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THE RUN ON REPO AND THE PANIC OF 2007-2008*

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Abstract

The Panic of 2007-2008 was essentially a run on the sale and repurchase market (the "repo" market), which is a very large, short-term market that provides collateralized financing for a large range of securitized products. Repurchase agreements are economically like demand deposits; they play the same role as demand deposits, but for firms operating in the capital markets. The run resulted in the insolvency of the banking system. We provide evidence for this by studying two main "state variables." The first of these state variables captures the state of the subprime market directly. The second state variable captures the breakdown in the repo market. We show that the subprime related asset classes' spreads move with the first state variable, but other types of securitization asset classes are only affected by the second state variable.

*We thank numerous participants in the capital markets for assistance with data.

How did a breakdown in one part of the housing market lead to a systemic crisis in the whole financial sector? In this paper, we provide some evidence on the cause of the subprime crisis and on how the financial crisis spread from the subprime housing market sector to the broad panic that we had by the end of 2008. We argue that the crisis is "systemic" because it was a run on the **sale and repurchase market** (the "repo" market), which stopped functioning, leading to massive deleveraging of participants.[1] In effect, the banking system became insolvent.

We show empirically that much of the panic can be understood through two main "state variables." The first of these state variables captures the state of the subprime market directly. The second state variable captures the breakdown in the sale-and-repurchase ("repo") markets that are critical for the short-term financing of our 21st century financial system. Using data that is not easily available and has not previously been studied in the academic literature, we identify many assets that move with each of these state variables. For the most part, we take a low-tech approach here, relying entirely on pictures to make our argument. We believe that these pictures are a great aid for anyone trying to make sense of this crisis. We also provide some preliminary formal tests (the rest is in progress).

Our argument is that the repo market is essentially a demand-deposit market for firms and funds. In traditional banks, individuals deposit their excess cash in return for the liquidity of a demand deposit, backed by the "collateral" of FDIC insurance. In "wholesale banks" – which include the institutions formerly known as investment banks – other institutions "deposit" excess cash in return for the liquidity of a short-term loan agreement, backed by high-grade collateral of the wholesale bank. The collateral makes the deposits safe in the sense that it is highly likely that depositors will get their money back. Gorton and Pennacchi (1990) have described the production of this type of debt as the essential role of banks. That is, "banks" create *informationally-insensitive* securities, like demand deposits. "Information insensitivity" means that the securities are immune from adverse selection when trading. No agent finds it profitable to produce private information about these securities. As we discuss below, the banking system has evolved so that a range of new securities have been produced which were informationally-insensitive, namely securitized bonds. Securitization growth fueled the growth of the repo market.

In a panic, informationally-insensitive securities become informationally sensitive, leading to no trade because of adverse selection (see Gorton and Pennacchi (1990)). Historically, pre-Fed banking panics followed an information "shock" near the peak of the business cycle. Upon learning of the coming downturn depositors ran to their banks to withdraw cash. See Gorton (1988). In such an event, the banking system is insolvent because it cannot honor contractual demands with respect to demand deposits; there is no private agent capable of buying the assets of the banking system at a price that allows banks to honor their contractual demands. Although private bank clearinghouses issued their own currency, in significant amounts, to

[1] Throughout, terms in **bold** are defined in a glossary, Appendix 2.

honor demand deposit withdrawals, there apparently was not enough for economic agents to make transactions, such as buying goods and meeting payrolls.[2] Contemporaneous commentators describe the situation as a "currency famine."[3] There is also a "currency premium" that arose.[4] Finally, economic agents hoarded cash; see, e.g., Andrew (1908) and Sprague (1910). What happened in 2007 and 2008 in U.S. financial markets follows this same pattern. There is a shock, our first state variable, which leads to a run (in the repo market), as evidence by our second state variable. The "currency premium" is essentially our second state variable. There is also hoarding of cash and a "currency famine," though these are harder to demonstrate empirically.

Key to our argument is the empirical demonstration of the temporal sequence of events. In particular, we show that spreads on subprime-related asset classes and subprime-related firms move together with movements in the first state variable. But, the spreads on other asset classes, non-subprime-related structured products, move only with the repo market shock, as indicated by the second state variable. In other words, the systemic aspect of the crisis is the collapse of the repo market.

Repo markets involve very short-term deposits, usually overnight, although a repo may be rolled (i.e., renewed for another day). Like a demand deposit which may be withdrawn at any time, a repo, typically overnight, need not be rolled. Repo traders do not have time to analyze the credit risk, or any other risk, of the collateral backing the deposit. That is the essence of an informationally-insensitive security. We document that, in effect, when the subprime shock hits, this market becomes informationally-sensitive: spreads increase and repo haircuts also increase. In the limit, the institutional arrangements in the repo market are simply not capable of changing fast enough to adapt to this change. When this happens, the entire market can shut down, as was seen in some asset classes in late 2008. One way to think of this shut down is to imagine what might happen if treasury-bond investors suddenly had to deal with the information necessary to evaluate the future profits of specialized companies; it is not that treasury-bond investors are constitutionally incapable of such evaluation, it is rather that their current evaluation methods are not set up to do it.

Following this introduction, Section I summarizes the building blocks of the paper: the financing of the subprime housing market, and the role of the repo market in the

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[2] The clearinghouse private money was a claim on the coalition of banks, rather than a liability of any individual bank. By broadening the backing for the claim, the clearinghouse made the claim safer, a kind of insurance. Gorton (1985) and Gorton and Mullineaux (1987) discuss the clearinghouse response to panics. Also, see Gorton and Huang (2006).

[3] See, for example, "The Currency Famine of 1893," John De Witt Warner, Sound Currency, vol. ii, no. 6 (February 15, 1895), p. 339. See Sprague (1910), Lauck (1907), and Noyes (1910) for further details.

[4] For example, Andrew (1908), speaking of the panic of 1907: "The currency premium made its first appearance in New York at the end of October, as the result of offers by Western banks to pay a bonus for large blocks of money…" (p. 291). Also, see Sprague (1910).

modern financial system. In this section, we also describe our two state variables, which are chosen to proxy for the state of these building blocks. In Section II, we show how different groups of assets move differentially with each of these state variables, and discuss why some of these assets were crucial for understanding the panic towards the end of 2008. Section II is based on figures. Some formal tests are reported in Section III. In Section IV we focus in more detail on the repo market. We document the rise in repo haircuts, which are the equivalent to withdrawals from the "bank." And we show that there was a scarcity of collateral (a "currency famine") because large amounts of previously eligible assets were no longer used in repo. Section V concludes. Appendix 1 contains a brief non-technical discussion of the methodology used to compute the "spreads" used in the paper. We also provide a short glossary, in Appendix 2, where terms in the text that are in **bold** are briefly defined. Appendix 3 contains a brief discussion of some legal aspects of repo agreements.

I. The Transformation of Banking and the Evolution of the Subprime Mortgage Market

A traditional bank is an institution that accepts deposits and makes loans, which are then held on the balance sheet of the bank until maturity. Loans are *informationally-intensive* in that they involve production of private information, while deposits are *informationally-insensitive* in that their value has a low variance. Gorton and Pennacchi (1990) argue that the creation of informationally-insensitive securities means in particular that these securities are immune from adverse selection problems when used in transactions. Since 1934 deposit insurance further guarantees the value of these securities.

In the last twenty-five years banking has evolved dramatically as a number of financial innovations have blurred the lines between "banking" and the capital markets. Loan sales and securitization allow the traditional assets of banks to be traded in the capital markets.[5] Derivatives also now allow the nature of the cash flows, and attendant risks, to be altered. We refer to the institutions at the nexus of these activities as wholesale banks (or as the "shadow banking system"), and we briefly describe some the features of wholesale banking in the paragraphs below.

Of particular interest to the present crisis are the innovations relating to the subprime mortgage market, a new market which allowed a large number of new people to access credit for home purchases. These mortgages were overwhelmingly financed via securitization, and then resecuritization. Securitization of subprime mortgages and securitization generally required significant growth in the repo market, which is the central interface between dealer banks and buyers of securitization bonds (called "tranches").

[5] See, e.g., Gorton and Souleles (2006), Gorton and Pennacchi (1995), Gorton (1994).

A. Financial Innovation and the Subprime Mortgage Market

Home ownership for all Americans has been a long-standing national goal. This goal was behind the origins of modern housing finance during the Great Depression with the New Deal's National Housing Act of 1934 (see, e.g., Fishback, Horrace and Kantor (2001)). For example, as President Bush put it in 2004: "Not enough minorities own their own homes. … One thing I've done is I've called on private sector mortgage banks and banks to be more aggressive about lending to first-time home buyers." [6] The private sector responded.

The subprime mortgage market is a financial innovation, aimed at providing housing finance to (disproportionately poor and minority) people with some combination of spotty credit histories, a lack of income documentation, or no money for a down payment. Historically, this group was perceived by banks as too risky to qualify for the usual mortgage products, for example, a 30-year fixed rate mortgage. As explained by Gorton (2008), the innovation was to structure the mortgage to effectively make the maturity two or three years. This was accomplished with a fixed initial period interest rate, but then at the "reset date" having the rate rise significantly, essentially requiring the borrower to refinance the mortgage. With rising home prices, borrowers would build equity in their homes and would be able to refinance.

The innovation was a success, if measured in terms of originations. In the years 2001-2006, about $2.5 trillion of subprime mortgages were originated.[7] In 2005 and 2006, a total of $1.2 trillion of subprime mortgages were originated, a large portion of which was likely refinancings of previous mortgages.

B. The Transformation of Banking

An important part of the subprime mortgage innovation was how the mortgages were financed. In 2005 and 2006, about 80 percent of the subprime mortgages were financed via securitization, that is, the mortgages were sold in **residential mortgage-backed securities** (RMBS), which involves pooling thousands of mortgages together, selling the pool to a **special purpose vehicle (SPV)** which finances their purchase by issuing investment-grade securities (i.e., bonds with ratings in the categories of Aaa, Aa, A, Baa) with different seniority (called "tranches") in the capital markets. Securitization does not involve public issuance of equity in the SPV. SPVs are bankruptcy remote in the sense that the originator of the underlying loans cannot claw back those assets if the originator goes bankrupt. Also, the SPV is designed so that it cannot go bankrupt.[8]

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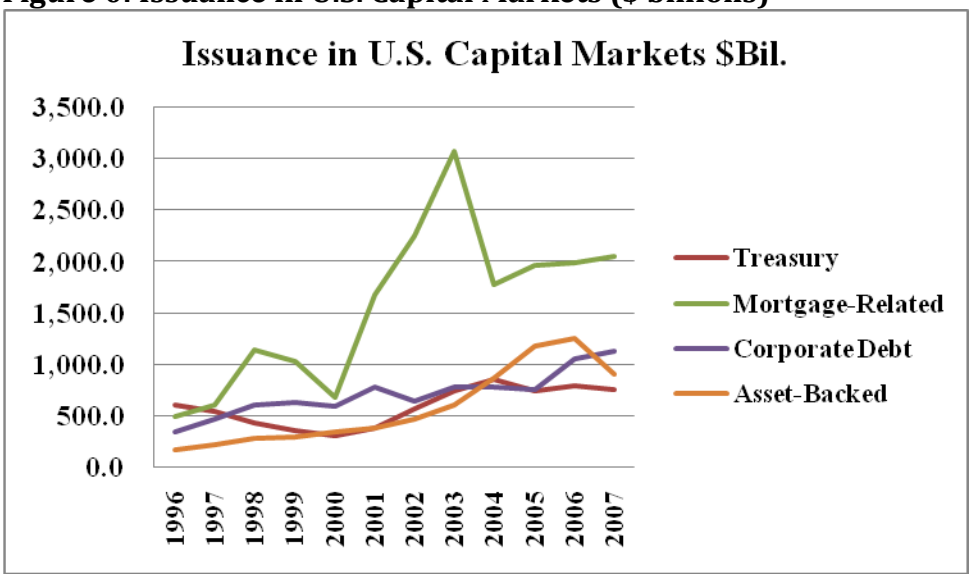
[6] See http://www.whitehouse.gov/news/releases/2004/03/20040326-15.html .

[7] See Inside Mortgage Finance, The 2007 Mortgage Market Statistical Annual, Key Data (2006), Joint Economic Committee (October 2007).

[8] On the process of securitization generally see Gorton and Souleles (2006).

Securitization is a very important source of financing. The figure below shows the annual issuance of debt in the important fixed income markets in the U.S.

Figure 0: Issuance in U.S. Capital Markets ($ billions)



Sources: U.S. Department of Treasury, Federal Agencies, Thomson Financial, Inside MBS & ABS, Bloomberg.

The figures demonstrates that: (1) the mortgage-related market is by far the largest fixed-income market in the U.S., by issuance; but further, (2), that restricting attention to non-mortgage instruments, the asset-backed securitization market is very large, exceeding the issuance of all corporate debt in the U.S. in 2004, 2005, and 2006. Overall, the figure shows that securitization is a very large, significant, part of the capital markets.

Securitization essentially creates a kind of bank, the special purpose vehicle (SPV), which finances itself by issuing tranches (bonds) in the capital markets to finance portfolios of loans (e.g., home mortgages, auto loans, credit card receivables). There are several important features of securitization transactions. The underlying portfolios are large, but homogenous in that they are the same type of loan, e.g., automobile receivables, credit card receivables, student loans. The tranches are based on seniority, but all tranches are investment-grade. The sponsoring firm, i.e., the originator of the loans in the underlying portfolio, holds the equity, and there may be other credit enhancements to ensure that the tranches are investment-grade. See Gorton and Souleles (2006). While the structure of these transactions may be complicated, the tranches are designed to, in effect, be informationally-insensitive. These are the bonds that will serve as collateral in the repo market.

Placement and trade of these SPV liabilities is facilitated by the repo market, a form of collateralized lending centered in the dealer banks. The repo market is discussed below.

The rise of the shadow banking system was accompanied by a number of other innovations, as well. Among these are **credit default swaps** (CDS) and **collateralized debt obligations** (CDOs).[9] Credit default swaps are derivative contracts under which one party insures another party against a loss due to default with reference to a specific corporate entity, securitization bond, or index. For our purposes, the CDS spread, which is the fixed coupon paid by the party providing the protection, is an indication of the risk premium with regard to the specified corporate entity. CDOs are securitizations of corporate bonds or asset-backed or mortgage-backed securities. CDOs are relevant here for two reasons. First, the underlying CDO portfolios contained tranches of subprime securitizations, making their value sensitive to subprime risk. And second, like asset-backed securities generally, they depend in large part on the repo market.

