Stearns’s repo transactions.

The idea was to keep Bear Stearns going through the weekend in order to have enough time to organize a takeover before the markets opened in Asia on Sunday evening. New York Fed officials and bankers from JPMorgan Chase worked over the weekend to evaluate Bear Stearns’s positions. Initially, market rumors mentioned J.C. Flowers, a private equity fund, as a second bidder, but as time passed it became clear that a takeover by JPMorgan Chase would be the preferred option to minimize the systemic risk. Bear Stearns was simply too interconnected to be allowed to suddenly fail. A big party had to step in to minimize counterparty credit risk.

At that point, Bear Stearns had little bargaining power left and it was agreed that J.P.Morgan Chase would acquire Bear Stearns for US\$ 236 million, or US\$ 2 per share. The Fed agreed to grant a US\$ 30 billion loan in nonrecourse financing. This action shocked many market observers, given that Bear Stearns’s shares had traded at around US\$ 150 less than a year before.

On Sunday night, the Fed cut the discount rate from 3.5 percent to 3.25 percent and opened the discount window to investment banks via the new Primary Dealers Credit Facility (PDCF).

Overall, the market valued the deal positive for JPMorgan Chase, as its shares gained

2.7 percent on Monday, March 17. Government officials were not necessarily unhappy about the low equity offer because it reduced future moral hazard in two ways: 1) it punished excessive risk taking by Bear Stearns, and 2) it rewarded prudent banking by JPMorgan Chase in that the bank could take over Bear Stearns's assets at a distressed price. Note that Bear Stearns' equity holders lost almost everything, while debt holders did not lose anything. Not surprisingly, bond holders were eager for the takeover to go through and bought up shares to ensure a favorable vote. Nevertheless, the hostility among many equity holders was such that uncertainty about the completion of the deal remained, which led to a continued bleeding of Bear Stearns's customer base. To overcome this hostility, JPMorgan Chase increased its share offer to US\$ 10. Also, the New York Fed's loan was improved, and JPMorgan Chase agreed to assume the first US\$ 1 billion of losses.

3.2 Quant Hedge Funds

At first sight, it is not obvious why quant funds, which were not overly exposed to subprime mortgage products, became embroiled in such turmoil at the end of July and beginning of August.

Quant funds use statistical models to exploit market inefficiencies. One subgroup, statistical arbitrage funds ("stat arbs"), focuses on high-frequency trading, or a trading horizon of only a few hours or days. These funds try to identify short-term price reversals by disentangling information-driven permanent shocks from demand-driven temporary shocks using volume profiles and histories of prices. This strategy involves high trading activity, which limits the total fund size because of trading and price-impact costs. In general, these funds are very information-technology-intensive and typically employ mathematicians, physicists, and computer scientists rather than financial economists. One of the most prominent fund is arguably Renaissance's Medallion fund. These stat-arb funds got caught by the continuous unwinding of value stocks. Initially, hoping that these stocks would rebound, the funds took on a leveraged long position on these value stocks. However, as losses mounted and margins spiked, they subsequently had to shed these positions at fire-sale prices.²³

In contrast, other quant funds like AQR, Goldman Sachs' Global Alpha fund, or BGI also employ lower-frequency strategies that rely more on economic models. One of their

²³See also Khandani & Lo (2007), which simulates returns for hypothetical stat-arb funds for the early days in August 2007.

“bread and butter” strategies is to be long on value stocks that have high book-to-market ratios and to be short on growth stocks that have low book-to-market ratios. This portfolio is often referred to as HML (“high minus low”) and was used as a risk factor by Fama & French (1992) and Fama & French (1993). Panel A in Figure 4 below depicts the return of a zero-investment portfolio that is long on value stocks and short on growth stocks starting from January 2007.²⁴ While the excess return of this portfolio is historically positive (except for certain periods such as during the run-up of the technology bubble) it was negative in this period, particularly in the summer of 2007. The losses were most pronounced from August 1–9, seven consecutive days with large losses. While these losses may not seem catastrophic, one must keep in mind that hedge funds lever up their trading, multiplying not only expected returns but also volatility and potential losses.²⁵

Quant funds also employ momentum strategies, which involve buying recent winner stocks and selling recent losers. These strategies also pointed toward selling value stocks in August. At the same time, the carry-trade strategy, which involves buying currencies that pay a high interest rate and selling low-interest-bearing currencies, became stale and was unwound.²⁶ Panel B in Figure 4 depicts the accumulated return of a carry trade Exchange Traded Fund (ETF) offered by Deutsche Bank.

