***Preliminary and Incomplete***

# The Flight from Maturity*

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**Abstract**

Why did the failure of Lehman Brothers make the financial crisis dramatically worse? Our answer is that following the initial runs on repo and asset-backed commercial paper, the financial crisis was a process of a build-up of risk *during* the crisis. During the crisis market participants tried to preserve the "moneyness" of money market instruments by shortening their maturities – the flight from maturity. We show that the flight from maturity was manifested in a steepening of the term structures of spreads in money markets. The failure of Lehman Brothers was the tipping point of this build-up of systemic fragility. We produce a chronology of the crisis which formalizes the dynamics of the crisis. We test for common breakpoints in panels, showing the date of the subprime shock and the dates of runs in the secured and unsecured money markets.

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> "The Lehman episode was not just a disaster for Lehman. It was a disaster for our country. And like any calamity, it should be subjected to careful, independent scrutiny." Timothy Geithner, written testimony before the House Financial Services Committee, April 20, 2010.

## 1. Introduction

Why did the failure of Lehman Brothers make the financial crisis dramatically worse? We argue that the financial system became increasingly fragile *during* the crisis, so that even a small shock would have led to a large response *at that point in the crisis*. During the crisis lenders in the money markets sought to shorten the maturities of their loans while borrowing banks sought to lengthen the maturities. Lenders wanted to be able to exit quickly while banks sought to avoid roll risk, forcing them to sell assets at fire sale prices. The desperate struggle manifests itself in the term structures of money market spreads becoming positively sloped, and increasingly so, finally culminating in a sudden massive exit at any sign of trouble – Lehman. We empirically produce a narrative of the crisis that documents the dynamic process of the build-up of fragility during the crisis. We show that a "crisis" is not just a "shock." "Shocks" are endogenous.

Our explanation builds on the idea that private money is inherently fragile. Financial crises are events in which private money loses its "moneyness."[1] In the recent crisis, this occurred in the money markets. Money markets in normal times have very low spreads and repo has low haircuts. But, market participants sought to recreate the moneyness of these instruments. This can be done by asking for improved collateral, or tighter screening of issuers, and in particular, maturity of the private money can be decreased. During the crisis this ongoing decrease in maturity meant that there was a build-up of fragility, as financial firms were increasingly financed overnight creating the conditions for a sudden massive exit. Any shock would suddenly result in massive withdrawals.

Our argument conflicts with the standard view of the crisis. In this view, a "crisis" corresponds to a "shock." As expressed for recent events, the financial crisis of 2007-2008 involved two distinct phases, corresponding to two distinct shocks, the "subprime shock" and the "Lehman shock," e.g. Mishkin (2011). First, there was the period from August 2007 to August 2008 which started with a shock to subprime residential mortgages and a disruption in financial markets, but real GDP continued to rise.

[1] In the nomenclature of Dang, Gorton and Holmström (2012), money that was "information-insensitive" becomes "information-sensitive," meaning that **

Some economists predicted a mild recession.[2] But, in mid-September 2008, the failure of Lehman Brothers caused a much more virulent global financial crisis, the second phase—"the imminent collapse of the global financial system" (Bernanke, 2009). Thus the widespread view of the crisis is that it was caused by the disorderly liquidation of Lehman Brothers, the view that informs the Dodd-Frank legislation. Some economists attributed this to policy failure: the Fed should not have let Lehman fail.[3]

In this paper, we argue that this view of the crisis is not accurate. Rather, the crisis was an ongoing build-up of fragility starting before August 2007 and continuing, finally resulting in the Lehman failure, in effect caused by this build-up of fragility. The build-up was the result of market participants trying to recreate moneyness by, among other things, shortening maturities. The process of increasing moneyness is protracted, involving spreads increasing, maturities shortening, and repo haircuts increasing. Thus, a crisis is a dynamic process in which "shocks" are essentially endogenous.[4]

Understanding the dynamics of the crisis requires determining the timing of important events. In Section 2 we provide a model of the money market which shows the timing of events: spreads rise, the term structure of spreads increases, and lastly haircuts rise. The model is three periods, but the process is repeated during the crisis. We document the model chronology, and its repetition, by showing that it matches an empirical chronology of the crisis. The empirical chronology is based on locating the dates of structural breaks in panel data sets, based on the methodology of Bai (2010). Our chronology dates the first structural break in panels of spreads on subprime-related instruments, secured money market instruments (repo), unsecured money market instruments, CDS measures of the risk in financial firms, and price-based measures of real economic activity.

The chronology of the crisis is also very important because it allows us to formalize the notion of a financial crisis. What is a "crisis"? A financial crisis can be defined as a common breakpoint in the different forms of bank-produced money. In a crisis short-term bank debt becomes suspect and banks are unable to satisfy demands for cash. But, individual crisis episodes have unique features and it has

[2] Lucas (2009, p. 67) wrote that, "Until the Lehman failure the recession was pretty typical of the modest downturns of the post-war period . . . After Lehman collapsed and the potential for crisis had become a reality, the situation was completely altered." And, according to Blinder (2009), "everything fell apart after Lehman . . . After Lehman went over the cliff, no financial institution seemed safe. So lending froze, and the economy sank like a stone. It was a colossal error, and many people said so at the time" (Blinder 2009).

[3] For example, Taylor (2009) and Meltzer(2009) have articulated this view.

[4] This is the viewpoint of Gorton and Ordoñez (2012) who show that a credit boom can result in a crisis due to a "small shock", one that would not have caused a crisis had there been no credit boom.

been impossible to empirically formalize the notion of a crisis to date. For example, Boyd, De Nicolò, and Loukoianova (2011), examining a cross country panel of modern financial crises, point out that it has been difficult to date the start of crises, or even to determine whether there has been a crisis in some cases. Existing data sets of international crises do not agree on start dates or on crisis episodes. We seek to formalize the crisis dating for the events of 2007-2008 and, in the process, understand crises.

We date the subprime shock and the resulting financial crisis, coming some months later. The crisis was first located in the money markets, and emanated outwards. We show that the repo market was the first money market to be disrupted, followed by the other (unsecured) money markets. But, this was only the beginning. We also trace subsequent breakpoints, in spreads, the term structures of spreads, haircuts, the risk of financial firms, and so on, to determine the dynamics of the crisis. We find that repo spreads, term structure and haircuts show second breakpoints *before* Lehman. The unsecured money market instruments show a second breakpoint coincident with Lehman. We subsequently make this precise.

Once bank money becomes suspect, the dynamics of the crisis depend upon the response of market participants. As the final step in our analysis, we document the build-up of fragility by showing that the maturities of money market instruments shortened starting in July 2007. However, only in the case of commercial paper (CP) is issuance data that can be used to directly examine maturity. We show how the maturity of CP declined during the crisis even though the quality of the issuers was improving. Due to a lack of issuance data, we also focus on a prediction of the model, that the term structures of money market spreads rises during the crisis. The "spread" refers to the particular money market rate minus the "riskless" rate for a given maturity. The "term structure of spreads" refers to the spreads at different maturities. During normal times the spreads are all very low and the term structure of spreads is flat (as we document), corresponding to money market instruments being near-riskless.

Low spreads on money market instruments are consistent with money markets being integrated via arbitrage. Although the money markets have different clienteles, some large U.S. banks can trade in federal funds, LIBOR, commercial paper, and sale and repurchase (repo) markets to keep the rates in line. If money market instruments are "money," then the acceptable maturities in the market should be a matter of indifference to participants, and the term structure of spreads should be flat. We find that in the pre-crisis period this was, in fact, the case.

During the crisis this changes. If there is a desire by borrowers to borrow at longer maturities and a desire by lenders to lend at shorter maturities then the term structure of spreads will become upward sloping (as shown in the model). This reflects the differing concerns of borrowers and lenders. Banks want to lock-in funding and so they offer to pay a higher rate for longer maturity borrowing, and a lower rate for shorter maturities. But, lenders are only willing to lend short, keeping open their option to exit. In other words, lenders care about shortening the maturity – the flight from maturity-- when they are concerned about being in a position to get their cash at very short notice. An upward sloping term structure of spreads is an indication of these concerns on the parts of borrowers and lenders. During the financial crisis spreads widen and the term structures of spreads steepen dramatically. The steepening of the term structures of spreads indicates an increase in fragility as lenders position themselves to demand cash at very short notice.

As maturities shortened, the economy faced a hair trigger in which the smallest shock could cause a large sudden exit from the money markets. This occurs around Lehman Brothers and only thereafter is the real economy affected. The real economy does not show a structural break until January 2008. The NBER dates the start of the recession as December 2007.

The paper proceeds as follows. In Section 2 we outline the model and the results. The bulk of the model is in Appendix A. In Section 3 we review the design of money market instruments and present the data that we will use. In Section 4 we analyze the spreads on money market instruments before and during the crisis. The chronology of the financial crisis is produced and analyzed in Section 5. We find breakpoints in different panels of data. We determine the date of the subprime shock, the date of the run on repo and the subsequent runs on unsecured instruments. We also date the start of the real effects of the crisis. We also date later breaks. In Section 6 we document the build-up in fragility during the crisis, that is, the maturity shortening. Commercial paper issuance reduced maturities. And we examine the term structure of spreads in the money markets. Section 7 provides the overall chronology of the crisis and an associated discussion. Section 8 concludes.

## 2. A Model of the Money Market

In this section we present a very simplified model to illustrate some propositions that will be the focus of attention in the empirical work. In subsection A we first discuss some simple mechanics of how sale and repurchase agreements (repo) work, which will be our focus although the model applies as well to

asset-backed commercial paper or, indeed, any money market instrument that is short-term and may not be rolled over at its maturity date. In subsection B we consider a (representative) bank which enters the first period, in which the crisis is starting, with assets that were previously completely financed via repo that is now maturing, and so the bank needs to refinance the assets with new lenders. The bulk of the model and its solution are in the Appendix.

### A. The Mechanics of Repo Haircuts and Collateral

Under a repo contract the lender deposits (or lends) money with the borrower (the bank) for a short period of time at interest and receives bonds as collateral to ensure the safety of the deposit. The collateral is marked-to-market. The return on the bonds used as collateral accrues to the bank. The collateral is important to the lender/ depositor (we will use these terms interchangeably) because if the borrowing bank fails, then the lender can legally sell the collateral in the market to try to recover his loan amount.

The collateral may be haircut. A haircut means that the initial value of the collateral is greater than the loan amount. If the borrower fails, then this overcollateralization makes it more likely that the lender can recover the loan amount, in a market where he may face adverse selection for example. A positive haircut means that the collateral must be partially financed by the bank. If the haircut on existing collateral was zero and becomes positive, the bank has to raise funds, by for example selling assets.

Suppose a bank which wants to finance assets worth V with debt (D) and equity (E), so V=D+E. A haircut is defined as follows: $H \stackrel{\text{def}}{=} 1 - \frac{D}{V}$ which implies that the amount lent to the bank by the lender, where the collateral is V, is D=V(1-H). Substituting this into the balance sheet identity (V=D+E) shows that E=HV, which is the amount of equity that the bank would have to raise to back the asset. If the haircut is zero, then with respect to these assets, the entire amount can be repo-financed.

A haircut is only important to a lender if there is a positive probability that the borrower will default. If there is no chance of the borrower defaulting, then the borrower strictly prefers that H=0 and lenders are indifferent. In the setting we consider below, the bank already has assets that it was financing via repo with zero haircuts. Suppose those exiting assets now need to be refinanced, and if haircuts become positive then (assume that) the bank must sell assets at (the fire sale) price of $\phi<1$, per dollar. In this setting, haircuts are clearly a last resort.

**Lemma:** Assume that the only way the bank can raise money is by selling assets. The sale price is price of $\phi<1$, per dollar. Then the repo haircut is only positive if the borrower cannot compensate the lender for the risk of default by raising the repo rate.

**Proof:** First, it is clear that there is a loss for the bank from selling assets. The assets are earning R (=1+r). To raise one dollar of equity requires selling $1/\phi$, so the loss to the bank is $R/\phi$. The only gain from this is that (1-H) per dollar of assets avoid this loss because they do not need to be sold.

In the model in the Appendix agents are risk neutral and the riskless interest factor rate is one (i.e., the riskless rate is zero). First order conditions for the (risk neutral) lender are of the form:

$$Prob\ Bank\ Solvent\ \ R + (Prob\ Bank\ Insolvent)\phi \geq 1.$$

The most the bank can promise as the repo rate is R, which is the rate in equilibrium. If the bank becomes insolvent, then the collateral is sold by the lender for $\phi$. If, given the probabilities, R is not high enough to compensate the lender for the loss $\phi<1$, so that the FOC does not hold, then H>0 to obtain:

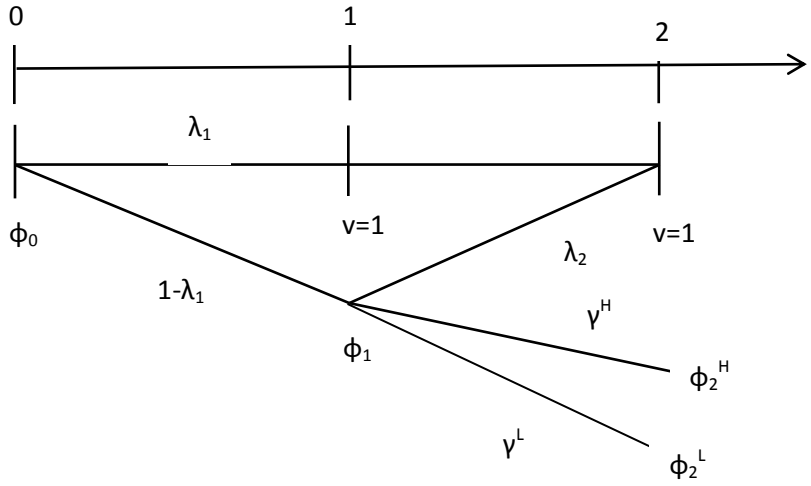
$$Prob\ Solvent\ \ R + \frac{(Prob\ Insolvent)\phi}{(1-H)} \geq 1,$$

which increases the return to the lender in the insolvency state. //

### B. Overview of the Money Markets Model

We consider a world with three dates, t=0, 1, 2. All agents are risk neutral and competitive. The riskless interest rate is zero. There is no discounting. The collateral value is risky and per dollar evolves as shown below.

**Figure 1: Evolution of (per dollar) Collateral Value**




The figure shows the per dollar value of the collateral at each date and node, and the probabilities of reaching that node. With probability $\lambda_1$ the collateral value, V, does not change, indicated as v=1 (per dollar). If $\lambda_1 = 1$, then the lower path to node $\phi_1$ and beyond does not occur. We call the case of $\lambda_1 \approx 1$ "normal times." Alternatively, if $\lambda_1 < 1$, then there is the possibility of a crisis.

All agents know the current state of the economy, that is, the node the economy is currently at. In particular, they know when they are at node $\phi_1$. There is a crisis with probability $1-\lambda_1$ in which case the per dollar collateral value goes down to $\phi_1 < 1$. The collateral has a final payoff at t=2. From node $\phi_1$ there are three possible outcomes: *recovery* (which occurs with probability $\lambda_2$), *deterioration* to $\phi_2^H$ (which occurs with probability $\gamma^H$), and *disaster* (which occurs with probability $\gamma^L$). These are the prior probabilities. So, $\lambda_2 + \gamma^H + \gamma^L = 1$.

Upon arriving at $\phi_1$, all agents learn which one of the low outcomes, $\phi_2^H$ or $\phi_2^L$, is eliminated. In other words, the three possible prior outcomes from node $\phi_1$ are narrowed to two, one of which is always recovery. We will refer to these states as {recovery, deterioration} and [recovery, disaster}. Upon arriving at $\phi_1$, all agents learn which one of the low outcomes, $\phi_2^H$ or $\phi_2^L$, is eliminated. The posterior possibilities and updated probabilities are: {recovery and deterioration}, with associated updated probabilities $\lambda_2^{H'}$ and $\gamma^{H'}$, or {recovery and disaster} with associated updated probabilities $\lambda_2^{L'}$ and $\gamma^{L'}$.

We assume the following.

**A1.** The crisis is systemic: $\lambda_1 < 1$ is not diversifiable.

The parameters $\lambda_1$ and $\lambda_2$ are economy-wide. Different collateral types are determined by the exogenous parameters: $\gamma^H$, $\gamma^L$, $\phi_1$ and $\phi_2^H$ and $\phi_2^L$. So, even in normal times, that is when $\lambda_1 \approx 1$, the spreads on different money market instruments can differ by small amounts, discussed further below.

**A2.** In a crisis, fundamentals are getting worse: $\phi_2^L < \phi_2^H < \phi_1 < \phi_0 < 1$, i.e., the collateral value is deteriorating over time if there is no recovery. Also, $\phi_1 > \lambda_2^{L\prime} + \gamma^{L\prime}\phi_2^L$.

The last expression says that the per dollar price at t=1 and node $\phi_1$ exceeds the expected per dollar value at t=2 in the state {recovery, disaster}.

**A3.** Fire sale prices: $\phi_1$ and $\phi_0$ are below the expected (per dollar) value, i.e., they are fire sale prices. E.g., $\phi_1 < \lambda_1 + \gamma^H\phi_2^H + \gamma^L\phi_2^L$.

Strictly speaking A3 is not necessary for any results. It says, however, that there is an inefficiency from the bank having to sell assets to raise money.

**A4.** No external fund raising in a crisis ($\phi_1$): at t=0 and t=1 the bank can only raise money by selling assets.

A4 says that in a financial crisis a bank cannot raise external funds by issuing bonds or equity. Combined with A2 and A3, this means that if the bank needs to raise money, due to haircuts rising, or more generally no rollover at node $\phi_1$, then it can only sell assets at a loss. As the above lemma shows, the bank would clearly like to avoid this.

**A5.** The probability of bank solvency at t=0, $\lambda_1 + (1-\lambda_1)\lambda_2$ is sufficiently high that haircuts are zero at t=0.

Assumption A5 says that the even though $\lambda_1 < 1$, initially the bank can raise the offer rate on one- and two-period repo to compensate for the crisis risks.

**A6.** Endogenous bankruptcy: If the amount that has to be raised by the bank, because haircuts rise or the one-period repo, or other money market instrument, does not roll at t=1, is greater than $D$ then the bank is bankrupt.

It is natural to think that the bank is insolvent if the final state at t=2 is $\phi_2^L$ or $\phi_2^H$. But, strictly speaking this is not necessary for any results.

These assumptions narrow down possible equilibria to the one which has features we will look for in the data. Equilibrium occurs when lenders and borrowers maximize profits and repo markets (for one and two period loans) clear (which may be at a corner solution).

Prior to date t=0 it was normal times during which borrowers and lenders were indifferent between one- and two-period repo loans; further, haircuts were zero. And the term structure of repo rates was flat. Now, at t=0, and $\lambda_1$ <1; there is a crisis. The bank has a very limited objective: refinance the existing assets with new short-term debt. Because of the crisis $\phi_0$<1, reflecting the crisis and it is so low (by the lemma) that the bank wants to avoid haircuts on either one or two-period loans.

By backward induction, start at t=1. At t=1, one-period repo that was initiated at t=0 must be rolled. At node $\phi_1$ agents learn which of the outcomes, deterioration or disaster, has been eliminated. They then update and decide whether to roll or not. If the state is {recovery deterioration}, then in the Appendix we show conditions under which the following holds.

**Proposition 1 (Run on Repo):** If the expected payoff on the collateral in the {recovery, disaster} state is too low, then the lender does not roll the one-period repo at t=1.

If the amount that does not roll exceeds $D$ then the bank is bankrupt. Forcing the bank into bankruptcy in this case allows the collateral backing the two-period repo to be sold early, which saves $\phi_1 - \lambda_2^{L\prime} + \gamma^{L\prime}\phi_2^L$>0. We show in the Appendix that in a crisis lenders will choose $D > D$ at t=0 so that if the realization is {recovery, disaster} then there is a run on repo and the bank is forced into insolvency. If the realization is {recovery, deterioration}, then the haircut on the final one-period repo will become positive, causing the bank to have to sell assets, but the bank is not forced into bankruptcy (under the parameters we assume).

Now, what happens at t=0? Borrowers do not want haircuts to become positive. Also, borrowers prefer to borrow for two-periods because they want to avoid roll risk since $\lambda_2$>0, that is, recovery is always one possible outcome from node $\phi_1$. On the other hand, lenders want to borrow short because they want the option value of exiting at t=1 if the future includes disaster.

Let $R_t^i$ be the interest factor $(1+r_t^i)$ on an i-period repo loan (k=1 or 2) starting at t=0. And let $R_1^{1*}$ be the equilibrium forward rate on a one period loan starting at t=1. In the Appendix we prove that:

**Proposition 2 (Term structure of spreads positive in a crisis):** $R_0^2 > R_0^1 R_1^{1*}$.

$R_0^2 > R_0^1 R_1^{1*}$ is the situation where the term structure of spreads becomes positively sloped whereas in normal times it is flat: $R_0^2 = R_0^1 R_1^{1*}$.

We can summarize the as follows. The sequence of events we will observe in equilibrium is:

- Prior to the crisis spreads on money market instruments are low (but differ because they have different characteristics (the parameters $\gamma^H$, $\gamma^L$, $\phi_1$ and $\phi_2^H$ and $\phi_2^L$ in the model). The term structure of money market spreads will be flat. And haircuts are zero (or low).
- At the start of the crisis, spreads will increase compared to normal times because the crisis is nondiversifiable. But haircuts will remain at zero initially. The spread increase will differ across money market instruments insofar as they have different characteristics.
- The term structure of spreads, flat before the crisis, becomes positive.
- Haircuts will only increase later, at t=1 and node $\phi_2$ if one possible outcome is deterioration.
- At t=1 and node $\phi_2$, if disaster is one possible outcome, the there is a run on repo (i.e., lenders won't roll) which will cause the bank to become insolvent at t=1.

The model is solved in the Appendix.

The above sequence can be repeated and protracted in reality, with spreads rising repeatedly, the term structure of spreads rising repeatedly, and haircuts rising repeatedly. These dynamics occur because as fundamentals deteriorate, lenders struggle to retain the moneyness of the instruments, while borrowers want to lend long and avoid haircuts and rollover risk. The event of a t=1 bank failure is the model counterpart to Lehman.