C. The ABX Indices

By the beginning of 2006, the growth in the subprime securitization market led to the creation of several subprime-related indices. Specifically, dealer banks launched the ABX.HE (ABX) index in January 2006. The ABX Index is a credit derivative that references 20 equally-weighted subprime RMBS tranches. There are also sub-indices linked to a basket of subprime bonds with specific ratings: AAA, AA, A BBB and BBB- . Each sub-index references the 20 subprime RMBS bonds with the rating level of the subindex. Every six months the indices are reconstituted based on a pre-identified set of rules, and a new vintage of the index and sub-indices are issued. The index is overseen by Markit Partners. The dealers provide Markit Partners with daily and monthly marks.[10]

Gorton (2009) argues that the introduction of the ABX indices is important because it opened a (relatively) liquid, publicly observable market which priced subprime risk. The other subprime-related instruments, RMBS and CDOs, did not trade in publicly observable markets. In fact, securitized products generally have no secondary trading that is publicly visible. Thus, for our purposes the ABX indices are important because of the information revelation about the value of subprime mortgages, which in turn depends on house prices. Keep in mind that house price indices, like the S&P Case-Shiller Indices, are calculated with a two month lag.[11] Furthermore, house price indices are not directly relevant because of the complicated structure of subprime securitizations (see Gorton (2008)).

We will focus on the BBB tranche, which is representative of the riskier levels of subprime securitization. We refer to this tranche of the 2006-1 issue simply as "ABX". Figure 1 shows the spread of this index against a proxy for the risk free rate,

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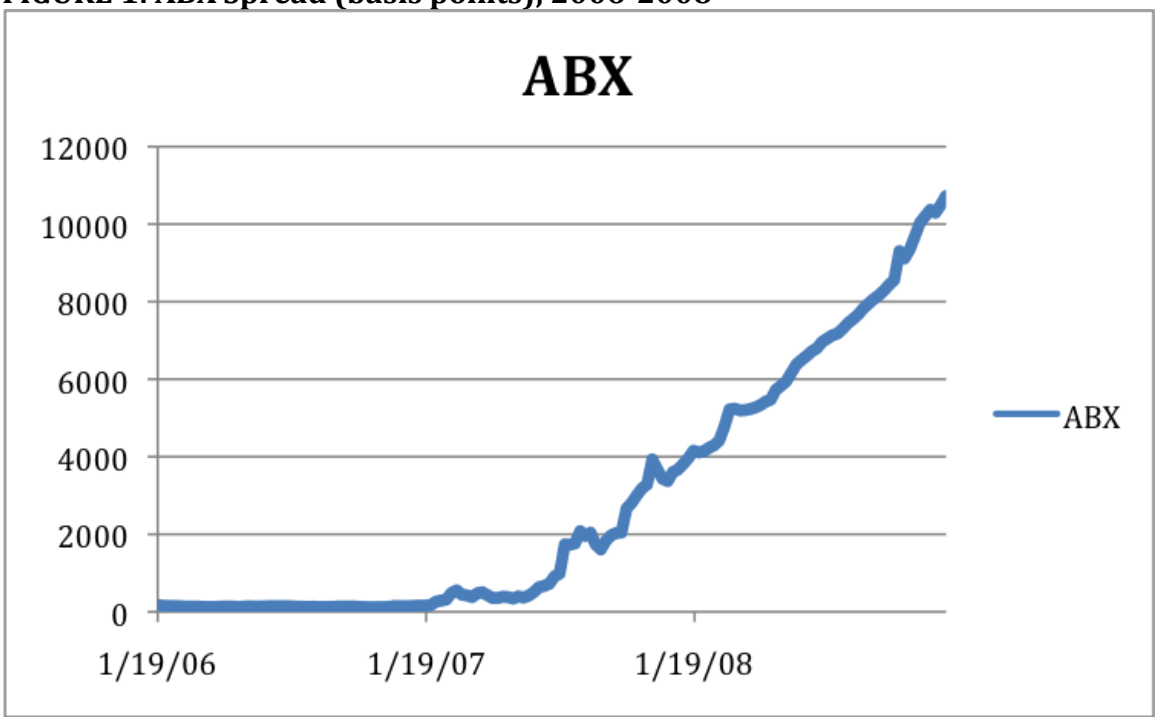
[9] Other innovations, like structured investment vehicles, collateralized loan obligations, synthetic CDOs, and so on, are discussed in Gorton (2008).

[10] See http://www.markit.com/information/products/abx.html.

[11] See http://www2.standardandpoors.com/portal/site/sp/en/us/page.topic/indices_csmahp/0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0.html .

from inception in January 2006 until the end of 2008. Appendix A briefly discusses the data and explains how these spreads can be calculated from underlying transaction prices. For our purposes in the body of the paper, we will just think of all spreads as a risk premiums and abstract from the details.

FIGURE 1: ABX Spread (basis points), 2006-2008



As Figure 1 shows, the ABX spread grew steadily throughout 2007 and 2008. The early growth is somewhat hidden by the scaling, a veil that we will remove in the next section by showing subperiods. Overall, the subprime securitization market demonstrated steady deterioration, with few interruptions, since the beginning of 2007. In contrast, during its first year of existence, this spread held steady near 150 basis points (bps).

We now know that the steadily increasing ABX spread reflected the decline in subprime housing prices, but this information was not directly available at the time because house price indices are computed with a lag. The ABX was the only market where this information was revealed.

D. Short-term Financing and the Repo Market

A demand deposit is a contract under which money is placed in a bank, with the right to ask for cash to be returned on demand. In principle, there is no maturity. Depositors "roll" their deposits as long as they do not need the cash and as long as they view the bank as being solvent. In a 19th century banking panic in the U.S., depositors ran to their banks en masse and demanded cash in exchange for their demand deposits. The current crisis is a banking panic and, as such, the banking

system is essentially insolvent, as we will show below. As discussed above, the key difference is that the current crisis involves a broader set of financial institutions than just chartered commercial banks, and the "bank run" occurred in the repo market, which is a financial contract economically equivalent to a demand deposit, as we will discuss.

A repurchase agreement (or "repo") is a financial contract used by market participants as a financing method to meet short and long term liquidity needs. A repurchase agreement is a two-part transaction. The first part is the transfer of specified securities by one party, the "bank," to another party, the "depositor," in exchange for cash. The depositor holds the bond, the bank has the cash. The second part of the transaction consists of a contemporaneous agreement by the bank to repurchase the securities at the original price, plus an agreed upon additional amount on a specified future date. The most commonly used master agreement for documenting repo is the PSA/ISMA Global Master Repo Agreement (GMRA). It is important to note that repurchase agreements, like derivatives, do not end up in bankruptcy court if one part defaults. The nondefaulting party has the option to simply walk away from the transaction, keeping either the cash or the bonds. See Appendix 3.

Another aspect of repo is also noteworthy, namely, the bonds used to provide collateral can be rehypothecated – essentially they can be "spent" in other transactions. **Rehypothecation** means that the bond can be used as collateral in another transaction, potentially with a different counterparty. E.g., party A accepts a bond as collateral in, from A's point of view, a "reverse" repo, and then provides the bond to party C as collateral in a derivative transaction.[12] See Johnson (1997). Rehypothecation is very important because there is an enormous demand for collateral. Rehypothecation is akin to being able to write a check on the "deposit." For example, derivative securities generally involve collateral agreements (according to ISDA 63 percent of OTC derivatives trades are subject to collateral agreements). The International Swap and Derivatives Association estimates that there is over $2 trillion of collateral in use in 2008; see ISDA (2008). The demand for informationally-insensitive debt to be used as collateral will play an important role in our story. See also Krishnamurthy and Vissing-Jorgensen (2008).

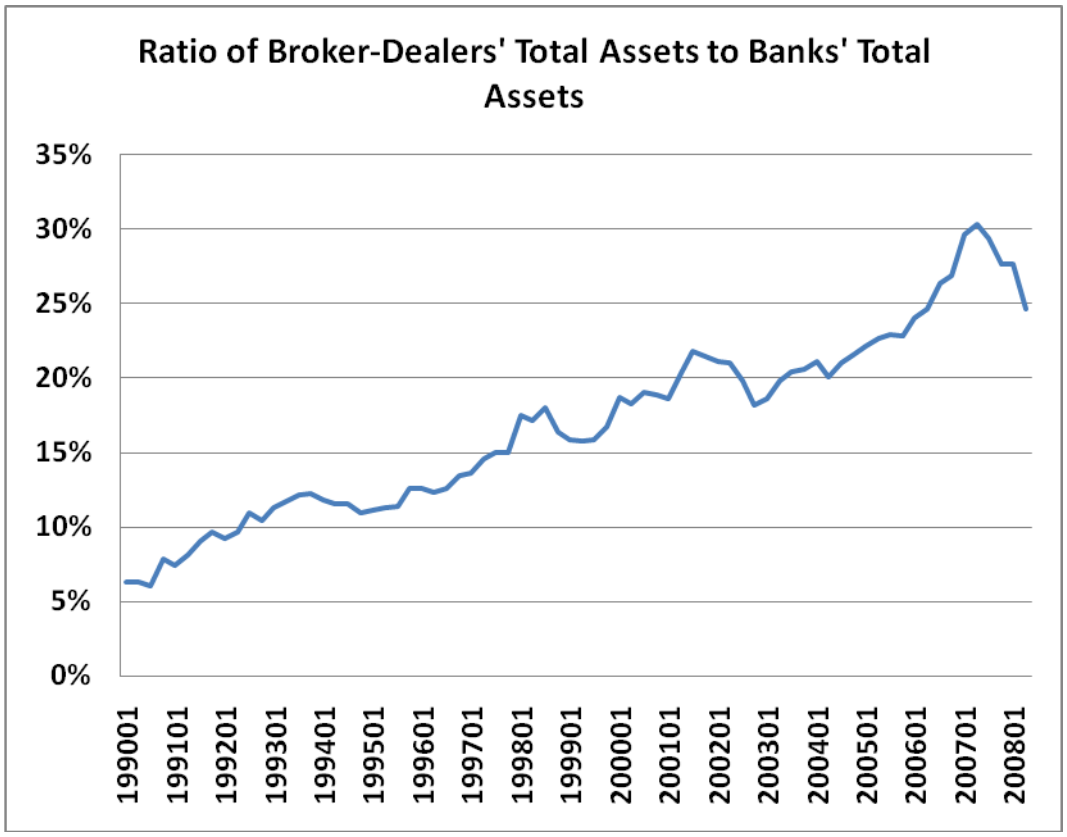
The sale and repurchase (repo) market is an important form of financial intermediation that has developed extensively as securitization has become more important. Because securitization, by definition, does not reside on-balance sheet until maturity, an infrastructure of selling, placing, and trading tranches of securitization transactions developed. What developed was an extension of the traditional repo market, which originally only supported trade in U.S. treasury

[12] The "borrower" in a repo transaction provides the bond as collateral. The "depositor," the party depositing the money in exchange for the bond is engaging in a "reverse repo," and is sometimes said to be "reversing in the bond."

bonds, to structured products. While we describe the repo market in more detail below, the important point is that it is a kind of deposit market.

While there are no official statistics on the overall size of the repo market, it may be about $12 trillion (though that may involve double counting of repo and reverse repo), compared to the total assets in the U.S. banking system of $10 trillion.[13] According to Hördahl and King (2008), "the (former) top US investment banks funded roughly half of their assets using repo markets, with additional exposure due to off-balance sheet financing of their customers" (p. 39). One way to get a sense of the growth in the securitization-based wholesale banking system is to compare the total assets in the traditional banking system to the total assets in the dealer banks. For this purpose, Federal Flow of Funds data are available, and this is shown in the figure below.

FIGURE 2



Source: Federal Flow of Funds.

[13] Hördahl and King (2008) report that repo markets have doubled in size since 2002, "with gross amounts outstanding at year-end 2007 of roughly $10 trillion in each of the U.S. and euro markets, and another $1 trillion in the UK repo market" (p. 37). They report that the U.S. repo market exceeded $10 trillion in mid-2008, including double counting. See Hördahl and King (2008), p. 39. According to Fed data, primary dealers reported financing $4.5 trillion in fixed income securities with repo as of March 4, 2008.

The figure shows that the ratio of broker-dealer total assets to banks' total assets has grown from about six percent in 1990 to a peak of 30 percent in 2007.

Financing in the repo market creates a maturity mismatch, akin to the traditional banking problem of funding long-term loans and mortgages with demand deposits. While today, the problem of traditional bank runs on solvent banks has largely been solved, with the movement of assets away from the traditional banking sector into differently regulated institutions, the maturity mismatch has once again become a large problem. In contrast to the problem in traditional banks, runs on wholesale banks are neither well-understood nor easy to fix.

To understand the maturity mismatch in wholesale banks, consider a hypothetical investment bank, "I-bank", at the beginning of 2008. Consistent with the leverage at its competitors, I-bank had approximately $400 billion in assets supported by an equity base of $12 billion. While most of these assets are in the form of securities, many of the securities are relatively illiquid, or are held in such quantities that it is not feasible to sell them all at once. In contrast, of the $388 billion in liabilities, approximately $100 billion would be classified as "short-term," much of which had maturities less than one week. In normal times, I-bank would easily refinance these liabilities as they came due. As discussed, one common mechanism for these financings is repo. That is, the borrower/bank raises money by "selling" an asset to the lender/depositor, with a promise to repurchase the asset at a later date (often this is just one day later – an "overnight repo"). The transaction will typically take place at some small discount the initial margin or, "haircut" to the market value, which provides a cushion to the lender/depositor in case the asset loses value and the borrower defaults on the repurchase. From an economic perspective, a repo is just a secured loan, with cash given over a short time, and where the collateral is provided by the underlying asset. As such, the interest rate on a repo loan will depend on both the quality of the collateral and the credit worthiness of the borrower. In ordinary times, I-bank could use many of their relatively illiquid assets as collateral.

Financing via the repo market exposes banks to the risk that the repos will not be rolled, which is economically equivalent to depositors withdrawing their money. One way this can happen, is for repo "depositors" to decide not to roll their positions, which is tantamount to withdrawal. Another way is for "depositors" to seek greater comfort by asking for higher haircuts, essentially a partial withdrawal of funds. Higher haircuts mean that each bank seeking to raise money via repo needs to use more of its own equity to finance its balance sheet. If the bank does not have enough equity, it has to sell assets. If this causes asset prices to fall, because all intermediaries are selling assets at the same time, haircuts can increase further. There is no way for these firms to delever and remain solvent. Our hypothetical I-bank had only $12 billion of equity to support $400 billion of assets. With either a small decrease in prices, perhaps reflected only by increases in the haircuts, I-bank will not be able to stay solvent. Then, just as in the 19th century panics, the panic

results in system insolvency. The problem here is also the same as faced by the 19th century banks: on the day before the panic, the demand deposits were sticky and effectively comprised a long-run capital stock for the banks. On the day after the panic, these deposits were gone. Substitute "repo loans" for "demand deposits" and we have the problem for wholesale banks in this panic.

E. Interbank Markets and the LIBOR-OIS Spread (LIBOIS)

Our proxy for the state of the interbank market and, in particular, the repo market, is the spread between 3-month LIBOR and the **Overnight Index Swap** (OIS) rate.