Quant funds suffered for at least two reasons. First, it seemed that at least some other active funds that held mortgage products were also following the value-growth (HML) strategy. As mortgage products turned sour and became illiquid, the quant funds turned to reducing their relatively liquid value-growth positions. As the Wall Street saying goes: *“If you can’t sell what you want to sell, sell what you can sell.”* Second, quant funds had some exposure to corporate credit risk. As the subprime mortgage problems spilled over to the credit market, they suffered. Most importantly, given that many quant funds follow similar strategies, they sold similar assets, which led to “crowded trades.” Consequently, their capital was eroding at the same time, inducing their prime brokers to increase margins. This triggered a vicious cycle—a liquidity spiral—that will be discussed in Section 4.

²⁴While academics use a broad-brushed construction of value-growth portfolios across the whole universe of U.S. stocks, hedge funds on Wall Street rely on “relative” value-growth portfolios. That is, they select value and growth stocks based on a book-to-market ratio relative to the industry average. In this way, they avoid overexposure to certain industries, such as oil firms, construction firms, or financials.

²⁵Fama & French (2006) wrote an interesting piece for Dimensional Funds Advisors (DFA) in which they express their distaste for DFA’s practice of leveraging up its HML factor by shorting more aggressively growth stocks and buying more value stocks. DFA does not actually short growth stocks, but only under-weights them in its portfolio.

²⁶See Brunnermeier et al. (2008) for an empirical analysis of the unwinding of carry trades.

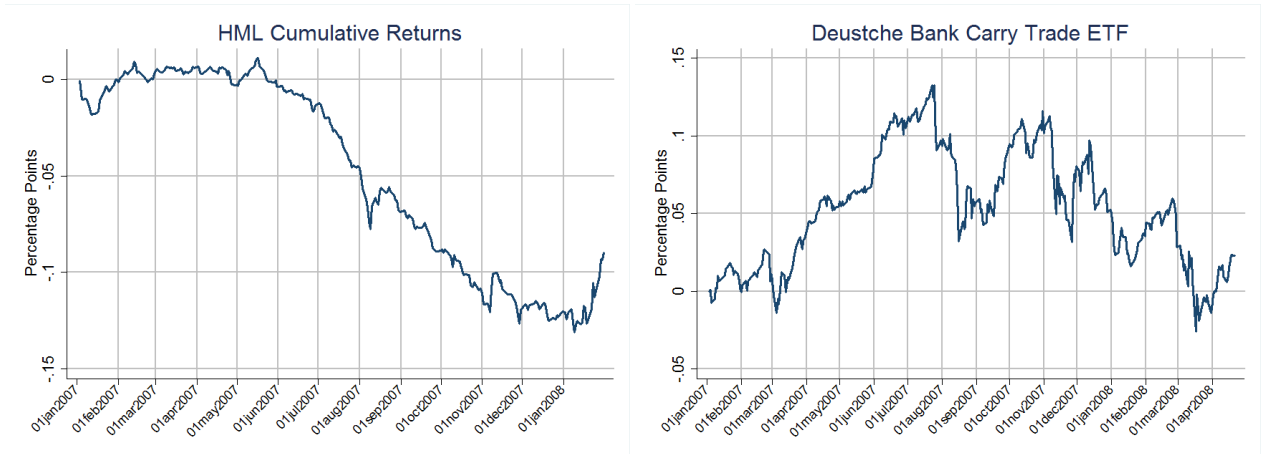


Figure 4: Panel A shows the cumulative return of the trading strategy that goes long on value stocks and shorts growth stocks. Panel B shows the accumulated return of the Deutsche Bank carry trade ETF. Sources: Ken French, Deutsche Bank.

4 Amplifying Mechanism of Liquidity Risk

The described sequence of events is a vivid reminder that liquidity is fragile, i.e., it can suddenly evaporate. Relatively small shocks, or instigators, can trigger liquidity spirals, causing liquidity to dry up suddenly and carrying the potential for a full-blown financial crisis. Liquidity spirals pose a crucial question: Why are funds withdrawn primarily when they are needed the most? This section outlines several mechanisms that amplify the initial (potentially trivial) shock.

Many amplification mechanisms operate through frictions that 1) limit optimal risk sharing and 2) prevent funds from flowing to investors who have the necessary expertise and know-how to invest. These investment opportunities can be real projects—as emphasized by the corporate finance literature—or trading strategies that arise when financial assets are mispriced. The frictions arise due to asymmetric information or due to non-verifiable information, resulting in incomplete contracts and markets.