## 3. The Money Markets

Money market instruments include U.S. Treasury bills and privately-produced instruments. Privately-produced money market instruments are short-term debt instruments that are liabilities of financial intermediaries. These were at the heart of the financial crisis, in particular asset-backed commercial paper (ABCP) and sale and repurchase agreements (repo). Money market instruments are money, serving as short-term stores of value for financial and nonfinancial firms, and for investors, like pension funds, institutional money managers, hedge funds, and money market funds. Money market instruments are not insured, but otherwise resemble demand deposits in important ways. In this section

we briefly review the relevant money market instruments and introduce the data that we will subsequently analyze.[5]

### A. Description of the Instruments

Privately-produced money market instruments include secured instruments, namely sale and repurchase agreements (commonly known as "repo"), and unsecured instruments that are backed by the issuer's assets, usually in the form of a portfolio of bonds of a financial firm or managed investment vehicle. Privately-produced money market instruments are designed to be as close to riskless as privately possible, so that they can function as money, as discussed below. Money market instruments are not insured by the government. They are, however, structured to be safe. They often have maturities of overnight or a few days, weeks, or sometimes months, and they are either secured by collateral or can only be issued by high-quality borrowers.

Repo involves providing specific collateral to depositors who are lending money. The collateral might be government bonds or privately-created "high quality" bonds, such as asset-backed securities. Depositors must agree with borrowers on the type of collateral and its market value, and then depositors/lenders take possession of the collateral.[6] If the counterparty fails, then the non-defaulting party can unilaterally terminate the transaction and sell the collateral (or keep the cash). In other words, in the U.S. repo is carved out of the bankruptcy process. This facilitates its use as money.

Unsecured money issuers are screened; they must be high-quality so the backing assets are viewed as near riskless. Commercial paper (CP) issuers are screened by the investors and rating agencies. Only high quality financial and nonfinancial firms can issue CP. CP does not have explicit insurance or specific collateral, but access to the CP market is reserved for low-risk issuers with strong credit ratings. And CP is also backed up by a bank line of credit (see, e.g., Moody's (2003), Nayar and Rozeff (1994)). Hence CP appears to have very low default risk. CP issuers are high quality, and if they deteriorate there is "orderly exit." When a firm's credit quality drops, perhaps as indicated by its rating, it cannot issue new CP because investors will not buy it. The firm may instead draw on its bank line. This process of "orderly exit" from the commercial paper market maintains the high quality of the issuers. Because of the

[5] We omit consideration of bankers' acceptances and wholesale certificates of deposit.

[6] The collateral is valued at market prices. During the period of the repo, there may be margin required to maintain the value of the collateral exactly. Overcollateralization, that is a loan for less than the value of the collateral, is referred to as a "haircut." For example, if a lender deposits $90 million and the collateral is worth $100 million, then there is said to be a 10 percent haircut.

possibility of exit occurring firms must maintain back-up lines of credit.[7] "Orderly exit" is discussed by Fons and Kimball (1991) and Crabbe and Post (1994).

Asset-backed commercial paper (ABCP) conduits are a special type of CP issuer. Such a conduit is a special purpose vehicle (a legal entity) that buys asset-backed securities, financing this by issuing commercial paper. See Covitz, Liang, and Suarez (2009) and Acharya, Schnabl and Suarez (2011). The activities of ABCP conduits are circumscribed by their governing documents, and are required to obtain the necessary ratings. One important feature of asset-backed commercial paper is that the conduits must have back-up liquidity facilities in case they cannot renew issuance of their commercial paper. These liquidity facilities cover the inability of the conduits to roll CP for any reason. In most cases these facilities are sized to cover 100 percent of the face amount of outstanding CP. They are typically provided by banks rated at least as high as the rating of the CP. See Fitch (August 23, 2007). Such a liquidity agreement is usable immediately if the commercial paper cannot be remarketed (rolled). There are no material adverse change (MAC) clauses in ABCP liquidity facilities. See Moody's Update (Prepared Remarks Sept. 12, 2007). If a conduit draws on its liquidity facility, the provider of the liquidity facility, usually the sponsoring bank, purchases bonds from the conduit or loans money to the conduit to purchase commercial paper in the case that the commercial paper cannot be issued.

We also examine the two largest interbank markets, the London interbank market (the "Euro-dollar" or "LIBOR" market) and the U.S. federal funds market. In the LIBOR market banks deposit excess U.S. dollars with other banks, sometimes referred to as "Eurodollar deposits," and earn interest at the London interbank offered rate (LIBOR).[8] The Eurodollar or LIBOR market involves large global banks, which are monitored by their domestic bank regulators. The LIBOR and federal funds markets are unsecured, but both rely on screening and monitoring by bank regulators.

Each money market has different clienteles. Regulated banks are the participants in the LIBOR and federal funds market. Only U.S. commercial banks can participate in the federal funds market. The repo banks are the financial institutions that can borrow in the repo market, a larger group than commercial banks, including most notably the old U.S. investment banks. Non-financial firms and non-bank financial

[7] The back-up lines were introduced after the Penn Central failure led to a crisis in the CP market; see Calomiris (1989, 1994) and Calomiris, Himmelberg and Wachtel (1995).

[8] LIBOR interest rates are based on a survey by the British Bankers' Association. The rate is the simple average of the surveyed bank rates excluding the highest and lowest quartile rates. The rates are announced by the BBA at around 11.00 am London time every business day. Such rates are estimated for maturities of overnight to up to 12 months and for 10 major currencies.
See http://www.bba.org.uk/bba/jsp/polopoly.jsp;jsessionid=aAEWKNo02dUf?d=103 .

firms can issue commercial paper.[9] However, these four major money markets are connected. While not all financial institutions have access to all four markets, as mentioned above, the largest U.S. banks are active as borrowers and lenders in all four markets. Because these banks would eliminate arbitrage opportunities across these markets, we would expect that all four money markets would display the same near-money-like riskless qualities; their spreads should be "low," and the term structure of spreads should be flat. In Section 5 we examine the proposition that money markets are near riskless.

The secured and unsecured markets behave differently (as we will show subsequently). On the one hand, repo involves specific collateral as opposed to the general credit of a firm or a conduit, whose asset portfolios may be high quality but hard to monitor. On the other hand, a depositor in the repo market may accept lower quality privately-issued bonds as collateral.

**B. Data**

We analyze the following money market instrument categories: federal funds; LIBOR (Eurodollars); general collateral repo (GC);[10] four categories of commercial paper: A2/P2 nonfinancial, A1/P1 asset-backed commercial paper, A1/P1 financial, and A1/P1 nonfinancial;[11] and six categories of repo, which differ by the type of privately-produced collateral used as backing: AAA/Aaa-AA/Aa asset-backed securities (ABS), including residential mortgage-backed (RMBS) and commercial mortgage-backed securities (CMBS), AAA/Aaa-A/A auto loan-backed, credit card receivables-backed and student loan-backed ABS, AAA/Aaa-AA/Aa collateralized loan obligations (CLOs), AAA/Aaa-AA/Aa corporate bonds, and A/A-Baa/BBB+ corporate bonds. In addition, we use a number of other series to capture to the state of the real economy, the state of the subprime market, and the state of the (at that time) investment banks.

Overall the data we will use are listed in Table 1. The first four rows are series that describe the real sector of the economy: the VIX index, the S&P 500 index return, the JP Morgan high yield index, and the Dow Jones investment grade index of credit default swaps. The next two rows are measures of subprime risk: two tranches of the ABX index, an index linked to subprime securitizations, and home equity loan

[9] CP issuance by nonfinancial firms is small as shown below.
[10] General collateral –GC-- repo is repo where the underlying collateral is U.S. Treasury debt.
[11] Commercial paper ratings are as follows: "Superior" CP is rated P1 by Moody's, A1+ or A1 by S&P, and F1+ or F1 by Fitch; The next category, "satisfactory," is rated P2 by Moody's, A2 by S&P, and F2 by Fitch.

securitizations.[12] "Financial CDS" refers to an equally-weighted index of the 5-year CDS on U.S. financial institutions, including some commercial banks and dealer banks.[13] We also use the individual banks' CDS prices. Then there are thirteen money market instruments, including four categories of commercial paper, fed funds, LIBOR, and the rates on seven categories of repo, including general collateral repo (GC).

We analyze spreads, where the spread is the promised contractual rate minus the federal funds target rate. All spreads are annualized. There is noise in the actual (effective) federal funds rate, as it deviates from the target, resulting in Fed action. For the spread calculation, other candidates are the Treasury bill rate or the overnight index swap rate (OIS) rate. These are affected during the crisis, but results are not significantly different if we use the OIS rate instead of the target federal funds rate.

## 4. Money Market Instruments Before and During the Crisis

To what extent are different money market instruments "money"? A simple way to look at this is to examine the spreads on money market instruments. Intuitively, money market instrument spreads should be low. But, they need not be the same if the degree of "moneyness" differs to some extent. As mentioned above, we use the fed funds target rate as the benchmark, but the results are not sensitive to the choice of benchmark.[14]

In examining spreads one issue that we must contend with is the presence of "seasonal effects" noted by previous researchers in some money market instruments and in commercial bank balance sheets. Allen and Saunders (1992) found window dressing behavior by banks. In particular, they found that money market instruments were the important liabilities facilitating temporary upward movements in total assets. Kotomin and Winters (2006) found associated spikes in federal funds rates and federal fund rate standard deviations. Also, see Griffiths and Winters (2005) and Musto (1997).

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[12] Because of clientele effects, different tranches of the ABX index did not always move together. The ABX index is a product of Markit; see http://www.markit.com/en/products/data/indices/structured-finance-indices/abx/abx.page . Background on the ABX can be found in Fender and Scheicher (2008).

[13] A "broker-dealer" or "dealer" bank refers to a financial intermediary which is licensed the Securities and Exchange Commission to underwrite and trade securities on behalf of customers. Broker-dealers are regulated under the U.S. Securities and Exchange Act of 1934.

[14] This is true for all money market instruments except for U.S. Treasury rates. Treasuries become a safe haven in the crisis and their yields fall for this reason.

In this paper we are not focusing on these seasonal effects.[15] In Appendix B we examine money market spreads during normal times with regressions that include calendar dummies for "seasonals," that is quarter-end dummies, first, 15th and last day of month dummies, and Monday and Friday dummies. Appendix B Table B1 presents regression results of money market spreads on different calendar dummies.[16] The results in Table B1 show that "seasonals" are very important in the money markets. Spreads increase quite significantly at various calendar dates.

Table 2 presents the intercepts from the regressions of the spreads on the calendar dummies, for different subsamples: prior to the crisis, during the crisis, and for three different stages of the crisis (corresponding to subsequently estimated breakpoints in the series). Table 2 allows us to see the relative ability of the private sector to produce "money."

Focusing first on the period prior to the crisis, the following is clear. All spreads are less than 11 bps. Also, note that the spreads on GC repo, A1/P1 financial CP, A1/P1 nonfinancial CP, and repo backed by the highest rated corporate bonds are significantly negative, that is they are below the target federal funds rate. Federal funds are unsecured, but banks are overseen by the Fed. GC repo is collateralized by U.S. Treasuries, so it is better collateral than federal funds, which is backed by a bank's portfolio. And, banks are examined, that is, screened. By screening issuers, the spreads on the highest quality CP and are negative. Similarly, repo backed by the highest quality corporate bonds shows negative spreads.

Relative to federal funds, it is hard for the private sector to replicate the moneyness of the best instruments. The other money market instruments are of lower quality in that the collateral is of lower quality or the issuers are of lower quality. Spreads on these categories are all positive, relative to the federal funds target rate. Finally, note that LIBOR is significantly higher than federal funds. Perhaps global banks are not screened as well as U.S. banks.

The categories with the highest spreads are repo backed by asset-backed securities with lower ratings and A2/P2 nonfinancial commercial paper. A2/P2 is the lowest (worst) rating for commercial paper and it had an average spread of 8.97 basis points. Also, repo which uses asset-backed securities (ABS), residential mortgage-backed securities (RMBS), or commercial mortgage-backed securities (CMBS),

[15] This is an area for future research.

[16] The appendix does not present all the regressions behind the results in Table 2 for the sake of space. Only the results for the period prior to the crisis are presented.

which have a rating below AA, had an average spread of 10.16 basis points.[17] After these two categories come LIBOR with a spread of 5.33 basis points. Prior to the crisis LIBOR was widely believed to correspond to AA risk. Next is repo with the same collateral, but rated AA or higher, at 5.16 basis points, and collateralized loan obligations rated AA or higher which has the same spread.

The spreads intuitively correspond to the quality of the money. There are clearly degrees of "moneyness" reflected in the spreads. It is apparent that not all privately-created money is the same. We do not know how much money of each category was being used, but in order for there to be data, there must have been some significant amount. The picture that emerges is one in which the private sector creates money of different quality and some types of money have spreads which may in part be risk premia.

What happened to the money markets in the crisis? We take as the crisis period the period following the first breakpoint in repo (discussed below). This is the column called "During the Crisis" in Table 2.[18] Note that money market instruments that are "high quality" show *reduced* spreads. These include federal funds, general collateral repo, and A1/P1 commercial paper, both financial and nonfinancial. This is the flight to quality, where some instruments are perceived as better money. But, all the other money market instruments' spreads show very large increases. Figure 1 displays the spreads (intercepts) before and during the crisis.

The other instruments, all privately-produced, show large spikes in their spreads; see Figure 1. For example, repo backed by residential mortgage-backed securities or commercial mortgage-backed securities, rated lower than AA, increase from 10.16 to an average of 98.59 basis points during the crisis. A1/P1 asset-backed CP rises from an average of 1.5 basis points in normal times to 40.28 basis points during the crisis.

The spread for fed funds is the average difference between the effective fed funds rate and the target rate. In Table 2 it is clear that during the crisis it became harder for the Federal Reserve System to keep the fed funds rate close to the target. Before the crisis the spread is less than half a basis point, at 0.32 basis points. But, during the crisis this rises to 8.06 basis points. And, in particular, during the period

[17] The largest asset types in ABS are student loans, car loans, and credit card receivables. Subsequently, we use ABS to indicate all types of securitizations. See Gorton and Metrick (2011) for details about securitization.

[18] As before, the table shows spreads calculated with regressions including the calendar dummies, as in Appendix Table A1.

labeled "Stage 2," it reaches a high of an average of 37 basis points. This is consistent with the results of Bech, Klee, and Stebunovs (2012) who show that the relation between the GC repo rate and the federal funds rate weakens during the crisis (in an error-correction model).

The table also shows the results for subperiods corresponding to the other breakpoints. The subperiods are (1) Pre-Crisis: prior to the crisis onset (the first breakpoint in repo discussed below, which is July 23, 2007); (2) Pre-Lehman: the crisis from the onset to Lehman (the second breakpoint in repo discussed below); (3) Lehman: the aftermath of Lehman until December 2008; and (4) After December 2008. The middle period of the crisis, which brackets the failure of Lehman Brothers, was the height of the crisis in terms of spreads. After December 2008, spreads are lower than in the Lehman period, except for all categories of repo using asset-backed securities as collateral. The spreads on repo backed by ABS just keep rising. ABS (including RMBS and CMBS) becomes information-sensitive and can't be used as collateral. See Gorton and Metrick (2012).

Figure 2 conveys a sense of what happened in the crisis. Figure 2 shows the spreads adjusted for the seasonal effects. The two vertical lines in the figure correspond to two of the breaks in the set of repo spreads (that we discuss shortly). Before the first break in repo, early in 2007, the spreads are tightly bunched, with the occasional uptick. There are two crisis regimes visible. The first occurs around August 2007 and last until the second repo break. The second starts with the Lehman bankruptcy. As we saw before, in Table 2, not all spreads widen. Spreads diverge as some instruments lose their moneyness and others become a safe haven.

Not surprisingly privately-produced money cannot replicate Treasury bills in terms of moneyness. When money is backed by risky collateral, that is, privately-produced collateral, the associated money market instruments have higher spreads. Spreads diverge when the crisis occurs. Some spreads compress while others widen significantly.

## 5. Understanding the Dynamics of the Crisis: A Chronology

In order to understand the dynamics of the crisis, we turn, in this section, to a formal statistical chronology of the recent financial crisis. We produce this chronology by locating structural breaks in panel data sets. We focus on the dating of the subprime shock, subsequent events in the money markets, the financial intermediaries at the center of the crisis, and the real economy. In this way, we build a narrative of the crisis and, in a way, test the sequence of events predicted by the model.

**A. Breakpoints Methodology**

To produce a chronology of the financial crisis we need to find random but common breakpoints in a number of series. We estimate breakpoints in different panel data sets, where each panel has a recognizable economic meaning.

Most studies of breakpoints focus on a single series, treating series separately. There is a large literature on change point estimation for univariate series and only a small but emerging literature on estimating common breakpoints in panel data.[19] For our study, basing the breakpoints on panel data offers several important advantages. First, it is possible to consistently estimate breakpoints using a panel, while there may be little or no power to looking at individual time series when there is not much data covering the crisis regime. In other words, in a univariate setting there may be little hope of detecting a regime switch when a single observation that may be an outlier can have a large effect on the estimate, or when one regime consists of only a few observations in time. In our setting the crisis period is short and comes at the end of the sample.

Second, and more importantly, it is quite natural that a financial crisis would result in common breakpoints. The concept of a crisis means, at least intuitively, that a number of series show a common breakpoint, though the date of the breakpoint is not known. A definition of a financial crisis is that it is a common breakpoint in money and banking. And this crisis then is followed by real effects. We seek to formalize this and, in the process, understand crises.

We follow the estimation approach of Bai (2010). The idea is to consider a panel of N series, as follows:

$$Y_{it} = \mu_{i1} + \sigma_{i1}\eta_{it}, \quad t = 1,2, \ldots, k_0$$

$$Y_{it} = \mu_{i2} + \sigma_{i1}\eta_{it}, \quad t = k_0+1, \ldots T$$

$$i = 1,2, \ldots, N$$

where $E(\eta_{it})=0$ and $var(\eta_{it})=1$, and for each i, $\eta_{it}$ is a linear process; there are other assumptions as well, see Bai (2010). The breakpoint, $k_0$ in means and variances is unknown. Consistent estimation requires that there are breakpoints in either the means or the variances (or both). Assuming a common breakpoint is more restrictive than assuming random breakpoints in the different series in the panel.

[19] On breakpoint estimation in general, see Perron (2005) and Hansen (2001). Bai (2010) provides the references to the other papers on the estimation of breakpoints in panels.

But, the assumption results in more precise estimation. The basic idea of Bai's approach is to exploit the cross-section information, sort of "borrowed power" relative to the non-panel approach.

There may be multiple breakpoints, so that after the first breakpoint is located, the two subsamples can be investigated further for other breakpoints, and so on. As yet the econometric theory does not exist for determining the number of breakpoints. We stop at four breakpoints and present three, as discussed later.

The breakpoint is estimated with quasi-maximum likelihood (QML). Let

$$\sigma_{i1}^2\ k\ = \frac{1}{k}\ \ {}_{t=1}^{k}(Y_{it} - Y_{i1})^2,\ \sigma_{i2}^2\ k\ = \frac{1}{T-k}\ \ {}_{t=k+1}^{T}(Y_{it} - Y_{i2})^2.$$

The QML objective function for series i is:

$$k\ log\ \sigma_{i1}^2\ k\ +\ T-k\ log\ \sigma_{i2}^2\ k\ ,$$

multiplied by one half. Analogously, for N series:

$$U_{NT}\ k\ =\ k\ \ {}_{i=1}^{N} log\ \sigma_{i1}^2\ k\ +\ T-k\ \ {}_{i=1}^{N} log\ \sigma_{i2}^2\ k\ .$$

The breakpoint estimator is $k = argmin_k U_{NT}\ k$ . Bai (2010) Theorem 5.1 shows that the breakpoint in this case can be consistently estimated.

Our approach is to group the data series into five different panels with recognizable economic content: (1) the real sector of the economy; (2) the subprime housing sector; (3) financial firms; (4) the unsecured money markets; and (5) the secured money markets. We further divide the financial firms to consider including and excluding Lehman. We also consider subsets of the real sector and subprime, as well.

The real sector is represented by the S&P 500 index return, the VIX index (the Chicago Board Options Exchange Market Volatility Index), the JP Morgan High Yield Bond Index, and the Dow Jones CDX.IG index of investment grade credit derivative premia. The subprime sector is represented by the spreads on tranches of the ABX index (an index of derivative premia linked to subprime bonds), and two series of subprime bond spreads. The financial sector is represented by an equally-weighted index of CDS premia on ten banks, including Lehman Brothers (see Table 1). Finally, there are the returns on thirteen money market instruments, including four categories of commercial paper, fed funds, LIBOR, and the rates on seven categories of repo, including general collateral. The returns on the money market instruments are

annualized overnight returns. We split the money market instruments into secured (repo), unsecured, and GC repo. Later, we also look at some individual money market series.

It is not restrictive to use prior economic reasoning to form the different panels. The methodology can still result in finding the same common breakpoint for different panels. In terms of the number of series in a panel, precision is improved with a larger number of series. Clearly, the confidence intervals depend on N. But, as a practical matter N can also be small. Bai (2010) provides a sense of the precision with Monte Carlo experiments where the number of series, N, in the panel ranges from one to 100.

Once the first breakpoint is found, the procedure, in principle, is to check the resulting two subperiods to search for the second breakpoint. We do this and with a few exceptions the second breakpoint is *subsequent* to the first breakpoint. The order that the procedure finds breakpoints need not be chronological. And, in a few cases a breakpoint, always the third or fourth, can come prior to the crisis. This seems to be due to the previously mentioned seasonal effects, which can resemble mini-crises in a sense.

After the first breakpoint is found, the subsequent breakpoints in each panel are (almost always) during the crisis period. But, these breakpoints are not necessarily chronologically ordered. So, chronologically the second breakpoint may come after the third breakpoint. Appendix B provides more information on the ordering of the breakpoints using the Bai procedure versus the chronological ordering. In what follows we show the breakpoints chronologically. The issue of the order in which the breakpoints are found and the chronological ordering not matching is discussed later and in Appendix C.

After finding a breakpoint in a panel, the individual series can be examined with a standard Chow test on each series. In unreported results, we find that all the individual series show breaks.