LIBOR is the rate paid on interbank loans, cash loans where the borrower receives an agreed amount of money either at call or for a given period of time, at an agreed interest rate. These loans are not tradable. Basically, a cash-rich bank "deposits" money with a cash-poor bank for a period of time. The rate on such a deposit is LIBOR, which is the interest rate at which banks are willing to lend cash to other financial institutions 'in size'. The British Bankers' Association's (BBA) London interbank offer rate (LIBOR) fixings are calculated by taking the average of a survey financial institutions operating in the London interbank market.[14] The BBA publishes daily fixings for Libor deposits of maturities up to a year.

From the 3-month LIBOR rate we will subtract a measure of interest rate expectations over the same term. This rate is the overnight index swap rate. The overnight indexed swap is a fixed-to-floating interest rate swap that ties the floating leg of the contract to a daily overnight reference rate (here, the fed funds rate).[15] The floating rate of the swap is equal to the geometric average of the overnight index over every day of the payment period. When an OIS matures, the counterparties exchange the difference between the fixed rate and the average effective fed funds rate over the time period covered by the swap, settling the trade on a net basis. Standard terms of one, two, three, six, and twelve months are available, but swaps can also be tailored to specific maturities. The fixed quote on an OIS should represent the expected average of the overnight target rate over the term of the agreement.

As with swaps generally, there is no exchange of principal and only the net difference in interest rates is paid at maturity, so OISs have little credit risk exposure. One significant difference between an OIS and a plain vanilla interest rate swap is that the floating rate leg of an OIS is determined and paid only at maturity. In a plain vanilla interest rate swap, the floating rate leg is determined at one settlement date and paid at the next, i.e., determined in advance and paid in arrears.

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[14] The BBA eliminates the highest and lowest quartiles of the distribution and average the remaining quotes. See Gyntelberg and Wooldridge (2008).

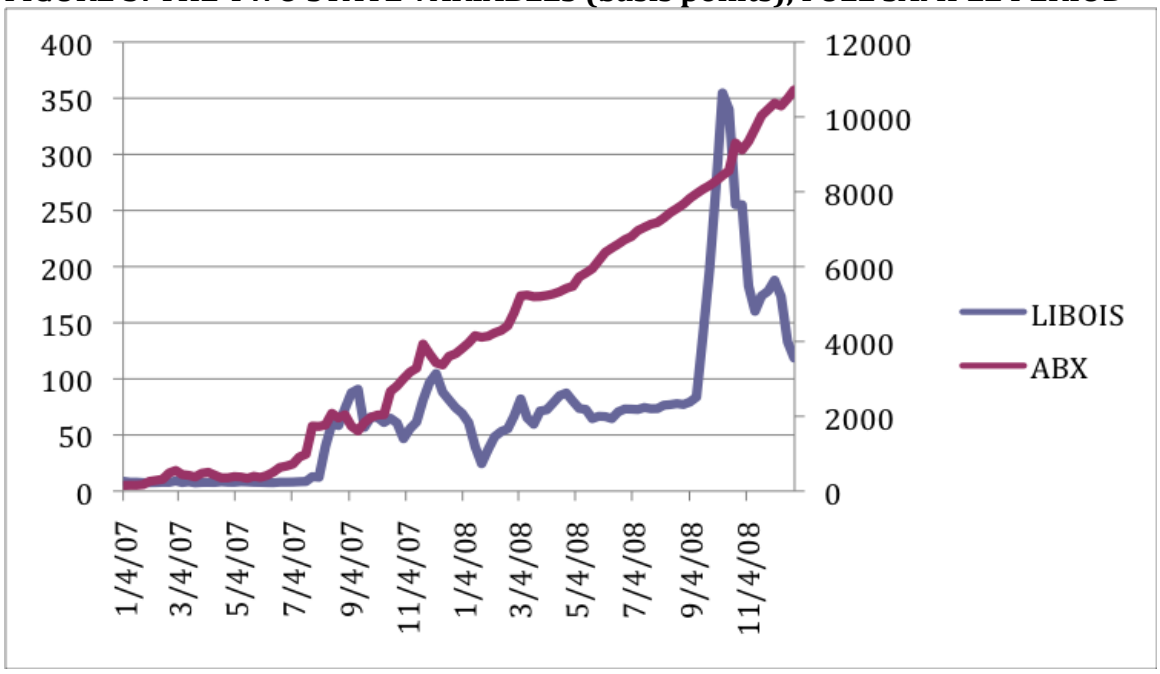
[15] There are equivalent swaps in other currencies, which reference other rates.

If there is no credit risk and no transactions costs, then the interest rate on an interbank loan should equal the overnight index swap (the expected fed funds cost of the loan). To see this consider an example: Bank 1 loans Bank 2 $10 million for three months. Bank 1 funds the loan by borrowing $10 million each day in the overnight fed funds market. Further, Bank 1 hedges the interest rate risk by entering into an overnight index swap under which Bank 1 agrees to pay a counterparty the difference between the contracted fixed rate and the overnight fed funds rate over the next three months. In the past arbitrage has kept this difference below 10 bps.

If the spread between LIBOR and the OIS widens, there is an apparent arbitrage opportunity. But, banks are not taking advantage of it. Why? The answer is that there is counterparty risk: that is, Bank 1 worries that Bank 2 will default and so there is a premium between the expected interest rates over the period, the OIS rate, and the rate on the loan, LIBOR. This is equivalent to a "currency premium," referred to by observers of 19th century panics. We refer to the spread between LIBOR and the OIS as the "LIBOIS", which is our second state variable.

In the following graphs, we place the two state variables together over different periods. Beginning with the next figure, our "full period" is from January 1, 2007 through December 25, 2008. In some figures of Section III, we also add some data from January 2009. In these pictures, it is easy to see why these two variables represent two distinct forces. Figure 3 shows both variables over the full 2007-8 period. For the ABX, we use the 2006-1 BBB tranche in all cases.

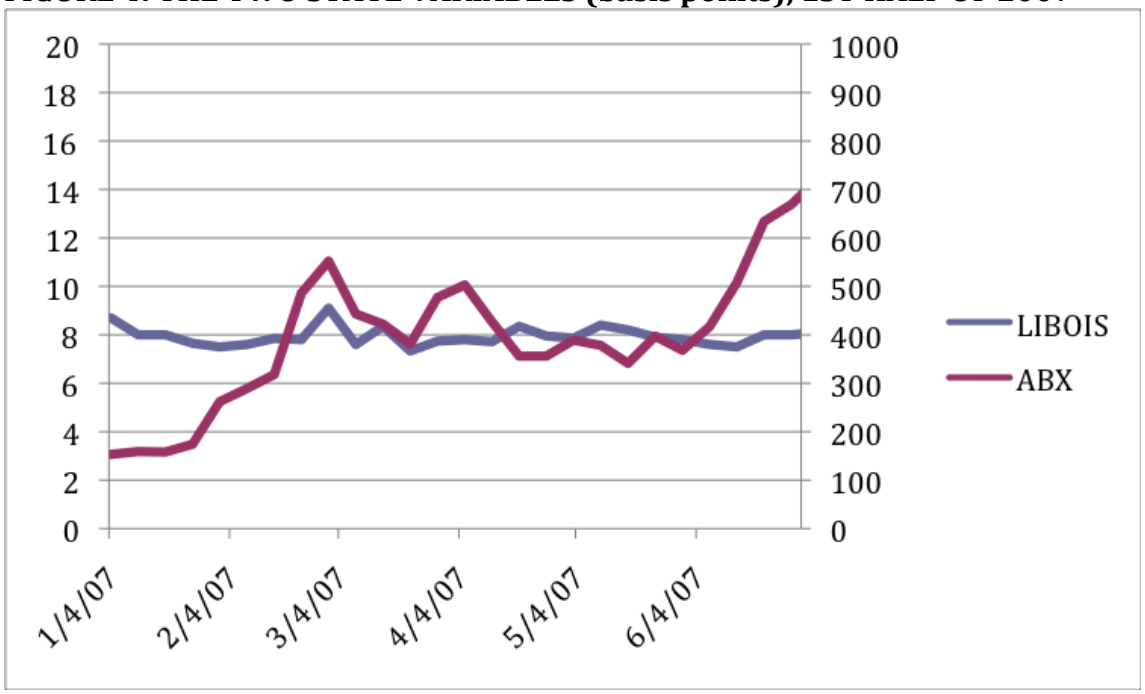
FIGURE 3: THE TWO STATE VARIABLES (basis points), FULL SAMPLE PERIOD



Notes: ABX is for the 2006-1 BBB tranche. LIBOIS on left-hand Y-axis, ABX spreads on right-hand y-axis. Both scales are in basis points.

During the full period, the ABX makes a steady rise, whereas the LIBOIS shows two jumps in August 2007 and September 2008. These months are not particularly special for the ABX. Furthermore, the LIBOIS recovers some ground at the end of 2008, while the ABX continues to collapse. Pictures of the subperiods can better illustrate this difference.

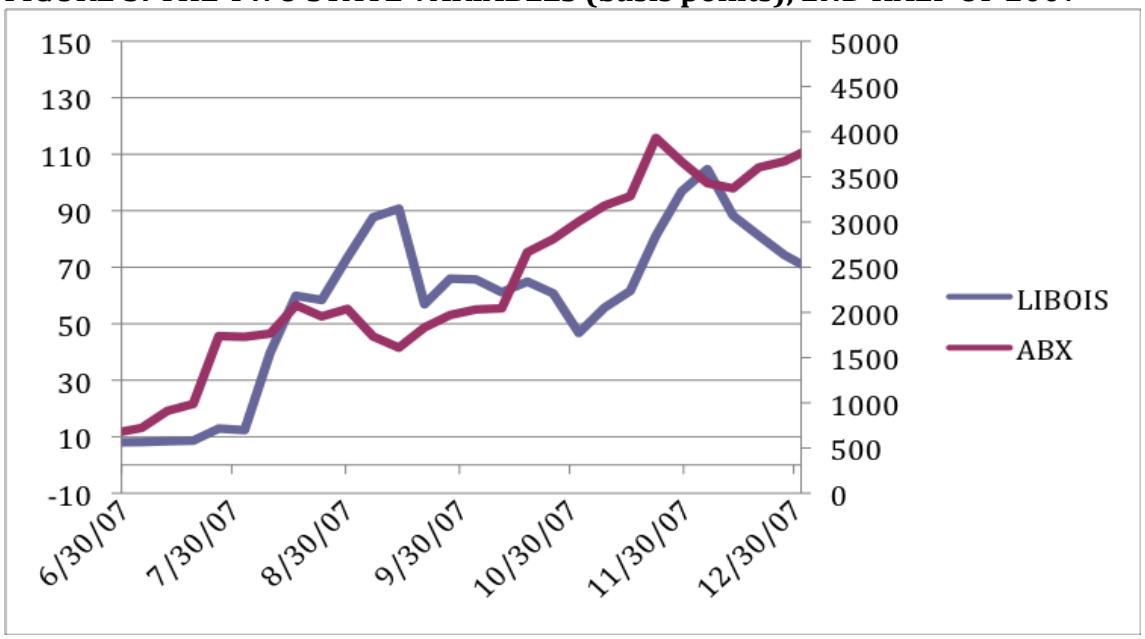
FIGURE 4: THE TWO STATE VARIABLES (basis points), 1ST HALF OF 2007



Notes: ABX is for the 2006-1 BBB tranche. LIBOIS on left-hand Y-axis, ABX spreads on right-hand y-axis.

The first six months of 2007 were ordinary for the vast majority of fixed income assets. It is only when we look at subprime-specific markets that we begin to see the seeds of the crisis. The ABX begins the year at 153 **basis points** (bp), which is close to its historical average (in 2006), where there had been almost no volatility. The first signs of trouble appear at the end of January, and by March 1 the spread was 552bp. The next sustained rise came in June, reaching 669bp by the end of that month. In contrast, the LIBOIS hardly moved during the period, steady at around 8bp. The interbank market was calm before the gathering storm.

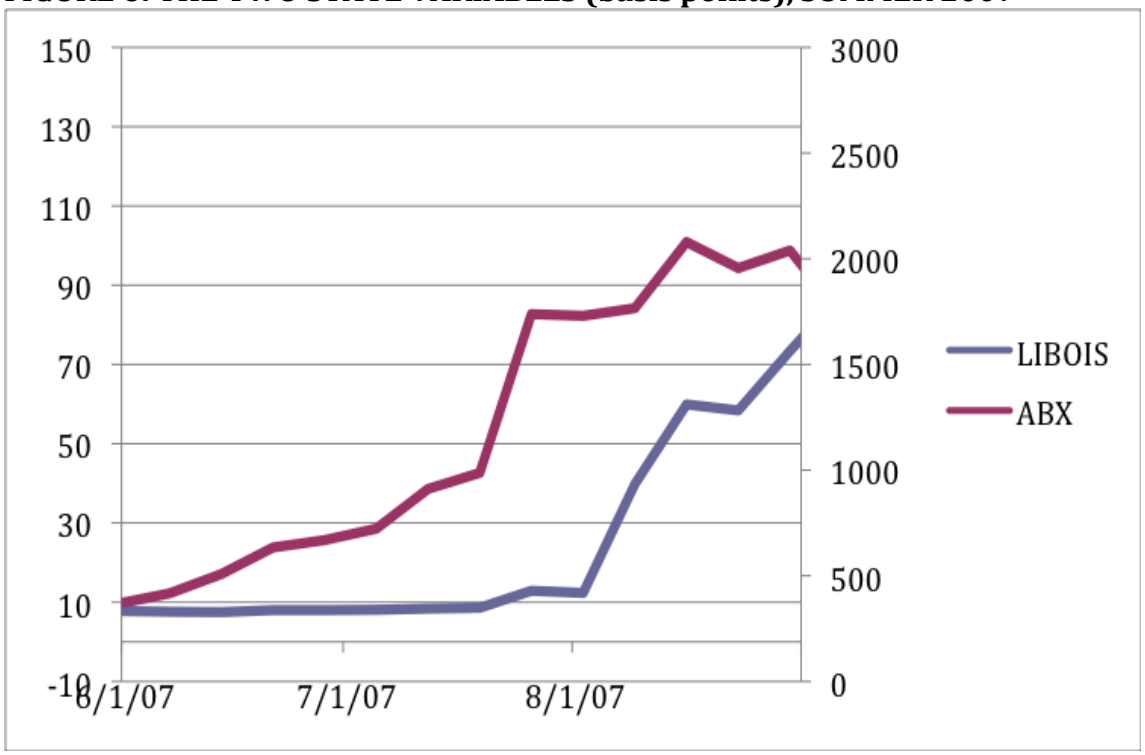
FIGURE 5: THE TWO STATE VARIABLES (basis points), 2ND HALF OF 2007



Notes: ABX is for the 2006-1 BBB tranche. LIBOIS on left-hand Y-axis, ABX spreads on right-hand y-axis.

