A Black Swan in the Money Market*

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ABSTRACT

At the center of the financial market crisis of 2007-2008 was a highly unusual jump in spreads between the overnight inter-bank lending rate and term London inter-bank offer rates (Libor). Because many private loans are linked to Libor rates, the sharp increase in these spreads raised the cost of borrowing and interfered with monetary policy. The widening spreads became a major focus of the Federal Reserve, which took several actions—including the introduction of a new term auction facility (TAF)—to reduce them. This paper documents these developments and, using a no-arbitrage model of the term structure, tests various explanations, including increased risk and greater liquidity demands, while controlling for expectations of future interest rates. We show that increased counterparty risk between banks contributed to the rise in spreads and find no empirical evidence that the TAF has reduced spreads. The results have implications for monetary policy and financial economics.

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On Thursday, August 9, 2007 traders in New York, London, and other financial centers around the world suddenly faced a dramatic change in conditions in the money markets where they buy and sell short-term securities. The interest rate on overnight loans between banks—the effective federal funds rate—jumped to unusually high levels compared with the Fed's target for the federal funds rate. Rates on inter-bank term loans with maturities of a few weeks or more surged as well, even though no near-term change in the Fed's target interest rate was expected. Many traders, bankers, and central bankers found these developments surprising and puzzling after many years of comparative calm.

The turmoil did not disappear the next day. The overnight interest rate whipsawed sharply down on Friday as the New York Fed pumped liquidity into the market, with the rate overshooting the target on the down side by a large margin. Even more worrisome was that *term* inter-bank rates, those for loans lasting a month to several months, moved up further on Friday despite the increase in liquidity provided by central banks. Rates on term lending, such as the Libor one- and three-month rates, seemed to have become disconnected from the overnight rate and thereby from the Fed's target for interest rates. It was as if banks suddenly demanded more liquidity or had grown reluctant to lend to each other, perhaps because of fears about the location of newly disclosed losses on sub-prime mortgages.

As we now know, that Thursday and Friday of August 2007 turned out to be just the start of a remarkably unusual period of tumult in the money markets, perhaps even qualifying as one of those highly unusual "black swan" events that Taleb (2007) has recently written about (see Cecchetti 2008 for a full discussion of the events leading up to and including the crisis). The episode raises important questions for monetary theory and

policy. At a minimum, the sharp increases in spreads provide new data to stress test our theories of the term structure of interest rates. Moreover, the money market represents the first stage of the monetary transmission channel, where monetary policy actions first come in contact with the rest of the financial system and the entire economy. Term money market rates, such as 3-month Libor, affect the rates on loans and securities from home mortgages to business loans. A poorly functioning money market impinges on the availability and cost of credit to businesses and households and jeopardizes the effectiveness of monetary policy.

The Federal Reserve made several attempts to improve conditions in money markets and thereby reduce the spread between term inter-bank lending rates and the overnight rate. Early on, it lowered the penalty on borrowing at the discount window bringing the discount rate below the prevailing Libor rate, and it strongly encouraged banks to borrow. But banks were reluctant to borrow from the discount window and there was little response. Then in December 2007—four months after the crisis began—the Fed introduced a major new lending facility, the Term Auction Facility (TAF), through which banks could borrow from the Fed without using the discount window.

The purpose of this paper is to document these unusual developments in money markets, assess various theories underlying them, and evaluate the impact of policy actions like the Term Auction Facility. In the original draft of this paper, written in February 2008, we put forth the hypothesis, based on a simple financial market model, that the Term Auction Facility would not reduce the spreads between Libor and the federal funds rate when correcting for term expectations, contrary to the purpose of the facility. We also provided statistical tests that could not reject this hypothesis. However,

because the spread narrowed from December 2007 through February 2008 after the TAF was introduced, central bank officials and others judged that the TAF was working. For example, Mishkin (2008), speaking in mid February of 2008 and noting the decline in the term spread, stated that "the TAF may have had significant beneficial effects on financial markets." Soon thereafter, however, the spread widened again, adding evidence to support the theoretical hypothesis put forth in this research. The renewed stress in the markets also gave rise to a host of new Federal Reserve actions and lending facilities.[1]

Though the financial turmoil persists, we view the introduction of these new facilities and actions as marking the beginning of a new phase of the crisis, where new policy responses will be evaluated and tested. Accordingly, this study focuses on the first phase of the crisis, more specifically, the period from Thursday, August 9, 2007 through Thursday, March 20, 2008. Sufficient observations have accumulated during the 161 trading days of this first phase to draw several conclusions that are of interest from a theoretical perspective and may be useful to policy makers going forward.

1. The August 9 Break Point: Target, Effective, and Term Fed Funds

Figure 1 focuses on three money market interest rates which nicely illustrate the changes in market conditions in August 2007—(1) the target for the federal funds interest rate as set by the Federal Open Market Committee, (2) the daily effective overnight federal funds rate in the market, and (3) the interest rate on 3-month Libor. The Libor interest rate in the London inter-bank market in dollars is essentially the same as the

[1] On Tuesday March 11 the new Term Securities Lending Facility (TSLF) and the expansion of the TAF from $60 billion to $100 billion was announced. On Friday March 14 a new loan package to Bear Stearns through JP Morgan was announced. On Sunday March 16 a new Primary Dealers Credit Facility (PDCF) was announced.

interest rate on term fed funds for comparable maturities, so we focus on the former in this study. (Nothing material would change if we focused on rate on term fed funds directly.)

First, observe in Figure 1 that the volatility of the effective federal funds rate (the average rate at which overnight fed funds actually transact) relative to the target increased after August 9. During the period from the start of the year through August 8, 2007, the standard deviation of the difference between the effective funds rate and the target was only 3 basis points. From August 9, 2007 to March 20, 2008 the standard deviation was 20 basis points. Note that the steadiness of the federal funds rate at 5.25 percent may be one of the reasons for the relatively small misses in the earlier period, but if you include the years back to the beginning of 2002 the volatility is 6 basis points, still much less than the 20 basis points seen during the period that we study. There have been other periods where the effective funds rate was more volatile, particularly before the Fed became more transparent about its interest rate setting. Taylor (2001) presents a model that focuses on effective fed funds rate volatility.

Second, and this is the main focus of our paper, observe how the spread between 3-month Libor and the Fed's overnight federal funds rate target increased dramatically starting in August and fluctuated erratically after that. During the year before August 9, 2007, the 3-month Libor spread above the target federal funds averaged only 11 basis with a standard deviation of a mere 1 basis point—a period of very low volatility. Similar changes in spreads between term rates and overnight rates are apparent for other Libor maturities and for several other countries, as we document below.

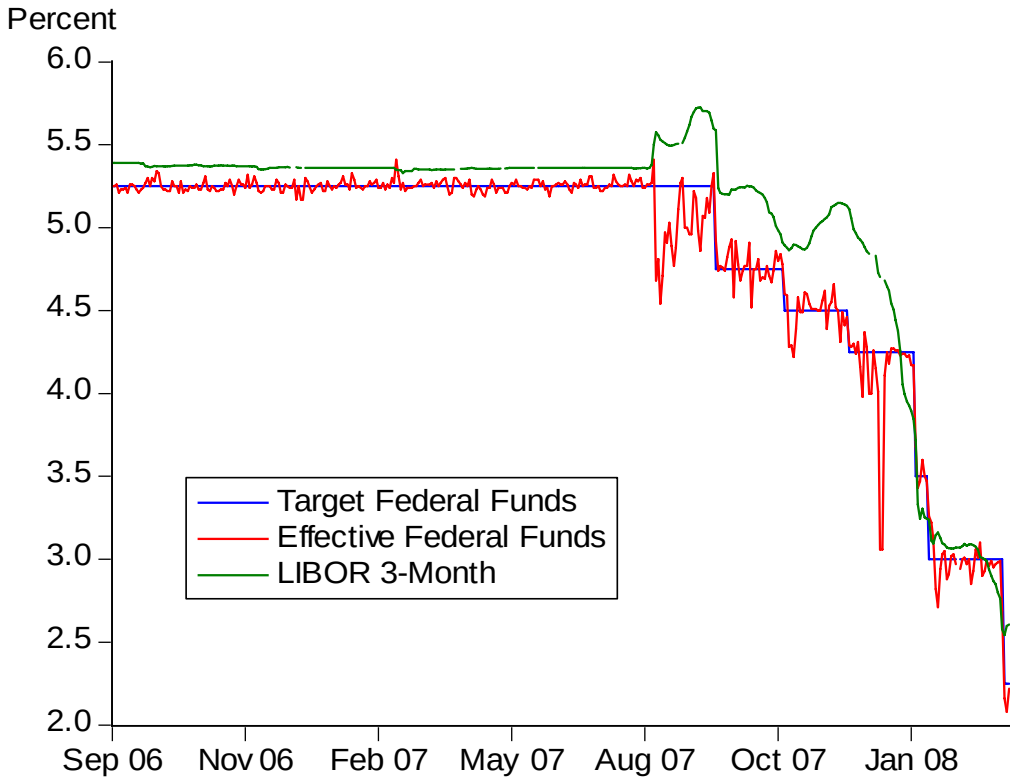


Figure 1. Key money market rates from September 2006 to March 2008

2. Potential Explanations

Ever since the turmoil began, traders, bankers, economists, and others have offered explanations for the dramatic increase in the Libor spread. We think it is useful to categorize the many explanations into several types.