Finally, note that we are not testing sudden breaks against the alternative hypothesis of gradual or smooth structural changes. Chen and Hong (2012), for example, propose a test for smooth structural changes in time series, but not panels. The Bai procedure and the tests for smooth changes both test against the alternative of no change, and we cannot test to determine whether the change is sudden or gradual.

**B. The Initial Crisis Breakpoint Chronology**

How did the crisis evolve? Table 3 addresses this question. Table 3, Panel A, provides the breakpoints

located for the different panel data sets shown in the table.[20] The table also provides 99 percent confidence intervals for the breakpoints in terms of dates.[21] The main results are as follows.

The subprime shock occurs in the first quarter of 2007, on January 4, 2007. If we look only at the ABX tranches then the break occurs on January 25, 2007. If we only look at the two subprime series, the break is March 22, 2007. This timing is consistent with the failures of a number of subprime originators and the downgrades of subprime bonds by the rating agencies. See the chronology in Gorton (2008).

The next breakpoint occurs in the repo market on July 23, 2007. This is also when the breakpoint for the dealer banks' CDS occurs, whether we include Lehman or not. This is the start of the financial crisis, a run on the banks as described by Gorton (2010) and Gorton and Metrick (2012). The breakpoints here confirm this aspect of the crisis, that is, the breakpoint for the repo spreads and for the dealer bank CDS is the same date.

The unsecured money market instruments, CP, fed funds, and LIBOR, show a breakpoint on August 8, 2007. Note that the 99 percent confidence intervals for the secured and unsecured money market instruments statistically distinguish the two dates for the repo markets and the unsecured money markets. There is a difference between the secured and unsecured markets.

The crisis, starting in the third quarter of 2007, begins to affect the real sector later. The real sector, measured by the VIX, and the returns on the S&P500, the JPM HY Index, and the DJ CDX.IG, shows a break on January 3, 2008. The NBER dates the start of the recession in December 2007. If we separate the equity-related series from the bond-related series and only look at the VIX and the S&P, then the break is September 12, 2008 –nine months later. Lehman Brothers' failed on September 15, 2008, within the 99 percent confidence interval for the break in this latter case. The Troubled Asset Relief Program (TARP) became law on October 3, 2008.

In Table 4 we look at a single series, as one might expect that ABCP and GC repo, for example, might behave differently. Indeed, ABCP by itself shows a break July 27, 2007, and the 99 percent confidence interval overlaps with the first break for repo. This is consistent with the run on ABCP, which resulted in

[20] Chow tests on each individual series using the breakpoint date confirm that each series shows a break at each of the dates.

[21] Bai (2010) does not explain how to construct confidence intervals in the case of possible breaks in the means and variances of series. But, Professor Bai very kindly provided this as a private communication, which we appreciate very much.

banks taking conduit assets back via liquidity facilities, and then financing this at least in part via repo. Also, note that when looking at GC repo as a single series, there is a break on August 13, 2007.

As we will show later, from the end of 2007 to the fall of 2008, the crisis evolved and fragility was building up. We can build on the chronology so far by looking at subsequent break points.

**C. Dynamics of the Crisis: Subsequent Breakpoints**

As mentioned above, the Bai (2010) procedure can be applied again to the two subperiods determined by the first break, to determine the next break in a given panel.[22] We focus on the money markets. Table 3, Panel B, shows the second and third breakpoints in the money market panels. The main findings are as follows.

There is a second breakpoint in the repo markets on August 14, 2008, *a month before Lehman*. The unsecured money markets, i.e., CP, Fed Funds, LIBOR, show a second break *with the Lehman* failure on Sept 12, 2008, but the Lehman failure of September 15$^{th}$ is within the 99 percent confidence interval. Once again there is a difference between the secured and unsecured markets. There is a third break for all money market instruments December 15, 2008.

Detail is also provided in Table 4. In this table we show the breaks for the single series of the GC repo spread and the single series of the ABCP spread.

Our findings on money markets are summarized with the chronology shown in Figure 3. The figure shows three clusters of breakpoints. The first cluster is in July and August of 2007, the start of the crisis. Repo breaks first, then asset-backed commercial paper (ABCP). Then the remaining unsecured money market instruments and finally GC repo show breaks.

The second cluster of breakpoints is the month *before* Lehman's failure, when repo, ABCP, GC repo, and unsecured (except ABCP) all show breaks. Then, there is the aftermath of Lehman, the third cluster.

This chronology with three clusters in particular reveals the importance of the second cluster. One may think of the first cluster as a reaction to the subprime shock. And, the third cluster to the effects of Lehman. Our focus is on the second cluster, which Lehman was a part of, perhaps the result of. We turn to this next.

[22] See Appendix C for more detail on the Bai procedure.

## 6. The Flight from Maturity

In this section we examine the shortening of maturity, or flight from maturity, an attempt to recreate the moneyness of money market instruments. Fragility built up during the financial crisis because the maturities of money market instruments were reduced. This build-up leads to the Lehman collapse, as money market instruments were then on a hair trigger. We can see this directly in the maturities of CP that was issued. And, we can see it indirectly by looking at the term structure of spreads.

### A. Commercial Paper: Issuance and Maturity Structure

Commercial paper is the only money market instrument where we can analyze the maturity structure of the paper issued. Commercial paper issued by ABCP conduits and by financial firms dramatically declined during the crisis. Commercial paper issued by nonfinancial firms was less affected but was never quantitatively as important as ABCP and CP issued by financial firms. Issuance of commercial paper for various types of issuers and for different maturities is shown in Table 5 and Figure 4. The table shows the average daily issuance of commercial paper for the categories of issuer shown. The table also divides the data by time period. There are five time periods shown: before 2007, 2007 before the crisis, the crisis before Lehman, the crisis around Lehman, and the crisis after December 2008.

Looking at the average issuance it is clear that the two nonfinancial CP categories (A2/P2 and AA) are the smallest issuers by far while ABCP is the largest and rises up until Lehman before collapsing. The other important category is AA financial. This is much smaller than ABCP. AA financial issuance shrinks during the crisis in the pre-Lehman period, recovers a bit, and then shrinks again.

Table 5 also shows the percentage of average issuance in each subperiod that has maturities in the maturity buckets shown. For a given category of issuer, looking down the column shows the trend in the maturity structure of the CP issued in that subperiod. The most important categories of issuer of CP in terms of amounts are ABCP and AA financial firms. Figure 4 is a bar chart which summarizes the trend in issuance of CP with maturities in the 1-4 day bucket, as a percentage of average issuance over the subperiod. ABCP shows a rising trend, even before the crisis. In the pre-crisis period 60 percent of the ABCP was 1-4 days maturity. During the crisis it rises in the pre-Lehman subperiod, and again during the Lehman subperiod. It then subsides. AA financial firms' issuance of 1-4 day CP declines over the first three subperiods. Then it rises when Lehman collapses.

The figure is suggestive. But, we now turn to a more careful look at the data. Table 6 shows the results of testing for breakpoints with regard to the maturity structure of the outstanding paper. The table examines the short/long ratio which is the ratio of the amount of CP issued with a maturity of less than 20 days (over a 30 day window) divided by the amount of CP issued with a maturity of 20 days or greater (over a 30 day window). The table shows that the first breakpoint occurs June 13, 2007 *before the break in repo rates*. In other words, maturities are shortening as concerns build-up. This is consistent with the model of Section 2. This is evidence of a build-up of fragility prior to our dating of the run on repo.

The second breakpoint occurs in the immediate aftermath of the Lehman bankruptcy (September 15, 2008) on September 26, 2008. Figure 5 shows the short/long ratio for AA-rated ABCP. The two breakpoints are clearly visible.

Figure 6 shows a measure of interbank credit risk, the LIBOR minus overnight index swap (OIS) rate spread, together with the 30-day rolling short/long ratio. The LIBOR minus OIS spread is the most common measure of interbank counterparty risk. The pattern is remarkable. The tendency for the ABCP maturity to shorten moves very closely with counterparty risk, as bank counterparties become riskier, their conduits are kept on a much shorter leash in terms of maturity in the CP market.

Table 7 provides more detailed information on the breakpoints for overnight issuance, one-month issuance, and three-month CP issuance. Table 7 shows the first break in overnight issuance was on May 31, 2007, several months before breaks in money market spreads. This is consistent with anecdotal evidence that maturities were shortening as lenders were becoming nervous in the spring and summer of 2007. For one-month issuance the first breakpoint is September 24, 2007. And for three-month issuance the first breakpoint is March 8, 2007. These dates are consistent with anecdotal evidence that maturities were shortening prior to the run on repo. Overnight issuance was increasing and three-month issuance was decreasing.

Unfortunately, we do not have issuance data for other money markets instruments. So, next we turn to examining the term structure of money market spreads for evidence of maturity shortening prior to and during the crisis.

**B. The Term Structure of Spreads**

As discussed above, in normal times the term structure of spreads is flat and near zero when the money market instruments are information-insensitive because of high collateral quality or because of screening out all but high quality issuers. Flat and low spreads are consistent with money market instruments displaying "moneyness." Market participants determine the longest maturity at which it is possible to maintain the moneyness of an instrument. At the acceptable maturities it is then a matter of indifference to participants which instruments are used as money, and the term structure of spreads should be flat. We find that in the pre-crisis period this was, in fact, the case.

A crisis is an event in which money loses its moneyness; it becomes information-sensitive, as we saw above in the case of repo. Market participants can attempt to re-engineer the money to recover its ability to function as money. Reduction of maturity is the one main method for this. But, in a crisis, the borrowers want to lock-in financing for longer term. If there is a desire by borrowers to borrower at longer maturities and a desire by lenders to lend at shorter maturities then the term structure of spreads will become upward sloping. Lenders want to shorten maturity –the flight from maturity— because they want to be in a position to get their cash on very short notice. An upward sloping term structure of spreads is an indication of this concern on the part of the borrowers and the lenders. During the financial crisis spreads widen and the term structures of spreads steepen dramatically. The steepening of the term structure of spreads indicates an increase in fragility as lenders position themselves to demand cash at very short notice.

Table 8 shows the spreads for overnight, one month, and three-month maturities for the different money market instruments during different subperiods.[23] Table 8 can be viewed by looking at the spreads for different maturities across a specific subperiod, or by looking at a given maturity and looking down across the subperiods.

Some highlights from Table 8 are as follows. First, in the case of overnight federal funds, the actual (average) federal funds rate deviates from the target by the most in the aftermath of Lehman. As noted before, this is some evidence that it was becoming harder for the Fed to control money markets via intervention in the federal funds market.

[23] When the maturity is longer than one day, we use OIS rather than the federal funds target rate as the benchmark to determine the spread.

With regard to GC repo, note that because GC repo uses U.S. Treasuries as collateral, it is safer than federal funds and so the GC repo spread is negative at all maturities prior to the crisis. In the pre-Lehman crisis period, there appears to be a flight to GC repo as the spread becomes much more negative, but is roughly flat across maturities. But, in the aftermath of Lehman note that the overnight GC repo spread becomes very negative(-56.32 bps), and the spread for one-month and three-month GC repo become positive, suggesting that lenders are scared of these maturities. This positive slope persists after December 2008.

The LIBOR spread curve is slightly positive in the pre-crisis period, but steepens during the crisis, and even more so after Lehman. The commercial paper spread curves are near flat or slightly upward sloping prior to the crisis, but then steepen. AA financial CP and AA nonfinancial CP have larger negative overnight spreads which peak (at their highest negative values) after Lehman. These curves become very steep.

In the case of repo backed by private collateral, Panel C, the repo term structure of spreads is essentially flat in the pre-crisis period. During the crisis, the spreads are higher for longer maturities; the slope of the term structure rises. Looking down a column, the overnight spread is monotonically increasing for each repo backed by private collateral except for the cases where the collateral is corporate bonds. In the cases of one-month and three-month maturities, the spreads peak during the Lehman aftermath.

We now look directly at slopes of different points on the term structures of spreads. The slope measure is the difference between the one-month and one-day spreads, the difference between the three-month and one day spreads, and the difference between the three-month and one-month spread. For example, the slope is:

[Rate at one month – OIS rate for one month] minus [rate overnight – FF target overnight.

The other points on the slope are similar; for longer maturities where there is no federal funds (FF) target, we use the OIS rate for that maturity. Table 9 shows different measures of the slope of the term structure of spreads at points on the term structure for the different money market instruments during different subperiods.

Looking down a column for a given money market instrument shows how the spread difference changed at that point on the term structure over the different subperiods. For example, in Panel A federal funds at the one month minus one day point saw the difference increase dramatically in the pre-Lehman and

Lehman phases of the crisis. The same pattern appears for GC repo and LIBOR, also in Panel A. This same pattern holds for CP (Panel B) and repo (Panel C). It also holds for the middle column, the difference between the 3-month and overnight spreads, which also rise dramatically. Less dramatic is the 3-month minus 1-month spread difference.

It is perhaps easier to see what is going on with figures. Figures 7-10 display the term structure of spreads for LIBOR, federal funds, A2/P2 nonfinancial CP, and repo backed by ABS/RMBS/CMBS collateral rated less than AA. The LIBOR spread term structure progressively steepens during the crisis, as does the federal funds term structure of spreads. A2/P2 nonfinancial commercial paper dramatically steepens by December 15, 2008. Repo backed by ABS/RMBS/CMBS collateral rated less than AA shows the most dramatic increase in the term structure of spreads.

Table 10 shows the breakpoints for the slopes, where the slope is measured as the one-month/overnight spread. The breakpoint for the repo slope is July 23, 2007, the same date as the breakpoint in the repo spreads. Unsecured money market instruments' slopes break on August 8, 2007, also the same as the breakpoint for their spreads. The subsequent breakpoints are also the same, that is, they are coincident with the breakpoints for their respective spreads.

Overall, the quantity and price data point in the same direction, namely, that maturity shortens during the crisis.

**C. CP Issuance and Screening**

If shortening maturity does not work to regain information-insensitivity, then for unsecured instruments there must be tightened screening of issuers. We find some suggestive evidence on this. First, we look at the changes in S&P short-term credit ratings for 176 financial firms and report the results in Table 11. During the crisis of 2007-2009, a considerable proportion of these firms were downgraded. For example, 39% of firms with A-1+, the highest short-term rating, before the crisis were downgraded to A-1. And 36% of the firms rates A-1 were downgraded by one or more notches. Correspondingly, financial firms were forced to reduce their reliance on commercial paper. Table 12 presents the aggregated balance sheet for financial firms in 2007 and 2008. The total commercial paper issued by financial firms was cut by $142 billion. In 2007, commercial paper accounted for 8.6% of total liabilities. This percentage decreased to 7.4% in 2008. Keep in mind that we do not know the maturities of the CP that continues to be issued, but anecdotally it is shorter maturity than it was previously.

**D. Repo Haircuts**

With repo, lenders can ask for better collateral, and as we saw above, there was a flight to Treasuries. Another method for regaining the moneyness for repo when the collateral is privately-produced bonds is to raise haircuts.

As discussed in Gorton (2010) and Gorton and Metrick (2012), increasing repo haircuts corresponds to withdrawing cash from the banking system. For example, suppose a lender in the repo market deposits $100 million overnight at interest. To keep the deposit safe the bank provides $100 million of bonds (valued at market prices). The depositor takes possession of these bonds. The next morning suppose the borrower wants to renew or roll the repo. If the lender is nervous, he may offer to lend $90 million but wants to keep the $100 million of bonds at collateral (getting $10 million dollars of cash back from the borrower). This is called a 10 percent haircut. It corresponds to a withdrawal of $10 million from the bank because now the bank has to finance this amount from other sources.

The model of Section 2 predicts that haircuts only increase as a last resort. In the model to preserve moneyness market participants first reduce maturities and only finally raise haircuts, withdrawing from the bank. The timing of breakpoints in the repo haircuts relative to the spreads is thus of particular importance. Table 13 shows the breakpoints in the panel of the six categories of repo that use privately-produced collateral. Recall that the breakpoints in the slopes of the term structure of spreads for the different money market instruments are coincident with the breakpoints in spreads. With that in mind, the pattern of breakpoints in the haircuts is quite remarkable. Looking at the money market chronology of Figure 3 for reference, the first repo haircut breakpoint occurs on October 23, 2007, *after* the breaks in the spreads and slopes in the first cluster. The second breakpoint occurs on February 6, 2008, right around the time that the real effects of the crisis are felt. Not surprisingly, the third breakpoint is September 15, 2008, the day of Lehman's failure.

To summarize, increasing haircuts seems to have been a last resort, consistent with the model. First, spreads rise and maturities shorten and then haircuts go up.

### E. The Lehman Collapse

The subprime shock seems to have led to the response in the form of the events loosely labeled cluster one above. What was happening though was more than that. Prior to Lehman the overall maturity of money market instruments declined. By September 2008, Lehman financed most of its balance sheet with short-term repo financing, more than $200 billion a day.[24] Fragility had built up so that an enormous amount of debt was overnight, a hair trigger. This is cluster two. Then Lehman failure then occurs, followed by cluster three. Lehman was short $4.5 billion in cash on September 15, 2008.[25] There was no second shock in the sense that the dynamics of the crisis had created such a fragile situation that it seems that any small tipping point would have led to a run.

## 7. The Crisis Overview

Our analysis provides a narrative of the crisis that is more precise than any that has been produced for any crisis to date.[26] And, the chronology is consistent with the prediction of the model,

The findings can be summarized by referring to the chronology shown in Figure 11, Panels A and B.

Starting with Panel A, the subprime shock occurs on January 4, 2007. In response, the maturity of newly issued commercial paper shows a breakpoint in maturity issuance on June 13, 2007, which is when maturities started to shorten. Repo spreads and term structure slopes respond on July 23, 2007, the same time that dealer banks are shocked. This is the start of the crisis. On August 8, 2007, the other money market instruments are affected. Their spreads spike and their maturities start to shorten. Repo haircuts significantly increase on October 24, 2007. The real economy is affected starting on January 3, 2008.

The crisis evolution is shown in Panel B, where repo shows a second breakpoint August 14, 2008, also the date at which the repo term structure of spreads increases, i.e., there more maturity shortening. This is followed by the second breakpoint in repo haircuts, prior to Lehman. Subsequent to Lehman money markets essentially fall apart, with their spreads diverging as lenders flee some markets and pile into others (Treasuries and GC repo) in a flight to quality.

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[24] See In re Lehman Brothers Holdings Inc., et al., Chapter 11 Case No. 09-13555, Report of Anton R. Valukas ("The Valukas Report"), footnote 10, p. 3.

[25] The Valukas Report, footnote 48, p. 12.

[26] There are many narratives of crises. Well-known examples include Sprague (1910) and Andrew (1908 a, b) for crises during the U.S. National Banking Era and Wessel (2010) for the crisis of 2007-2008.

The chronology raises a number of questions, some of which we can answer and some of which we can only speculate about. Here, we briefly discuss these questions.

First, if the subprime shock occurred in the first quarter of 2007, why did it not result in financial market difficulties until the third quarter of 2007? We can only speculate about the answer to this question. One thing to keep in mind is that over-the-counter markets, like credit derivative markets for example, do not work like stock markets. Stock markets have centralized trading and readily observable prices. But over-the-counter markets have pairwise trading without centralized pricing. The price is only observed by the two counterparties. So, the price does not aggregate the information in the same way in OTC markets as in stock markets. It may simply take longer to percolate through markets. This is an issue for future research.

A second question is: Why was repo the first money market instrument to show a break? In the repo markets lenders became concerned about the quality of the bonds offered as collateral. Haircuts rose and repo market spreads also rose. See Gorton and Metrick (2012). Asset-backed commercial paper also faced runs but asset-backed commercial paper conduits were bailed out by their sponsors. Commercial paper spreads only showed a break later.

In 2007 Q2-Q3 ABCP conduits could not roll their CP (see Liang et al (2012)). Instead, they drew on their liquidity lines or financed via repo instead of CP. Liquidity lines were usually provided by the sponsoring banks of the ABCP conduits, so "drawing on the liquidity line" meant that banks ended up with the ABCP conduits' assets on their balance sheet. For example, HBOS announced on August 21, 2007 that its conduit Grampian would no longer issue CP, but that instead it would use liquidity facilities provided by HBOS. See Fitch (August 23, 2007).

Draw-downs under liquidity facilities resulted in assets covered by the facility coming back on intermediaries' balance sheets where they had to be funded. Much of this turns out to be funded in repo markets. Financial intermediaries financed the ABCP conduit assets in the repo market. In particular, money market funds (MMFs) increased their repo deposits/lending in 2008. MMFs became emboldened after many of them were bailed out by their sponsors in the fourth quarter of 2007. MMFs were exposed to the ABCP market turmoil in the third and fourth quarters of 2007 and faced the prospect of losses during the fourth quarter of 2007. But, these losses were borne by the MMF sponsors; see McCabe (2010). So, risk is building up in MMFs because they become one place where

former ABCP assets end up residing. Commercial banks are another apparent location, as they expand their balance sheets in 2008.

The second break in repo occurs 13 months after the first on August 14, 2008, a month before Lehman. Even with the improvements in the quality of money market instruments, there is a second crisis in repo in August 2008. And, then the unsecured money market instruments have a crisis with the failure of Lehman on September 15, 2008. Losses on Lehman Brothers' debt subsequent to the firm's bankruptcy in September 2008 caused the Reserve Primary Fund to "break the buck" leading to the U.S. Treasury Exchange Stabilization Fund to insure MMFs.

Still, maturities shorten, and there is a third break for all money market instruments on December 14, 2008. After December 14, 2008 the market recovered somewhat; the short/long ratio declined some and most spreads also decreased.

## 8. Conclusion

The canonical view of a financial crisis is that it is the result of a "shock." And, the crisis of 2007-2008, in the standard view, really was the result of a second "shock," namely the failure of Lehman Brothers. Why was Lehman a much bigger shock? The standard view is that it was unexpected. We argue that a financial crisis is more than a "shock." Fragility builds up in the financial system, creating conditions for what might otherwise be a small shock to have a large impact. The maturities of money market instruments started declining in July 2007, and anecdotally started declining much earlier for Bear Stearns and Lehman Brothers.

The financial crisis of 2007-2008 was started by a decline in home prices that followed a credit boom. In July 2007 there was a run on ABCP and on repo. Money market instruments were suspect, and to recreate there "moneyness" market participants shortened maturities, fleeing from maturity, putting the financial system on a shorter and shorter leash. This is the build-up of systemic risk. Ultimately, this did not work, and then there are withdrawals from the banking system in the form of refusals to continue funding or increases in repo haircuts. This process is one of building fragility *during the crisis* which itself has already started. Lehman was a result of this build-up of fragility. In this sense systemic risk is endogenous. A crisis is a dynamic process.