It is the second half of the year, particularly the month of August, where the LIBOIS first signals danger in the interbank market. From its steady starting value of 8 bp, LIBOIS grows to 13 bp on July 26, before exploding past its historical record to 40 bp on August 9, and to new milestones in the weeks ahead and peaking at 96 bp on September 10. As we will see in Section III, this period marked the initial shock for a wide swath of the securitization markets, particularly in high-grade tranches commonly used as collateral in the repo market. The ABX is also rising during this period, but the significant move begins earlier, and visually appears to lead the LIBOIS. From its starting value of 669 bp at the end of June, the spread rises to 1738 bp by the end of July, before any significant move in the LIBOIS. The next picture breaks out these key months in more detail.

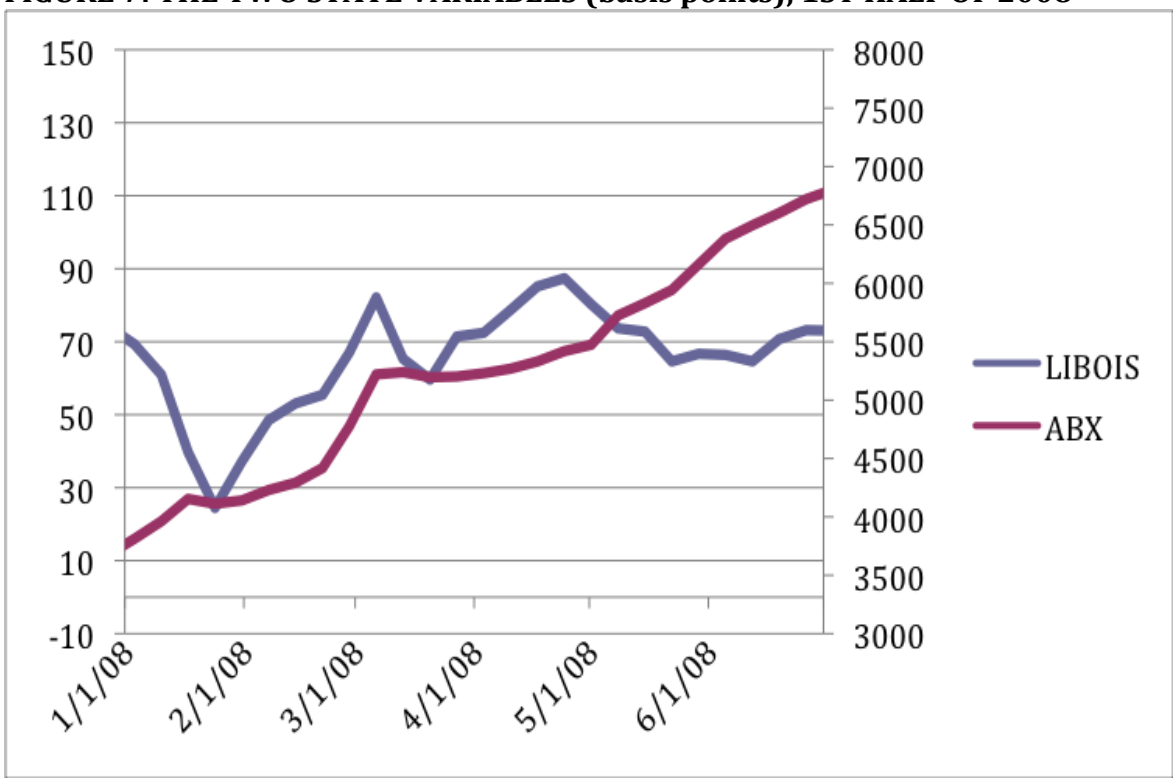
FIGURE 6: THE TWO STATE VARIABLES (basis points), SUMMER 2007



Notes: ABX is for the 2006-1 BBB tranche. LIBOIS on left-hand Y-axis, ABX spreads on right-hand y-axis.

Figure 6, which focuses on June through August of 2007, makes clear the temporal precedence of the move in the ABX.

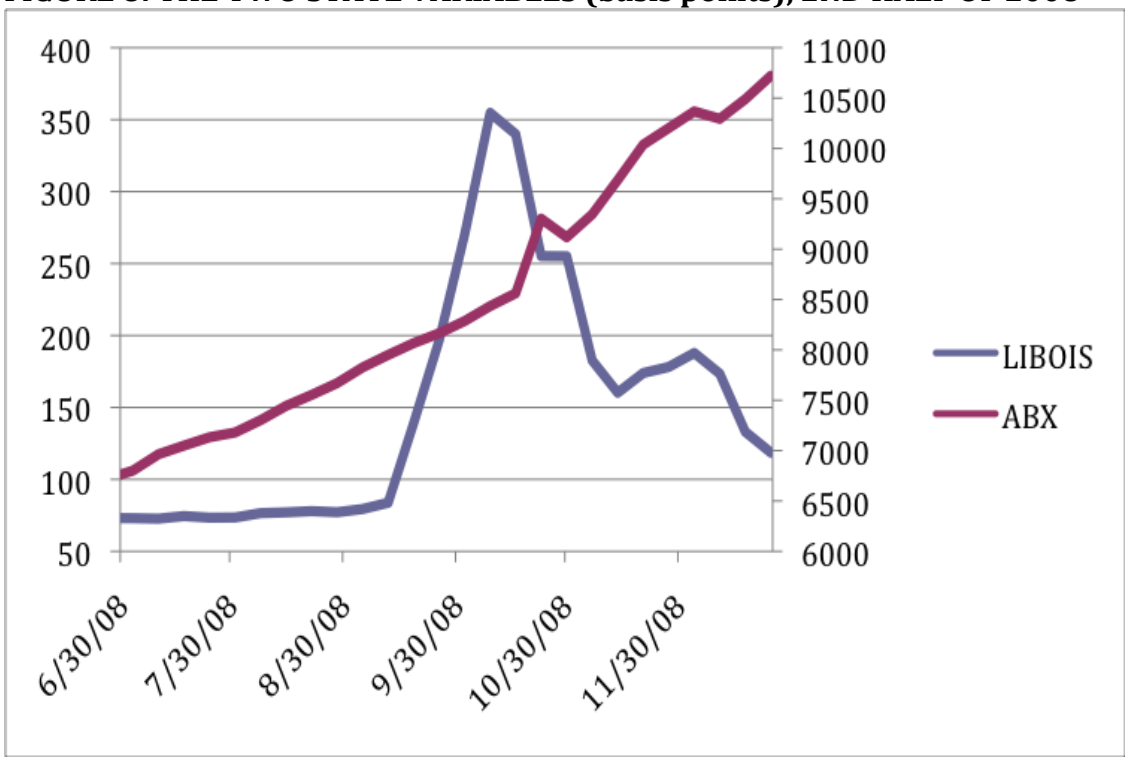
FIGURE 7: THE TWO STATE VARIABLES (basis points), 1ST HALF OF 2008



Notes: ABX is for the 2006-1 BBB tranche. LIBOIS on left-hand Y-axis, ABX spreads on right-hand y-axis.

In the first half of 2008, the ABX spread continues its steady rise, going from 3812 bp to 6721 bp over the six-month period. Once again, the LIBOIS is behaving differently from the ABX, with trading in a band between 30 and 90 bp. The reduction in the LIBOIS in January is followed by increases through February and March, coincident – or perhaps causal – of the trouble at Bear Stearns, which reached its climax with its announced sale to JP Morgan on March 16.

FIGURE 8: THE TWO STATE VARIABLES (basis points), 2ND HALF OF 2008



Notes: ABX is for the 2006-1 BBB tranche. LIBOIS on left-hand Y-axis, ABX spreads on right-hand y-axis.

In the second half of 2008, the full force of the panic hit asset markets, financial institutions, and the real economy. The ABX spread continued its steady rise, with prices of pennies on the dollar and spreads near 9000 bp by the end of the period. The LIBOIS, after a period of stability in the summer, began to rise in early September, and then passed the 100 bp threshold for the first time on the September 15 bankruptcy filing of Lehman Brothers. The subsequent weeks heralded near collapse of the interbank market, with the LIBOIS peaking at 364 bp on October 10, before falling back to 128 bp by the end of 2008.

LIBOIS first spikes in August 2007, corresponding to the run on the repo market, discussed further below. Why was there a second spike in LIBOIS? The fact that Lehman was not bailed out by the government apparently shocked market participants because it revealed the enormous potential problem of **daylight risk exposure**, which refers to the risk a party faces between the time a settlement payment is made and a corresponding payment is received during the same business day. Given the uncertainty about the solvency of institutions, and the now real possibility of bankruptcy, market participants were unwilling to let cash leave their hands without other parties paying first. In effect, we can think of this as being like a "cash-in-advance" constraint for short-term loan transactions. If everyone does this, transactions come to a halt. At the moment, we have no direct evidence of this, but we have some ideas of where to look.

F. Summary

So far, the story that emerges from these pictures has several chapters. The narrative on the ABX and the subprime market is relatively simple: a rise in the spread beginning in early 2007, accelerating beginning in June 2007 and then maintaining its rate of increase through the end of 2008. For the LIBOIS and the repo market, it is about two big shocks – August 2007 and September 2008 – with periods of relative stability (albeit at a historically high level) in between them. The first LIBOIS shock corresponds to the run on the repo market, for which we provide more evidence below. The second shock appears to be related to cash hoarding and the currency famine, whereby firms held cash and could not make transactions.

II. The Impact of the Shocks

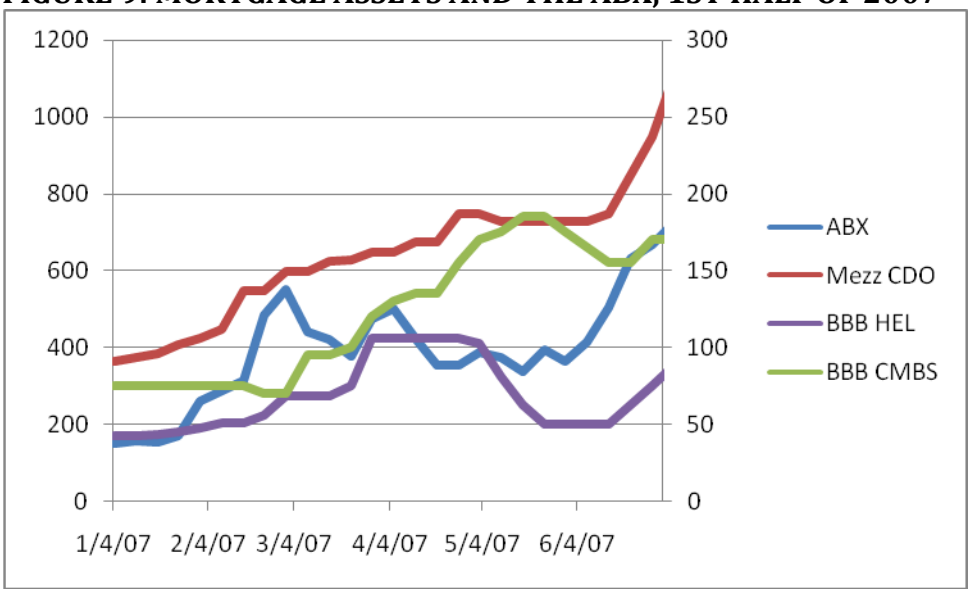
The collapse of the repo market is the systemic event. In this section we provide evidence of the impact of this collapse by showing how other, unrelated, asset classes were directly impacted. Later, we show the increase in the repo initial margins and evidence of the scarcity of collateral.

A. Assets Exposed Directly to the Subprime Market

a. Mortgage Assets

We first consider a set of assets that are directly related to the subprime mortgage market. It is not surprising that these markets move in tandem with the ABX – some are even linked to the ABX through arbitrage (when markets are properly functioning; see Gorton (2009)). The figure below shows the spreads on three asset classes and the BBB ABX index. The three asset classes are (1) BBB **Mezzanine CDO** ("Mezz CDOs") tranches; (2) BBB tranches of home-equity loan securitizations; and (3) the BBB tranches of **commercial mortgage-backed securities**.

FIGURE 9: MORTGAGE ASSETS AND THE ABX, 1ST HALF OF 2007

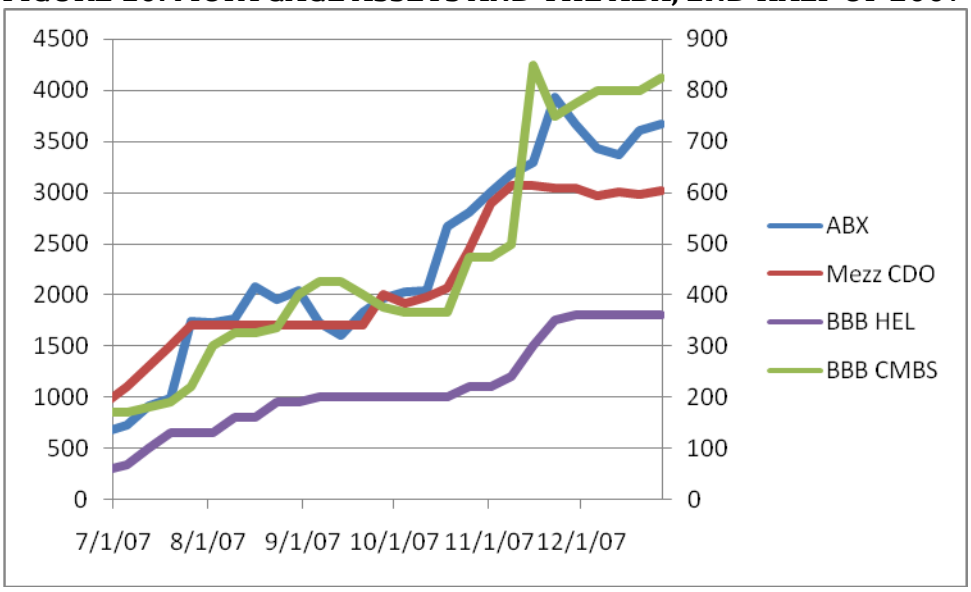


Notes: Other assets include Commercial Mortgage-Backed Securities (CMBS), BBB tranches of Mezz CDOs, and BBB-rated securitized Home-Equity-Loans (HEL). CMBS is on the right-hand y-axis, other assets are on the left-hand y-axis.

The ABX is the first of these assets to make a sustained rise in its spread, but the others are quick to follow. During this period, no other debt markets are affected.

Mezz CDO typical collateral composition included 77 percent subprime RMBS tranches, 12 percent other RMBS tranches, 6 percent other CDO tranches, and the remaining other (see Gorton (2008) for citations).