As financial products and markets become more complex, fewer investors are capable of valuing them correctly. This is particularly true for structured products, whose value depends on the correlation structure of default events, which is inherently difficult to estimate. Specialization introduces market segmentation and leads to more asymmetric information between expert and nonexpert investors.

Frictions that prevent price-correcting trades dissipate only slowly. The *speed of arbi-*

trage is reduced by constraints on both funding and knowledge. Expert investors need time to raise funds, and nonexpert investors need time to understand how to invest in complex assets.²⁷

Funding liquidity, the ease with which expert investors and arbitrageurs can obtain funding, is distinct from market liquidity.²⁸ Funding liquidity is high—and markets are said to be “awash with liquidity”—when it is easy to borrow money, either uncollateralized or with assets as collateral. Typically, informed traders, such as dealers, hedge funds, or investment banks, use the purchased asset as collateral and borrow (short term) against it, but they cannot borrow the entire price. The difference between the security’s price and collateral value, the margin, must be financed by the trader’s own capital.²⁹ An increase in margins or haircuts requires investors to use more of their own capital and forces traders to de-leverage their positions. Note that margin loans are very short term since margins can typically be reset daily. Financial institutions that rely primarily on short-term (commercial) paper or repo contracts have to constantly roll over their debt. Inability to roll over this debt—if, for example, the commercial paper has dried up—is equivalent to margins increasing to 100 percent. Capital redemptions or withdrawals of demand deposits have the same effect as an increase in margins. All three forms of funding liquidity risk—*margin funding risk*, *rollover risk*, and *redemption risk*—are thus three different incarnations of the same funding liquidity risk and arise primarily from a maturity mismatch between the purchased asset and its funding.

Note that the short-term funding of long-term projects or trading strategies may require the injection of additional funds in the future. In a frictionless world with complete markets (the Modigliani-Miller world), expert investors would simply approach financiers whenever new funding needs emerged. However, given financing frictions, funds may be unavailable or very expensive at certain points in time. Anticipating these future funding needs requires investors to carefully manage their funding liquidity and can lead to hoarding and reduced liquidity provision ex-ante. This type of funding liquidity risk is different from simple interest rate or duration risk in two ways: 1) it is often institution specific, and 2) it might involve outright credit rationing rather than just a change in the funding interest rate.

The second form of liquidity is *market liquidity*. It is high when it is easy to raise

²⁷See e.g. Mitchell et al. (2007) for some empirical evidence.

²⁸See Brunnermeier & Pedersen (2008).

²⁹If the trader uses a different asset as collateral, a haircut is subtracted from its value.

money by selling the asset (instead of by borrowing against it). That is, market liquidity is high when selling the asset does not depress the sale price too much.³⁰ Of course, this depends on the relative ease of finding somebody who takes on the other side of the trade. The literature distinguishes between three sub-forms of market liquidity:³¹ 1) the bid-ask spread (how much money do traders lose if they sell one share and buy it back right away?), 2) market depth (how many units can traders sell [buy] at the current bid [ask] price without moving the price even further?), and 3) market resiliency (if the price drops temporarily, how long will it take to bounce back?). While a single trader might move the price a bit, large price swings occur when "crowded trades" are unwound i.e., when several traders attempt to get out of identical positions in unison.

Everybody who stands ready to take on the other side of a trade provides market liquidity. This group includes everybody who submits a limit order that specifies willingness to buy the asset if the price drops below a certain limit. Because all limit orders are collected in the limit order book, its depth is a direct measure of market liquidity. It also includes potential investors who have not submitted a limit order but are ready to jump in whenever selling (buying) pressure causes a temporary price dip (rise). This group comprises dedicated market makers or other opportunistic traders who are constantly following the market, such as hedge funds and investment banks.

The mechanisms that explain why liquidity can suddenly evaporate operate through the interaction of market and funding liquidity.

4.1 Borrower's Balance Sheet Effects: Loss Spirals and Margin Spirals

Loss Spiral

Borrowers typically have to put their own capital at stake in order to avoid moral hazard or adverse selection problems. As the value of the borrowers' assets falls, their capital, i.e., net worth, erodes and thus the amount they can borrow falls. For example, if an investor buys US\$ 100 million worth of assets on 10 percent margin, he has to finance only US\$ 10 million with his own capital and can borrow up to US\$ 90 million. His leverage ratio is 1:9. As the value of the acquired asset declines—say, to US\$ 95M—the investor's net worth halves

³⁰At an abstract level, we can think about market liquidity and funding liquidity in the following way. Market liquidity refers to the transfer of the asset with its entire cash flow, while funding liquidity is like issuing debt, equity, or any other financial contract against a cash flow generated by an asset or trading strategy.