## Appendix A: Money Markets Model

All agents are risk neutral and competitive. The notation is as follows. All variables follow the notation introduced for the interest factor in the main text. Asset values, V, deposits, D, equity, E, haircuts, H, follow this notation: $X_t^k$ is the variable at time t for a loan of maturity k.

We solve the problem by backward induction, starting at t=1 and node $\phi_1$. At this date any one-period loans that were initiated at t=0 must be rolled. The initial one period loan, $D_0^1$ is now worth $R_0^1 D_0^1$, which is the amount that the lender has available to lend for the final period. Only $D_0^1$ is needed for refinancing ($R_0^1$ is consumed, and subsequently ignored for simplicity).

Concerning information, there are two cases depending on what was learned about the t=2 outcomes, i.e., whether deterioration or disaster is possible (recovery is always a possibility). An equilibrium at t=1 occurs when both lenders and borrowers are maximizing their (risk neutral) objective functions and the market for one-period loans clears. This occurs for some interest factor, $R_1^1$ and some haircut $H_1^1$. These depend on what was learned about whether deterioration or disaster is one of the possible t=2 outcomes. Recall that by A8, if deterioration ($\phi_2^L$) is one of the possible the final states (the other being recovery) then lenders refuse to lend at t=1 and the bank is rendered insolvent at t=1. We provide a condition for this assumption below.

We solve for the t=1 equilibrium in the other case, where ($\phi_2^H$) is one of the possible the final states. Denote the equilibrium interest factor as $R_1^{1^*}$ and the equilibrium haircut as $H_1^{1^*}$. In equilibrium the market clears, i.e., $D_1^{1^*} = D_0^1$.

**The t=1 Money Market: Lender's Problem**

Different haircuts depend on the state at t=1, which is recovery and either L (disaster) or H (deterioration). First consider the case that at t=1 and node $\phi_1$, the state is {recovery, deterioration}. The lender's problem is to determine how much of the available maturing amount, $R_0^1 D_0^1$, to roll, by choosing $D_1^1$ to max:

$$\lambda_2^{H\prime} \; R_1^1 D_1^1 \; + \gamma^{H\prime} \; \frac{D_1^1 \phi_2^H}{(1 - H_1^{1H})} \; + (D_0^1 - D_1^1)$$

The first order condition is: $\lambda_2^{H\prime} R_1^1 + \frac{\gamma^{H\prime} \phi_2^H}{(1 - H_1^1)} \geq 1$. (1)

The other case at t=1 and node $\phi_1$ is when the state is {recovery, disaster}. In this case, the lender's problem is to choose $D_1^1$ to max:

$$\lambda_2^{L\prime} \; R_1^1 D_1^1 \; + \gamma^{L\prime} \; \frac{D_1^1 \phi_2^L}{(1 - H_1^{1L})} \; + (D_0^1 - D_1^1)$$

The first order condition is: $\lambda_2^{L\prime} R_1^1 + \frac{\gamma^{L\prime} \phi_2^L}{(1 - H_1^{1L})} \geq 1$.

**Proposition 1 (Run on Repo):** If the expected payoff in a disaster is too low, then in the {recovery, disaster} state, the lender does not roll the one-period repo at t=1.

**Proof:** The first order condition cannot be satisfied if: $\lambda_2^{L\prime} R_1^1 < 1 - \frac{\gamma^{L\prime}\phi_2^L}{(1-H_1^{1L})}$. A sufficient condition for this is $1 - \frac{\gamma^{L\prime}\phi_2^L}{(1-H_1^{1L})}$<0, which occurs if $H_1^{1L} > 1 - \gamma^{L\prime}\phi_2^L$. This holds, for example, if $\phi_2^L = 0$. //

If the amount that does not roll exceeds $D$, then the bank is insolvent at t=1. This means that the two-period repo is terminated and the collateral is sold at t=1 for $\phi_1$, rather than at t=2 (an expected value of) for $\lambda_2^{L\prime} + \gamma^{L\prime}\phi_2^L$, per dollar. By A2 $\phi_1 > \lambda_2^{L\prime} + \gamma^{L\prime}\phi_2^L$. This savings is the benefit of forcing the bank into insolvency.

**The t=1 Money Market: Borrower's Problem**

We now turn to the borrower's problem at t=1. The bank chooses $D_1^1$ to max:

$$\lambda_2^{H\prime} R \quad V_0^1 - H_1^1 V_0^1 \phi_1 \quad - R_1^1 D_1^1$$

where R is the interest factor earned on the collateral.

The first order condition is: $R = R_1^1$. (2)

Equation (2) gives the equilibrium solution for $R_1^1$, and substituting (2) into (1) gives the solution for the haircut $H_1^1$. The market clears and $D_0^1 = D_1^1$, which is the equilibrium loan at t=1. Equilibrium values will subsequently be indicated with a "*".

**The t=0 Money Market: Lender's Problem**

At t=0 the lender's problem is to choose $D_0^1$ and $D_0^2$ to maximize:

$$\lambda_1 \quad R_0^1 D_0^1 \;\; R_1^{1*} + R_0^2 D_0^2 \quad \text{(No Crisis)}$$

$$+ \;\; 1 - \lambda_1 \;\; (\lambda_2) \quad D_0^1 \;\; R_1^{1*} + R_0^2 D_0^2 \quad \text{(Bank Recovers at t=1)}$$

$$+ \;\; 1 - \lambda_1 \;\; \gamma^{H\prime} \;\; \frac{\phi_2^H \;\; D_0^1}{1 - H_1^{1*}} + \;\; \phi_2^H D_0^2 \quad \text{(Deterioration: Bank Insolvent at t=2)}$$

$$+ \;\; 1 - \lambda_1 \quad \gamma^{L\prime} \;\; \{ \;\; \phi_1 D_0^1 + \phi_1 D_0^2 \;\; | if D_0^1 \geq D \} \;\; \text{(Disaster: Bank Insolvent at t=1; run on repo)}$$

$$+ \;\; 1 - \lambda_1 \quad \gamma^{L\prime} \;\; \{ \;\; \phi_1 D_0^1 + \phi_2^L D_0^2 \;\; | if D_0^1 < D \} \quad \text{(Disaster: Bank not insolvent until t=2)}$$

$$+ (M - D_0^1 - D_0^2) \qquad (3)$$

As indicated above, the first term corresponds to the case where there turns out to be no crisis and the lender is happy to roll $D_0^1$ at t=1. The second term is the case where node $\phi_1$ is reached but then there is recovery. The third term is the case where from node $\phi_1$ the deterioration outcome $\phi_2^H$ is reached at t=2. The bank is bankrupt at t=2 and the collateral backing both the amount rolled and the original two-

period loan are sold for $\phi_2^H$ per dollar. The one-period loan made at t=1 was overcollateralized due to the haircut. The fourth term is the case where disaster is a possible outcome at t=1. The outcome in this case depends on whether the amount of one-period repo that is not rolled in this case is sufficient to cause the bank to go bankrupt at t=1. Finally, there is the budget constraint. The lender has the amount M available to lend.

In the case where disaster is a possible outcome at t=1, it is better to be able to force the bank into bankruptcy at be able to sell the two-period collateral as well as the one-period collateral. This is because $\phi_2^L < \phi_1$.

If $D_0^1 \geq D$, then the first order conditions with respect to $D_0^1$ and $D_0^2$ are, respectively:

$$R_0^1\ R_1^{1*}\ \lambda_1 +\ \ 1-\lambda_1\ \lambda_2\ \ + (1-\lambda_1)\gamma^{H\prime}\phi_2^H\ \ \geq 1-(1-\lambda_1)\gamma^{L\prime}\phi_1 \qquad (4)$$

$$R_0^2\ \lambda_1 +\ \ 1-\lambda_1\ \lambda_2\ \ + (1-\lambda_1)\gamma^{H'}\phi_2^H \geq 1-(1-\lambda_1)\gamma^{L\prime}\phi_1 \qquad (5)$$

If $D_0^1 < D$, then the first order conditions with respect to $D_0^1$ and $D_0^2$ are, respectively:

$$R_0^1\ R_1^{1*}\ \lambda_1 +\ \ 1-\lambda_1\ \lambda_2\ \ + (1-\lambda_1)\gamma^{H\prime}\phi_2^H\ \ \geq 1-(1-\lambda_1)\gamma^{L\prime}\phi_1 \qquad (4')$$

$$R_0^2\ \lambda_1 +\ \ 1-\lambda_1\ \lambda_2\ \ + (1-\lambda_1)\gamma^{H'}\phi_2^H \geq 1-(1-\lambda_1)\gamma^{L\prime}\phi_2^L \qquad (5')$$

(4) and (4') are the same, but by A1, $\phi_1 > \phi_2^L$, which means (5) and (5') are not the same; it means that with respect to any two-period deposits, it is better to have $D_0^1 \geq D$.

As we will see below, the bank will offer a higher rate on two-period loans than on one-period loans – because of the chance for recovery, $\lambda_2$—but the lender will want to protect such two-period loans by ensuring that $D_0^1 \geq D$.

**The t=0 Money Market: Borrower's Problem**

We now turn to the borrower's problem at t=0. The bank enters the period with assets in place of $V \stackrel{\text{def}}{=} V_0^1 + V_0^2$. Let the return on these assets be R. The bank only makes a profit if it is solvent, which occurs with probability $\lambda_1$+(1-$\lambda_1$)$\lambda_2$ +$(1-\lambda_1)\lambda_2^H$. Recall that haircuts are zero initially. This means that $V_0^1 = D_0^1$ and $V_0^2 = D_0^2$. The borrowing bank's problem is to choose $D_0^1$ (and thereby implicitly $D_0^2$) to maximize:

$$\lambda_1 +\ \ 1-\lambda_1\ \lambda_2\ \ RV_0^1 - R_0^2 D_0^2\ \ + (1-\lambda_1)\lambda_2^{H\prime}\ R(V_0^1 - H_1^{1*}V_0^1\phi_1) - D_0^1 R_1^{1*}\ .$$

Note that in the event that node $\phi_1$ is reached and the state is {recovery, deterioration}, the bank must sell assets at a loss, $H_1^{1*}V_0^1\phi_1$. We assume that $H_1^{1*}V_0^1\phi_1 < D$, i.e., this does not result in bankruptcy for the bank.

Upon substitution this becomes:

$$\lambda_1 +\ \ 1-\lambda_1\ \lambda_2\ \ R(V-D_0^1) - R_0^2(V-D_0^1)\ \ + (1-\lambda_1)\lambda_2^H\ D_0^1(R - H_1^{1*}\phi_1) - D_0^1 R_1^{1*}\ .$$

The first order condition is:

$$1-\lambda_1\ \lambda_2^H\ R-H_1^{1*}\phi_1-R_0^1R_1^{1*}\ \leq\ \lambda_1+\ \ 1-\lambda_1\ \lambda_2\ [R-R_0^2] \qquad (6)$$

This first order condition says that the bank prefers two-period loans. That is:

**Proposition (Positive term structure of spreads):** $R_0^2 > R_0^1R_1^{1*}$.

**Proof:** Equation (6) can be rewritten as:

$$\frac{R-R_0^1R_1^{1*}}{R-R_0^2}-\frac{H_1^{1*}\phi_1}{R-R_0^2}=\frac{[\lambda_1+\ 1-\lambda_1\ \lambda_2]}{1-\lambda_1\ \lambda_2^H}.$$

$$\frac{R-R_0^1R_1^{1*}}{R-R_0^2}=\frac{[\lambda_1+\ 1-\lambda_1\ \lambda_2]}{1-\lambda_1\ \lambda_2^H}+\frac{H_1^{1*}\phi_1}{R-R_0^2}.$$

Note that $\frac{[\lambda_1+\ 1-\lambda_1\ \lambda_2]}{1-\lambda_1\ \lambda_2^H} > 1$, to the right-hand side is greater than one, which implies that $R_0^1R_1^{1*} < R_0^2$. //

## Appendix B: Seasonals in Money Market Spreads

In this appendix we briefly discuss the calendar effects or "seasonals" in money market spreads.

Appendix Table B1 shows regressions of the money markets spreads on calendar dummies, and shows that "seasonals" are important in money market spreads. There are spikes in many of the spreads at certain calendar dates. Just before the quarter end (five days before to the day before) and the date of the quarter-end and day after, show the largest increases. But, note that the largest increases on those dates are in the repo markets. Repo using all categories of private securities as collateral show significant spikes in spreads around the quarter-end. For example, repo that uses collateralized loan obligation tranches rates AA-AAA spikes by 77 basis points the day of the quarter-end and the next day. Repo backed by asset-backed securities composed of auto loans, credit card receivables, or student loans rated AA-AAA also spikes by 71 basis points on those days. Unsecured money market instruments show much lower increases on those dates. For example, LIBOR goes up 4 basis points, A1/P1 Financial CP goes up by 8 basis points, and A1/P1 asset-backed commercial paper goes up by 9 basis points.

There is more seasonal pressure on repo markets. A seasonal increase in the spread in repo suggests that borrowers are willing to pay more for cash at these seasonal dates than at other dates to finance the collateral. But, the depositors/lenders, on the other hand, appear to want their cash (and not the collateral) at these dates.

Why is there a large demand for cash at these dates? Large movements of cash which go from one party to another, especially if one party is the government so cash leaves the economy, could cause these spikes in spreads. In the period before the Federal Reserve System there were seasonal spikes in interest rates when cash had to move from cities to rural areas for planting season and then later for harvesting season. Indeed, such spikes were viewed as creating fragility in the system and were a major motivation for the founding of the Federal Reserve System.[27]

In the modern era since the founding of the Federal Reserve System there are several possible candidates for explaining seasonals. One candidate for large cash movements is the payment of estimated taxes by corporations. Another possibility is quarter-end "window dressing," which might show up for example in the excess reserves of banks, if they are engaged in window dressing.

[27] On seasonals in the money markets prior to the Fed see Kemmerer (1911). On seasonals and fragility prior to the Fed see Miron (1986). And, on the elimination of some of the seasonals in interest rates once the Fed comes into existence, see Mankiw, Miron and Weil (1987).

We examine these issues in Table B2. The table contains the intercepts on each money market instrument with no controls, in the first column, and also with the date dummies from Table B1, in the second column. The next two columns show the change in the intercept when two tax variables are (separately) used in the panel regression. The two variables are the same. In both columns, we report the fitted values. We first estimate the parameters for tax flow process. Then we use the average tax flow to replace the actual tax flow and calculate the fitted value. For the variable "Tax, all days average", we assume tax flow equals the average tax flow across all days. For the variable "Tax, Normal days", we assume that tax flow equals the average tax flow across normal days, excluding quarter-end, beginning, middle and end of each month. The second average tax flow is smaller than the first one.

The last column includes U.S. commercial banks' excess reserves. The intercept is adjusted for these variables by estimating the coefficient on the variable and then adding or subtracting the coefficient times the average of that variable. So, for example, in column 3 the coefficient times the average inflow of taxes to the government, averaged over all (business) days, shows no effect, as the intercepts change very little. When the middle of the month is excluded, the intercept does go down in most cases, but not by much.

Inclusion of the excess reserves variable does reduce the intercept for repo categories, but not by as much as the calendar dummies that we started with.

These calendar effects are a subject for future research.

## Appendix C: Chronology Breakpoints

In this appendix we briefly discuss the ordering of breakpoints.

As explained briefly in the main text, the Bai procedure finds a breakpoint for the given panel. The second breakpoint looks at the two subperiods defined by the first breakpoint and minimizes the sum of squared residuals over the whole sample using QML. The second breakpoint we find is usually after the date of the first breakpoint, but need not be. This means that we do not condition on the first breakpoint. In other words, the second breakpoint could be before the first breakpoint. Similarly, the third breakpoint is determined by looking at the ALL the subperiods determined by the first and second breakpoints.

The issues are illustrated by Figure C1, which shows two possible Bai orderings. The first breakpoint in both panels, A and B, is the crisis date. This is true in the data. In Panel A, the first three breakpoints occur at the crisis date and then chronologically in order. But, breakpoint four is before the crisis date. In general we are only interested in the first three breakpoints. However, we always calculate the fourth breakpoint because sometimes the ordering looks more like what is shown in Panel B.

In Panel B, the fourth breakpoint occurs during the crisis, and comes before the second breakpoint. But, the third breakpoint is before the crisis onset.

In order to understand the sensitivity of the procedure, particularly given the seasonals, we show the ordering according to the Bai algorithm and the chronological ordering. Table B1 provides examples for the most important panels. It illustrates the differences between the breakpoints found by the Bai algorithm and the chronological ordering of the breakpoints. In the table “Algorithm Order” equal 1 means that is the first breakpoint fund by the Bai procedure. “Chronological Order” means that after we found four breakpoints we sorted them chronologically and labeled them 1 through 4.

These issues are shown in Table C1.

**References**

Acharya, Viral, Philipp Schnabl, and Gustavo Suarez (2011), "Securitization without Risk Transfer," *Journal of Financial Economics*, forthcoming.

Allen, Linda and Anthony Saunders (1992), "Bank Window Dressing: Theory and Evidence," *Journal of Banking and Finance* 16, 585-623.

Andrew, A. Piatt (1908a), "Substitutes for Cash in the Panic of 1907," *Quarterly Journal of Economics* 22, 290–99.

Andrew, A. Piatt (1908b), "Hoarding in the Panic of 1907." *Quarterly Journal of Economics* 22, 497–516.

Bai, Jushan (2010), "Common Breaks in Means and Variances for Panel Data," *Journal of Econometrics* 157, 78-92.

Bech, Morten L., Elizabeth Klee, and Viktors Stebunovs (2012), "Arbitrage, Liquidity and Exit," Finance and Economics Discussion Series 2012-21, Board of Governors of the Federal Reserve System.

Bernanke, Ben (2009), "Reflections on a Year in Crisis." Speech at the Federal Reserve Bank of Kansas City's Annual Economic Symposium, Jackson Hole, Wyoming, August 21, 2009.

Blinder, Alan (2009), "Six Errors on the Path to the Financial Crisis", *New York Times* January 25.

Boyd, John, Gianni De Nicolò, and Elena Loukoianova (2011), "Banking Crises and Crisis Dating: Theory and Evidence," International Monetary Fund, working paper.

Calomiris, C.W., (1994), "Is the Discount Window Necessary: A Penn-Central Perspective," Federal Reserve Bank of St. Louis *Review*, 76, 31-56.

Calomiris, C.W., (1989), "The Motivations for Loan Commitments Backing Commercial Paper," Journal of Banking and Finance 1, 271-77.

Calomiris, Charles, Charles Himmelberg, and Paul Wachtel (1995), "Commercial Paper, Corporate Finance, and the Business Cycle: A Microeconomic Perspective," *Carnegie-Rochester Conference Series on Public Policy* 42, 203-250.

Chen, Bin and Yongmiao Hong (2012), "Testing for Smooth Structural Changes in Time Series Models via Nonparametric Regression," *Econometrica* 80, 1157-1183.

Covitz, Daniel M., Nellie Liang, and Gustavo A. Suarez (Forthcoming), "The Evolution of a Financial Crisis: Collapse of the Asset-Backed Commercial Paper Market," *Journal of Finance*.

Crabbe, Leland and Mitchell Post (1994), "The Effect of a Rating Downgrade on Outstanding Commercial Paper," *Journal of Finance* 49, 39-56.

Dang, Tri Vi, Gary Gorton, and Bengt Holmström (2011), "Ignorance and the Optimality of Debt for Liquidity Provision," working paper.

Fender, Ingo and Martin Scheicher (2008), "The ABX: How Do the Markets Price Subprime Mortgage Risk?," BIS *Quarterly Review* (September), 67-81.

Financial Crisis Inquiry Commission (2011), Final Report of the National Commission on the Causes of the Financial and Economic Crisis in the United States (Public Affairs).

Fitch Ratings (2007), "Asset-Backed Commercial Paper & Global Banks Exposure—10 Key Questions," *Special Report* (September 12, 2007).

Fons, Jerome and Andrew Kimball (1991), "Defaults and Orderly Exits of Commercial Paper Issuers, 1972-1990," *Moody's Special Report* (January).

Gorton, Gary (2008), "The Panic of 2007," in *Maintaining Stability in a Changing Financial System*, Proceedings of the 2008 Jackson Hole Conference, Federal Reserve Bank of Kansas City, 2008.

Gorton, Gary (2010), Slapped by the Invisible Hand: The Panic of 2007 (Oxford University Press).

Gorton, Gary and Andrew Metrick (2012), "Securitized Banking and the Run on Repo," J*ournal of Financial Economics* 104, 425-451.

Gorton, Gary and Andrew Metrick (2011), "Securitization," chapter in the Handbook of the Economics of Finance, volume 2, edited by George Constantinides, Milton Harris, and René Stulz, Elsevier, forthcoming.

Gorton, Gary and Guillermo Ordoñez (2012), "Collateral Crises," Yale working paper.

Griffiths, Mark and Drew Winters (2005), "The Turn of the Year Money Markets: Tests of the Risk-Shifting Window Dressing and Preferred Habitat Hypothesis," *Journal of Business* 78, 1337-1363.

Hansen, Bruce (2001), "The New Econometrics of Structural Change: Dating Breaks in U.S. Labor Productivity," *Journal of Economic Perspectives* 15, 117-128.

He, Zhiguo, Ingu Khang, and Arvind Krishnamurthy (2010), "Balance Sheet Adjustment in the 2008 Crisis," *IMF Economic Review* 58, 118-156.

Kemmerer, E. W. (1911), "Seasonal Variation in the New York Money Market," *American Economic Review* 1, 33-49.

Komotin, Vladimir and Drew Winters (2006), "Quarter-End Effects in Banks: Preferred Habitat or Window Dressing?," *Journal of Financial Services Research* 29, 61-82.

Lucas, Robert (2009), "In Defense of the Dismal Science," *The Economist*, August 8:67.

Mankiw, N. Gregory, Jeffrey Miron, and David Weil (1987), "The Adjustment of Expectations to a Change in Regime: A Study of the Founding of the Federal Reserve," *American Economic Review* 77, 358-374.

McCabe, Patrick (2010), "The Cross Section of Money Market Fund Risks and Financial Crises," Federal Reserve Board, working paper no. 2010-51.