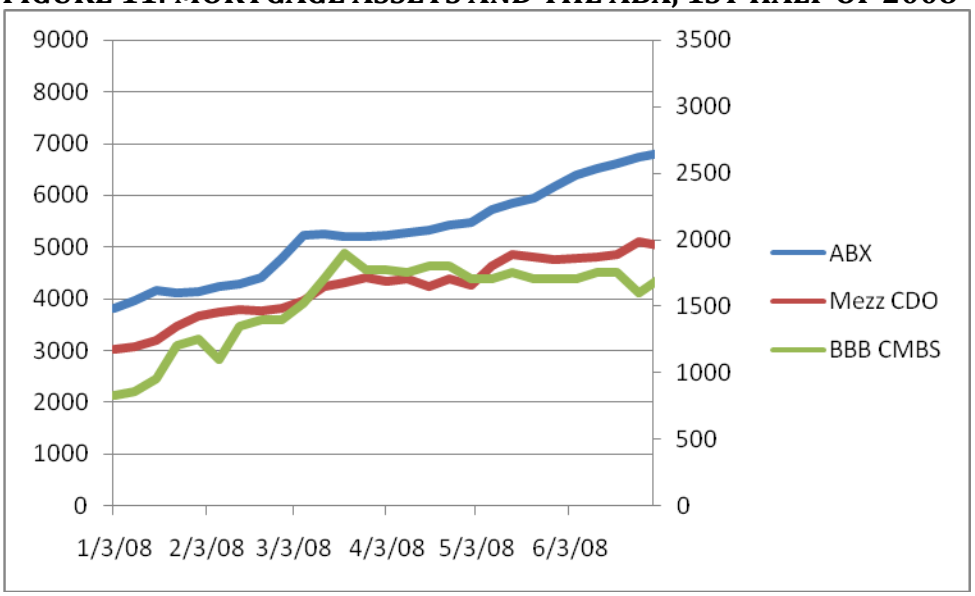
FIGURE 10: MORTGAGE ASSETS AND THE ABX, 2ND HALF OF 2007



Notes: Other assets include Collateralized Mortgage Backed Securities (CMBS), mezzanine trances of subprime collateralized debt offerings (CDO), and BBB-rated securitized Home-Equity-Loans (HEL), CMBS is on right-hand y-axis, other assets on left-hand y-axis.

All spreads in this figure move steadily upwards. Note that there is nothing particularly special about August 2007, which as we have seen was the crucial month for the LIBOIS.

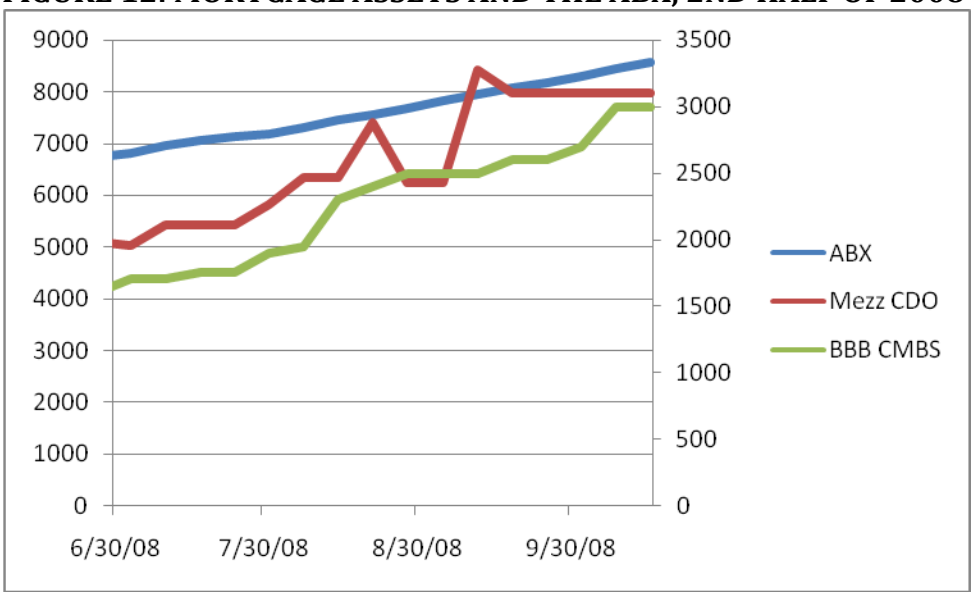
FIGURE 11: MORTGAGE ASSETS AND THE ABX, 1ST HALF OF 2008



Notes: Other assets include Collateralized Mortgage Backed Securities (CMBS), and mezzanine tranches of subprime collateralized debt offerings (CDO). CMBS is on right-hand y-axis, other assets on left-hand y-axis.

The subprime home-equity-loan tranches no longer had liquidity in 2008, so there are no data and they are omitted from this picture and the next one.

FIGURE 12: MORTGAGE ASSETS AND THE ABX, 2ND HALF OF 2008



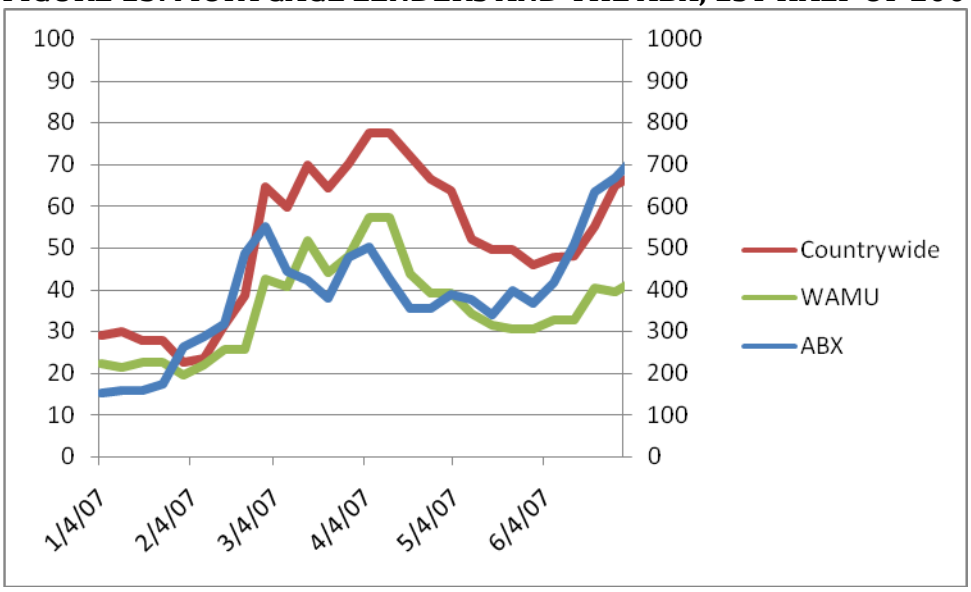
Notes: Other assets include Collateralized Mortgage Backed Securities (CMBS), and mezzanine trances of subprime collateralized debt offerings (CDO). CMBS is on right-hand y-axis, other assets on left-hand y-axis.

Subprime spreads go into the stratosphere.

b. Subprime Mortgage Lenders

The next group to react to the subprime crisis was the banks that were most active in the sector. The next picture shows the CDS spreads for Washington Mutual ("Wamu") and Countrywide, two of the banks with the greatest subprime activity.

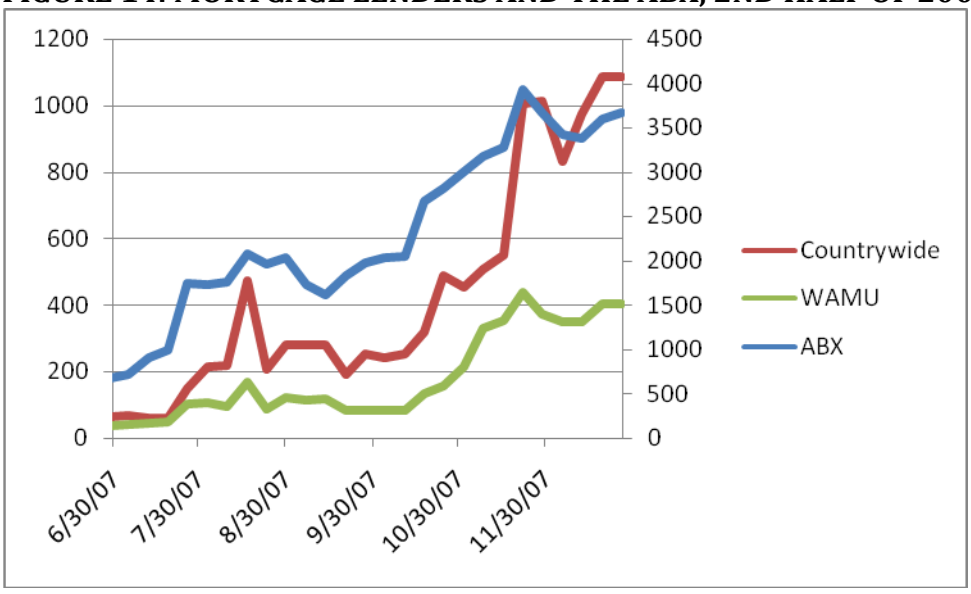
FIGURE 13: MORTGAGE LENDERS AND THE ABX, 1ST HALF OF 2007



Notes: Bank CDS spreads on left-hand y-axis, ABX spread on right-hand y-axis.

This figure shows that the CDS spreads began to rise slightly in February and March Other banks CDS spreads (not shown in figure) – Citigroup, JP Morgan, Bank of America – moved much later.

FIGURE 14: MORTGAGE LENDERS AND THE ABX, 2ND HALF OF 2007



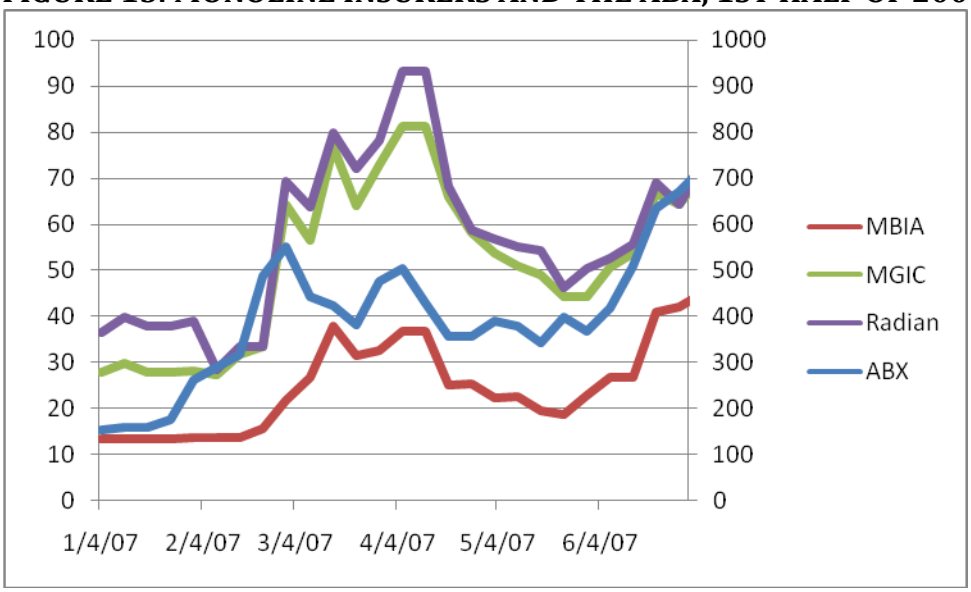
Notes: Bank CDS spreads on left-hand y-axis, ABX spread on right-hand y-axis.

In late 2007, the CDS spreads moved in tandem with the ABX. Countrywide also shows a significant spike during the August LIBOIS event. 2008 data is clouded by M&A activity and government intervention, so is not shown here.

c. Monoline Insurers

A final group to consider is comprised of firms that got little attention prior to the crisis: the **monoline insurers** of CDOs. These companies guaranteed portions of the CDO payments, and the CDS spreads of these companies moved closely with the ABX.

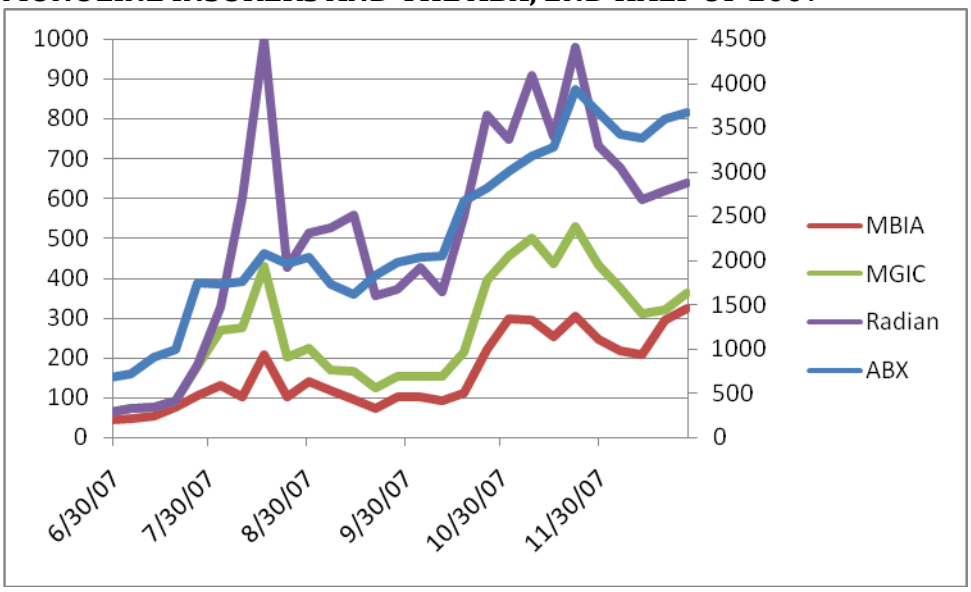
FIGURE 15: MONOLINE INSURERS AND THE ABX, 1ST HALF OF 2007



Notes: Insurer CDS spreads on left-hand y-axis, ABX spread on right-hand y-axis.

The ABX moved before the CDS for each of these companies, but in each case the CDS had moved by the spring.

MONOLINE INSURERS AND THE ABX, 2ND HALF OF 2007



Notes: Insurer CDS spreads on left-hand y-axis, ABX spread on right-hand y-axis.