First, and perhaps the most commonly mentioned explanation is "counterparty risk," which simply means banks became more reluctant to lend to other banks because of the perception that the risk of default on the loan had increased and/or the market price of taking on such risk had risen. Recall that inter-bank lending in the Libor market or term fed funds is unsecured.

Of course, this explanation has the virtue of reflecting the widely-reported reality that many banks were writing down the values of securities that they owned. These securities had either been downgraded in terms of quality or were backed by sub-prime mortgages that were becoming delinquent or going into foreclosure as housing prices stopped increasing and began to fall. Clearly, the continuing decline in housing prices and the slowing economy could easily raise the chances of a further deterioration in the value of mortgage-related assets on the banks' balance sheets. Moreover, the realization of the risks in derivative securities based on sub-prime mortgages triggered doubts about many other aspects of the derivative market, including the ability of credit default insurers to meet their obligations and the size and nature of the likely restructuring of the off-balance sheet operations know as structured investment vehicles (SIVs).

Another explanation, which might be called "liquidity risk," is that traders at one bank are reluctant to expose the traders' bank's funds during a period of time where those funds might be needed to cover the bank's own shortfalls. Effectively, the trader may not be given as much "balance sheet" to invest, which is perceived as a shortage of liquidity to the trader. While it is difficult to distinguish counterparty risk from liquidity risk, we note that the interest rate on CDs, which are also held by individuals and non-banks, follows Libor closely during this period. Hence, it is not only banks that are getting premiums when lending to banks, indicating that once counterparty risk is taken into account there is little additional role for liquidity risk as defined here.

A third and closely related explanation was often heard during the period of November and January. Banks needed liquidity to make sure that their own balance

sheets looked respectable in end-of-year financial reports, especially given the stress and scrutiny that many banks had been under.

The fourth explanation relates to expectations of future interest rate changes. Expectations of declining overnight rates, for example, will cause term Libor rates to decline as well, all else equal. Except for the very beginning of the turmoil period, this explanation would tend to bring the spread between the Libor rate and the target fed funds rate lower because of expectations of future interest rate decline due to policy easing. It is necessary to take account of this factor when assessing the other factors that could be moving the spread around. For example, if you look closely at Figure 1 you see that the spread between Libor and the fed funds target comes down before cuts in the federal funds rate. Indeed, toward the end of our sample in mid February, the spread narrowed significantly, but this could be due to expectations of future interest rate cuts. We therefore control for expectations of future interest rates in the analysis that follows.

3. A Model

In order to distinguish between these various explanations we need a model of money market interest rates through which we can interpret the risk, liquidity, and expectations factors that we have argued are important. It is essential to take out pure expectations effects, which always create differences between longer term interest rates and overnight fed funds. Recall that Libor is a term rate (3 month in Figure 1) and fed funds are one-day maturity.

Early models of the money market used for monetary policy developed in the1970s and 1980s (see Anderson and Rasche, 1982, for a review) are not sufficient for

this purpose because they neither account for forward-looking expectations nor risk premia. More recent finance models used by Ang and Piazzesi (2003) and others are more useful for this purpose. Moreover the earlier models used estimated demand functions for securities, an approach that is not possible to implement in the current situation, because available data is in the form of prices (in the form of interest rates), rather than quantities.

Our model focuses on three interest rates as defined below:

$i_t^{(n)}$ = libor rate with maturity n (with $n = 1$ defined to be the overnight federal funds rate)
$s_t^{(n)}$ = OIS with maturuity n (with $n = 1$ also the overnight federal funds rate; that is $s_t^{(1)} = i_t^{(1)}$)
$a_t^{(n)}$ = accepted bid on the term action facility (TAF) (n around 30 days)

The Overnight Indexed Swap (OIS) rate is closely connected to the average overnight interest rate expected to prevail over the next n days. An OIS is structured as follows: at maturity, the parties exchange the difference between the interest that would be accrued from repeatedly rolling over an investment in the overnight market and the interest that would be accrued at the agreed OIS fixed rate. The TAF is described in detail below.

Following the literature on arbitrage-free pricing of bonds, we write down term structure relations for the Libor (or fed funds) term structure interest rates. Let $P_t^{(n)}$ denote the price of a zero-coupon loan with n periods until maturity. Equation 1 relates the yield on the loan, $i_t^{(n)}$, to its price. The prices of zero-coupon loans follow the recursion given in equation 2, where m_{t+1} denotes the pricing kernel. As in Ang and Piazzesi (2003), we assume the pricing kernel takes the form shown in equation 3 and the market price of risk, λ_t, takes the linear form shown in equation 4, where x_t is a vector of variables that affect the price of risk.

(1) $i_t^{(n)} = n^{-1} \log(P_t^{(n)})$

(2) $P_t^{(n+1)} = E_t[m_{t+1} P_{t+1}^{(n)}]$

(3) $m_{t+1} = \exp(-i_t^{(1)} - 0.5\lambda_t^2 - \lambda_t \varepsilon_{t+1})$

(4) $\lambda_t = -\gamma_0 - \gamma_1 x_t$

Similar equations can be written down for the OIS and the TAF rates. In contrast to Libor loans, OIS transactions involve very little counterparty risk as no money changes hands until the maturity date. The only potential loss in the case of default by the counterparty is the difference between the two interest rates on which the OIS is based. There does exist interest rate risk reflecting uncertainty regarding the future path of interest rates. However, given the relatively short maturities of loans that we study, the market price of interest rate risk is likely typically to be small. In the following, we assume that the market price of risk associated with OIS transaction is constant. Loans from the TAF are collateralized and therefore also carry relatively small risk. We therefore assume that the market price of risk associated with TAF loans is likewise constant.

Taken together, this assumption of a constant market price of risk for OIS and TAF rates implies that as part of the null hypothesis of an absence of liquidity effects in the pricing of the various loans and abstracting from a constant differential risk premium, we have: $a_t^{(n)} = s_t^{(n)}$. Moreover, absent liquidity effects, we would not expect the λ_i for the inter-bank rates to be influenced by the TAF.

Under these assumptions, the OIS rate equals the average of the overnight interest rates expected until maturity. By subtracting the appropriate OIS rate from the term Libor yield, we are able to cleanse expectations effects from the Libor yield. Under our null hypothesis of no liquidity effects, the resulting difference in rates, $i_t^{(n)} - s_t^{(n)}$, reflects only the pricing of risk associated with Libor lending relative to the constant price of risk associated with OIS transactions. Thus, in the next section, we use this difference in yields as a measure of the effects of risk on yields. We will use several different measures of counterparty risk as explanatory variables in the price of risk, as explained below.[2]

4. Focusing on the Libor OIS spread

Figure 2 plots the spread between Libor and OIS during the same period as in Figure 1. It paints quite a different picture of the spread, and shows the value of removing expectations of future interest rates in analyzing term spreads. For example, looking at Figure 1 you might think the spread returned to normal by mid February. However, examination of Figure 2 shows that the spread is still quite large. In this chart and in the rest of our analysis we focus on 3-month Libor; similar results are found by looking at other maturities such as one-month Libor.

Figure 2 illustrates clearly how the spread between Libor and OIS jumped on August 9th. From December 4, 2001—the day when our OIS 3-month data begin—through August 8, 2007, the spread averaged 11 basis points with a standard deviation of 3.6 basis points. It jumped by 25 basis points above this average to 34 basis points on

[2] As described below, another measure of risk is the difference between rates on Libor and government repurchase agreements between banks.

August 9th and fluctuated wildly between a minimum of 30 basis points and a maximum of 106 basis points, averaging 65 basis points through March 20. The peak was reached on December 6, 2007, and was followed by big downward movements on December 12-14, 2007 and January 14-15, 2008. On March 20, it stood at 61 basis points, only slightly below the average since August 9, 2007, and clearly not a return to a "normal" level.