Meltzer, Allan (2009), "What Happened to the 'Depression'?," *Wall Street Journal*, April 31, 2009.

Miron, Jeffrey (1986), "Financial Panics, the Seasonality of the Nominal Interest Rate and the Founding of the Fed," *American Economic Review* 76, 125-140.

Moody's Investors Services (2007), "Moody's Update on Bank-Sponsored ABCP Programs: A Review of Credit and Liquidity Issues," International Structured Finance, *Special Report* (September 12, 2007).

Moody's Investors Services (2003), "The Fundamentals of Asset-Backed Commercial Paper," Structured Finance, *Special Report* (February 3, 2003).

Musto, David (1997), "Portfolio Disclosures and Year-End Price Shifts," *Journal of Finance* 52, 1861-82.

Nayar, Nandkumar, and Michael S. Rozeff (1994), "Ratings, Commercial Paper, and Equity Returns," *Journal of Finance* 49, 1431-1449.

Perron, Pierre (2006), "Dealing with Structural Breaks," chapter in Palgrave Handbook of Econometrics, Volume 1, edited by Terence Mills and Kerry Patterson (Palgrave Macmillan), 278-352.

Sprague, O. M. W. (1910), History of Crises under the National Banking System, Senate Document 538 (Washington DC: Government Printing Office).

Wessel, David (2010), In Fed We Trust: Ben Bernanke's War on the Great Panic (Crown Business).

| Table 1: Data Sources and Sample Periods | | | | |
|---|---|---|---|---|
| **Variable** | **Source** | **Sample Periods** | | **Description** |
| | | **Beginning** | **End** | |
| VIX | CBOE | 2000/1/1 | 2009/4/30 | CBOE Volatility Index |
| S&P 500 | Standard & Poor's | 2000/1/1 | 2009/4/30 | Standard & Poor's 500 Index return |
| JPM HY Index | Dealer Bank | 2003/4/10 | 2009/4/30 | J.P. Morgan High Yield Index |
| DJ CDX.IG | Dealer Bank | 2003/4/10 | 2009/4/30 | Dow Jones CDX Index (Investment grade) |
| ABX | Dealer Bank | 2006/1/19 | 2009/4/30 | Markit ABX.HE Index, 2006-1. AAA, BBB and BBB- |
| HEL | Dealer Bank | 2006/1/19 | 2008/1/3 | Home Equity Loan ABS spreads, AAA and BBB ratings |
| Financial CDS | Bloomberg | 2002/11/6 | 2009/4/30 | 5 Year CDS for Bank of America, JP Morgan, Citigroup, Wells Fargo, Wachovia, Goldman Sachs, Merrill Lynch, Morgan Stanley, Lehman Brother and Bear Stearns. |
| **Interbank Money Markets** | | | | |
| Fed Fund | Bloomberg | 2001/12/20 | 2009/4/30 | Effective Federal Fund rate |
| LIBOR | Bloomberg | 2001/12/20 | 2009/4/30 | LIBOR |
| OIS | Bloomberg | 2001/12/20 | 2009/4/30 | Overnight indexed swap |
| **Commercial Paper** | | | | |
| A2/P2 Nonfinancial | Federal Reserve | 2001/12/20 | 2009/4/30 | SIC code: 100-5999, 7000-9999. Programs with at least one "2" rating but no ratings other than "2" |
| AA Asset-backed | Federal Reserve | 2001/12/20 | 2009/4/30 | SIC code: 6189. Programs with at least one "1" or "1+" rating but no ratings other than "1" |
| AA Financial | Federal Reserve | 2001/12/20 | 2009/4/30 | SIC code: 6000-6999, excluding 6189. Programs with at least one "1" or "1+" rating but no ratings other than "1" |
| AA Nonfinancial | Federal Reserve | 2001/12/20 | 2009/4/30 | SIC code: 100-5999, 7000-9999. Programs with at least one "1" or "1+" rating but no ratings other than "1" |
| **Repo Categories** | | | | |
| GC | Bloomberg | 2001/12/20 | 2009/4/30 | General collateral repo rate |
| <AA ABS-RMBS / CMBS | Dealer Bank | 2005/10/3 | 2009/4/30 | Residential mortgage-backed security (RMBS) or commercial mortgage-backed security (CMBS) with ratings less than AA |
| A-AAA ABS-Auto / CC / SL | Dealer Bank | 2005/10/3 | 2009/4/30 | Asset-backed securities (ABS) comprised of auto loans, credit-card receivables, or student loans, with ratings between A and AAA, inclusive. |
| AA-AAA ABS-RMBS / CMBS | Dealer Bank | 2005/10/3 | 2009/4/30 | Residential mortgage-backed security (RMBS) or commercial mortgage-backed security (CMBS) with ratings between AA and AAA, inclusive. |
| AA-AAA CLO | Dealer Bank | 2005/10/3 | 2009/4/30 | Collateralized loan obligations (CDO) with ratings between AA and AAA, inclusive. |
| AA-AAA Corporates | Dealer Bank | 2005/10/3 | 2009/4/30 | Corporate bonds rated between AA and AAA, inclusive. |
| BBB+ / A Corporates | Dealer Bank | 2005/10/3 | 2009/4/30 | Corporate bonds rated between BBB+ and A, inclusive. |

**Table 2: Overnight Spreads Comparison**

| | Before the Crisis | During the Crisis | Crisis: Pre-Lehman | Crisis: Lehman | Crisis: After Dec 2008 |
|---|---|---|---|---|---|
| | Intercept | Intercept | Intercept | Intercept | Intercept |
| **Federal Funds** | -0.32 | -8.06 | -3.32 | -37.04 | 6.97 |
| | (-1.54) | (-4.3) | (-2.44) | (-6) | (5.46) |
| **GC Repo** | -3.83 | -22.49 | -23.27 | -56.32 | 11.02 |
| | (-14.38) | (-7.7) | (-6.96) | (-7.53) | (6.76) |
| **LIBOR** | 5.33 | 15.46 | 16.76 | 13.85 | 13.37 |
| | (33.06) | (4.65) | (10.76) | (1.03) | (7.55) |
| **A2/P2 Nonfinancial CP** | 8.97 | 80.03 | 47.52 | 172.89 | 87.34 |
| | (24.46) | (15.66) | (28.27) | (11.53) | (17.33) |
| **AA Asset-backed CP** | 1.47 | 40.28 | 37.52 | 50.78 | 38.4 |
| | (8.34) | (12.98) | (27.49) | (5.05) | (16.13) |
| **AA Financial CP** | -1.51 | -9.11 | -5.9 | -35.51 | 7.3 |
| | (-8.65) | (-5.3) | (-6.59) | (-6.1) | (4.83) |
| **AA Nonfinancial CP** | -1.9 | -7.47 | -3.01 | -36.53 | 7.73 |
| | (-10.98) | (-3.89) | (-3.33) | (-5.44) | (4.75) |
| **<AA ABS-RMBS / CMBS** | 10.16 | 98.59 | 49.12 | 136.94 | 207.36 |
| | (8.36) | (17.18) | (13.07) | (8.9) | (74.21) |
| **A-AAA ABS-Auto / CC / SL** | 3.23 | 56.7 | 30.07 | 83.06 | 108.9 |
| | (3.07) | (12.9) | (8.51) | (5.09) | (34.65) |
| **AA-AAA ABS-RMBS / CMBS** | 5.16 | 79.75 | 37.96 | 110.39 | 173.64 |
| | (4.24) | (15.13) | (10.65) | (7.01) | (70.07) |
| **AA-AAA CLO** | 5.16 | 93.18 | 45.75 | 125.99 | 202.31 |
| | (4.24) | (16.45) | (11.8) | (8.38) | (74.11) |
| **AA-AAA Corporates** | -0.82 | 15.16 | 11.58 | 19.18 | 21.65 |
| | (-0.92) | (3.71) | (3.71) | (1.02) | (8.73) |
| **BBB+ / A Corporates** | 1.91 | 25.71 | 18.45 | 35.82 | 37.11 |
| | (2.04) | (6.27) | (5.67) | (1.94) | (13.14) |

**Table 3: Crisis Chronology**

**Panel A: Common Break Points**

| Description | Num. of Securities | Break Point | Lower bound | Upper bound | Frequency | Beginning | End |
|---|---|---|---|---|---|---|---|
| Real Sector: VIX and S&P 500 | 2 | 2008/9/12 | 2008/9/12 | 2008/9/15 | Daily | 2000/1/1 | 2009/4/30 |
| Real Sector: VIX, S&P 500, JPM HY Index, DJ CDX.IG | 6 | 2008/1/3 | 2008/1/3 | 2008/1/10 | Weekly | 2003/4/10 | 2009/4/30 |
| Subprime: ABX only | 3 | 2007/1/25 | 2007/1/24 | 2007/1/29 | Daily | 2006/1/19 | 2009/4/30 |
| Subprime: HEL only | 2 | 2007/3/22 | 2007/3/22 | 2007/3/29 | Weekly | 2006/1/19 | 2008/1/3 |
| Subprime: ABX & HEL | 5 | 2007/1/4 | 2007/1/4 | 2007/1/11 | Weekly | 2006/1/19 | 2008/1/3 |
| Financial CDS: Include Lehman | 10 | 2007/7/23 | 2007/7/23 | 2007/7/24 | Daily | 2002/11/6 | 2008/9/12 |
| Financial CDS: Exclude Lehman | 9 | 2007/7/25 | 2007/7/25 | 2007/7/26 | Daily | 2002/11/6 | 2009/4/30 |
| Money Market: CP, Fed Fund, GC, LIBOR, Repo | 13 | 2007/7/23 | 2007/7/23 | 2007/7/24 | Daily | 2005/10/3 | 2009/4/30 |
| Money Market: Repo | 6 | 2007/7/23 | 2007/7/20 | 2007/7/25 | Daily | 2005/10/3 | 2009/4/30 |
| Money Market: CP, Fed Fund, GC, LIBOR | 7 | 2007/8/8 | 2007/8/8 | 2007/8/9 | Daily | 2005/10/3 | 2009/4/30 |

| Panel B: Multiple Break Points | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Description** | **Breaks** | **Number of Securities** | **Break Point** | **Lower bound** | **Upper bound** | **Frequency** | **Beginning** | **End** |
| | First | 13 | 7/23/2007 | 7/23/2007 | 7/24/2007 | Daily | 10/3/2005 | 4/30/2009 |
| CP, Fed Fund, GC, LIBOR, Repo | Second | 13 | 8/14/2008 | 8/14/2008 | 8/15/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 13 | 12/15/2008 | 12/15/2008 | 12/16/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | First | 7 | 8/8/2007 | 8/8/2007 | 8/9/2007 | Daily | 10/3/2005 | 4/30/2009 |
| CP, Fed Fund, GC, LIBOR | Second | 7 | 9/12/2008 | 9/12/2008 | 9/16/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 7 | 12/15/2008 | 12/15/2008 | 12/16/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | First | 6 | 7/23/2007 | 7/20/2007 | 7/25/2007 | Daily | 10/3/2005 | 4/30/2009 |
| Repo | Second | 6 | 8/14/2008 | 8/14/2008 | 8/15/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 6 | 12/15/2008 | 12/12/2008 | 12/17/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | First | 13 | 7/27/2007 | 7/26/2007 | 7/31/2007 | Daily | 10/3/2005 | 4/30/2009 |
| All CP | Second | 13 | 9/12/2008 | 9/11/2008 | 9/17/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 13 | 12/15/2008 | 12/15/2008 | 12/16/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | First | 7 | 8/6/2007 | 8/3/2007 | 8/8/2007 | Daily | 10/3/2005 | 4/30/2009 |
| Unsecured (Excluding ABCP) | Second | 7 | 9/12/2008 | 9/11/2008 | 9/17/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 7 | 12/15/2008 | 12/15/2008 | 12/16/2008 | Daily | 10/3/2005 | 4/30/2009 |

**Table 4: Spread Break Detail**

| Description | Breaks | Number of Securities | Break Point | Lower bound | Upper bound | Frequency | Beginning | End |
|---|---|---|---|---|---|---|---|---|
| ABCP | First | 1 | 7/27/2007 | 7/20/2007 | 8/6/2007 | Daily | 10/3/2005 | 4/30/2009 |
| | Second | 1 | 9/12/2008 | 9/5/2008 | 10/3/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 1 | 10/16/2008 | 10/16/2008 | 10/17/2008 | Daily | 10/3/2005 | 4/30/2009 |
| GC | First | 1 | 8/13/2007 | 8/1/2007 | 8/24/2007 | Daily | 10/3/2005 | 4/30/2009 |
| | Second | 1 | 9/12/2008 | 9/4/2008 | 10/6/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 1 | 12/15/2008 | 12/1/2008 | 1/12/2009 | Daily | 10/3/2005 | 4/30/2009 |

**Table 5: Commercial Paper Issuance**

| | Period | Avg. Issuance $ millions | 1-4 days | 5-9 days | 10-20 days | 21-40 days | 41-80 days | >=80 days |
|---|---|---|---|---|---|---|---|---|
| A2/P2 Nonfinancial | Before 2007 | $4,276.5 | 65% | 8% | 7% | 13% | 4% | 1% |
| | Pre-crisis | 6,045.7 | 77% | 7% | 5% | 8% | 3% | 1% |
| | Crisis: Pre-Lehman | 7,635.8 | 78% | 7% | 6% | 6% | 2% | 1% |
| | Crisis: Lehman | 5,660.3 | 70% | 11% | 10% | 7% | 2% | 1% |
| | Crisis: After Dec 2008 | 3,222.9 | 69% | 10% | 9% | 8% | 2% | 1% |
| AA Asset-backed | Before 2007 | 38,107.2 | 49% | 5% | 5% | 25% | 8% | 7% |
| | Pre-crisis | 60,945.9 | 61% | 4% | 4% | 20% | 5% | 6% |
| | Crisis: Pre-Lehman | 70,064.8 | 67% | 6% | 5% | 13% | 4% | 5% |
| | Crisis: Lehman | 71,613.5 | 74% | 5% | 3% | 8% | 3% | 6% |
| | Crisis: After Dec 2008 | 27,303.6 | 61% | 8% | 3% | 16% | 4% | 8% |
| AA Financial | Before 2007 | 18,080.0 | 77% | 6% | 4% | 6% | 4% | 3% |
| | Pre-crisis | 16,017.1 | 67% | 7% | 5% | 7% | 4% | 9% |
| | Crisis: Pre-Lehman | 9,712.8 | 55% | 7% | 6% | 11% | 6% | 14% |
| | Crisis: Lehman | 12,403.5 | 74% | 6% | 4% | 5% | 2% | 10% |
| | Crisis: After Dec 2008 | 8,563.6 | 75% | 5% | 3% | 7% | 3% | 8% |
| AA Nonfinancial | Before 2007 | 3,165.4 | 63% | 8% | 8% | 12% | 7% | 2% |
| | Pre-crisis | 1,475.2 | 53% | 9% | 9% | 10% | 11% | 7% |
| | Crisis: Pre-Lehman | 1,452.5 | 44% | 9% | 11% | 17% | 11% | 7% |
| | Crisis: Lehman | 1,945.8 | 38% | 6% | 10% | 21% | 18% | 8% |
| | Crisis: After Dec 2008 | 4,749.0 | 70% | 7% | 7% | 8% | 5% | 3% |
| Total CP | Before 2007 | 122,613.1 | 62% | 6% | 5% | 14% | 6% | 6% |
| | Pre-crisis | 167,143.0 | 68% | 5% | 4% | 13% | 4% | 6% |
| | Crisis: Pre-Lehman | 161,196.9 | 68% | 7% | 5% | 10% | 4% | 6% |
| | Crisis: Lehman | 158,015.5 | 71% | 6% | 4% | 8% | 4% | 7% |
| | Crisis: After Dec 2008 | 91,499.4 | 65% | 8% | 4% | 11% | 4% | 8% |
| Total CP(4) | Before 2007 | 63,629.1 | 59% | 6% | 5% | 18% | 7% | 5% |
| | Pre-crisis | 84,483.8 | 63% | 5% | 4% | 16% | 5% | 6% |
| | Crisis: Pre-Lehman | 88,866.0 | 66% | 7% | 5% | 12% | 4% | 6% |
| | Crisis: Lehman | 91,623.0 | 73% | 6% | 4% | 8% | 4% | 6% |
| | Crisis: After Dec 2008 | 43,839.1 | 65% | 7% | 4% | 13% | 4% | 7% |

Source: Federal Reserve H.15 Release, Historical Data

The subperiods are as follows: Before 2007: Jan. 1, 2001 to Jan. 1, 2007; Pre-crisis：Jan. 1, 2007 to Jul. 22, 2007; Crisis: Pre-Lehman: Jul. 23, 2007 to Aug. 14, Aug 2008; Crisis: Lehman: Aug. 15, 2008 to Dec. 14, 2008; Crisis: After Dec. 15, 2008 to Apr. 29, 2009.

**Table 6: Multiple Break Points For CP Issuance, Short/Long Ratio (30 day Rolling)**

| Description | Number of Securities | Break Point | Lower bound | Upper bound | Frequency | Beginning | End |
|---|---|---|---|---|---|---|---|
| First Break | 4 | 2007/6/13 | 2007/6/12 | 2007/6/15 | Daily | 2005/10/3 | 2009/4/30 |
| Second Break | 4 | 2008/9/26 | 2008/9/26 | 2008/9/29 | Daily | 2005/10/3 | 2009/4/30 |
| Third Break | 4 | 2009/1/26 | 2009/1/23 | 2009/1/28 | Daily | 2005/10/3 | 2009/4/30 |

**Table 7: Multiple Break Points For CP Issuance Level**

| **Description** | **Breaks** | **Number of Securities** | **Break Point** | **Lower bound** | **Upper bound** | **Frequency** | **Beginning** | **End** |
|---|---|---|---|---|---|---|---|---|
| | First | 4 | 5/31/2007 | 5/30/2007 | 6/4/2007 | Daily | 10/3/2005 | 4/30/2009 |
| Overnight | Second | 4 | 9/19/2008 | 9/18/2008 | 9/23/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 4 | 12/31/2008 | 12/31/2008 | 1/2/2009 | Daily | 10/3/2005 | 4/30/2009 |
| | First | 4 | 9/24/2007 | 9/14/2007 | 10/3/2007 | Daily | 10/3/2005 | 4/30/2009 |
| One-month | Second | 4 | 12/31/2007 | 12/6/2007 | 1/25/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 4 | 9/12/2008 | 9/5/2008 | 9/22/2008 | Daily | 10/3/2005 | 4/30/2009 |
| | First | 4 | 3/8/2007 | 2/28/2007 | 3/19/2007 | Daily | 10/3/2005 | 4/30/2009 |
| Three-month | Second | 4 | 12/4/2007 | 11/16/2007 | 12/20/2007 | Daily | 10/3/2005 | 4/30/2009 |
| | Third | 4 | 9/16/2008 | 9/11/2008 | 9/22/2008 | Daily | 10/3/2005 | 4/30/2009 |

**Table 8: Summary of the Spreads by Term to Maturity**

**Panel A: Fed Funds, General Collateral Repo, LIBOR**

| Series | Periods | Overnight | One-month | Three-month |
|---|---|---|---|---|
| Fed Fund | Pre-crisis | -0.32 | 4.15 | 5.97 |
| | | (-1.54) | (37.44) | (49.51) |
| | Crisis: Pre-Lehman | -3.32 | 45.59 | 66.09 |
| | | (-2.44) | (22.37) | (33.17) |
| | Crisis: Lehman | -37.04 | 163.31 | 225.91 |
| | | (-6) | (10.13) | (14.44) |
| | Crisis: After Dec 2008 | 6.97 | 38.39 | 105.95 |
| | | (5.46) | (26) | (34.75) |
| GC | Pre-crisis | -3.83 | -6.69 | -6.8 |
| | | (-14.38) | (-27.59) | (-25.9) |
| | Crisis: Pre-Lehman | -23.27 | -17.46 | -17.38 |
| | | (-6.96) | (-8.86) | (-10.39) |
| | Crisis: Lehman | -56.32 | 2.06 | 9.57 |
| | | (-7.53) | (0.87) | (4.34) |
| | Crisis: After Dec 2008 | 11.02 | 6.78 | 8.83 |
| | | (6.76) | (9.36) | (14) |
| LIBOR | Pre-crisis | 5.33 | 8.66 | 10.81 |
| | | (33.06) | (72.33) | (80.18) |
| | Crisis: Pre-Lehman | 16.76 | 47.39 | 65.27 |
| | | (10.76) | (24.13) | (39.43) |
| | Crisis: Lehman | 13.85 | 138.7 | 181.02 |
| | | (1.03) | (10.64) | (14.69) |
| | Crisis: After Dec 2008 | 13.37 | 23.75 | 97.43 |
| | | (7.55) | (22.39) | (50.67) |

The subperiods are as follows: Before 2007: Jan. 1, 2001 to Jan. 1, 2007; Pre-crisis：Jan. 1, 2007 to Jul. 22, 2007; Crisis: Pre-Lehman: Jul. 23, 2007 to Aug. 14, Aug 2008; Crisis: Lehman: Aug. 15, 2008 to Dec. 14, 2008; Crisis: After Dec. 15, 2008 to Apr. 29, 2009.