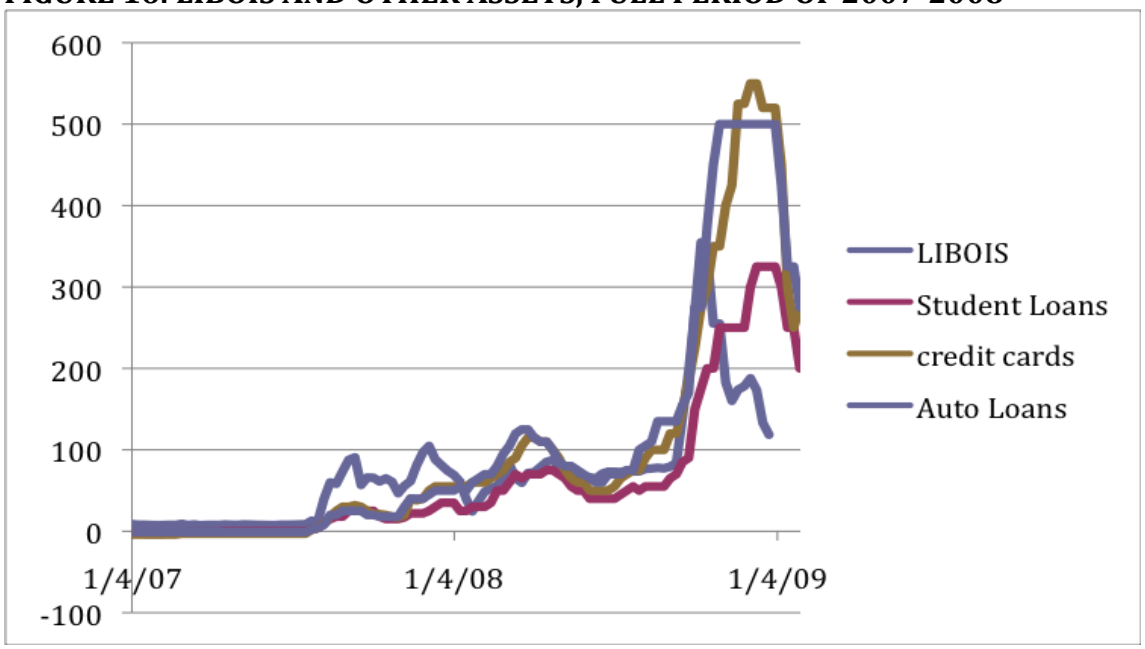
The scale of the problem became more apparent in the second half of the year. Note that all CDS series show a jump around August 2007. We conjecture that this jump is related to the LIBOIS event that is affecting dealer banks, as we see below. Monolines marking-to-market are vulnerable to spread increases caused by any disruption in these markets.

The subprime crisis first showed up in assets that directly linked to the subprime market, and then slightly later began to appear in the credit-risk of major lenders and issuers in this market. During the first half of 2007, only these players were affected, with no contagion to other markets.

B. Assets Exposed to the Repo Market

For the crisis to be a systemic event, it first must be the case that asset classes completely unrelated to subprime are affected. We next show how the LIBOIS is related to the spreads on various non-subprime high-grade structured product asset classes. We consider three representative asset classes: student loans, credit cards, and auto loans. In each case we take the AAA tranche of the shortest-maturity securitization. These are the closest thing to "risk free" or informationally insensitive assets that exist in the securitization space.

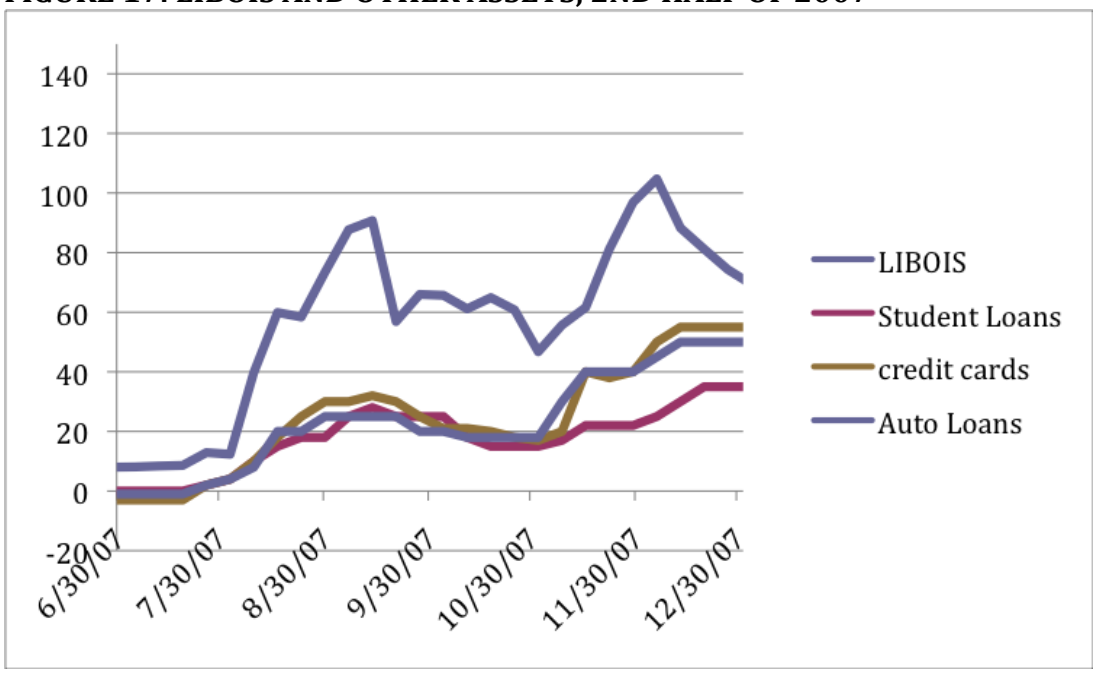
FIGURE 16: LIBOIS AND OTHER ASSETS, FULL PERIOD OF 2007-2008



In each case, the spreads at the beginning of 2007 are very close to zero, and in fact are negative in some cases. Even in late 2008, few traders would assess these assets as having any real default risk. So why do we ever see positive spreads? One plausible explanation is that each of these assets is commonly used as collateral in the repo market, and their ability to be used as a liquid substitute for cash depends

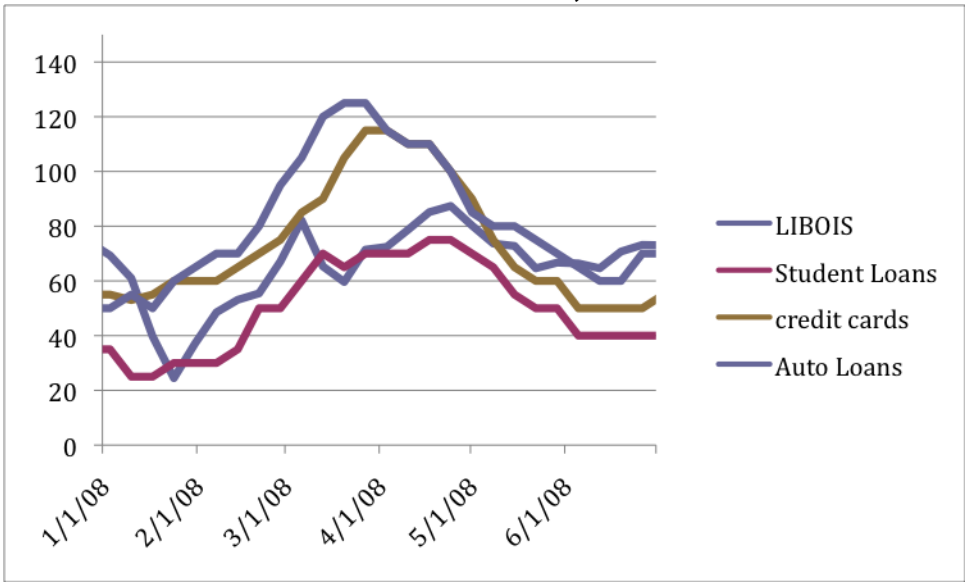
crucially on the ordinary functioning of that market. Then, when the repo market freezes up, these assets essentially become illiquid, and require an illiquidity premium on their returns. This explanation can reconcile the comovement of these assets with the LIBOIS. We further illustrate this comovement with the subperiod pictures shown below.

FIGURE 17: LIBOIS AND OTHER ASSETS, 2ND HALF OF 2007



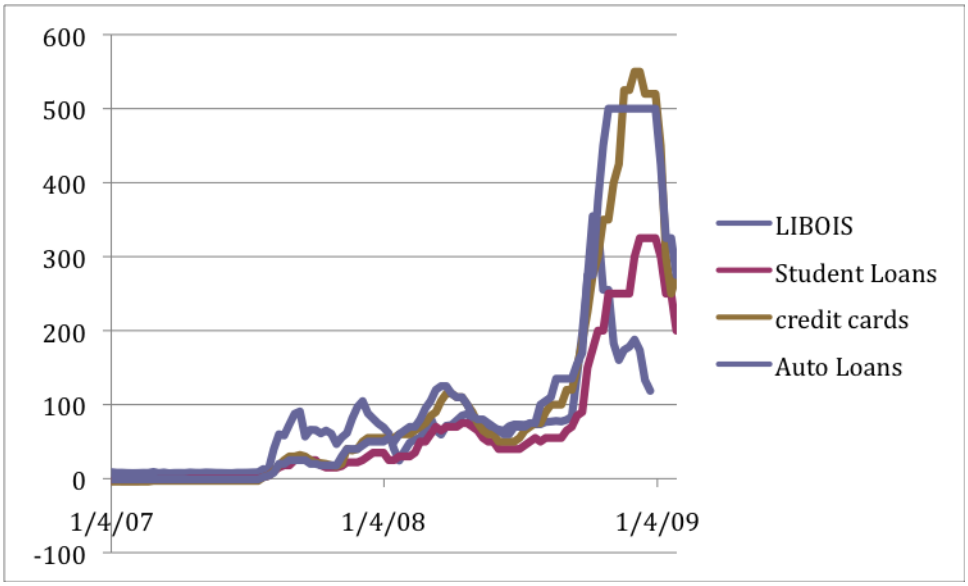
Since all of these spreads are essentially constant in the first half of 2007, we begin our subperiod pictures in the second half. Here, we see that the LIBOIS moves first with a sharp increase in August, but the other spreads also react, moving from near zero to over 20bp by the end of the month. All series show a further move in December.

FIGURE 18: LIBOIS AND OTHER ASSETS, 1ST HALF OF 2008



All series rise as we move towards the Bear Stearns failure in mid-March, with the spreads on other assets now about the same as the LIBOIS. All spreads fall together in the spring.

FIGURE 19: LIBOIS AND OTHER ASSETS, 2ND HALF OF 2008 (AND JAN 2009)



The acute phase of the crises hits all these spreads the same way, with sharp increases beginning in September and peaking in October. The LIBOIS then falls until the year end, with the other spreads dropping in January of 2009.

Overall, these pictures demonstrate striking similarities in the comovement of very different assets. Student loans, auto loans, and credit cards – all of the highest quality tranches – with no historical records of default, moving in tandem with short-term lending rates in the interbank market. This comovement suggests an

institutional explanation: the collapse of the repo market, and with it the availability of using these assets as alternatives to cash, causes spreads to widen to reflect the underlying illiquidity of these assets. This change in the liquidity of the balance sheet makes these wholesale banks vulnerable to runs, with the repo market playing the role of "deposit" in traditional banks.

III. Formal Tests

In this section we formally test whether the two state variables, discussed above, are determinants of changes in the spreads of various asset classes. While there is a small literature on corporate bond spreads (see Collin-Dufresne, Goldstein, and Martin (2001), and the citations therein), there are no studies of spreads on securitized products. Our data set consists of spreads on 240 different securitized products (different asset classes and tranches) as well CDS premiums for a variety of firms.

The empirical strategy is straightforward. We regress the change in the spread (normalized by its level) for each variable on the changes in the two state variables, ABX_D and LIBOIS_D, three lags of these state variable changes, and changes on a number of control variables. In this draft of the paper, we focus exclusively on the spreads discussed in Section IIB: AAA ABS spreads of credit cards (CARDS), student loans (STUDENT), and auto loans (AUTO).

The control variables are as follows. The 10-year constant maturity treasury rate, where the change is indicated by 10YTreasury_D. Also, the square of 10YTreasury_D, indicated by Sqr of 10YT_D. General changes in the economy are indicated by returns on the S&P index. SP500_ret is the weekly return of SP500 Index. General volatility or risk in the economy is proxied for by the VIX index, which is a weighted average of eight implied volatilities of near-the-money options on the S&P 100 index. We use the difference, indicated by VIX_D, that is, the difference of VIX index. The slope of the yield curve, where YCSlope_D is the difference in the yield curve slope, which is defined as the difference between the 10-year and 2-year Treasury bond interest rates.

The results are given in Table I. For all three spreads – CARDS, AUTO, STUDENT – the only significant factor is the LIBOIS. F-tests for the join significance of the LIBOIS variables are highly significant in each case. The ABX is not significant, nor are any of the control variables. The lack of influence from the other control variables is striking: these AAA tranches do not appear to have any real economic risk, but instead are affected only by disruptions in the repo market.

Table I
Regression Result

For each bond i, using weekly data from January 4, 2007 to December 18,2008, we estimate the following regression $\Delta CS_t^i = \alpha + \sum_{l=0}^{3} \Delta ABX_{t-l} + \sum_{m=0}^{3} \gamma_m^i \Delta LIBOIS_{t-m} + \sum_{n=1}^{4} \delta_n^i Ctrl_t^n$,where$\Delta CS_t^i$ is the percentage change of credit spread of bond i at period t, ΔABX_t is the parentage change of the ABX index at period t, and $\Delta LIBOIS_t$ is the percentage change of the spread between the 3-month LIBOR and the Overnight Index Swap (OIS) rate at period t. $Ctrl_t^n$ are our four control variables, which are Δr_t^{10}, the change in yield on the 10-year Treasury and its square $(\Delta r_t^{10})^2$, $\Delta slope_t$ the change in 10-year minus 2-year Treasury yields, ΔVIX_t the change in implied volatility of S&P 500 (VIX index), and $S\&P_t$ the return on S&P 500. The credit spreads of three AAA level structured products are examined. CARDS is the credit card ABS. AUTO is the prime auto loans and STUDENT is the student loans. Panel A shows the coefficient estimates with t-statistics in parenthesis. Panel B shows the F-statistics of the hypothesis tests. Corresponding p-value is reported in parenthesis. The null hypothesis of Test 1 is the sum of all coefficients of ΔABX and its lags is zero. The null hypothesis of Test 2 is the sum of all coefficients of $\Delta LIBOIS$ and its lags is zero.