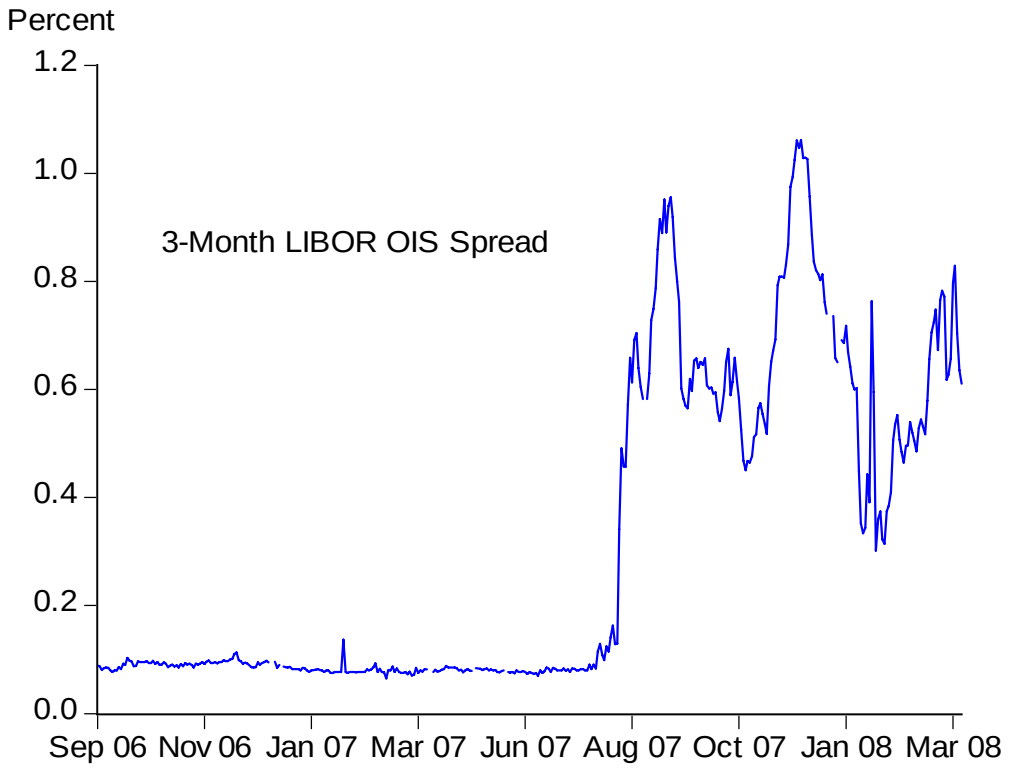


Figure 2. Taking out the pure expectations effects

Looking at spreads going back to December 2001 illustrates just how unusual this episode has been. Figure 3 plots the same data as in Figure 2, but starting in December 2001. As mentioned above, the spread on August 9 was 25 basis points above the pre-August 9, 2007 average. That is 7 times the standard deviation before August 9—more

than a 6-sigma event. The mean through March 20 was 16 standard deviations above the old mean, which under normality would have been an extraordinarily improbable event.

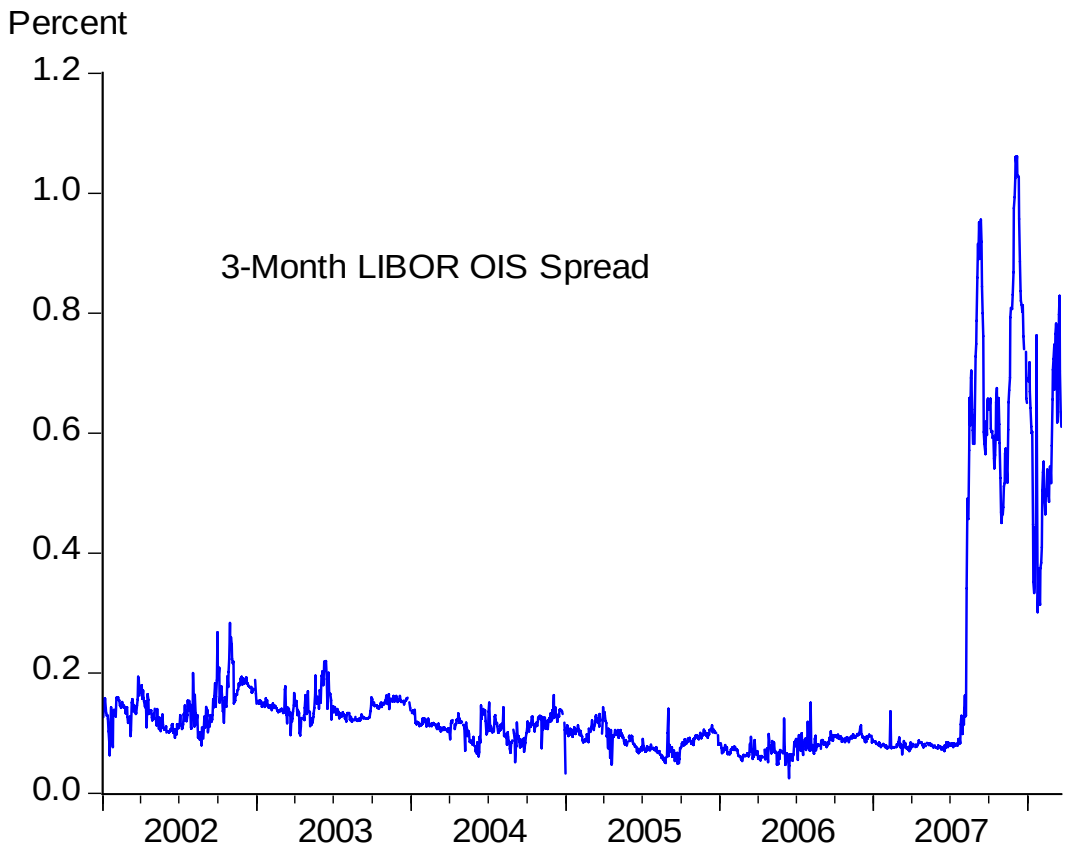


Figure 3. A Black Swan in the Money Market?

Another way to remove expectations effects is to look at the spread between unsecured inter-bank lending (Libor) and secured inter-bank government Repos (Repurchase Agreements backed by Treasury securities) of the same maturity, in this case, three months. By focusing on the difference between secured and unsecured lending, this spread may be a better way to extract pure risk. However, we find much

more noise in this spread than in the Libor-OIS spread. Traders we have consulted attribute this noise to technical factors such as tax considerations and collateral delivery glitches. Figure 4 shows this measure of the risk spread. It is clearly noisier than the spread shown in Figures 2 and 3, making the recent financial turmoil appear less improbable than suggested by evidence based on Libor-OIS spreads. Nonetheless, these past episodes were not nearly as large or persistent as those during the period staring in August 2007. Because of this noise we will focus on the Libor-OIS spread as the main "dependent variable" in the remainder of this paper, using the Libor-Repo spread along with other measures of risk (discussed in Section 6) as independent variables.

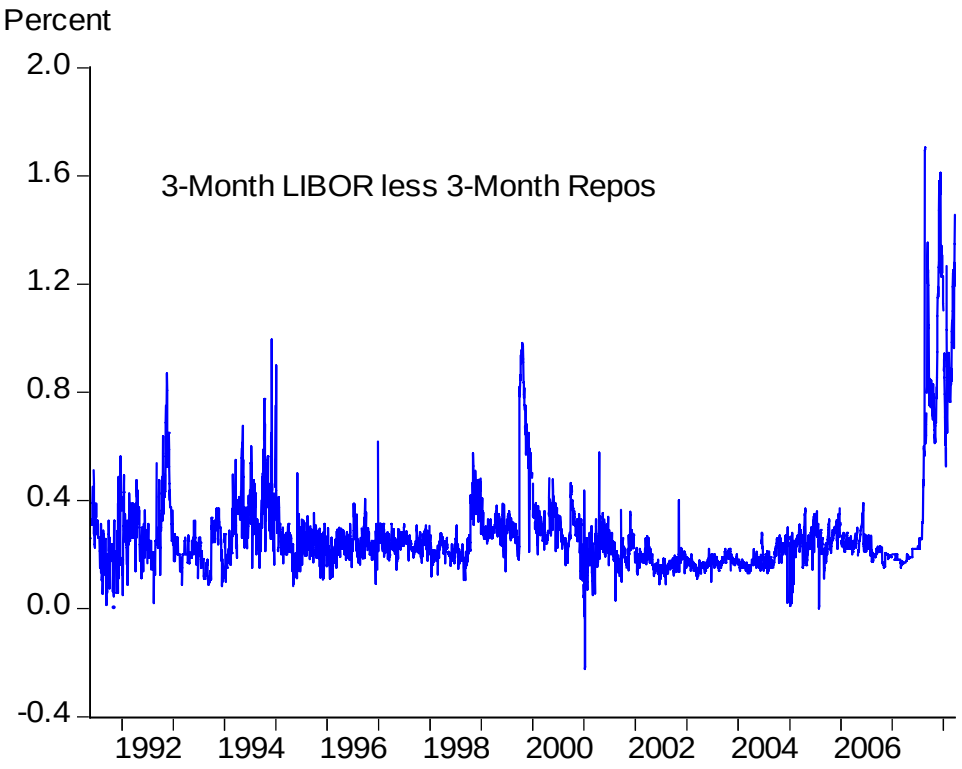


Figure 4. Another Way to Remove Expectations Effects

5. Overnight Funds Volatility: Counterparty Risk or Increased Tolerance to Misses

Thus far we have shown how important it is to take out expectations effects in order to assess the increase in risk and liquidity premia in the inter-bank market. It is also possible to focus directly on the increase in volatility of the effective funds rate relative to its target as set by the FOMC. Figure 5 shows the difference between the effective fed funds rate and the target fed funds rate.

There are several possible explanations for the increased volatility or "misses" of the effective rate from the target. One is the same counterparty risk that is offered as an explanation for the spread seen in the term lending market. Fed funds trades are largely bilateral. Hence, rates can differ from trade to trade, even at the same point in time. If traders are more circumspect about some borrowers than others, then this will show up in increased dispersion of the rates in these bilateral trades at each point in time. Since the effective daily rate is estimated from these trades, its increased volatility could reflect the increased dispersion. If so, then the increase in volatility in the overnight market provides some corroborating evidence that counterparty risk may be part of the explanation for the increased spread in the term market.