| Panel B: Commercial Paper | | | | |
|---|---|---|---|---|
| Series | Periods | Overnight | One-month | Three-month |
| A2/P2 Nonfinancial CP | Pre-crisis | 8.97 | 16.41 | 18.54 |
| | | (24.46) | (36.2) | (28.27) |
| | Crisis: Pre-Lehman | 47.52 | 77.1 | 89.6 |
| | | (28.27) | (31.11) | (36.19) |
| | Crisis: Lehman | 172.89 | 351.97 | 361.65 |
| | | (11.53) | (13.12) | (8.94) |
| | Crisis: After Dec 2008 | 87.34 | 122.49 | 144.01 |
| | | (17.33) | (6.44) | (7.68) |
| AA Asset-backed CP | Pre-crisis | 1.47 | 3.27 | 2.86 |
| | | (8.34) | (21.99) | (13.6) |
| | Crisis: Pre-Lehman | 37.52 | 67.37 | 74.87 |
| | | (27.49) | (20.65) | (27.64) |
| | Crisis: Lehman | 50.78 | 139.06 | 176.49 |
| | | (5.05) | (9.85) | (13.35) |
| | Crisis: After Dec 2008 | 38.4 | 40.08 | 66.32 |
| | | (16.13) | (21.98) | (8.84) |
| AA Financial CP | Pre-crisis | -1.51 | -0.57 | 0.13 |
| | | (-8.65) | (-4.21) | (0.69) |
| | Crisis: Pre-Lehman | -5.9 | 26.27 | 51.52 |
| | | (-6.59) | (17.95) | (27.71) |
| | Crisis: Lehman | -35.51 | 88.39 | 135.27 |
| | | (-6.1) | (10.58) | (11.01) |
| | Crisis: After Dec 2008 | 7.3 | 17.58 | 46.38 |
| | | (4.83) | (14.03) | (6.81) |
| AA Nonfinancial CP | Pre-crisis | -1.9 | -2.85 | -0.08 |
| | | (-10.98) | (-15.72) | (-0.26) |
| | Crisis: Pre-Lehman | -3.01 | 7.01 | 11.71 |
| | | (-3.33) | (7.89) | (7.13) |
| | Crisis: Lehman | -36.53 | 16.94 | 76.08 |
| | | (-5.44) | (6.01) | (9.95) |
| | Crisis: After Dec 2008 | 7.73 | 1.46 | 12.25 |
| | | (4.75) | (1.72) | (7.32) |

| Panel C: Repo | | | | |
|---|---|---|---|---|
| Series | Periods | Overnight | One-month | Three-month |
| <AA ABS-RMBS / CMBS | Pre-crisis | 10.16 | 10.8 | 9.26 |
| | | (8.36) | (33.33) | (68.28) |
| | Crisis: Pre-Lehman | 49.12 | 92.06 | 111.52 |
| | | (13.07) | (30.53) | (34.84) |
| | Crisis: Lehman | 136.94 | 303.66 | 346.8 |
| | | (8.9) | (16.92) | (19.21) |
| | Crisis: After Dec 2008 | 207.36 | 238.79 | 312.3 |
| | | (74.21) | (147.24) | (172.87) |
| A-AAA ABS-Auto / CC / SL | Pre-crisis | 3.23 | 4.82 | 4.26 |
| | | (3.07) | (15.87) | (31.35) |
| | Crisis: Pre-Lehman | 30.07 | 73.58 | 91.23 |
| | | (8.51) | (27.47) | (34.2) |
| | Crisis: Lehman | 83.06 | 219.67 | 266.07 |
| | | (5.09) | (13.34) | (16.5) |
| | Crisis: After Dec 2008 | 108.9 | 118.17 | 192.13 |
| | | (34.65) | (65.71) | (81.12) |
| AA-AAA ABS-RMBS / CMBS | Pre-crisis | 5.16 | 6.8 | 6.26 |
| | | (4.24) | (20.99) | (46.16) |
| | Crisis: Pre-Lehman | 37.96 | 81.95 | 102.2 |
| | | (10.65) | (29.26) | (35.29) |
| | Crisis: Lehman | 110.39 | 277.03 | 320.17 |
| | | (7.01) | (15.91) | (18.31) |
| | Crisis: After Dec 2008 | 173.64 | 205.1 | 278.62 |
| | | (70.07) | (148.22) | (153.48) |
| AA-AAA CLO | Pre-crisis | 5.16 | 6.8 | 6.26 |
| | | (4.24) | (20.99) | (46.16) |
| | Crisis: Pre-Lehman | 45.75 | 89.22 | 113.12 |
| | | (11.8) | (27.21) | (33.84) |
| | Crisis: Lehman | 125.99 | 292.47 | 335.23 |
| | | (8.38) | (15.83) | (17.99) |
| | Crisis: After Dec 2008 | 202.31 | 233.76 | 307.28 |
| | | (74.11) | (144.43) | (170.74) |
| AA-AAA Corporates | Pre-crisis | -0.82 | -2.7 | -2.24 |
| | | (-0.92) | (-11.39) | (-18.62) |
| | Crisis: Pre-Lehman | 11.58 | 54.4 | 72.15 |
| | | (3.71) | (25.36) | (35.25) |
| | Crisis: Lehman | 19.18 | 155.36 | 202.09 |
| | | (1.02) | (10.62) | (14.65) |
| | Crisis: After Dec 2008 | 21.65 | 31.09 | 105.05 |
| | | (8.73) | (23.48) | (51.83) |
| BBB+ / A Corporates | Pre-crisis | 1.91 | 0.64 | 1.47 |
| | | (2.04) | (1.89) | (10.17) |
| | Crisis: Pre-Lehman | 18.45 | 61.58 | 79.64 |
| | | (5.67) | (26.05) | (35.58) |
| | Crisis: Lehman | 35.82 | 172.07 | 218.79 |
| | | (1.94) | (11.54) | (15.49) |
| | Crisis: After Dec 2008 | 37.11 | 46.4 | 120.36 |
| | | (13.14) | (35.63) | (53.5) |

**Table 9: The Term Structures of Spreads**

**Panel A: Fed Funds, General Collateral Repo, LIBOR**

| Series | Periods | 1m/1d | 3m/1d | 3m/1m |
|---|---|---|---|---|
| Fed Fund | Pre-crisis | 4.46 | 6.28 | 1.82 |
| | | (18.45) | (25.3) | (23.81) |
| | Crisis: Pre-Lehman | 48.91 | 69.41 | 20.5 |
| | | (19.53) | (29.39) | (19.72) |
| | Crisis: Lehman | 200.36 | 262.96 | 62.6 |
| | | (10.87) | (13.82) | (10.77) |
| | Crisis: After Dec 2008 | 31.22 | 98.97 | 67.57 |
| | | (12.27) | (25.49) | (23.65) |
| GC | Pre-crisis | -2.87 | -2.99 | -0.12 |
| | | (-10.14) | (-9.97) | (-0.76) |
| | Crisis: Pre-Lehman | 5.81 | 5.89 | 0.07 |
| | | (2.71) | (2.3) | (0.09) |
| | Crisis: Lehman | 59.33 | 64.9 | 6.12 |
| | | (8.62) | (8.74) | (5.26) |
| | Crisis: After Dec 2008 | -4.23 | -2.19 | 2.04 |
| | | (-2.67) | (-1.43) | (4.72) |
| LIBOR | Pre-crisis | 3.31 | 5.45 | 2.14 |
| | | (17.23) | (27.19) | (28.61) |
| | Crisis: Pre-Lehman | 30.65 | 48.42 | 17.87 |
| | | (13.19) | (23.24) | (18.62) |
| | Crisis: Lehman | 124.8 | 167 | 42.31 |
| | | (8.25) | (10.75) | (15.26) |
| | Crisis: After Dec 2008 | 10.45 | 84.1 | 73.68 |
| | | (4.53) | (25.48) | (47.45) |

The subperiods are as follows: Before 2007: Jan. 1, 2001 to Jan. 1, 2007; Pre-crisis：Jan. 1, 2007 to Jul. 22, 2007; Crisis: Pre-Lehman: Jul. 23, 2007 to Aug. 14, Aug 2008; Crisis: Lehman: Aug. 15, 2008 to Dec. 14, 2008; Crisis: After Dec. 15, 2008 to Apr. 29, 2009.

| Panel B: Commercial Paper | | | | |
|---|---|---|---|---|
| Series | Periods | 1m/1d | 3m/1d | 3m/1m |
| A2/P2 Nonfinancial | Pre-crisis | 7.42 | 9.37 | 1.92 |
| | | (23.53) | (18.21) | (5.23) |
| | Crisis: Pre-Lehman | 29.57 | 41.36 | 12.94 |
| | | (12.72) | (18.5) | (9.04) |
| | Crisis: Lehman | 179.08 | 200.91 | 35.16 |
| | | (9.31) | (7.31) | (3.2) |
| | Crisis: After Dec 2008 | 35.14 | 50.39 | 9.76 |
| | | (2.26) | (3.16) | (0.78) |
| AA Asset-backed | Pre-crisis | 1.79 | 1.38 | -0.4 |
| | | (9.1) | (5.54) | (-3.13) |
| | Crisis: Pre-Lehman | 29.85 | 37.4 | 7.4 |
| | | (10.35) | (16.26) | (5.41) |
| | Crisis: Lehman | 88.27 | 125.7 | 37.42 |
| | | (8.14) | (10.58) | (5.07) |
| | Crisis: After Dec 2008 | 2.15 | 28.39 | 26.24 |
| | | (0.92) | (4.19) | (3.52) |
| AA Financial | Pre-crisis | 0.94 | 1.67 | 0.7 |
| | | (4.64) | (7.04) | (5.54) |
| | Crisis: Pre-Lehman | 32.18 | 57.43 | 25.24 |
| | | (17.69) | (26.67) | (19.44) |
| | Crisis: Lehman | 122.77 | 154.72 | 39.58 |
| | | (11.64) | (10.38) | (5.56) |
| | Crisis: After Dec 2008 | 10.27 | 40.05 | 29.41 |
| | | (5.84) | (5.9) | (4.25) |
| AA Nonfinancial | Pre-crisis | -0.96 | 1.71 | 1.31 |
| | | (-4.12) | (4.72) | (6.55) |
| | Crisis: Pre-Lehman | 10.05 | 15.27 | 3.5 |
| | | (7.59) | (6.91) | (2.99) |
| | Crisis: Lehman | 52.27 | 113.83 | 56.95 |
| | | (6.34) | (7.82) | (8.39) |
| | Crisis: After Dec 2008 | -5.11 | 6.54 | 12.45 |
| | | (-4.58) | (4) | (6.84) |

| Panel C: Repo | | | | |
|---|---|---|---|---|
| Series | Periods | 1m/1d | 3m/1d | 3m/1m |
| <AA ABS-RMBS / CMBS | Pre-crisis | 0.63 | -0.9 | -1.54 |
| | | (0.63) | (-0.76) | (-5.7) |
| | Crisis: Pre-Lehman | 42.84 | 62.23 | 19.45 |
| | | (11.57) | (17.2) | (14.65) |
| | Crisis: Lehman | 165.75 | 209.16 | 43.14 |
| | | (5.51) | (6.89) | (15.98) |
| | Crisis: After Dec 2008 | 31.51 | 104.99 | 73.51 |
| | | (13.12) | (33.18) | (51.18) |
| A-AAA ABS-Auto / CC / SL | Pre-crisis | 1.57 | 1.02 | -0.55 |
| | | (1.78) | (0.99) | (-2.24) |
| | Crisis: Pre-Lehman | 43.53 | 61.01 | 17.65 |
| | | (11.73) | (16.83) | (16.33) |
| | Crisis: Lehman | 136.2 | 182.73 | 46.39 |
| | | (4.75) | (6.3) | (14.9) |
| | Crisis: After Dec 2008 | 9.35 | 83.26 | 73.96 |
| | | (3.04) | (23.5) | (41.92) |
| AA-AAA ABS-RMBS / CMBS | Pre-crisis | 1.63 | 1.09 | -0.54 |
| | | (1.62) | (0.92) | (-2) |
| | Crisis: Pre-Lehman | 43.92 | 64.1 | 20.25 |
| | | (11.83) | (17.77) | (15.78) |
| | Crisis: Lehman | 165.75 | 209.16 | 43.14 |
| | | (5.51) | (6.89) | (15.98) |
| | Crisis: After Dec 2008 | 31.53 | 105.02 | 73.51 |
| | | (13.4) | (33.3) | (50.53) |
| AA-AAA CLO | Pre-crisis | 1.63 | 1.09 | -0.54 |
| | | (1.62) | (0.92) | (-2) |
| | Crisis: Pre-Lehman | 43.27 | 67.11 | 23.89 |
| | | (11.56) | (18.23) | (16.46) |
| | Crisis: Lehman | 165.37 | 208.4 | 42.76 |
| | | (5.53) | (6.9) | (15.73) |
| | Crisis: After Dec 2008 | 31.53 | 105.02 | 73.51 |
| | | (13.4) | (33.3) | (50.53) |
| AA-AAA Corporates | Pre-crisis | -1.87 | -1.42 | 0.45 |
| | | (-2.34) | (-1.67) | (2.49) |
| | Crisis: Pre-Lehman | 42.81 | 60.41 | 17.75 |
| | | (11.65) | (16.83) | (17.14) |
| | Crisis: Lehman | 136.2 | 183.06 | 46.72 |
| | | (4.75) | (6.33) | (15.04) |
| | Crisis: After Dec 2008 | 9.49 | 83.4 | 73.95 |
| | | (3.3) | (24.62) | (39.02) |
| BBB+ / A Corporates | Pre-crisis | -1.27 | -0.44 | 0.83 |
| | | (-1.52) | (-0.48) | (2.97) |
| | Crisis: Pre-Lehman | 43.14 | 61.02 | 18.05 |
| | | (11.7) | (16.99) | (17.34) |
| | Crisis: Lehman | 136.2 | 183.06 | 46.72 |
| | | (4.75) | (6.33) | (15.04) |
| | Crisis: After Dec 2008 | 9.35 | 83.26 | 73.96 |
| | | (3.04) | (23.5) | (41.92) |

**Table 10: Multiple Break Points for Slopes**

| Description | Breaks | Number of Securities | Break Point | Lower bound | Upper bound | Frequency | Beginning | End |
|---|---|---|---|---|---|---|---|---|
| CP, Fed Fund, GC, LIBOR, Repo | First | 13 | 7/23/2007 | 7/23/2007 | 7/24/2007 | Daily | 10/3/2005 | 4/30/2009 |
| CP, Fed Fund, GC, LIBOR, Repo | Second | 13 | 8/14/2008 | 8/14/2008 | 8/15/2008 | Daily | 10/3/2005 | 4/30/2009 |
| CP, Fed Fund, GC, LIBOR, Repo | Third | 13 | 12/15/2008 | 12/15/2008 | 12/16/2008 | Daily | 10/3/2005 | 4/30/2009 |
| CP, Fed Fund, GC, LIBOR | First | 7 | 8/8/2007 | 8/8/2007 | 8/9/2007 | Daily | 10/3/2005 | 4/30/2009 |
| CP, Fed Fund, GC, LIBOR | Second | 7 | 9/12/2008 | 9/12/2008 | 9/16/2008 | Daily | 10/3/2005 | 4/30/2009 |
| CP, Fed Fund, GC, LIBOR | Third | 7 | 12/15/2008 | 12/15/2008 | 12/16/2008 | Daily | 10/3/2005 | 4/30/2009 |
| Repo | First | 6 | 7/23/2007 | 7/20/2007 | 7/25/2007 | Daily | 10/3/2005 | 4/30/2009 |
| Repo | Second | 6 | 8/14/2008 | 8/14/2008 | 8/15/2008 | Daily | 10/3/2005 | 4/30/2009 |
| Repo | Third | 6 | 12/15/2008 | 12/12/2008 | 12/17/2008 | Daily | 10/3/2005 | 4/30/2009 |

**Table 11: Changes in Short-term Ratings for Financial Firms during the Crisis**

| | Total | A-1+ | A-1 | A-2 | A-3 | B | C | D | No Rating |
|---|---|---|---|---|---|---|---|---|---|
| A-1+ | 48 | 29 | 19 | | | | | | |
| | | -0.6 | -0.39 | | | | | | |
| A-1 | 60 | 4 | 36 | 14 | 1 | 3 | | | 2 |
| | | -0.06 | -0.6 | -0.23 | -0.01 | -0.05 | | | -0.03 |
| A-2 | 46 | | 3 | 30 | 4 | 5 | | | 4 |
| | | | -0.06 | -0.65 | -0.08 | -0.1 | | | -0.08 |
| A-3 | 13 | | | 1 | 8 | 3 | | | 1 |
| | | | | -0.07 | -0.61 | -0.23 | | | -0.07 |
| B | 8 | | | | 1 | 3 | 2 | | 2 |
| | | | | | -0.12 | -0.37 | -0.25 | | -0.25 |
| D | 1 | | | | | | | 1 | |
| | | | | | | | | -1 | |

This table reports the changes in S&P short-term credit ratings for financial firms during the crisis of 2007-2009. Financial firms are defined as the firms with SIC code from 6000 to 6999. To be included in the sample, the firms must have a S&P short-term credit rating before June 30th 2007. The first two columns present the number of firms for different ratings on June 30th 2007. The third to eighth column shows the number of firms for different ratings on June 30th 2009. The transition probabilities are presented in parentheses.

**Table 12: The Liability Structure of Financial Firms: 2007 to 2008**

| (in millions) | 2007 | | 2008 | |
|---|---|---|---|---|
| Total Debts | 6,558,396 | 100.00% | 5,670,953 | 100.00% |
| Total Commercial Paper | 564,364 | 8.60% | 421,032 | 7.40% |
| Total Revolving Credit | 65,221 | 1.00% | 138,133 | 2.40% |
| Total Senior Bonds and Notes | 2,818,906 | 43.00% | 2,551,541 | 45.00% |
| Total Subordinated Bonds and Notes | 225,657 | 3.40% | 271,893 | 4.80% |
| Total Term Loans | 212,892 | 3.20% | 400,264 | 7.10% |
| Total Trust Preferred | 102,538 | 1.60% | 119,890 | 2.10% |
| Total Capital Leases | 2,582 | 0.00% | 2,611 | 0.00% |
| Other Borrowings | 2,577,771 | 39.30% | 1,772,505 | 31.30% |

This table reports the aggregated debt structure for financial commercial paper issuers from 2007 to 2008. To identify the financial commercial paper issuers, we first get the list of firms which have received short-term credit ratings from Moody's or Standard & Poor's before 2007. Then we restrict our attention only to financial firms and identify 229 financial firms that have short-term ratings. The debt data is from Capital IQ. We are able to find the debt data for 77 of these 229 financial firms. And 13 of the 77 firms have never issued any commercial paper since 2001. So the final sample includes 64 financial firms, which cover most important commercial banks, investment banks and insurance firms in U.S.

**Table 13: Breaks in Repo Haircuts**

| | Break point | Lower bound | Upper bound |
|---|---|---|---|
| First Break | 2007/10/23 | 2007/10/23 | 2007/10/24 |
| Second Break | 2008/2/6 | 2008/2/6 | 2008/2/7 |
| Third Break | 2008/9/15 | 2008/9/15 | 2008/9/16 |

**Table B1: Overnight Spreads, Before the Crisis**

| | Intercept | Quarter-end, Day (-15,-11) | Quarter-end, Day (-10,-6) | Quarter-end, Day (-5,-1) | Quarter-end, Day (0,1) | Quarter-end, Day (2,5) | Calendar Day, 1st | Calendar Day, 15th | Calendar Day, 30th or 31th | Monday | Friday |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fed Fund | -0.32 | 0.64 | -0.02 | 1.76 | 6.56 | 0.19 | 2.75 | 5.88 | 4.99 | 2.48 | 0.16 |
| | (-1.54) | (0.99) | (-0.03) | (2.83) | (5.88) | (0.27) | (3.09) | (7.2) | (6.06) | (6.46) | (0.44) |
| GC | -3.83 | 0.84 | -2.42 | -1.58 | -2.1 | 0.24 | 4.3 | 6.83 | 4.69 | 2.2 | -0.61 |
| | (-14.38) | (1.02) | (-2.97) | (-1.98) | (-1.48) | (0.27) | (3.8) | (6.59) | (4.49) | (4.52) | (-1.29) |
| LIBOR | 5.33 | 0.53 | -0.36 | 4.16 | 12.76 | 1.22 | 1.19 | 5.92 | 6.61 | 1.57 | -0.17 |
| | (33.06) | (1.06) | (-0.72) | (8.26) | (14.73) | (2.19) | (1.71) | (9.46) | (10.25) | (5.13) | (-0.6) |
| A2/P2 Nonfinancial | 8.97 | 1.24 | -0.26 | 6.11 | 10.63 | 2.56 | 1.91 | 6.99 | 6.31 | 2.5 | 0.92 |
| | (24.46) | (1.1) | (-0.23) | (5.6) | (5.45) | (2.04) | (1.22) | (4.9) | (4.34) | (3.68) | (1.42) |
| AA Asset-backed | 1.47 | 1.07 | -0.32 | 4.8 | 9.34 | 1.7 | 2.95 | 7.31 | 6.65 | 2.37 | 0.33 |
| | (8.34) | (1.97) | (-0.6) | (9.15) | (9.84) | (2.82) | (3.92) | (10.65) | (9.5) | (7.25) | (1.06) |
| AA Financial | -1.51 | 0.56 | -1.61 | 3.42 | 8.07 | 1.73 | 3.15 | 6.96 | 6.46 | 2.51 | -0.25 |
| | (-8.65) | (1.03) | (-3.01) | (6.57) | (8.66) | (2.88) | (4.23) | (10.2) | (9.29) | (7.72) | (-0.82) |
| AA Nonfinancial | -1.9 | 1.12 | -0.27 | 4.67 | 6.99 | 1.64 | 3.33 | 7.09 | 6.55 | 2.53 | 0.34 |
| | (-10.98) | (2.1) | (-0.5) | (9.1) | (7.62) | (2.77) | (4.55) | (10.56) | (9.57) | (7.93) | (1.13) |
| <AA ABS-RMBS / CMBS | 10.16 | 1.3 | 13.52 | 67.8 | 77.07 | -1.12 | -2.64 | -0.29 | 2.28 | -1.96 | 5.88 |
| | (8.36) | (0.32) | (3.45) | (19.8) | (6.11) | (-0.31) | (-0.52) | (-0.06) | (0.51) | (-0.85) | (2.71) |
| A-AAA ABS-Auto / CC / SL | 3.23 | 0.63 | 10.97 | 54.64 | 71.28 | -1.28 | -2.53 | -0.09 | 2.06 | -1.43 | 5.1 |
| | (3.07) | (0.18) | (3.24) | (18.46) | (6.54) | (-0.41) | (-0.58) | (-0.02) | (0.54) | (-0.72) | (2.72) |
| AA-AAA ABS-RMBS / CMBS | 5.16 | 1.3 | 13.52 | 67.8 | 77.07 | -1.12 | -2.64 | -0.29 | 2.28 | -1.96 | 5.88 |
| | (4.24) | (0.32) | (3.45) | (19.8) | (6.11) | (-0.31) | (-0.52) | (-0.06) | (0.51) | (-0.85) | (2.71) |
| AA-AAA CLO | 5.16 | 1.3 | 13.52 | 67.8 | 77.07 | -1.12 | -2.64 | -0.29 | 2.28 | -1.96 | 5.88 |
| | (4.24) | (0.32) | (3.45) | (19.8) | (6.11) | (-0.31) | (-0.52) | (-0.06) | (0.51) | (-0.85) | (2.71) |
| AA-AAA Corporates | -0.82 | 1.57 | 8.56 | 37.64 | 25.98 | -1.66 | -2.24 | 0.16 | 1.55 | -1.08 | 2.46 |
| | (-0.92) | (0.53) | (2.96) | (14.88) | (2.79) | (-0.62) | (-0.6) | (0.04) | (0.47) | (-0.63) | (1.54) |
| BBB+ / A Corporates | 1.91 | 2 | 10.78 | 56.46 | 48.69 | -1.46 | -2.65 | 0.2 | 2.17 | -1.92 | 4.02 |
| | (2.04) | (0.64) | (3.58) | (21.43) | (5.02) | (-0.52) | (-0.68) | (0.05) | (0.64) | (-1.09) | (2.41) |