	Credit Spreads		
	CARDS	AUTO	STUDENT
	Panel A: Coefficient estimates		
Intercept	0.022	0.028	-0.011
	(0.57)	(0.52)	(-0.29)
ΔABX_t	-0.173	-0.323	0.467
	(-0.77)	(-1.03)	(2.21)
ΔABX_{t-1}	0.037	-0.075	0.131
	(0.16)	(-0.24)	(0.63)
ΔABX_{t-2}	0.331	0.282	-0.193
	(1.5)	(0.92)	(-0.94)
ΔABX_{t-3}	-0.305	-0.385	-0.178
	(-1.35)	(-1.23)	(-0.74)
$\Delta LIBOIS_t$	0.390	0.140	0.438
	(3.4)	(0.88)	(4.49)
$\Delta LIBOIS_{t-1}$	0.244	0.452	0.117
	(2.3)	(3.07)	(1.31)
$\Delta LIBOIS_{t-2}$	0.115	0.003	0.137
	(1.07)	(0.02)	(1.52)
$\Delta LIBOIS_{t-3}$	0.035	0.162	-0.003
	(0.34)	(1.11)	(-0.03)
Δr_t^{10}	0.026	-0.077	0.019
	(0.12)	(-0.24)	(0.09)
$(\Delta r_t^{10})^2$	0.201	0.094	0.169
	(0.32)	(0.11)	(0.32)
$S\&P_t$	-0.680	1.790	-0.378
	(-0.36)	(0.68)	(-0.23)
ΔVIX_t	-0.010	0.004	0.002
	(-0.6)	(0.17)	(0.15)
$\Delta slope_t$	-0.197	0.235	0.154
	(-0.77)	(0.66)	(0.7)
	Panel B: F-Test		
Test 1	0.07	0.76	0.37
	(0.79)	(0.38)	(0.55)
Test 2	18.06	8.74	19.62
	(<0.01)	(<0.01)	(<0.01)

IV. The Repo Market

We turn in this section to examine the repo market directly. We have argued that the LIBOIS variable is a proxy for the state of the repo market. But, we have not looked directly at the repo market. Looking at the repo market directly is important to understand why the run on repo constituted a systemic event.

In the repo market, anxiety about counterparty risk and about the value of the collateral caused "depositors" to be concerned about engaging in repo. The concern is about the borrowing bank defaulting and the depositor not being able to recover the collateral or about being able to recover the collateral, but finding that its value is lower than expected. Once these bonds become informationally sensitive, much more due diligence needs to be done to understand their risks. But, these bonds are incredibly complicated; see Gorton (2008).

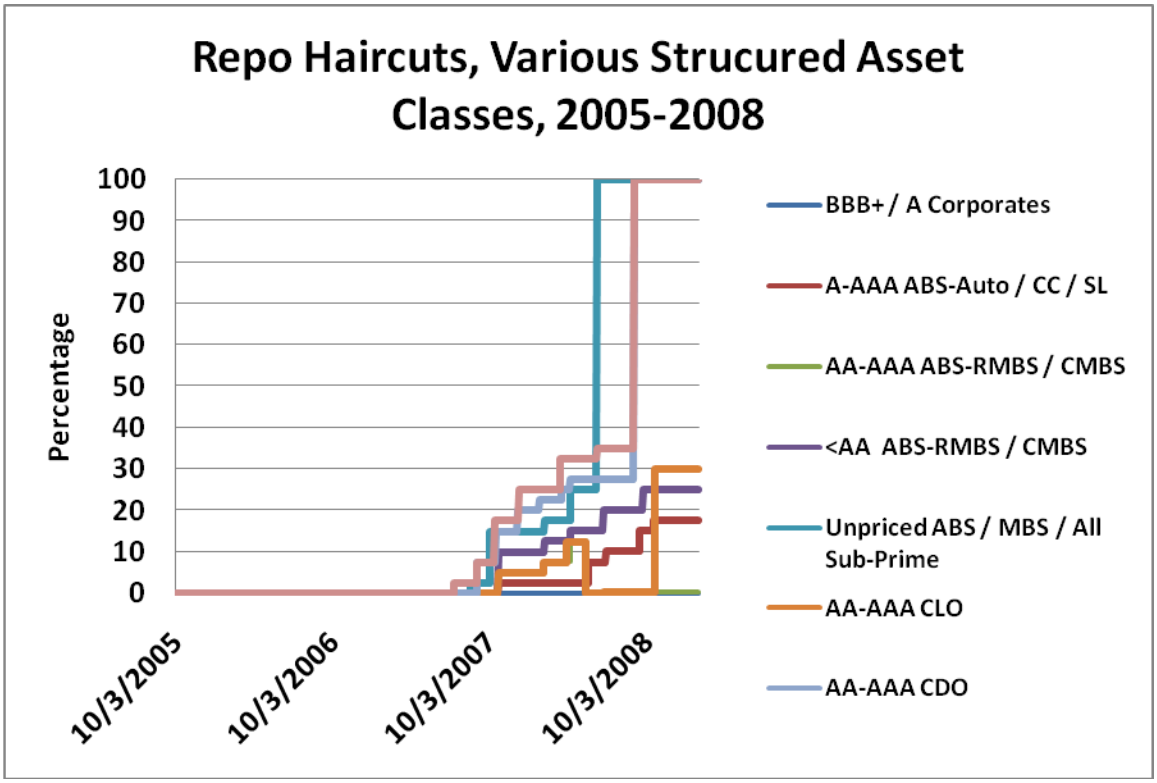
a. Repo Haircuts

One way to protect against the risk of counterparty failure and uncertainty about collateral value is to require overcollateralization, that is, an increase in the initial margin or "haircut." The depositor deposits less than the value of the bond, but has the bond as collateral. From the borrowing bank's point of view, the entity funding the bond, this means that for a bond worth $100, only an amount less than that can be borrowed, perhaps $95, i.e., a haircut of 5 percent. An increase in the haircut is tantamount to a withdrawal of cash for deposits in the traditional banking sector.

There are no official statistics on repo haircuts, but Gorton (2009) shows the results of a survey. However, the figures below are much more extensive. The figures are based on daily data about the inter-dealer repo market, and cover a wide variety of asset classes. Figure 20 shows the percentage haircuts over the period 2005-2008. The asset classes shown are listed in the legend to the figure. "Unpriced" means that these asset classes do not have independent pricing that can be verified, e.g., from Bloomberg or Reuters.

Note that all the haircuts are zero until the summer of 2007! Throughout the period BBB+/A corporate bonds retain their zero haircut. The three asset classes that show increases in their haircuts in August and September of 2007 are: unpriced CLO/CDO tranches; unpriced ABS/MBS/all subprime; and AA-AAA CDO tranches. Unpriced CLO/CDO tranches go from a zero haircut to 2.5 percent in July. Unpriced ABS/MBS/all subprime goes from a zero to a 2.5 percent haircut in August, and high-grade CDO tranches go from zero to 7.5 percent haircuts on September 5, 2007. These three categories are the most risky asset classes, either because they are directly linked to subprime risk, or because, being "unpriced" their value has the most uncertainty.

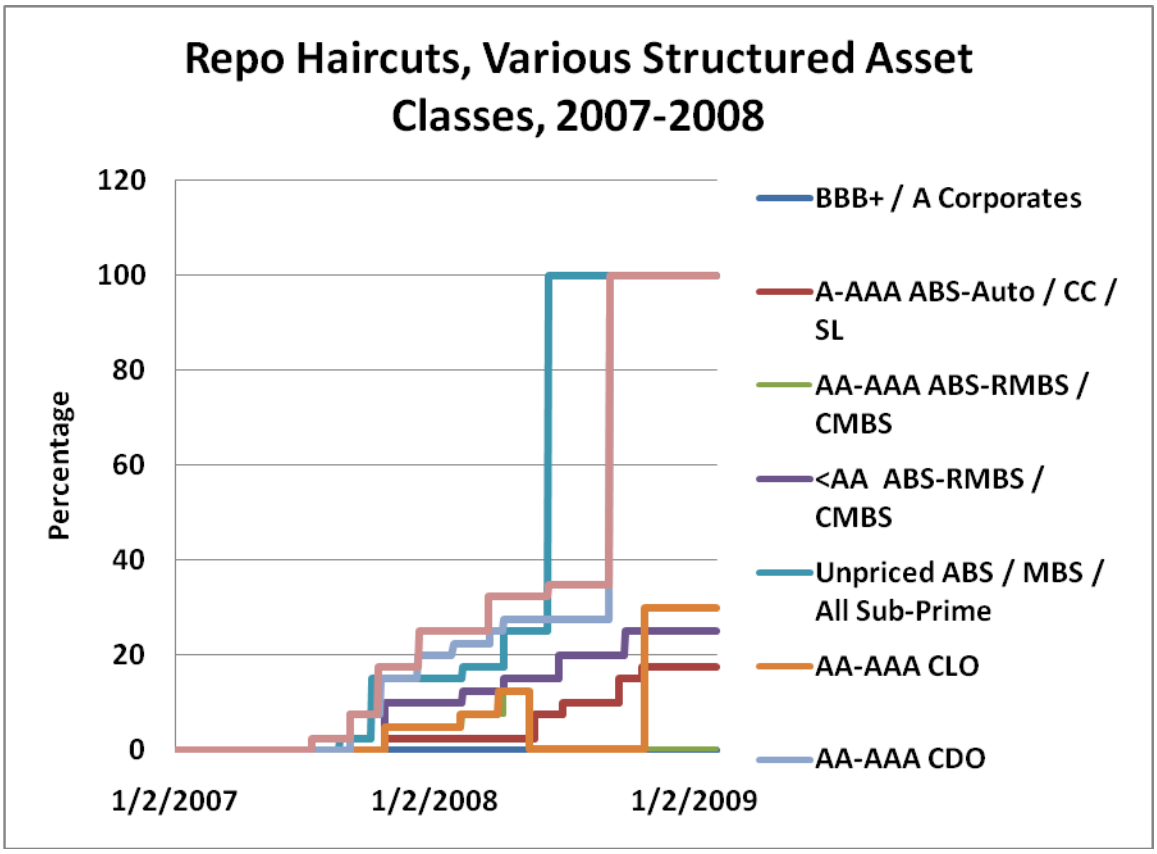
FIGURE 20



The non-subprime asset classes and asset classes that were viewed as very safe, e.g. AAA credit cards, move subsequently. This is a bit easier to see in Figure 21, which shows the percentage haircuts over the period 2007-2008. The following asset classes move to positive haircuts in October 2007: A-AAA ABS (auto, credit cards and student loans) move from zero haircut to 2.3 percent haircut; AA-AAA RMBS/CMBS mover from zero to 5 percent haircuts; RMBS and CMBS rated A or BBB went from zero to 10 percent haircuts. Meanwhile the other asset classes are facing step functions of increasing haircuts. The market disappears completely when haircuts reach 100 percent!

When the run on repo – the increase in haircuts – reaches non-subprime related asset classes, the crisis became a systemic event. To understand this, take as benchmark a repo market size of, say, $6 trillion. With zero haircuts, this is the amount of financing that banks can achieve in the repo markets. When the weighted average haircut reaches, say, 20 percent, then banks have a shortage of $1.2 trillion. They must issue new securities to raise this amount or sell assets. In the crisis, some amount was raised early on by issuing new securities. But, this fell far short of what was needed. Selling assets drives asset prices down which has two affects. First, it means that even less can be raised in the repo market, as haircuts are made to the market value not the face value. Second, under mark-to-market accounting declining asset prices reduce equity. Unable to raise sufficient new resources and with declining asset prices, the banking system is essentially insolvent.

FIGURE 21



b. Repo Fails and the Scarcity of Collateral

Another indication that the repo market has dried up is the spike in repo fails for U.S. Treasuries. When haircuts rose broad classes of assets that previously were eligible for repo at zero haircuts were no longer offered in the repo market. The "currency famine" of the 19th century panics became a collateral famine in the 21st century panic. Because collateral is rehypothecated, there was not enough collateral to be "spent" in transactions.

The evidence of this collateral famine is in repo fails of U.S. Treasuries. A settlement failure, or "fail," is a situation where the counterparty that "deposited" money in exchange for a bond, in this case a Treasury bond, cannot find a Treasury bond to return. Total fails in Treasury repos reached a record $5.1 trillion in October 2008. For comparison, total fails averaged $165 billion per week between 1990 (when the Fed started collecting data) to July 2007.

Figure 22 shows repo fails in Treasuries for the entire period for which there is data.

Figure 22

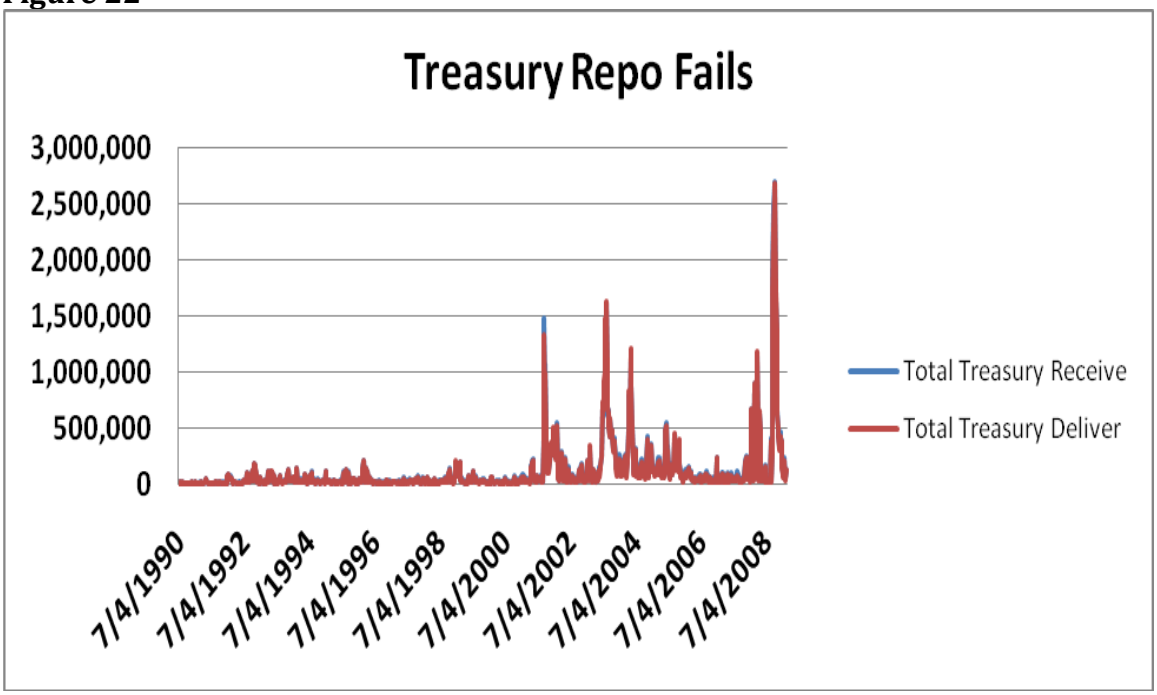
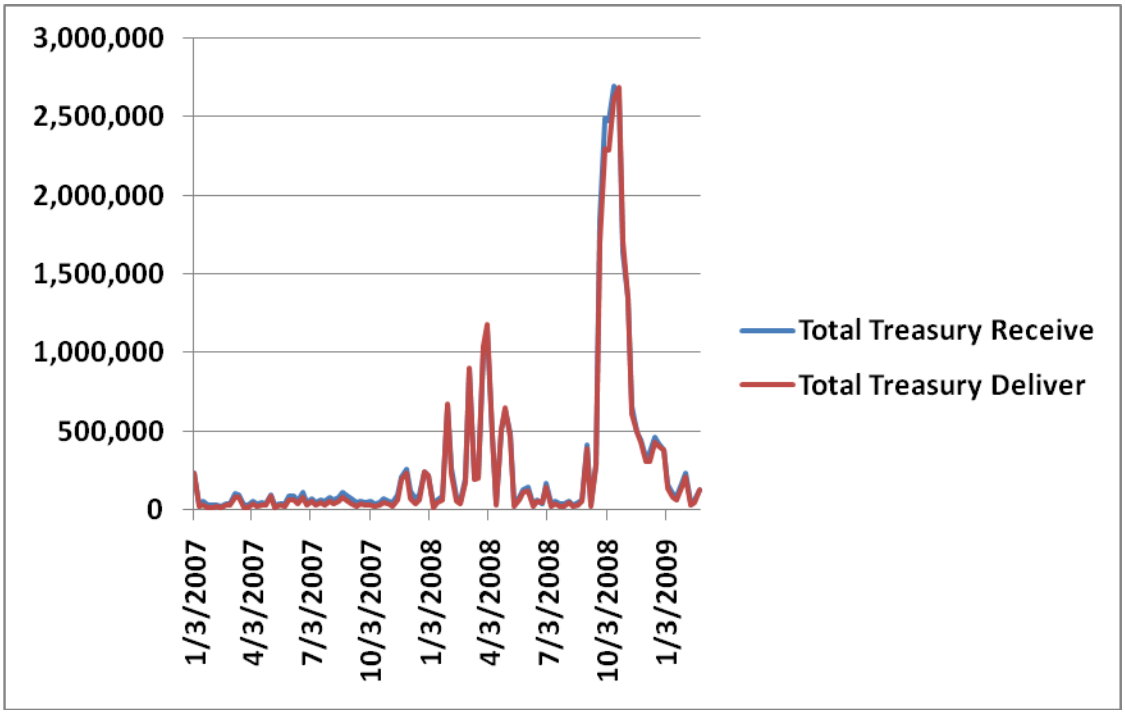


Figure 23 narrows the window to look at the period 2007 to February 25, 2009.