Another explanation is that the underlying volatility in intraday trading in the fed funds market may have been driven by the New York Fed's trading desk acting to prevent the rate from spiking above the target. Indeed, there is a noticeable downward bias in the misses during this period.

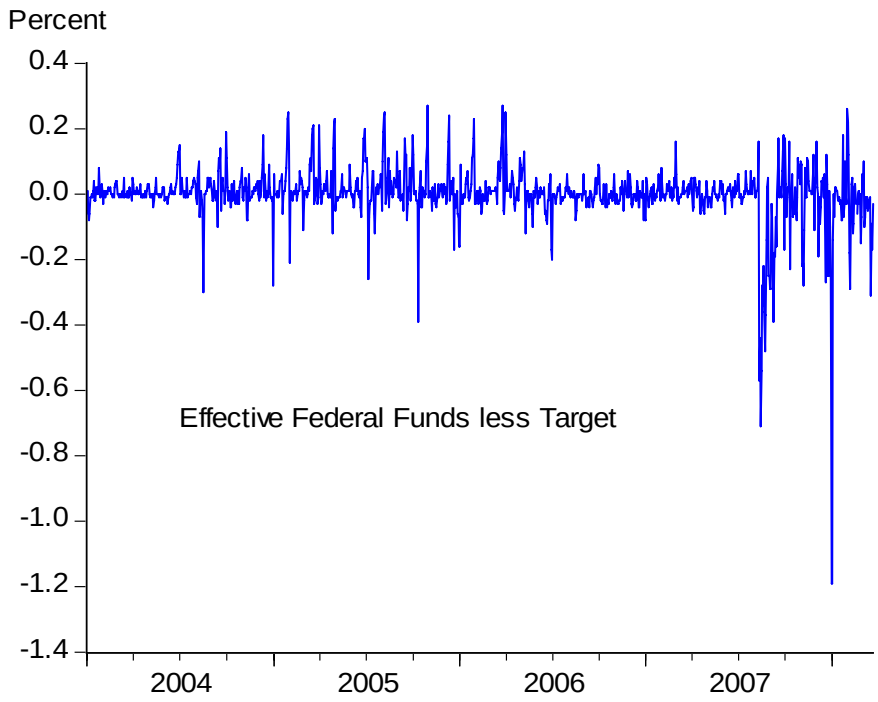


Figure 5. Increased Volatility in the Overnight Federal Funds Market

6. Measures and Indicators of Counterparty Risk

In this section, we consider a range of possible indicators of counterparty risk. To the extent that these are timed with the black swan event documented in Figure 2, they may offer evidence that such sources of risk, rather than more general liquidity concerns, were the main reason for the increased spread in the Libor markets.

Asset Backed Commercial Paper versus Dealer Placed Commercial Paper

Another market that has been under extreme stress during this period is the market that grew as a mechanism for financing the purchase of home mortgages in the process of assembling them into various derivative securities. Because the commercial

paper was backed by these mortgages or by the mortgage pools, they are called asset-backed commercial paper. They are a potential measure of the counterparty risk in commercial banks because banks held this paper either directly or indirectly through their Structured Investment Vehicle operations.

Figure 6 shows the spread between asset-backed commercial paper and dealer-placed commercial paper, which excludes the more risky asset-backed issues, letter-of-credit issues, and direct issues from firms. Clearly, there was an increase in the spread about the same time as the Libor spreads increased and the patterns of decline and the ups and downs also have similarities. To the extent that this is a good indicator of counterparty risk, this timing lends support for the counterparty risk explanation.

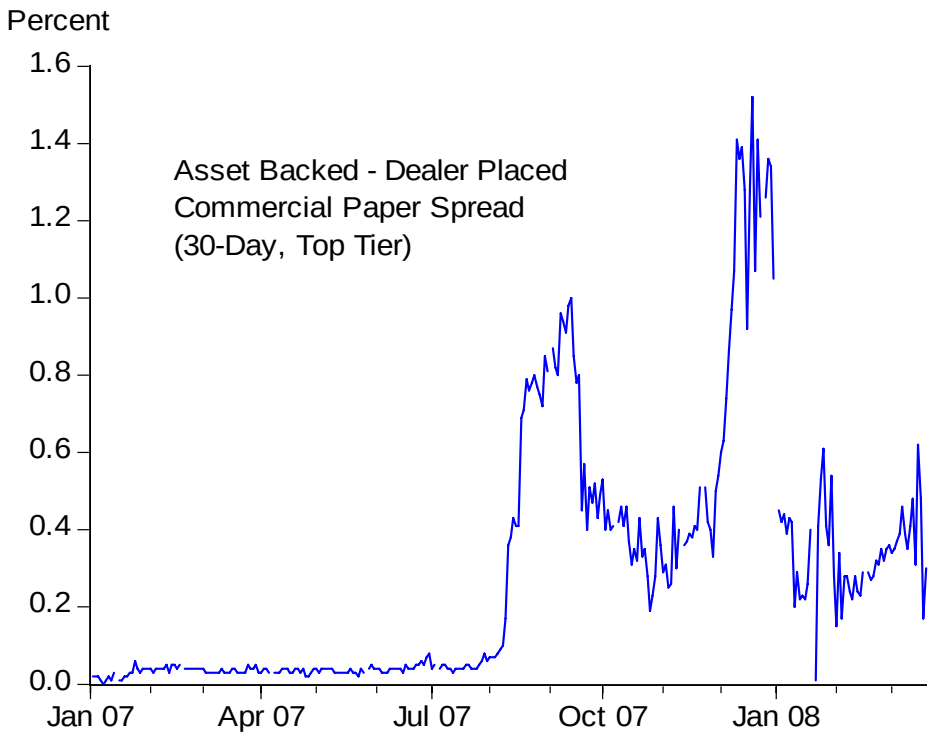


Figure 6. Asset Backed Commercial Paper Spreads Increased about the Same Time as Libor Spreads

Credit Default Swaps

Another measure of counterparty risk is the probability that banks might default on their debt. These probabilities can be assessed using the premiums on credit default swaps (CDS) that are like insurance policies for corporate bonds. The buyer of a credit default swap pays a periodic fee to a seller in exchange for the promise of a payment, in the event of bankruptcy or default, of the difference between the par value and the market value of the corporate bond. Figure 7 shows the rapidly rising rates on five-year CDS for several major financial institutions through March 20, 2008 including Bear Stearns. Note the increase starting in July of 2007. Figure 8 focuses on four large commercial banks. Unlike the asset backed commercial paper spread, there is no evidence of a decline in risk at the time that the Libor spreads declined.