**Table B2: Intercept Comparison**

| | No Control | Date Dummies | Tax, all days average | Tax, Normal days | Excess Reserve, Normal days |
|---|---|---|---|---|---|
| **Fed Fund** | 0.89 | -0.32 | 0.89 | 0.66 | 0.80 |
| **GC** | -3.24 | -3.83 | -3.22 | -3.43 | -3.03 |
| **LIBOR** | 6.56 | 5.33 | 6.56 | 6.34 | 6.32 |
| **A2/P2 Nonfinancial** | 10.86 | 8.97 | 10.84 | 10.60 | 10.53 |
| **AA Asset-backed** | 3.10 | 1.47 | 3.09 | 2.80 | 2.84 |
| **AA Financial** | -0.20 | -1.51 | -0.22 | -0.48 | -0.41 |
| **AA Nonfinancial** | -0.28 | -1.9 | -0.30 | -0.58 | -0.52 |
| **<AA ABS-RMBS / CMBS** | 16.44 | 10.16 | 16.49 | 16.53 | 13.88 |
| **A-AAA ABS-Auto / CC / SL** | 8.40 | 3.23 | 8.44 | 8.45 | 6.41 |
| **AA-AAA ABS-RMBS / CMBS** | 11.44 | 5.16 | 11.49 | 11.53 | 8.88 |
| **AA-AAA CLO** | 11.44 | 5.16 | 11.49 | 11.53 | 8.88 |
| **AA-AAA Corporates** | 2.45 | -0.82 | 2.51 | 2.62 | 1.01 |
| **BBB+ / A Corporates** | 6.84 | 1.91 | 6.92 | 6.99 | 4.73 |

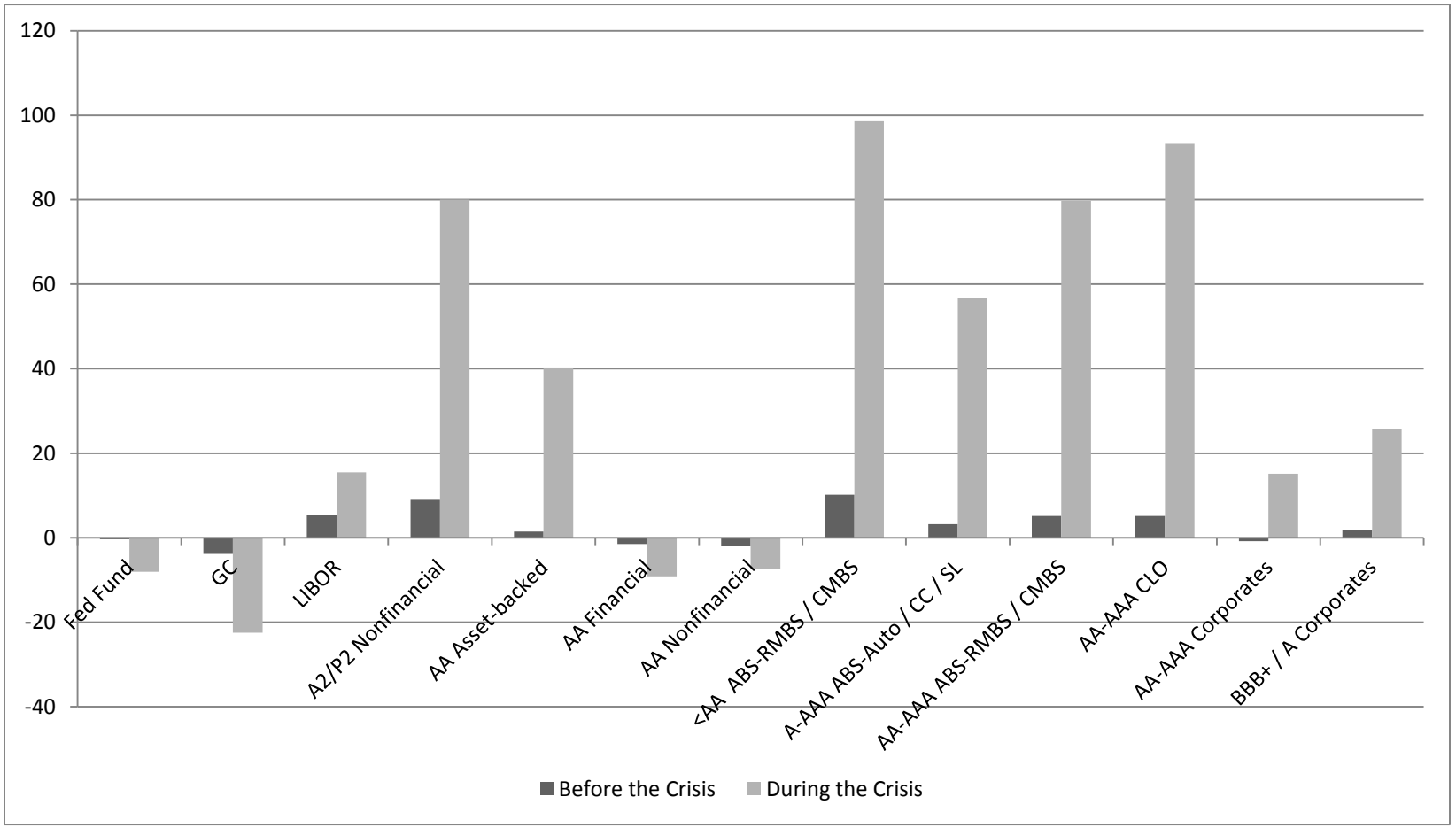
**Table C1: Breakpoint Ordering**

| Panel A: Spreads | | | | |
|---|---|---|---|---|
| CP, Fed Fund, GC, LIBOR, Repo | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 7/23/2007 | 7/23/2007 | 7/24/2007 |
| 2 | 2 | 8/14/2008 | 8/14/2008 | 8/15/2008 |
| 3 | 4 | 12/15/2008 | 12/15/2008 | 12/16/2008 |
| CP, Fed Fund, GC, LIBOR | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 8/8/2007 | 8/8/2007 | 8/9/2007 |
| 2 | 2 | 9/12/2008 | 9/12/2008 | 9/16/2008 |
| 3 | 4 | 12/15/2008 | 12/15/2008 | 12/16/2008 |
| Repo | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 2 | 7/23/2007 | 7/20/2007 | 7/25/2007 |
| 4 | 3 | 8/14/2008 | 8/14/2008 | 8/15/2008 |
| 3 | 4 | 12/15/2008 | 12/12/2008 | 12/17/2008 |
| All CP | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 7/27/2007 | 7/26/2007 | 7/31/2007 |
| 2 | 2 | 9/12/2008 | 9/11/2008 | 9/17/2008 |
| 3 | 4 | 12/15/2008 | 12/15/2008 | 12/16/2008 |
| Unsecured (Excluding ABCP) | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 8/6/2007 | 8/3/2007 | 8/8/2007 |
| 2 | 2 | 9/12/2008 | 9/11/2008 | 9/17/2008 |
| 3 | 4 | 12/15/2008 | 12/15/2008 | 12/16/2008 |
| ABCP | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 7/27/2007 | 7/20/2007 | 8/6/2007 |
| 2 | 2 | 9/12/2008 | 9/5/2008 | 10/3/2008 |
| 3 | 4 | 10/16/2008 | 10/16/2008 | 10/17/2008 |
| GC | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 2 | 8/13/2007 | 8/1/2007 | 8/24/2007 |
| 4 | 3 | 9/12/2008 | 9/4/2008 | 10/6/2008 |
| 2 | 4 | 12/15/2008 | 12/1/2008 | 1/12/2009 |

| Panel B: Haircut | | | | |
|---|---|---|---|---|
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 2007/10/23 | 2007/10/23 | 2007/10/24 |
| 3 | 2 | 2008/2/6 | 2008/2/6 | 2008/2/7 |
| 4 | 3 | 2008/6/30 | 2008/6/30 | 2008/7/1 |
| 2 | 4 | 2008/9/15 | 2008/9/15 | 2008/9/16 |

| Panel C: 1 Month/ Overnight Spread Slopes | | | | |
|---|---|---|---|---|
| Panel A: Spreads | | | | |
| CP, Fed Fund, GC, LIBOR, Repo | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 7/23/2007 | 7/24/2007 | 7/23/2007 |
| 2 | 2 | 8/15/2008 | 8/18/2008 | 8/15/2008 |
| 3 | 4 | 12/19/2008 | 1/2/2009 | 12/19/2008 |
| CP, Fed Fund, GC, LIBOR | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 8/8/2007 | 8/9/2007 | 8/8/2007 |
| 2 | 2 | 9/12/2008 | 9/16/2008 | 9/12/2008 |
| 3 | 4 | 12/19/2008 | 1/2/2009 | 12/19/2008 |
| Repo | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 7/23/2007 | 7/25/2007 | 7/20/2007 |
| 3 | 2 | 8/14/2008 | 8/15/2008 | 8/14/2008 |
| 2 | 4 | 12/17/2008 | 1/5/2009 | 12/11/2008 |
| All CP | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 8/8/2007 | 8/10/2007 | 8/7/2007 |
| 2 | 2 | 9/12/2008 | 9/17/2008 | 9/11/2008 |
| 3 | 4 | 12/19/2008 | 1/2/2009 | 12/19/2008 |
| Unsecured (Excluding ABCP) | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 8/8/2007 | 8/10/2007 | 8/7/2007 |
| 2 | 2 | 9/12/2008 | 9/16/2008 | 9/12/2008 |
| 3 | 4 | 12/19/2008 | 1/2/2009 | 12/19/2008 |
| ABCP | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 8/9/2007 | 8/20/2007 | 8/1/2007 |
| 3 | 2 | 9/12/2008 | 9/18/2008 | 9/10/2008 |
| 2 | 4 | 1/2/2009 | 1/27/2009 | 11/25/2008 |
| GC | | | | |
| Algorithm Order | Chronological Order | Breakpoint | Lower Bound | Upper Bound |
| 1 | 1 | 8/10/2007 | 8/23/2007 | 7/31/2007 |
| 3 | 2 | 9/12/2008 | 9/17/2008 | 9/11/2008 |
| 2 | 4 | 12/18/2008 | 1/27/2009 | 11/19/2008 |

**Figure 1: Money Market Spreads Before and During the Crisis (bps)**




Before and during the crisis are distinguished by July 23, 2007, the first break we find in the repo spreads. Shown are averages for before and after.

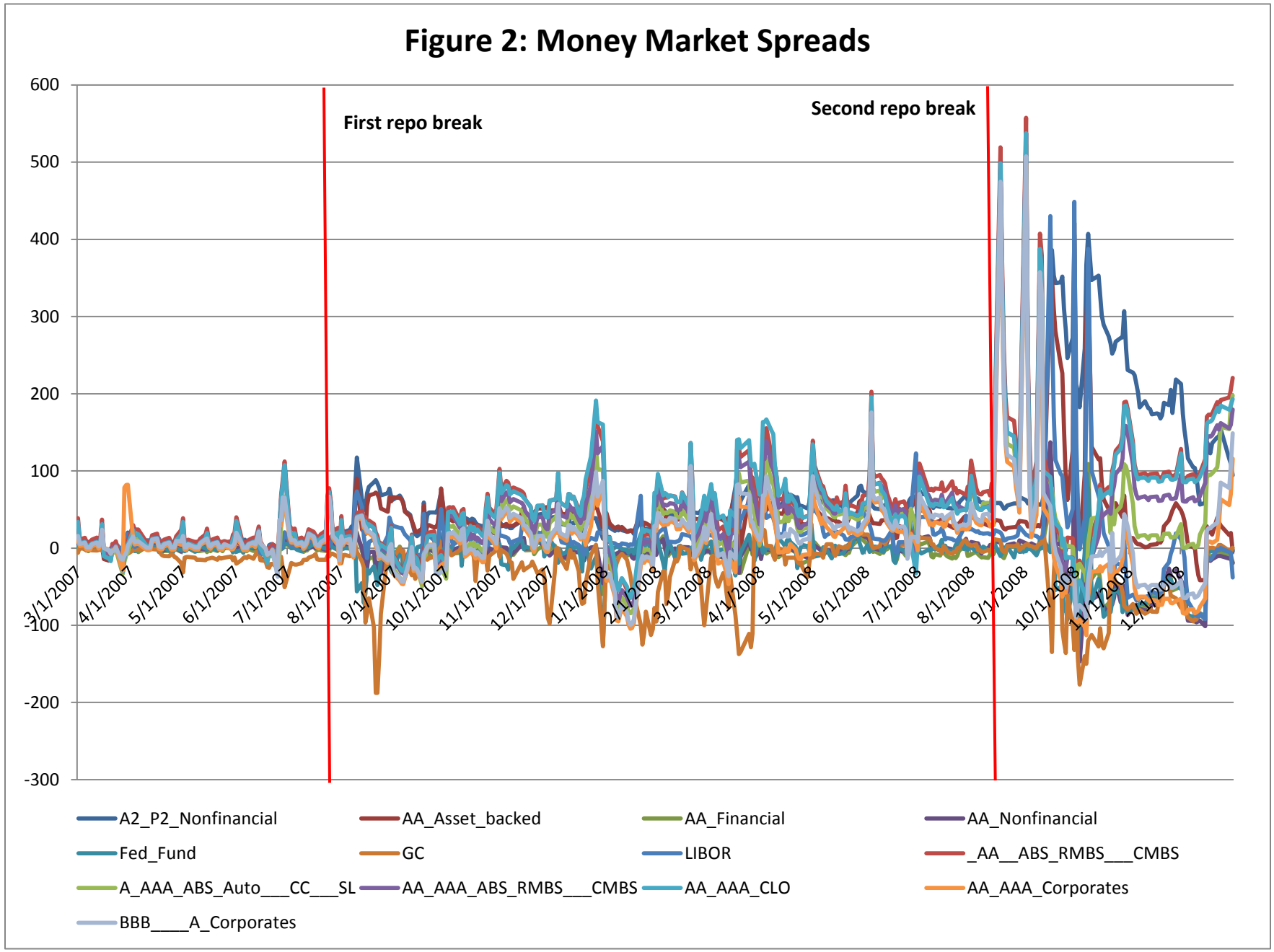


Figure 2: Money Market Spreads
First repo break
Second repo break
600
500
400
300
200
100
0
-100
-200
-300
3/1/2007
4/1/2007
5/1/2007
6/1/2007
7/1/2007
8/1/2007
9/1/2007
10/1/2007
11/1/2007
12/1/2007
1/1/2008
2/1/2008
3/1/2008
4/1/2008
5/1/2008
6/1/2008
7/1/2008
8/1/2008
9/1/2008
10/1/2008
11/1/2008
12/1/2008
A2_P2_Nonfinancial
AA_Asset_backed
AA_Financial
AA_Nonfinancial
Fed_Fund
GC
LIBOR
_AA__ABS_RMBS___CMBS
A_AAA_ABS_Auto___CC___SL
AA_AAA_ABS_RMBS___CMBS
AA_AAA_CLO
AA_AAA_Corporates
BBB____A_Corporates

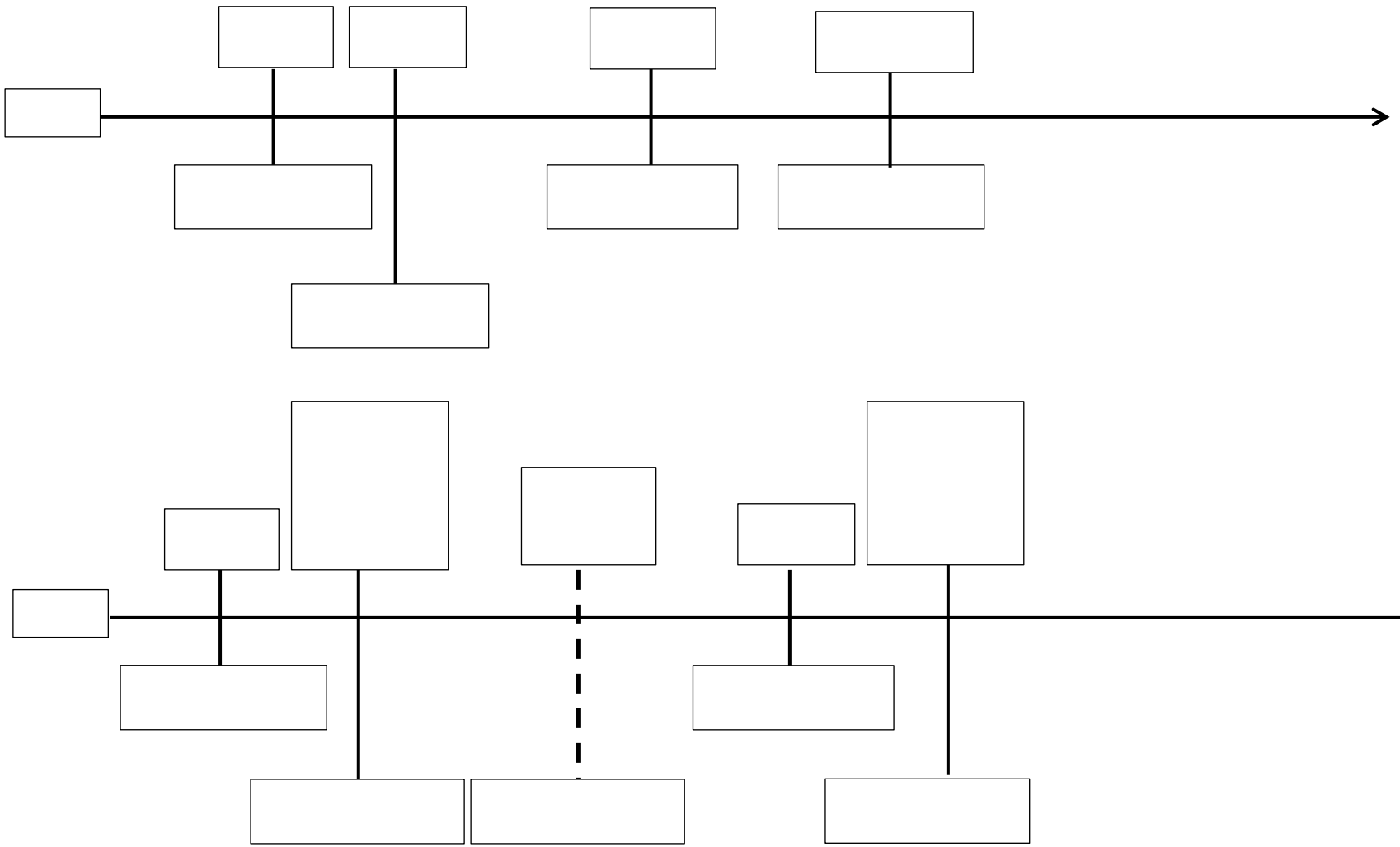
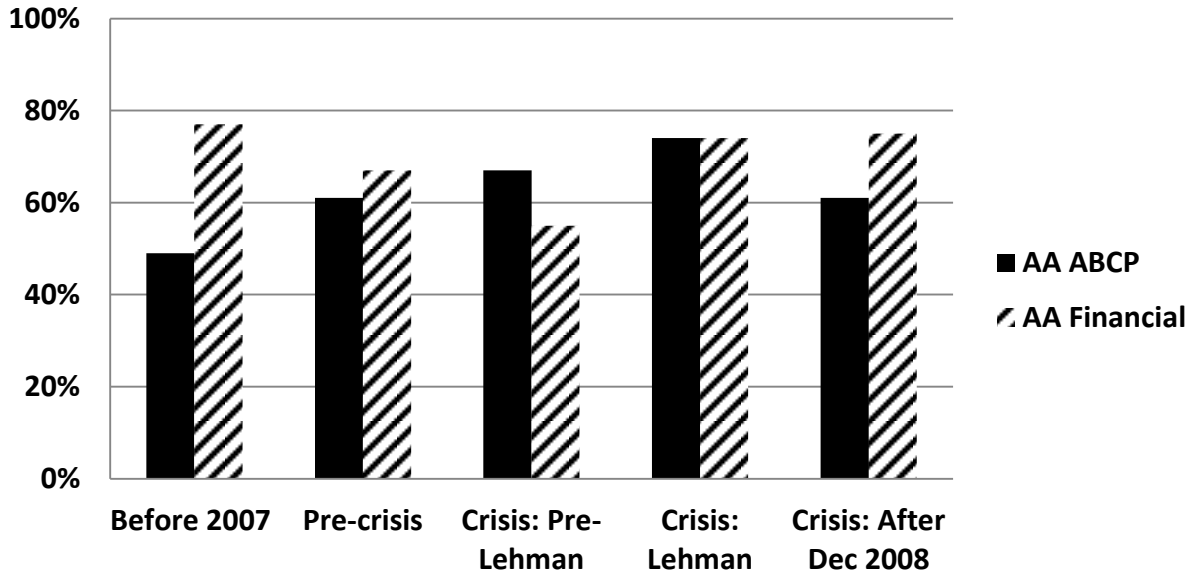