³¹See, e.g., Kyle (1985).

to US\$ 5 million. Holding his leverage ratio constant, the investor is forced to almost halve his position exactly when the price is low. These sales depress the price further, inducing even further sales and so on. This *loss spiral* is the first of two liquidity spirals that arise in equilibrium since other potential expert buyers face similar constraints at that time³² or find it more profitable to conduct “predatory trading.”³³

Margin Spiral

A price reduction that results from a lack of liquidity is likely to be temporary, and expert investors face a great buying opportunity. One might think that lenders would be willing to lower lending standards by reducing margins.³⁴ However, in reality, exactly the opposite happens. Margins and haircuts spike at times of large price drops. The increase in margins (lending standards) leads to an additional *margin spiral*, as demonstrated in Brunnermeier & Pedersen (2008). Because of higher margins, the borrower has to lower his leverage ratio.³⁵ This lowers the price and forces more sales, increasing margins and creating a vicious cycle, or “margin spiral.”

The following figure illustrates both liquidity spirals. Note that the loss and margin spirals reinforce each other and ultimately lead to large price effects, heightened volatility, and fire sales.

Theoretically, the spike in margins can be rationalized in three different ways: 1) higher future volatility, 2) increased asymmetries in information, and 3) nonrational behavior on the part of lenders.

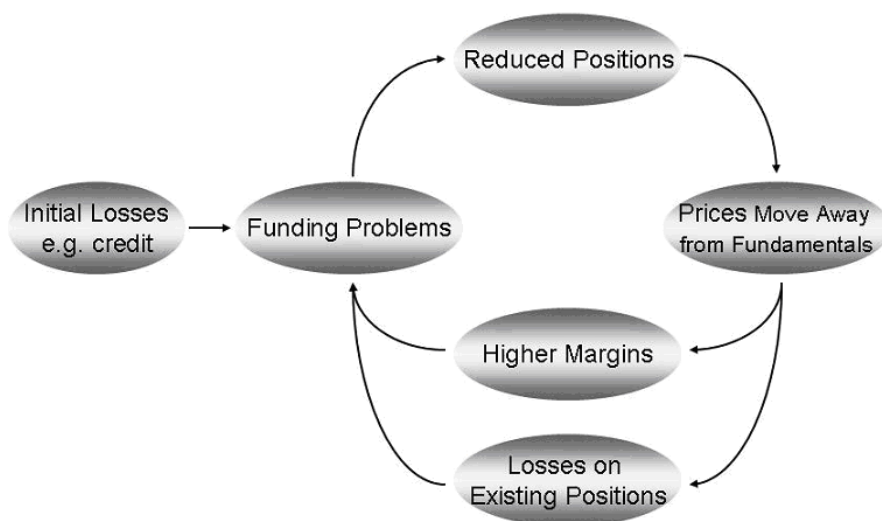
An additional margin spiral emerges in Brunnermeier & Pedersen (2008), since permanent price shocks are accompanied by *higher future volatility* of the collateral asset that only slowly returns to normal levels. This description is particularly applicable to structured products, such as CDOs, whose value depends on the correlation structure of the underlying assets. The exact extent of a shift in the correlation is learned only slowly, and consequently the volatility of the collateral spikes and recedes only gradually. To play it safe, a financier, after observing a sharp price drop, might be reluctant to roll over short-term ABCP, or a prime broker might increase its margin to take into account that future

³²As pointed out in the seminal paper by Shleifer & Vishny (1992).

³³Brunnermeier & Pedersen (2005) and Carlin et al. (2007).

³⁴Indeed, most academic papers, e.g., Bernanke et al. (1996), Geanakoplos (2003), Gromb & Vayanos (2002), and He & Krishnamurthy (2008) focus on the loss spiral but margins decrease at times of crisis, leading to the opposite of a margin spiral - a cushioning effect.