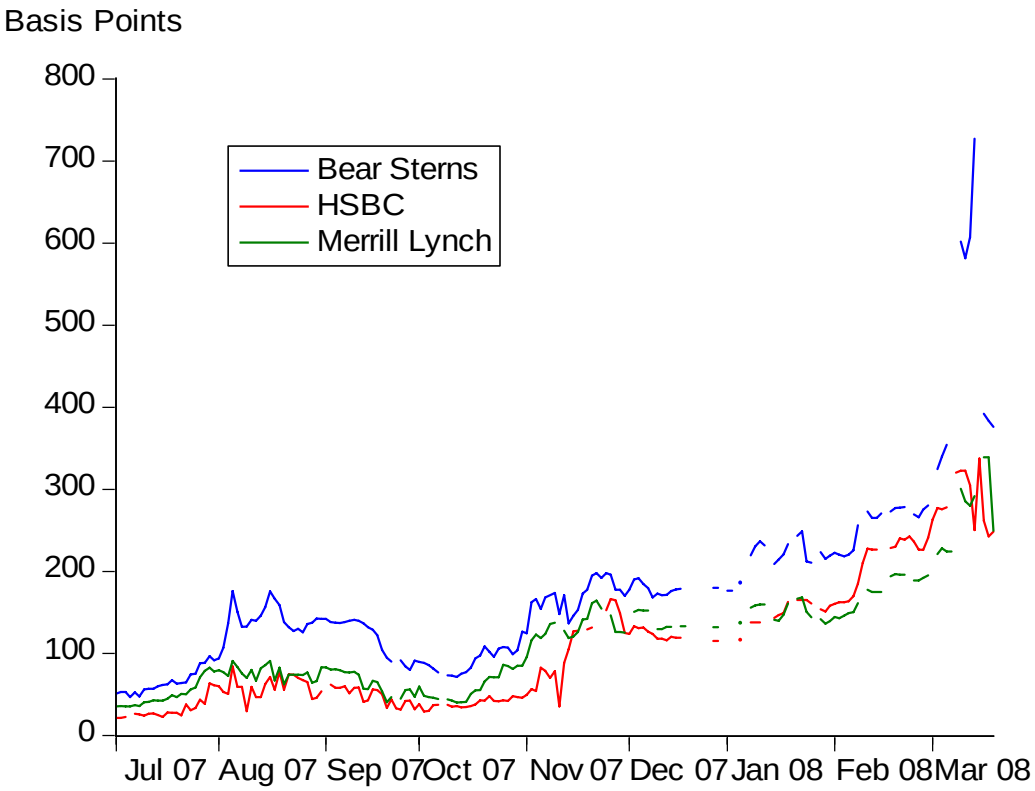


Figure 7. Rapidly Rising Risks as measured by CDS rates

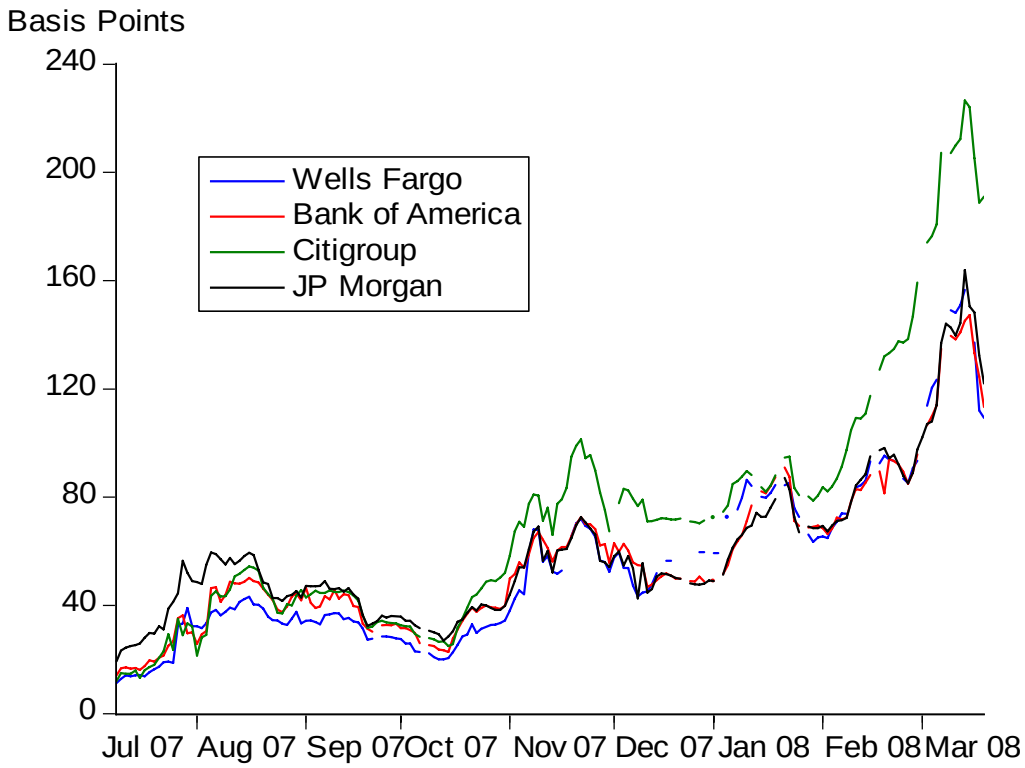


Figure 8. Risks at four major banks also rose though not so sharply.

Developments in other Countries

The turmoil affecting money markets has not limited to the United States. Spreads between term and overnight inter-bank lending have risen in Canada, Europe, and Japan, at the same time as in the United States. The similarities and differences across countries help illuminate the possible sources of the rise in these spreads.

Euro Libor and Pound Sterling Libor Figure 9 shows the Libor spreads for loans in Euros and Pound Sterling using the same OIS adjustment method we used to calculate the U.S. dollar Libor spreads in Figure 2. We plot these other two spreads along with the dollar spread since 2004. All three spreads move closely together, indicating that

whatever the source of these spreads, it is affecting money markets for all three currencies in the same way. This close correspondence in spreads is not as surprising as it first may appear. In fact, there is considerable overlap in the lists of banks that are included in the Libor survey in these three countries, as we document in the Appendix.

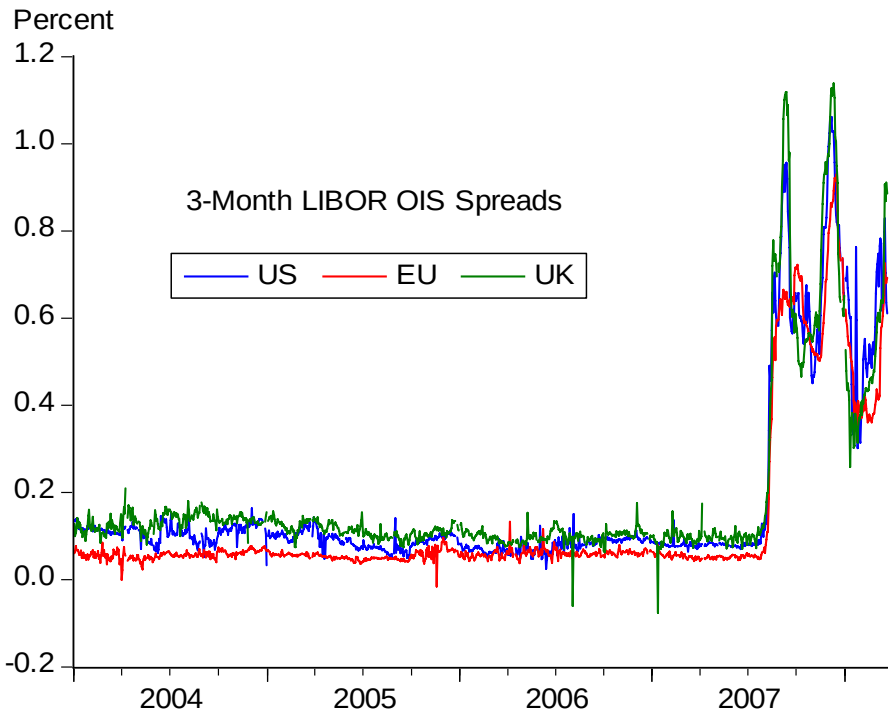


Figure 9. Libor spread increased in three major currencies in August 2007

Yen Libor and Tibor. Another useful indicator is a comparison of the Libor rate denominated in Yen to that of the Tibor, the rate on inter-bank loans between Japanese banks in the Tokyo markets. In the appendix, we report the banks in the two surveys. Figure 10 shows these two rates since the mid 1990s. Note that the chart shows the Libor yields themselves, not spreads. Japanese interest rates have been much lower than

interest rates in the United States, Europe or the UK. Nonetheless, spreads can and do develop between different types of inter-bank lending and indicate risk factors in the banking sector. Indeed, in the late 1990s, Japanese banks experienced sizable spreads on inter-bank lending comparable to what is being experienced in New York and London in this recent episode of stress. As explained by Peek and Rosengren (2001) and Corvig, Low, and Melvin (2004), risks in the banking sector in Tokyo caused interest rates on inter-bank loans to rise in Tokyo compared with London. In other words, Tibor rates rose relative to Libor rates, as shown in Figure 10 and Figure 11, which shows the Tibor-Libor spread for three-month loans.

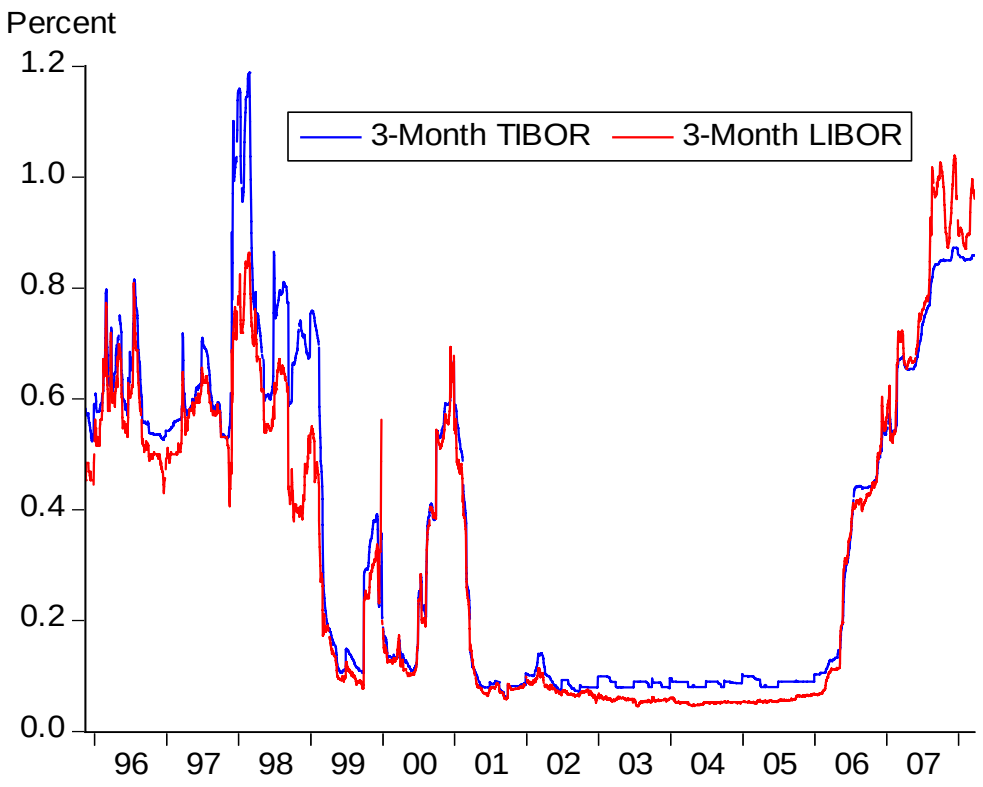


Figure 10. Pattern of Tibor and Libor since 1990s

This pattern of Tibor-Libor spreads has reversed, with Tibor rates now lower than corresponding Libor rates. One interpretation is that the demand for liquidity has not risen as much for Japanese banks as for the major banks in these other markets. In our view, a more probable explanation is that the risks associated with inter-bank loans from American and European banks have increased relative to those for loans among Japanese banks. Accordingly, the "negative Japan premium" or Japan discount provides another measure of counterparty risk among banks in New York, London, and Frankfurt.