**Figure 4: CP 1-4 Day Maturity Issuance by ABCP Conduits and AA Financial Firms, as a percentage of average issuance**



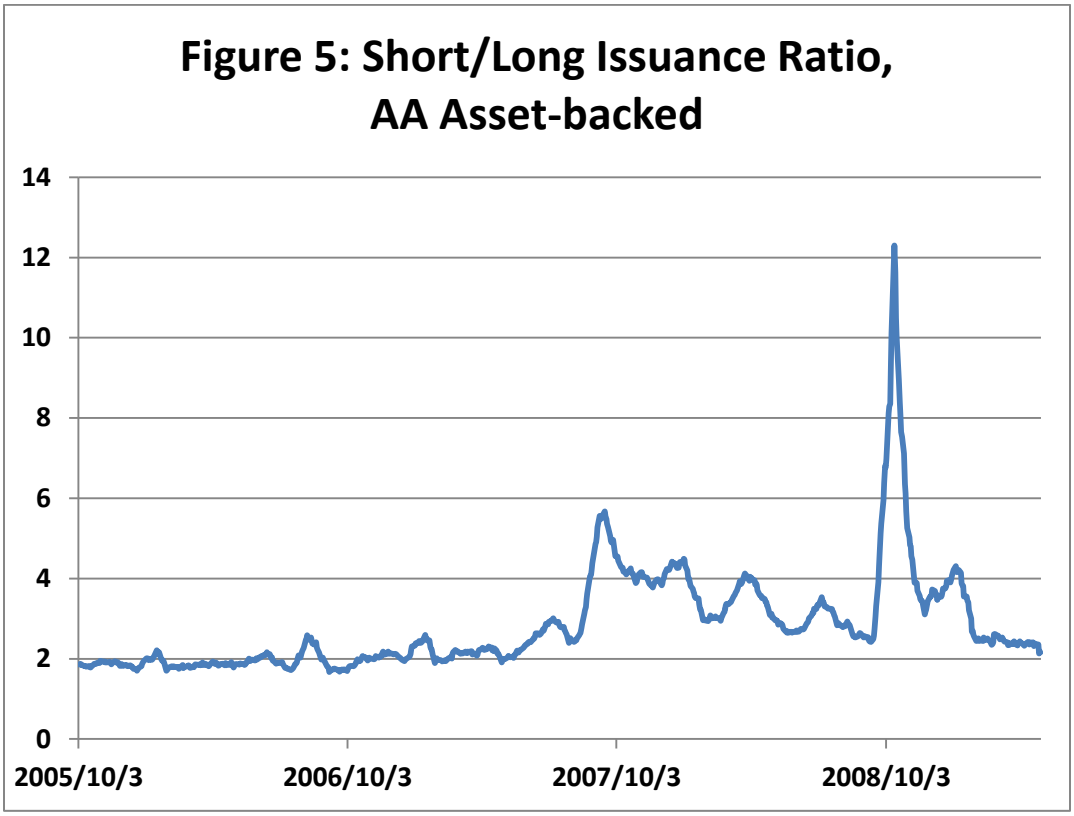


Figure 5: Short/Long Issuance Ratio,
AA Asset-backed
14
12
10
8
6
4
2
0
2005/10/3
2006/10/3
2007/10/3
2008/10/3

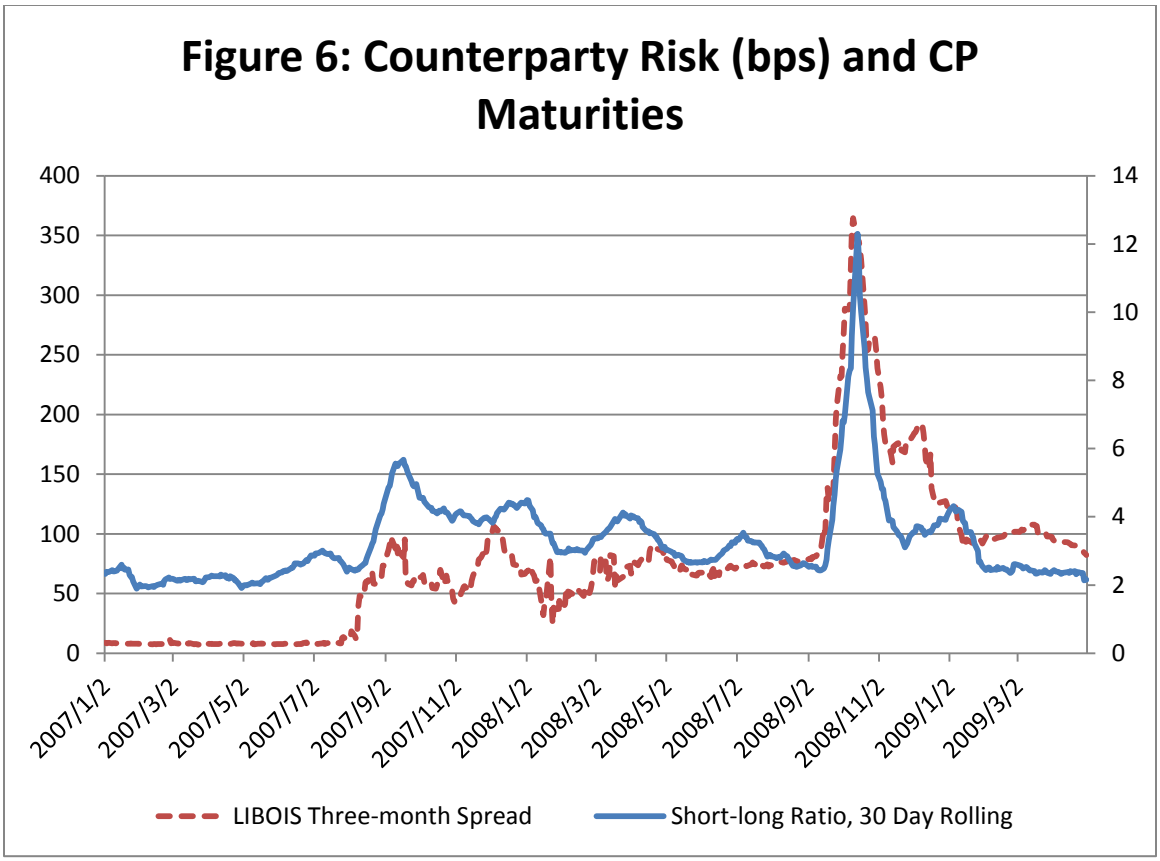


Figure 6: Counterparty Risk (bps) and CP Maturities
400
350
300
250
200
150
100
50
0
14
12
10
8
6
4
2
0
2007/1/2
2007/3/2
2007/5/2
2007/7/2
2007/9/2
2007/11/2
2008/1/2
2008/3/2
2008/5/2
2008/7/2
2008/9/2
2008/11/2
2009/1/2
2009/3/2
LIBOIS Three-month Spread
Short-long Ratio, 30 Day Rolling

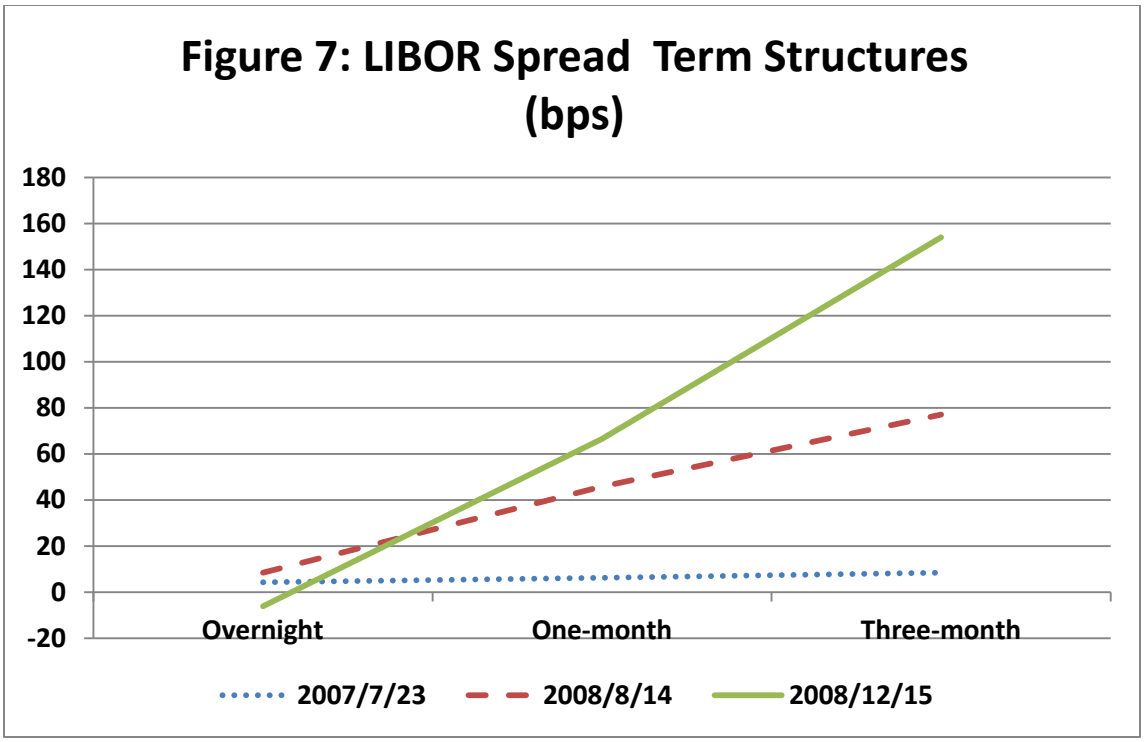


Figure 7: LIBOR Spread Term Structures (bps)
180
160
140
120
100
80
60
40
20
0
-20
Overnight
One-month
Three-month
2007/7/23
2008/8/14
2008/12/15

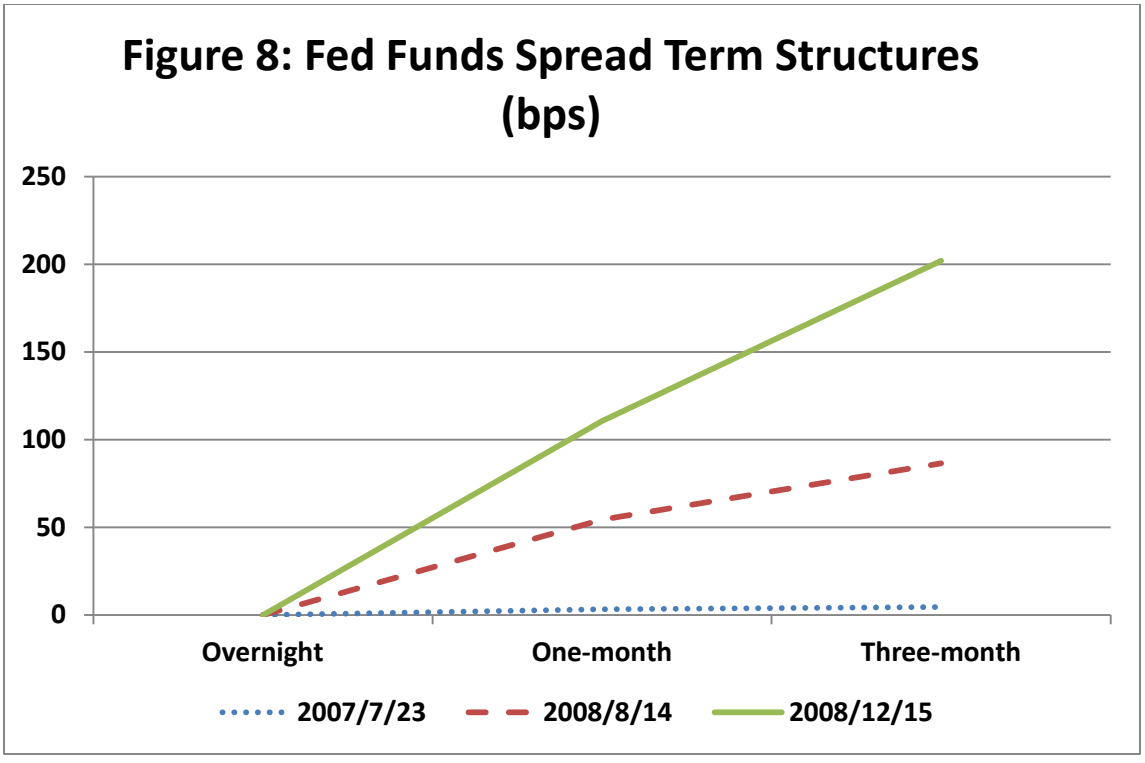


Figure 8: Fed Funds Spread Term Structures (bps)
250
200
150
100
50
0
Overnight
One-month
Three-month
2007/7/23
2008/8/14
2008/12/15

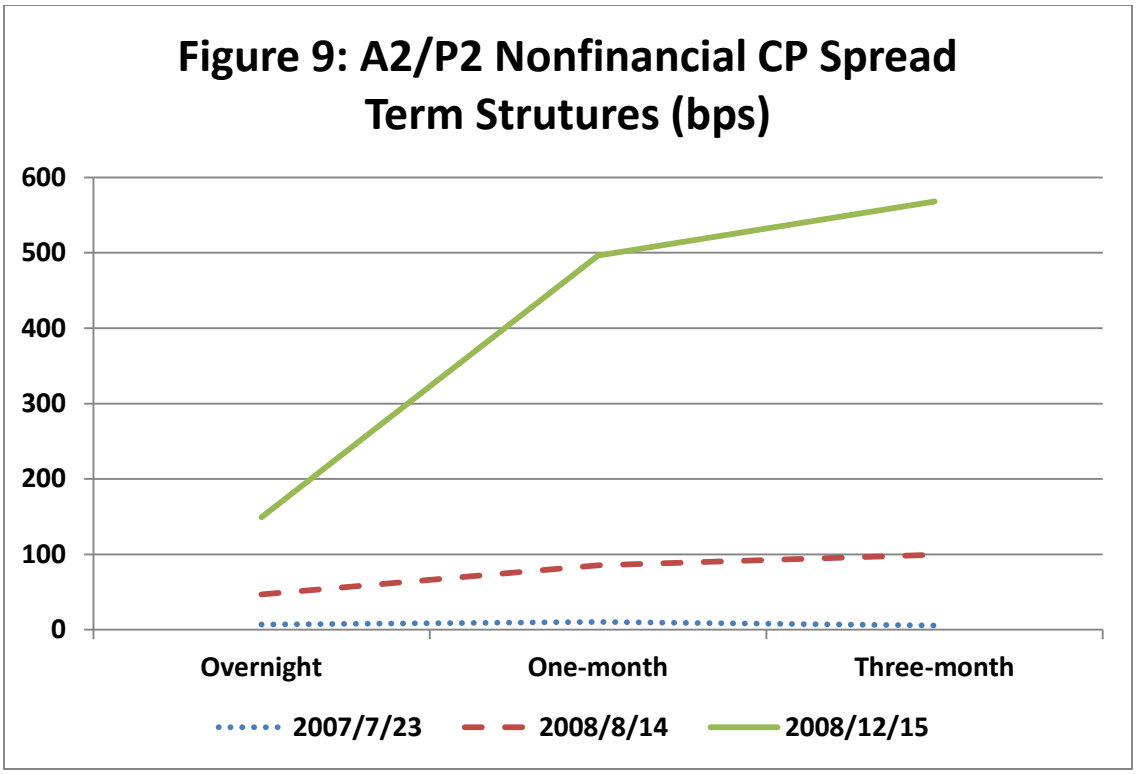


Figure 9: A2/P2 Nonfinancial CP Spread Term Strutures (bps)
600
500
400
300
200
100
0
Overnight
One-month
Three-month
2007/7/23
2008/8/14
2008/12/15

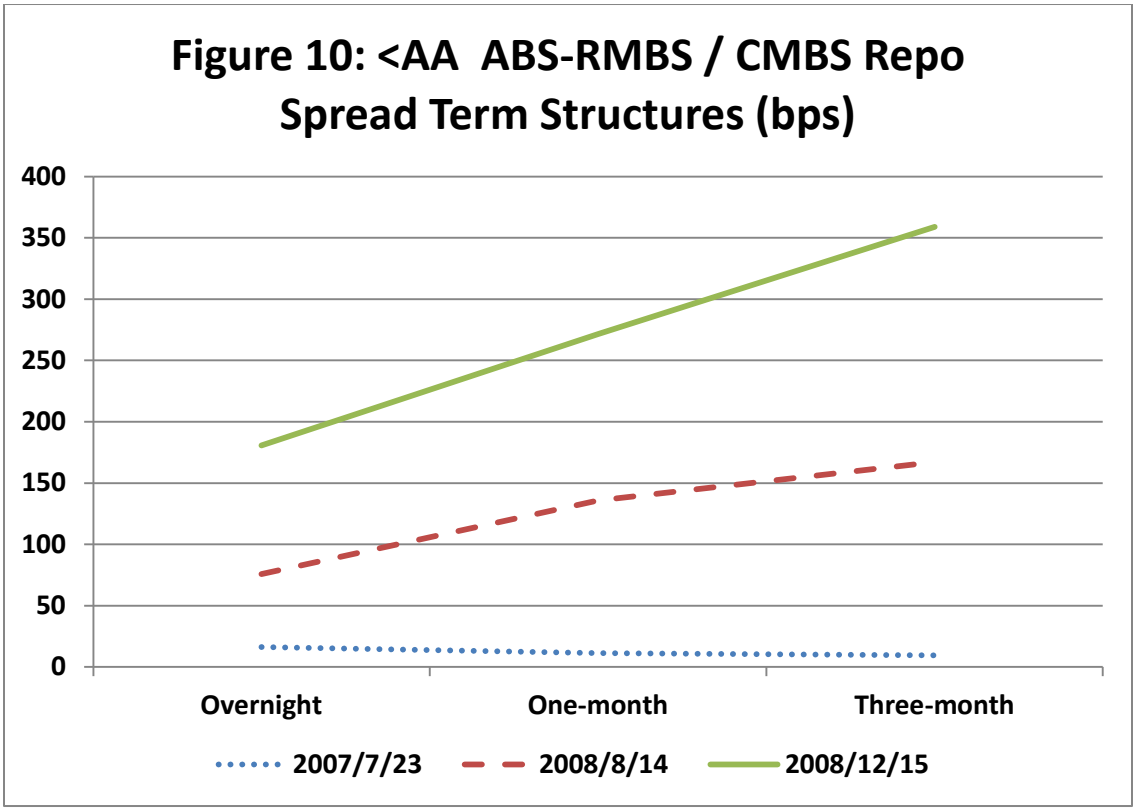


Figure 10: <AA ABS-RMBS / CMBS Repo Spread Term Structures (bps)
400
350
300
250
200
150
100
50
0
Overnight
One-month
Three-month
2007/7/23
2008/8/14
2008/12/15

**Figure 11, Panel A: Crisis Chronology, based on first break points**

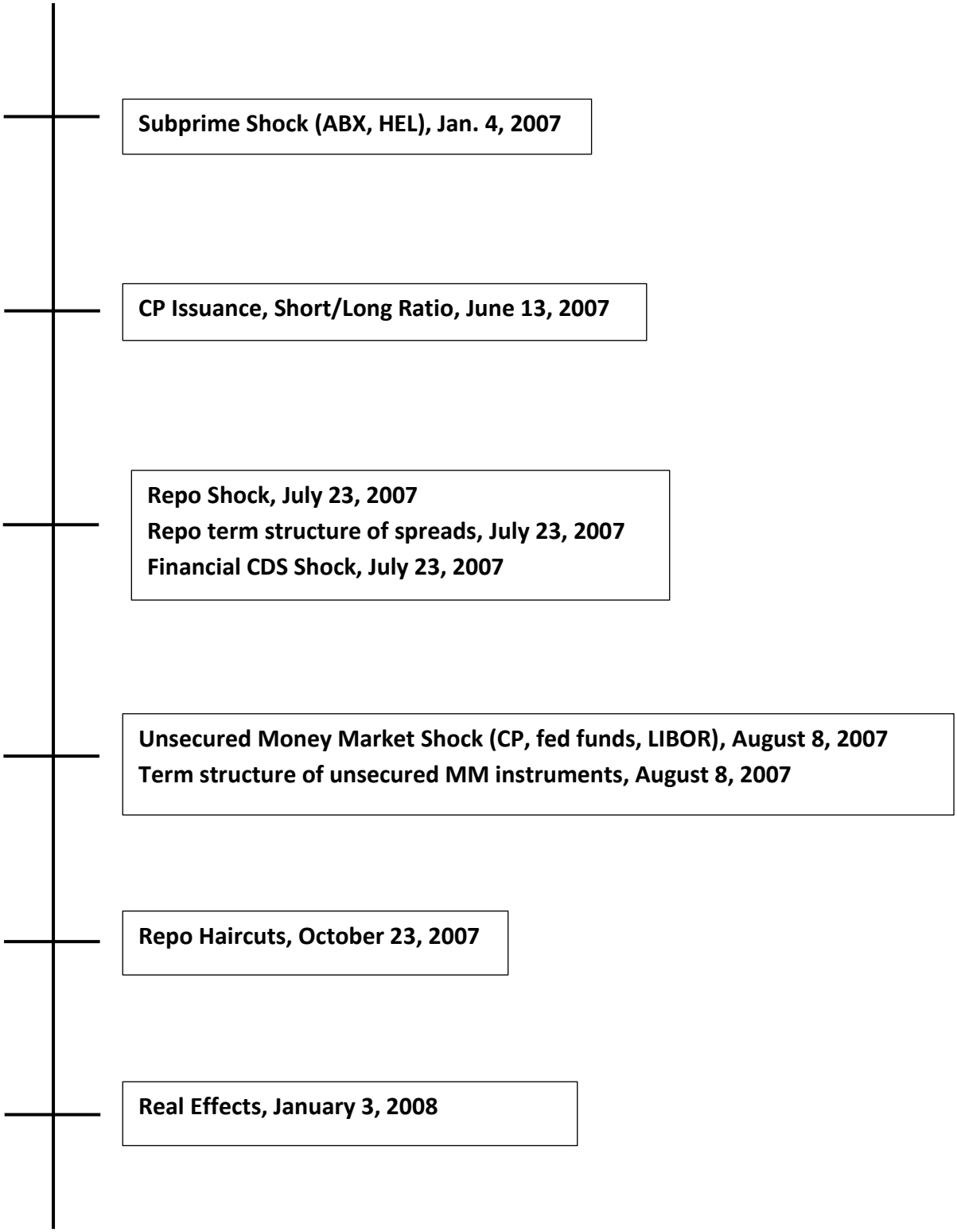


**Figure 11, Panel B: Crisis Chronology continued, based on second break points**