³⁵See Adrian & Shin (2008) for empirical evidence on deleveraging due to margin spiral.



volatility might be higher. Indeed, in August 2007, the ABCP market dried up completely, implying an effective margin of 100 percent, i.e., zero lending. This extreme reaction occurred when suddenly ABCP could no longer be considered a cash substitute. That is, while overcollateralization prior to the crisis guaranteed that highly rated ABCP was almost like cash—i.e., credit-risk free—the sudden increase in the volatility of the collateral made it necessary to evaluate the credit risk of ABCP more carefully, requiring an expertise that the typical ABCP investor does not have. Since it takes time to gain this expertise, the first natural response is to withdraw from the ABCP market altogether. Again, this increase in margins occurs even though the hedge fund might face a great buying opportunity at the time of crisis if the price dip turned out to be only temporary.³⁶

An *increase in asymmetric information* induces financiers to increase margins. Financiers become especially careful about accepting assets as collateral if they fear receiving a particularly bad selection of existing assets. They might, for example, be worried that the SIV that issues ABCP sold the good, “sellable” assets and left as collateral the bad,

³⁶Of course, every cash-strapped hedge fund manager would like to convince his prime broker that the price decline is only temporary, even when it is not true. The consequence is that hedge fund managers cannot credibly communicate the likely nature of the crisis to their financiers, their prime brokers, and their client investors.

less valuable “lemons.”

Finally, if lenders *naively* set margins based on value-at-risk estimates using past data, a large price drop can also lead to higher margins. In this case, financiers wrongly ignore that the price drop potentially generated a great buying opportunity.

Mark-to-market and Liquidity Spiral

Mark-to-market makes losses visible and hence feeds the loss spiral. However, it has the advantage of also making losses transparent, thereby reducing asymmetric information and alleviating (as argued above) the margin spiral. The overall effect of mark-to-market is therefore not easily determined.

Note that the loss spiral is more pronounced for stocks with low market liquidity. This suggests that funds first sell their liquid stocks and are reluctant to shed their illiquid assets. It also explains why liquid-value stocks suffered more than illiquid-value stocks. The opposite is true for growth stocks, which hedge funds were short. This particularly hurt quant hedge funds that are heavily exposed in these liquid-value-growth trading strategies.

For so-called level 3 assets—which include many structured products—market liquidity is so low that no reliable price exists. The mark-to-market approach has to give way to the mark-to-model method for valuation of these assets. The mark-to-model method grants the owners considerable discretion. Selling some of these assets would establish a low price and force the holder to mark down remaining holdings. Hence, investors are even more reluctant to do this and prefer to sell assets with higher market liquidity first.

Liquidity Spirals in a Dynamic Setting

Note that funding constraints need not be binding for liquidity spirals to arise. Simply the fear that the constraint might be binding in the future makes speculators and arbitrageurs reluctant to correct mispricing and provide market liquidity.³⁷

4.2 Lending Channel

So far, we have focused on the balance sheets of the borrowers and have assumed that lenders have deep pockets. When lenders also have limited capital, they restrict their lending as their financial situations worsen. We can distinguish two main mechanisms.

³⁷This is the same concept as limits to arbitrage. See Shleifer & Vishny (1997).

Static: Moral Hazard in Monitoring

Most lending is intermediated by banks that have special expertise in monitoring a borrower's investment decisions. For intermediators to exert sufficient effort in monitoring, they must have enough at stake. If their net worth falls, they may reduce this effort, forcing the market to fall back to direct lending without monitoring. Direct lending results in higher default rates and consequently higher interest rates.³⁸

Dynamic: Precautionary Hoarding

In a dynamic setting, lenders might suffer some interim shocks and subsequently need funds for their own projects and trading strategies. In a frictionless world, the lenders can simply approach others at short notice whenever this interim shock hits. However, in a world with financing frictions, such funds may be very expensive or simply unavailable in these future states of the world. Anticipating these future funding needs requires a funding liquidity management that can lead to hoarding, or limited liquidity provision ex-ante. In other words, lenders typically hold a “funding cushion” in order to be prepared for their own adverse events. Only funding in excess of this cushion is loaned to others. Precautionary hoarding increases when 1) the likelihood of interim shocks increases, and 2) outside funds are difficult to obtain at these times.

The recent troubles in the interbank lending market are a good example of hoarding behavior by individual banks. As it became apparent that conduits, SIVs, and other off-balance-sheet vehicles were likely to draw on credit lines by their sponsored bank, each bank's uncertainty about its funding needs skyrocketed. At the same time, it became more uncertain whether banks could tap into the interbank market after the interim shock since other banks had their own “SIV exposure.” These effects led to a sharp spike in the interbank market interest rate, LIBOR, in both levels and volatility (see Figure 2 in Section 3).³⁹

4.3 Runs on Financial Institutions

So far, the focus here has been on mechanisms in which each financier's withdrawal makes it optimal for others to withdraw as well. The initial trigger was due to an increase in

³⁸See, e.g., Holmström & Tirole (1997).