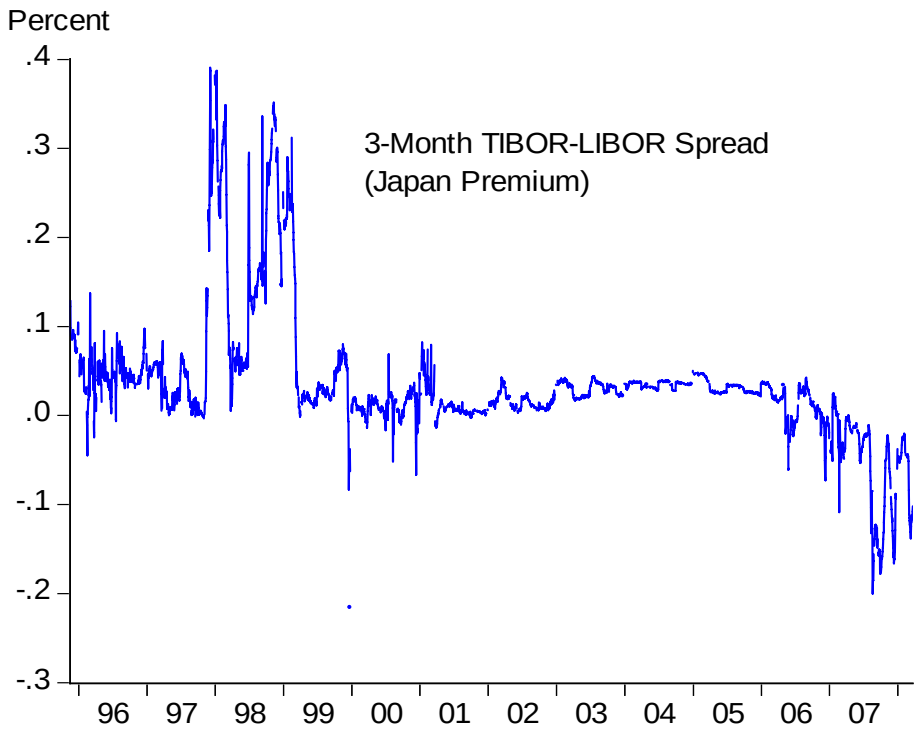


Figure 11. Unlike the Japan premium in the 1990s the Tibor-Libor spread turned negative fell when Libor spreads increased in the United States and Europe

Swiss Libor. Finally we look at Libor loans denominated in Swiss Francs. The Swiss National Bank (SNB) follows a different strategy for monetary operations than the Federal Reserve, the European Central Bank, or the Bank of England. The Swiss National Bank targets the three-month Libor rate and adjusts the amount of liquidity in the overnight market to hit its target. (For a theoretical analysis of such a policy framework, see McGough, Rudebusch, and Williams, 2005). Hence, if there is an increase in the spread between three-month Libor and the overnight rate, then the SNB will take actions to reduce the overnight rate by providing extra liquidity to the market. (Jordan and Kugler,, 2004.) As a result, a very different pattern emerges in the overnight and term Libor rates. However, the same evidence of risk emerges if one looks at the spread between overnight and term rates.

These actions can be seen clearly in Figure 12. With a target for 3-month Libor of 2.75 percent, the overnight rate declined, rose, and declined again while the Libor rate remained relatively steady. Hence, the spread between Libor and overnight rates was realized by moving the overnight rate around. The way this works is nicely illustrated in the period from August 2007 through March 2008.

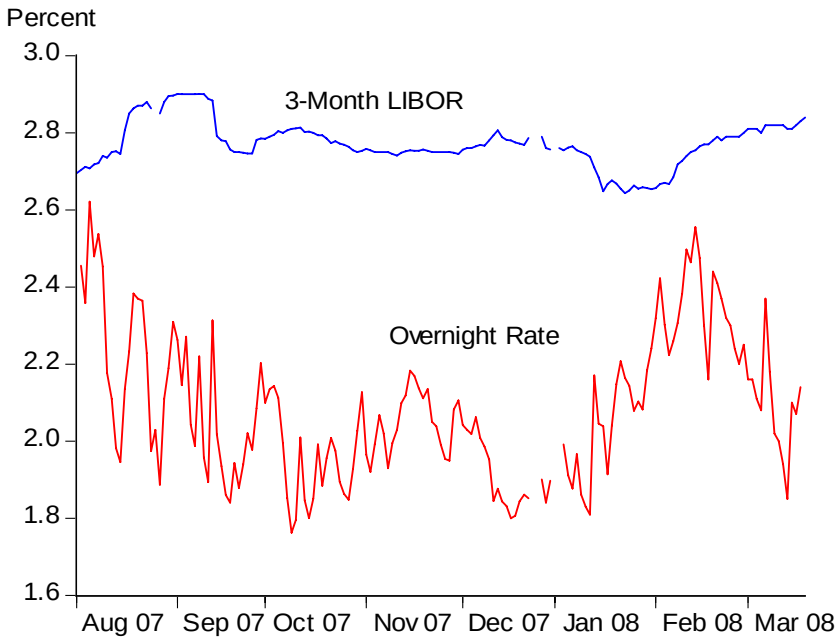


Figure 12. Term Libor spread in Switzerland resulted in a temporary decline in the overnight rate with current operating procedures at the SNB

7. The Term Auction Facility

In an effort to lower the unusual term lending spreads documented in Figure 2, the Federal Reserve took a number of actions. First it lowered the spread between the discount rate and the fed funds target directly and encouraged more discount window borrowing. But, banks did not increase their borrowing to any large degree. Second, in December 2007, the Federal Reserve established a new facility called the term auction facility (TAF) to provide liquidity directly to financial institutions at a longer duration, and thereby drive down the spread on term lending relative to overnight loans. According to the Federal Reserve Board, by injecting "term funds through a broader range of counterparties and against a broader range of collateral than open market operations, this facility could help ensure that liquidity provisions can be disseminated

efficiently even when the unsecured interbank markets are under stress" (Board of Governors of the Federal Reserve, 2007).

The TAF was first announced on Dec 12, 2007. The TAF allows financial institutions to make bids for term borrowing from the Fed, with maturities typically of 28 days. Beginning in late December of 2007, two TAF auctions have been held each month. Table 1 provides key information about each of the auctions that occurred during the period of our study. TAF loans are collateralized following the procedures used for discount window borrowing. The Board of Governors sets the auction amount and the minimum bid allowed for the interest rate, which is set equal to the OIS rate corresponding to the term of the loan. The interest rate on the loans is determined in a single-price auction and is reported as the "TAF" rate in Table 1. The spread between the TAF rates and the OIS rate at the time bids were taken averaged around 50 basis points for the first two auctions, but then fell in subsequent auctions, before rising again to around 40 basis points in the first auction of March, 2008.

Table 1
Term Auctions Facility (TAF)

Day of Bid	Settlement	Term (days)	Amt ($B)	Min. Rate	TAF Rate	1-Month Libor	Bid/Cover Ratio
12/17/07	12/20/07	28	20	4.17	4.650	4.965	3.08
12/20/07	12/27/07	35	20	4.15	4.670	4.896	2.88
01/14/08	01/17/08	28	30	3.88	3.950	4.081	1.85
01/28/08	01/31/08	28	30	3.10	3.123	3.281	1.25
02/11/08	01/24/08	28	30	2.86	3.010	3.139	1.95
02/25/08	02/28/08	28	30	2.81	3.080	3.124	2.27
03/10/08	03/13/08	28	50	2.39	2.800	2.935	1.85

Note: the 1-month labor rate refers to the rates on the day the TAF bids were submitted.

Early reports on the effectiveness of the TAF were generally favorable. The auctions were oversubscribed and the TAF rates were below the one-month Libor rate prevailing at the time that bids were submitted, as seen in Table 1. Moreover, as noted above, Libor-OIS spreads fell sharply between late December and mid January. Figure 13 shows the dates of the TAF auctions with vertical lines along with the Libor-OIS spreads at one- and three-month maturities. After the first two auctions, the TAF rate has been between 4 and 16 basis points below the prevailing one-month Libor rate.