Repo fails in Treasuries are an indication of the scarcity of Treasuries, a scarcity due to a general lack of collateral. And the reason for this lack of collateral is that securitized bonds' haircuts became economically prohibitive.

V. Conclusion

How did problems in the subprime mortgages cause a systemic event? Our answer is that there is a run in the repo market which made the banking system insolvent.

The banking system has changed, with wholesale banks playing an increasing role alongside the traditional banks. Securitization is a form of banking, which creates significant amounts of low risk, informationally insensitive, securities. Wholesale banks receive significant financing from the repo market, which plays the same economic role as demand deposits do in traditional banks.

We show that one large area of wholesale banking – the securitization of subprime home mortgages – began to weaken in early 2007, and continued to decline throughout 2007 and 2008. The first systemic event occurs in August 2007, with a shock to the repo market that we demonstrate using the "LIBOIS", the spread between the LIBOR and the OIS. The reason that this shock occurred in August 2007 – as opposed to any other month of 2007 – is perhaps unknowable. We hypothesize that the market slowly became aware of the risks associated with the subprime market, which then led to doubts about repo collateral and wholesale-bank solvency. At some point – August 2007 in this telling – a critical mass of such fears led to the first "run" on repo, with lenders no longer willing to provide short-term finance at historical spreads and haircuts.

After August 2007, the wholesale bank model was under pressure, with small equity bases stretched by increasing haircuts on high-grade collateral. We see evidence of this pressure in the comovement of spreads on a wide variety of AAA and AA credits. This pressure contributed to the forced rescue of Bear Stearns in March 2008 and the failure of Lehman Brothers In September 2008. The second systemic event and run on repo occurred with the failure of Lehman. We attribute this second event to the surprise of Lehman's "non rescue", which forced Repo lenders to reevaluate the default probabilities of the other wholesale banks and freeze some Repo markets out of any liquidity. In this second event, we see parallels to 19th century banking crises in traditional banks, with cash-in-advance constraints, and a famine of liquidity leading to premia on even the safest of assets.

Appendix 1: The Spread Data

The data we use come from dealer banks. One indication of the quality of the data is that it is the source for marking-to-market the books of some major institutions. The data set comprises 240 series of spreads on structured products, credit derivative indices, and a smaller set of single-name credit derivatives. In each case, the banks capture the "on-the-run" bond or tranche, which would be the spreads of interest to market participants. The spreads are typically to swaps. Some examples include spreads on credit card securitization tranches, auto loan securitization tranches, and all other major securitization classes. Also included are spreads on collateralized debt obligation tranches and collateralized loan obligation tranches. Some series date back to January 2001. The bank captures transactions prices in this broad range of products.

Spreads are not a common variable of analysis for financial economists, who prefer to focus on returns. As a practical matter, however, interest rate risk is frequently hedged, leaving credit risk as the focus. Credit spreads isolate the risk of default and the recovery rate. Thus, when assessing fixed income securities, investors focus on spreads as a common measure for determining how much they are being paid to bear the credit risk embedded in a security.

For fixed rate instruments, the spread is the yield spread, i.e., the difference between the yield-to-maturity of the credit risky instrument and the benchmark instrument (LIBOR) with the same maturity.

Floating rate instrument prices are converted to a spreads by determining the discount margin, which is the fixed amount to be added to the current LIBOR rate that is required to reprice the bond to par. The discount margin measures the yield relative to the current LIBOR rate and so does not take into account the term structure of interest rates.

The discount margin, dm, satisfies the following relationship:

$$P = 100 + \sum_{i=1}^{n} \frac{100(qm - dm)/m}{(1 + y_i + dm)^i}$$

where:

P = Price of the floating rate note (FRN) per $100 face value;

qm = Quoted margin on FRN;

dm = discount margin;

y_i = Assumed value of the reference rate (LIBOR) in period i;

n = number of period until maturity;

m= number of period per year.

The formula shows that if the quoted margin is equal to the discount margin, then the second term is zero and the FRN is valued at par. If the current price of the floater differs from par, then the discount margin is nonzero. The discount margin assumes that the cash flows over the remaining life of the bond are determined by the current reference rate value. The margin is selected so that the present value of the cash flows is equal to the security's price. The discount margin is a measure which is similar to yield-to-maturity for fixed rate instruments. It expresses the price of an FRN relative to the current LIBOR level. See Fabozzi and Mann (2000).

Appendix 2: Glossary

Asset-Backed Securities (ABS): An asset-backed security is a bond which is backed by the cash flows from a pool of specified assets in a **special purpose vehicle** rather than the general credit of a corporation. The asset pools may be residential mortgages, in which case it is a **residential mortgage-backed security** (RMBS), commercial mortgages – a **commercial mortgage-backed security** (CMBS), automobile loans, credit card receivables, student loans, aircraft leases, royalty payments, and many other asset classes.

Basis Point (bp): A **basis point** is one hundredth of a percentage point (0.01%).

Credit Default Swaps (CDS): A **credit default swap** is derivative contract in which one party agrees to pay the other a fixed periodic coupon for the specified life of the agreement. The other party makes no payments unless a specified credit event occurs. Credit events are typically defined to include a material default, bankruptcy or debt restructuring for a specified reference asset. If such a credit event occurs, the party makes a payment to the first party, and the swap then terminates. The size of the payment is usually linked to the decline in the reference asset's market value following the credit event.

Collateralized Debt Obligations (CDOs): A CDO is a special purpose vehicle, which buys a portfolio of fixed income assets, and finances the purchase of the portfolio via issuing different tranches of risk in the capital markets. These tranches are senior tranches, rated Aaa/AAA, mezzanine tranches, rated Aa/AA to Ba/BB, and equity tranches (unrated). Of particular interest are ABS CDOs, CDOs which have underlying portfolios consisting of **asset-backed securities** (ABS), including **residential mortgage-backed securities** (RMBS) and **commercial mortgage-backed securities** (CMBS).

Commercial Mortgage-backed Securities (CMBS): See asset-backed securities, above.

Daylight Risk Exposure: Daylight risk exposure is a kind of settlement risk,. Daylight risk occurs when a party faces possible loss between the time a settlement payment is made in a securities transaction and a corresponding payment is received (usually in another currency) on the same business day.

LIBOR: The London Interbank Offered Rate (LIBOR) is a series of interest rates, of different maturities and currencies, at which banks offer to lend fund to each other. These rates are calculated by the British Bankers' Association as the averages of quotes contributed by a panel of banks and announced at 11:00 Am local time in England. This is called the rate "fixing." Quotes are ranked and the top and bottom quartiles are discarded. LIBOR is fixed for 15 different maturities, from overnight to

one year, and in ten international currencies. Similar fixing arrangements exist in many markets around the world. See Gyntelberg and Wooldridge (2008).

Mezzanine ABS CDOs, Mezzanine CDO ("mezz CDOs"): A Mezzanine ABS CDo refers to a collateralized debt obligation where the underlying portfolio consists of tranches of different asset-backed securities that are rates AA, A, or BBB 9and the subcategories, e.g. Baa1 or BBB+, etc.). "Mezzanine refers to the ratings AA, A BBB and subcategories.

Monoline Insurers, Monoline Insurance Companies ("monolines"): Insurance companies that are restricted to one line of the business, the business of issuing financial guarantees on bonds, that is insurance against the loss due to default of specified bonds. The first such company was AMBAC Financial Group Inc., formed in 1971, followed by MBIA formed in 1983. In 1989 a law in New York limited the sale of financial insurance products by those companies solely to bond insurance, making them "monolines."

Overnight Index Swap (OIS): An Overnight Indexed Swap (OIS) is a fixed/floating interest rate swap where the floating leg of the swap is tied to a published index of a daily overnight rate reference. The term ranges from one week to two years (sometimes more). At maturity, the two parties agree to exchange the difference between the interest accrued at the agreed fixed rate and interest accrued through geometric averaging of the floating index rate on the agreed notional amount. This means that the floating rate calculation replicates the accrual on an amount (principal plus interest) rolled at the index rate every business day over the term of the swap. If cash can be borrowed by the swap receiver on the same maturity as the swap and at the same rate and lent back every day in the market at the index rate, the cash payoff at maturity will exactly match the swap payout: the OIS acts as a perfect hedge for a cash instrument. Since indices are generally constructed on the basis of the average of actual transactions, the index is generally achievable by borrowers and lenders. Economically, receiving the fixed rate in an OIS is like lending cash. Paying the fixed rate in an OIS is like borrowing cash. Settlement occurs net on the earliest practical date. There is no exchange of principal. The index rate used is typically the weighted average rate for overnight transactions as published by the central bank (e.g., the effective fed funds rate).

Rehypothecation: Derivative and repo transactions often involve the pledge of collateral from one party to another, under specified circumstances. The right to use such collateral pledged to them in another, unrelated, transactions is referred to as the "right of rehypothecation." I.e., the right of a secured party to sell, pledge, assign, invest, use, comingle, etc. the posted collateral. See Johnson (1997).

Repurchase Agreements (repo), **Reverse Repurchase Agreements** (reverse repo): A sale and repurchase agreement, known as a "repo" for short, is a sale of a security combined with an agreement to repurchase the same security at a specified price at the end of the contract. Economically, a repo is a secured or collateralized

loan, that is, a loan of cash against a security as collateral. From the point of view of the borrower of the cash (who is putting up the security as collateral), it is a reverse repurchase agreement, or "reverse repo." The collateral pledged by borrowers towards the repo has a "**haircut**" or "initial margin" applied, which means the collateral is valued at slightly less than market value. This haircut reflects the perceived underlying risk of the collateral and protects the lender against a change in its value. Haircuts are different for different asset classes and ratings.

Residential Mortgage-backed Security (RMBS): See asset-backed securities, above.

Securitization: The process of financing by segregating specified cash flows, from loans originated by a firm (the "sponsor") and selling claims specifically linked to these specified cash flows. This is accomplished by setting up another company, called a **special purpose vehicle** (SPV) or special purpose entity, and then selling the specified cash flows to this company, which purchases the rights to the cash flows by issuing (rated) securities into the capital market. The sponsor services the cash flows, that is, makes sure that the cash flows are arriving, etc. The SPV is not an operating company in the usual sense. It is more of a robot company in that it is a set of rules. It has no employees or physical location.

Special Purpose Vehicle (SPV): An SPV or special purpose entity (SPE) is a legal entity which has been set up for a specific, limited, purpose by another entity, the sponsoring firm. An SPV can take the form of a corporation, trust, partnership, or a limited liability company. The SPV may be a subsidiary of the sponsoring firm, or it may be an "orphan" SPV, one that is not consolidated with the sponsoring firm for tax, accounting, or legal purposes (or may be consolidated for some purposes but not others). An SPV can only carry out some specific purpose, or circumscribed activity, or a series of such transactions. An essential feature of an SPV is that it be "bankruptcy remote," that is, that the SPV never be able to become legally bankrupt. The most straightforward way to achieve this would be for the SPV to waive its right to file a voluntary bankruptcy petition, but this is legally unenforceable. The only way to completely eliminate the risk of either voluntary or involuntary bankruptcy is to create the SPV in a legal form that is ineligible to be a debtor under the U.S. Bankruptcy Code.

Appendix 3: The Repo Contract and Bankruptcy

Sale and repurchase agreements, like derivatives, have a special status under the U.S. Bankruptcy Code. Congress has long recognized that it is important to protect financial markets from the potential contagion of the failure of one party to a transaction to spread to other parties. The original version of the Bankruptcy Code did not explicitly recognize repos, nor did it entitle them to safe harbor protection (i.e., allow repo parties to avoid having their claims settled in bankruptcy). The stability of the repo market was one of the concerns addressed in the 1984 amendments to the Code and also as part of the Bankruptcy Abuse Prevention and Consumer Protection Act of 2005.

When a debtor files for protection under any chapter of the U.S. Bankruptcy Code, it automatically triggers an injunction or "automatic stay" against any action by any creditor against the debtor or the debtor's property. However, the new section added to the Code in 1984 (Section 559) exempts "repurchase agreements" from the automatic stay. Moreover, it provides that the "exercise of a contractual right of a repo participant or financial participant to cause the liquidation, termination or acceleration of a repurchase agreement" under an *ipso facto* clause "shall not be stayed, avoided or otherwise limited by operation of any provision of [the Bankruptcy Code]." In other words, the section allows a party to a repurchase agreement to unilaterally enforce the termination provisions of the agreement as a result of a bankruptcy filing by the other party. Without this protection, a party to a repo contract would be a debtor in the bankruptcy proceedings.

The safe harbor provision for repo transactions was recently upheld in court in a case involving American Home Mortgage Investment Corp. suing Lehman Brothers. See Schweitzer, Grosshandler, and Gao (2008).

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