³⁹Note that futures contracts based on LIBOR provide only partial insurance since the LIBOR is only an indicative quote and each individual's bank borrowing rate can differ from LIBOR, especially when its situation worsens.

volatility of a collateral asset or an increase in asymmetric information. Now, we examine the dynamic considerations in which funding liquidity evaporates because everybody tries to preempt others.

In a classic bank run—such as the one on Northern Rock—everybody has an incentive to be first at the bank teller or the first on the bank’s Web site. People who withdraw their money early get their full amount while those who move late might not. Late movers receive less for two reasons: 1) if the run occurred for fundamental reasons—say the bank invested in bad projects, such as granting low-quality subprime mortgages—there may not be enough left to fully pay those who withdraw late, and 2) if the run occurred for funding-liquidity reasons, early withdrawals force a bank to liquidate long-maturity assets at fire-sale prices because market liquidity is low. The sale of long-maturity assets below their fair value leads to an erosion of the bank’s wealth and leaves less for people who withdraw their money late. Under both scenarios, every investor has an incentive to preempt others and run to the door (only the English queue in an orderly fashion in the midst of a bank run).⁴⁰

Runs can also occur on other financial institutions. For example, when every prime broker tries to raise its margins before others do, there is a run on the hedge fund. Similarly, not rolling over commercial paper is a run on the issuer of ABCP. In the case of Bear Stearns, hedge funds ran on their own prime broker in March 2008. Hedge funds park a sizable amount of liquid wealth with their prime brokers. That is especially true if they hold short positions, since the revenue from selling the asset short, plus an extra margin, has to be held in the brokerage account as collateral. Moreover, brokers can lend out certain clients’ assets to raise funds, e.g., in the repo market. When hedge fund clients leave, this funding base breaks away and the prime broker is in trouble. Naturally, no client wants to be the last to leave.

Finally, while classic models of runs focus on debt holders, one may argue that the problem also extends to equity holders such as investors in a hedge fund. Equity holders who withdraw their capital receive a share of the fund’s net asset value (NAV). In this case, an early-mover advantage arises, since fund managers first sell liquid assets. To illustrate this point, consider a fund that holds US\$ 50 million in cash and US\$ 50 million in hard-to-

⁴⁰Diamond & Dybvig (1983) is the seminal paper on bank runs. In Allen & Gale (2004) fire-sale prices are endogenous. Allen & Gale (2007) and Freixas & Rochet (1997) and references therein, are further useful references. See also Diamond & Rajan (2000) and Diamond & Rajan (2005). Bernardo & Welch (2004) and Morris & Shin (2004) study runs on financial markets.

sell illiquid securities that at short notice can be sold only for US\$ 30 million. If the fund services early withdrawals using its cash cushion, then early withdrawers receive their full share of the mark-to-market NAV of US\$ 100 million. Once the fund has to sell the illiquid asset, the NAV declines and late withdrawers receive only their percentage share of what the illiquid asset can be sold for. In fact, many SIV rulebooks require the SIV to sell liquid assets first.

Of course, one solution to this liquidity-driven run would be to sell more of the illiquid asset earlier. However, this lowers the fund's performance and may cause more investors to withdraw their money (not for liquidity reasons but for fundamental reasons). Thus, fund managers face a "Catch 22" situation: Selling illiquid assets first may prevent liquidity-driven runs, but it may cause fundamental runs.

Are lock-up periods and early-withdrawal penalties the answer to this problem? In principle yes, but in practice hedge fund managers are afraid to use them because they might signal a lack of confidence in the firm's trading strategy. Even more problematic is that many funds that have lock-ups in place grant side deals to "special investors," undermining the whole system of lock-ups. A regulation that enforces lock-ups, which was briefly in place in the U.S. before it was overturned in court, would eliminate this troubling signaling aspect.

In sum, there are several reasons for the first-mover advantage that makes financial institutions in general, and not only banks, subject to runs on them.

4.4 Network effect

In all our settings so far, we have assumed a dedicated lending sector that lends funds to borrowers. In reality, however, most financial institutions are lenders and borrowers at the same time. Our modern financial architecture consists of an interwoven network of financial obligations. This is made evident by the fact that the number of outstanding derivatives contracts vastly exceeds the number of underlying securities. For example, the notional amount of CDS contracts totaled US\$ 45 trillion in 2007, while the value of the underlying corporate bond market was only US\$ 5 trillion. The discrepancy arises because many of the outstanding obligations between financial institutions could be netted out in multilateral netting agreements. In this section, we show how an increase in counterparty credit risk can cripple netting arrangements, creating additional funding needs and potential systemic

risk.