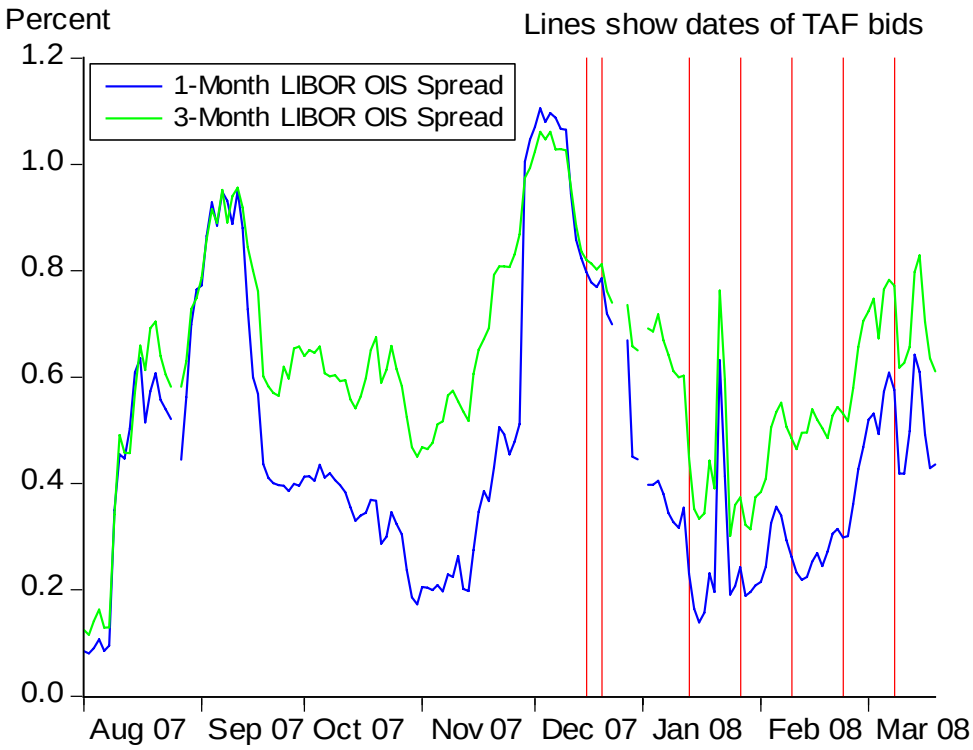
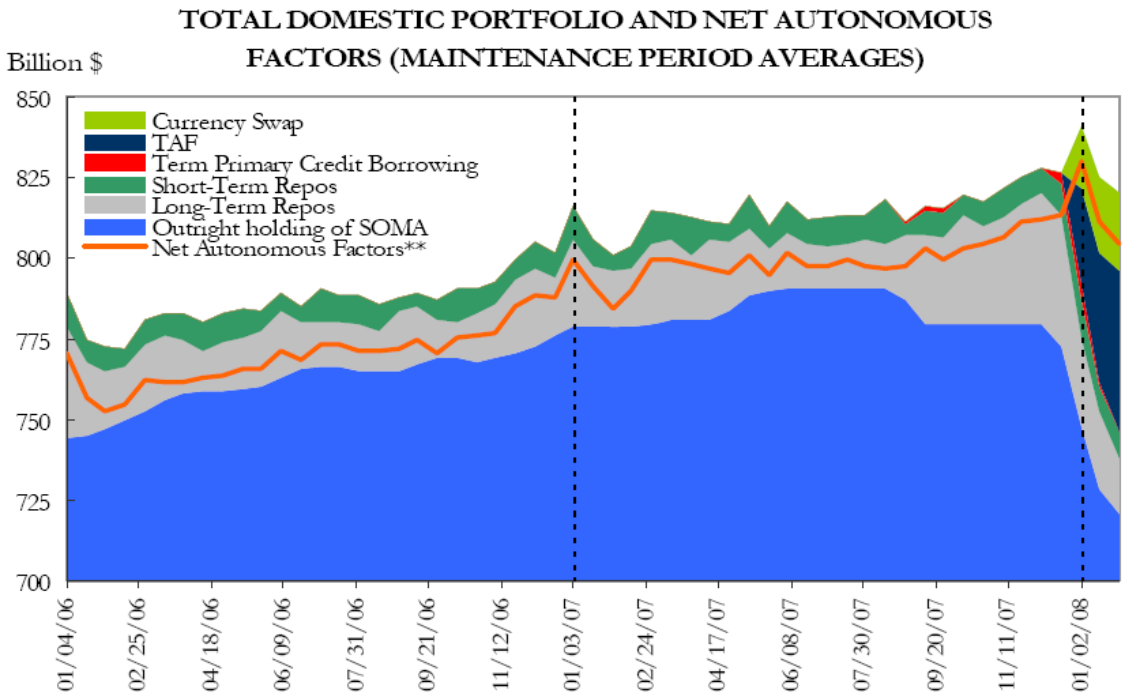


Figure 13. Timing of the TAF auctions and Libor – OIS spreads

At the same the TAF was introduced, other central banks, including the Bank of Canada, the Bank of England, the European Central Bank (ECB), and the Swiss National

Bank, also took measures to increase term lending. The ECB and SNB launched their own term auction facilities starting in December of 2007. These auctions are summarized in the Appendix. The ECB and SNB participated in TAF auctions in December and January that occurred on days in which the Fed held TAF auctions. No further ECB or SNB TAF auctions took place during our sample (they have since restarted after the end of our sample). In addition, the Bank of Canada and the Bank of England increased their term repo lending in December and January; those programs were they curtailed (they, too, have since restarted).



**Short term RPs are defined as repos with a term less than 7 calendar days and long term RPs are defined as repos with a term greater than or equal to 7 calendar days. The exception is the 6-day RP on November 15, 2007, which is being categorized as a long term repo*
*** Net Autonomous Factors (assets minus liabilities) are exclusive of swap lines established in December*
Source: Federal Reserve Bank of New York, *Domestic Open Market Operations in 2007*, February 2008

Figure 14 TAF did not increase the total amount of liquidity

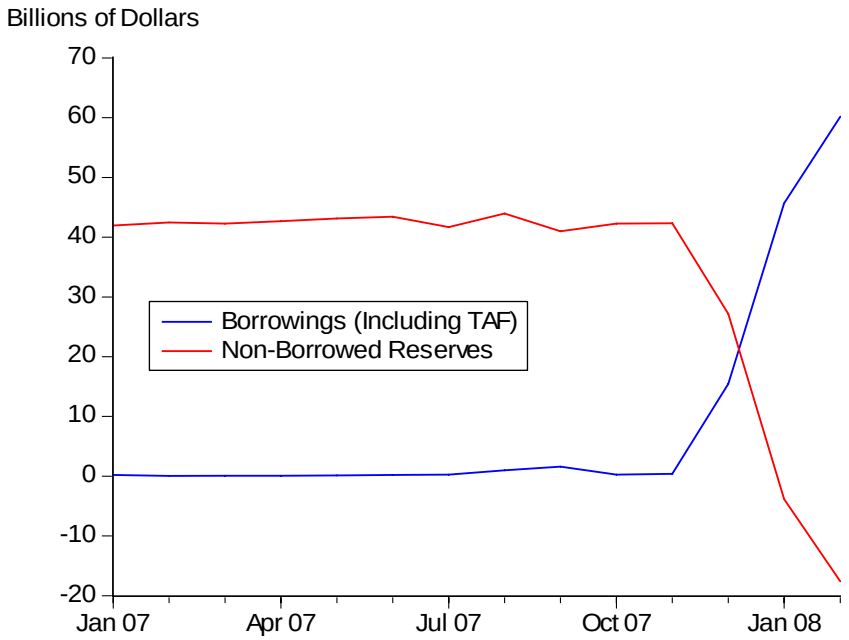


Figure 15. As TAF borrowings from the Fed go up, non-borrowed reserves decline to offset the increase, keeping total reserves unchanged

In assessing the effects of the TAF, it is important to note that it does not increase the amount of total liquidity in the money markets. Any increase in liquidity that comes from banks borrowing from the Fed using the TAF will be offset by open market sales of securities by the Fed to keep the total supply of reserves from falling rapidly. The actions are essentially automatic in the sense that the Fed must sell securities to keep the federal funds rate on target. Figure 14 shows that this is indeed what has happened under the TAF. The System Open Market Account reduced its outright holdings of securities (light blue area) by essentially the same amount as the TAF (dark blue area). This can also be seen in Figure 15: Note that TAF borrowings have increased dramatically only to be completely offset by a sharp decline in non-borrowed reserves leaving total bank reserves at the Fed largely unchanged.

8. Econometric Tests

In this section, we endeavor to test how various factors—including the risk measures explored in previous sections, and liquidity measures like the TAF—affect the Libor-OIS spread. Simply put, the term structure model described in this paper implies that risk factors should affect the spread and the TAF should not, and this is what we would like to test. To be sure, by focusing on the impact of the TAF on the spread we do not mean to imply that the Federal Reserve did not have other goals in creating the TAF, including reducing the stigma associated with discount window borrowing by banks. Nevertheless, reducing the spread was one of the purposes of the TAF and one of the ways suggested to measure its success. For example, as stated by Mishkin (2008), "Isolating the impact of the TAF on financial markets is not easy, particularly given other recent market developments and the evolution of expectations regarding the federal funds rate. Nonetheless, the interest rates in term markets provide some evidence that the TAF may have had significant beneficial effects on financial markets….term funding rates have dropped substantially relative to OIS rates: The one-month spread exceeded 100 basis points in early December but has dropped below 30 basis points in recent weeks--though still above the low level that prevailed before the onset of the financial disruption last August." See also Board of Governors (2008) for similar comments regarding the purpose and early evaluation of the effects of the TAF.