Network risk is best illustrated by means of an example that is related to the Bear Stearns crisis in March 2008. Imagine a hedge fund that at the time had an interest rate swap agreement with Goldman Sachs. That is, both parties had agreed to swap the difference between a floating interest rate and a fixed interest rate. Now suppose that the hedge fund offsets its obligation through another swap, this time with Bear Stearns. In the absence of counterparty credit risk, the hedge fund is fully hedged; the two swap agreements can be netted, i.e., reduced to a single one between Goldman and Bear Stearns. However, Goldman will not agree to this netting arrangement if it fears that Bear Stearns might default on its commitment.

In fact, this is what happened in March 2008. On Tuesday, March 11, one of Goldman's derivatives groups sent an e-mail to its hedge fund client announcing that it would no longer honor netting arrangements that exposed them directly to Bear Stearns. This exacerbated Bear Stearns's problems further and was presumably a contributing factor that triggered the run on Bear Stearns.

Let us extend this hypothetical example to see how an increase in perceived counterparty credit risk can be self-fulfilling and create additional funding needs. Suppose that Bear Stearns had an offsetting swap agreement with a private equity fund, which in turn offset its exposure with Goldman Sachs, as shown in Figure 7.⁴¹ In this example, all parties are fully hedged and, hence, a multilateral netting arrangement could eliminate all exposures. However, since all parties are aware only of their own contractual agreements, they may not know the full situation and therefore become concerned about counterparty credit risk. Goldman's refusal to be directly exposed to Bear Stearns blocks netting and forces the hedge fund and private equity fund to put additional liquid funds aside as protection against the perceived risk that Bear Stearns may default. If the funds do not have large enough funding cushions, they might go under with Bear Stearns, triggering a systemic crisis.

Network and gridlock problems are more easily overcome if a clearing house or other central authority or regulator knows who owes what to whom. Therefore, multilateral netting agreements, such as the service provided by SwapClear, can stabilize the system.

⁴¹For more details see Brunnermeier (2008). A number of other papers consider network effects in financial markets. For example, Eisenberg & Noe (2001) shows that there exists a (unique) clearing payment vector that clears the obligations in a setting with complete information. Allen & Gale (2000) consider a simple network in a banking model à la Diamond & Dybvig (1983).

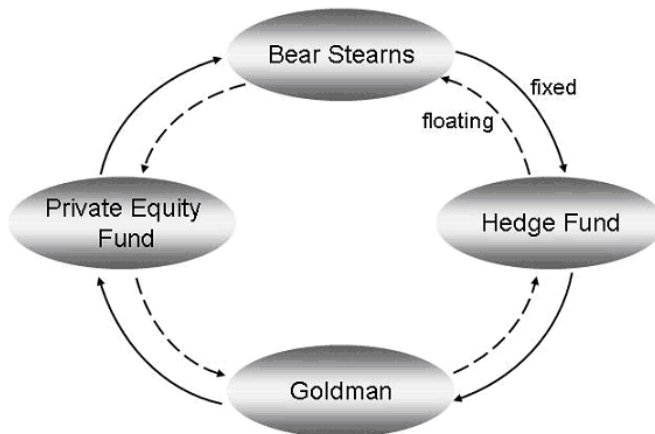


Figure 5: A network of interest rate swap arrangements which theoretically could be fully netted in a multilateral netting agreement. However, since each party knows only its own contractual obligations, Goldman’s doubts about Bear Stearns’s creditworthiness make netting impossible, which creates additional funding needs.

However, the introduction of structured products that are typically traded over the counter has made the web of obligations in the financial system opaque, consequently increasing systemic risk.

4.5 Aversion to Knightian Uncertainty

One of the central puzzles related to the current financial crisis is that only a few players are willing to step in when prices drop. While the above mentioned mechanisms rely on financial frictions and lack of expertise, Caballero & Krishnamurthy (2008) argue that, in times of crisis, investors have a difficult time assigning probabilities to the different possible outcomes. This argument seems reasonable, especially for structured products, since there is only limited historical data available for forecasting. Since investors are averse to not being able to assign probabilities—i.e., they dislike what economists call “Knightian uncertainty”—they will ask for an additional uncertainty premium for holding risky assets. This uncertainty-aversion effect comes on top of the increased volatility. It helps explain

why asset prices can drop significantly even in situations where the financial system as a whole is well capitalized.

5 Conclusion

While each crisis has its own specificities, it is surprising how “classical” the 2007-08 crisis is. From the trigger set off by an increase in delinquencies in subprime mortgages, a full-blown liquidity crisis emerged, primarily because of a mismatch in the maturity structure that involved banks’ off-balance-sheet vehicles and hedge funds. What was new about this crisis was the extent of securitization. Not only did it make more opaque the exposure of institutions’ structured credit products to credit counterparty risk, but it also made these products more difficult to value (in large part owing to the difficulties in estimating correlation parameters).

The additional uncertainty created by these factors later led to spillover effects in other market segments that were not directly linked to subprime mortgages. While it is difficult to say at this early stage how the crisis will ultimately play out, we should expect to see the financial turmoil spilling over to the real economy with potentially sizable macroeconomic implications. Moreover, the crisis has taught us that we need to rethink our current regulatory framework to reflect recent financial innovation.

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Appendix

A Difference between Conduits, SIVs, and SIV-lites

There are several differences between conduits, SIVs, and SIV-lites. ABCP *conduits* hold unconditional credit lines for 100 percent of the face value of the outstanding ABCP. In addition, the sponsoring bank often provides credit enhancement—i.e., some protection against the underlying assets defaulting or becoming impaired. As a consequence, investors in ABCP conduits implicitly rely on the sponsoring bank’s credit quality.

SIVs are exposed to funding liquidity risk since they hold credit lines that only partially cover their outstanding ABCPs. Typically, they cover the 10 to 25 percent of outstanding senior debt. But even when SIVs have no recourse based on a formal contractual credit line, the sponsoring bank may feel compelled to bail out the SIV in an effort to protect the bank’s reputation. These implicit credit lines motivated by reputation have no implications for capital requirements. Also, unlike conduits, the SIV-ABCP does not entertain credit enhancements. However, SIVs typically invest in less risky assets. Furthermore, they are “overcollateralized” since they have a cushion in the form of an equity tranche that absorbs the first defaults. SIVs are open-ended vehicles and their (typically structured) capital is dynamic. That is, SIVs can change their size and financing (including leverage) over their life spans. Around 26 percent of their liabilities are in ABCP, 68 percent in medium-term notes (MTNs), and 7 percent in capital/mezzanine notes.⁴²

SIV-lites, in contrast to SIVs, are closed and their capital is static. That is, their capital base is set at launch, and the maximum permitted leverage is fixed. SIV-lites tend to invest in US RMBS (>95 percent), are aggressively structured, and have credit lines that are subject to market-value tests. In some sense, they are a hybrid of SIVs and the extremely passive CDO-SPVs. SIV-lites are a newer financial innovation than standard SIVs and had only about US\$ 12 billion under management in August 2007. In other words, they make up only a tiny fraction of the ABCP market.

The following table provides a quick overview of the differences between conduits, SIVs, and SIV-lites.

⁴²CITI (2007), “Global Structured Credit Strategy,” September 13.

Table 1: Contrasting Conduits, SIVs, and SIV-lites.

	Conduits	SIVs	SIV-lites
Assets	<ul style="list-style-type: none"> ■ US\$ ≈1,400bn ■ Not tradable loans ■ Less risky ■ ≈11% RMBS ■ ≈11% ABS/CDOs 	<ul style="list-style-type: none"> ■ US\$ ≈400bn ■ Assets are traded ■ Less risky ■ ≈43% fin. inst. debt ■ ≈23% RMBS ■ ≈11% CDOs 	<ul style="list-style-type: none"> ■ US\$ ≈12bn ■ Assets are traded ■ Risky ■ > 95% US RMBS
Liabilities		<ul style="list-style-type: none"> ■ 26% ABCP ■ 68% MTN ■ 7% capital/mez.notes 	
Capital structure	<ul style="list-style-type: none"> ■ Nonstructured 	<ul style="list-style-type: none"> ■ Structured ■ Open ■ Dynamic (change size/financing) 	<ul style="list-style-type: none"> ■ Structured (aggressively) ■ Closed ■ Static (like CDOs)
Credit enhancement	<ul style="list-style-type: none"> ■ Some (sponsoring bank) 	<ul style="list-style-type: none"> ■ No (but overcollateralized) 	<ul style="list-style-type: none"> ■ No
Liquidity enhancement (credit line)	<ul style="list-style-type: none"> ■ Contractual 100% 	<ul style="list-style-type: none"> ■ Contractual < outstanding ABCP ■ Reputational 	<ul style="list-style-type: none"> ■ Contractual credit line is subject to market-value tests