Our tests are performed with simple regressions, summarized in Tables 2 and 3. In each regression we use daily data, as presented in the charts above, during the sample period from January 2, 2007 through March 20, 2008, a span of time that includes both

the market turmoil period and a comparable period of time before the turmoil. The dependent variable in each case is either the three-month Libor–OIS spread, shown in Table 2, or the one-month Libor-OIS spread, shown in Table 3. The independent variables are various indicators of counterparty risk, including the asset backed commercial paper spread (CP spread), credit default swaps for major banks (CDS-CITI and CDS-BOA), the Tibor-Libor spread (for the 3 month maturity regression only), and the Libor-Repo spread. These variables are listed in left hand columns. Each regression also includes a TAF dummy (TAF) which is one on each of the TAF bid submission dates and zero elsewhere. There are five sets of regressions corresponding to the different risk measures. For each of the risk measures, we report OLS regressions as well as regressions corrected for first-order serial correlation (AR(1)), with the estimated serial correlation coefficient $\boldsymbol{\rho}$ reported.

Table 2
Three-Month Libor-OIS Spread

	1	2	3	4	5	6	7	8	9	10
Constant	0.1430	0.3650	0.1650	0.2296	0.1081	0.2107	0.1012	0.5642	-0.0206	0.2709
	(0.2467)	(0.1898)	(0.0388)	(0.1933)	(0.0394)	(0.2029)	(0.0302)	(0.3729)	(0.0197)	(0.1428)
CP Spread	0.7885	0.0450								
	(0.0925)	(0.0584)								
CDS-CITI			0.0043	0.0034						
			(0.0008)	(0.0010)						
CDS-BOA					0.0069	0.0055				
					(0.0010)	(0.0016)				
Tibor-Libor Spread							-4.4926	-0.6549		
							(0.4270)	(0.3199)		
Libor-Repo Spread									0.6715	0.1340
									(0.0405)	(0.0726)
TAF	0.0645	0.0208	0.0797	0.0041	0.0875	0.0050	0.1595	0.0250	-0.0198	0.0162
	(0.0545)	(0.0150)	(0.1449)	(0.0076)	(0.1513)	(0.0086)	(0.0493)	(0.0123)	(0.0269)	(0.0119)
AR(1)		0.9833		0.9806		0.9808		0.9864		0.9788
		(0.0111)		(0.0147)		(0.0143)		(0.0119)		(0.0123)
R^2	0.707	0.980	0.438	0.983	0.473	0.984	0.623	0.976	0.877	0.981

Note: Newey-West standard errors are reported under coefficient estimates.

Table 3
One-Month Libor-OIS Spread

	1	2	3	4	5	6	7	8
Constant	-0.0002	-0.6458	0.1327	0.1726	0.0942	0.1336	-0.0163	0.1650
	(0.2553)	(0.3031)	(0.0308)	(0.1823)	(0.0303)	(0.1924)	(0.0246)	(0.0895)
CP Spread	0.0524	0.1919						
	(0.0528)	(0.0516)						
CDS-CITI			0.0029	0.0023				
			(0.0006)	(0.0011)				
CDS-BOA					0.0047	0.0045		
					(0.0008)	(0.0012)		
Libor-Repo Spread							0.5779	0.1637
							(0.0651)	(0.1011)
TAF	0.2369	0.0317	0.1218	0.0051	0.1243	0.0056	-0.0082	0.0186
	(0.0967)	(0.0134)	(0.1746)	(0.0104)	(0.1815)	(0.0115)	(0.0407)	(0.0138)
AR(1)		0.9821		0.9706		0.9743		0.9656
		(0.0131)		(0.0213)		(0.0201)		(0.0184)
R^2	0.034	0.964	0.269	0.961	0.288	0.964	0.797	0.966

Note: Newey-West standard errors are reported

In all cases, the risk measures enter with the correct sign and are usually highly significant in both the one-month and the three-month maturity regressions. In contrast, the TAF dummy variable is always insignificant or of the wrong sign. The common theme of these results is that (1) one can easily reject the null hypothesis that the counterparty risk factors are not significant in the Libor OIS spread and (2) one cannot reject the null hypothesis that the TAF has no effect.

9. Conclusion

In this paper we documented the unusually large spread between term Libor and overnight interest rates in the United States and other money markets beginning on August 9, 2007. We also introduced a financial model to adjust for expectations effects and to test for various explanations that have been offered to explain this unusual development.

The model has two implications. Fist is that counterparty risk is a key factor in explaining the spread between the Libor rate and the OIS rate, and second is that the TAF should not have an effect on the spread. Since the TAF does not affect total liquidity, expectations of future overnight rates, or counterparty risk, the model implies that it will not affect the spread. Our simple econometric tests support both of those implications of our model.

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Appendix

Appendix Tables 1 and 2 provide lists of banks participating in the various Libor surveys and the Tibor survey in 2007. The U.S., Euro, and UK lists all include the same 14 banks (out of 16 banks in each survey). The Libor is computed taking the average of rates in the survey, after dropping the 25 percent highest and 25% lowest rates. The Tibor is computed by averaging the rates in the survey, after dropping the two highest and two lowest rates.

Appendix Table 3 summarizes the results from the TAF auctions held by the European Central Bank and the Swiss National Bank during our sample period. Note that the European Central Bank TAF auction was structured so that the TAF rate was identical to that from the corresponding TAF auction held by the Federal Reserve.

Appendix Table 1. Banks in Libor Survey (2007)

United States	Euro	UK	Switzerland
Bank of America	Bank of America	Bank of America	
Bank of Tokyo – Mitsubishi UFJ	Bank of Tokyo – Mitsubishi UFJ	Bank of Tokyo – Mitsubishi UFJ	Bank of Tokyo – Mitsubishi UFJ
Barclays Bank	Barclays Bank	Barclays Bank	Barclays Bank
Citibank NA	Citibank NA	Citibank NA	Citibank NA
Deutsche Bank	Deutsche Bank	Deutsche Bank	Deutsche Bank
HSBC	HSBC	HSBC	HSBC
JP Morgan Chase	JP Morgan Chase	JP Morgan Chase	JP Morgan Chase
Lloyds TSB Bank	Lloyds TSB Bank	Lloyds TSB Bank	Lloyds TSB Bank
Rabobank	Rabobank	Rabobank	
Royal Bank of Scotland Group	Royal Bank of Scotland Group	Royal Bank of Scotland Group	Royal Bank of Scotland Group
UBS AG	UBS AG	UBS AG	UBS AG
West LB AG	West LB AG	West LB AG	West LB AG
HBOS	HBOS	HBOS	
Royal Bank of Canada	Royal Bank of Canada	Royal Bank of Canada	
Credit Suisse	Credit Suisse	Abbey National	Credit Suisse
Norinchukin Bank	Société Générale	BNP Paribas	Société Générale

Appendix Table 2. Banks in Japan's Libor and Tibor Surveys (2007)

Libor	Tibor
Bank of Tokyo –Mitsubishi UFJ	Bank of Tokyo – Mitsubishi UFJ
Mizuho Corporate Bank	Mizuho Corporate Bank
Norinchukin Bank	Norinchukin Bank
SMBCE	SMBCE
Bank of America	Mizuho Bank, Ltd.,
Barclays Bank	Resona Bank
Citibank NA	Saitama Resona Bank
Deutsche Bank	The Bank of Yokohama,
HSBC	Mitsubishi UFJ Trust and Banking Corporation
JP Morgan Chase	Mizuho Trust and Banking Co
Lloyds TSB Bank	The Chuo Mitsui Trust and Banking Co.
Rabobank	The Sumitomo Trust and Banking Co.
Royal Bank of Scotland Group	Shinsei Bank
UBS AG	Aozora Bank
West LB AG	DEPFA Bank
Société Générale	Shinkin Central Bank

Appendix Table 3. ECB and SNB Term Auctions Facilities (TAF)

Day of Bid	Settlement	Term (days)	Amt ($B)	Min. Rate	TAF Rate	1-Month Libor	Bid/Cover Ratio
Swiss National Bank							
12/17/07	12/20/07	28	4	4.17	4.170	4.965	4.25
01/14/08	01/17/08	28	4	3.88	3.88	4.081	2.72
European Central Bank							
12/17/07	12/20/07	28	10	4.17	4.650	4.965	2.21
12/21/07	12/27/07	35	10	4.15	4.670	4.896	1.41
01/14/08	01/17/08	28	10	3.88	3.950	4.081	1.48
01/28/08	01/31/08	28	10	3.10	3.123	3.281	1.24

Note: 1-month labor rate refers to rates on the day bids were submitted in the Federal Reserve TAF.