CHAPTER 2

STRESS IN BANK FUNDING MARKETS AND IMPLICATIONS FOR MONETARY POLICY

In the current crisis, bank funding markets have struggled to provide liquidity across the banking sector and thus to act as a conduit for monetary policy in mature economies. This chapter examines the reasons for the recent difficulties in these markets and the effects on the interest rate channel of monetary policy transmission. It finds that elevated interbank spreads are not just the product of how interbank rates are calculated and that the recent pressures have been principally driven by concerns about bank distress risk, with U.S. dollar liquidity strains playing a significant role in the European money markets. Empirical work shows that aspects of the transmission of policy rate changes are far less reliable, particularly in the United States. Policy interventions to further broaden access to emergency liquidity may be necessary to constrain systemic risks but are unlikely to resolve bank funding stresses until broader policy measures, including those aimed at the underlying counterparty credit concerns, are implemented.

The persistence of high interbank rates in the main advanced economies since the current crisis began in the summer of 2007 is startling, even as central banks have taken unprecedented steps to ease conditions. After a period of some moderation of pressures following the rescue of Bear Stearns in mid-March, ongoing concerns about the health of financial institutions and the reemergence of financial distress in September brought back renewed pressures to interbank rates. Uncollateralized interbank rates serve as a benchmark for a significant proportion of financial derivative instruments, and therefore have important knock-on effects for other financial markets as well as borrowers with interest rates indexed to interbank rates. In addition to having adverse consequences for banks' cost of funding, elevated interbank rate spreads may also have serious effects on the transmission of monetary policy. A change in the central bank policy rate (typically an overnight rate) is designed to be transmitted through interbank and money market interest rates, ultimately influencing consumer and business lending rates and therefore domestic demand. However, the interconnections between money and other credit markets that have developed over the past two decades mean that disruptions to the money and funding markets can have adverse macroeconomic consequences.

This chapter examines the current stress in interbank markets from three perspectives. First, the basic microstructure of how interbank markets operate is examined. The discussion includes an assessment of whether the quoted London Interbank Offered Rate (LIBOR) and euro counterpart (the Euro Interbank Offered Rate, or Euribor) are currently distorted.[1]

Note: This chapter was written by a team led by Brenda González-Hermosillo and Mark Stone, and comprised of Andreas Jobst, John Kiff, Paul Mills, Miguel Segoviano, and Seiichi Shimizu. Vance Martin (University of Melbourne), Alin Mirestean, and Jean Salvati assisted in the empirical work, and Yoon Sook Kim provided research assistance.

[1]The LIBOR, calculated by the British Bankers' Association, and the Euribor, calculated by the European Banking Federation, are benchmarks based on expected marginal unsecured funding costs of a creditworthy bank in the interbank market at various maturities out to one year. In contrast, the Euro Overnight Index Average

Second, uncollateralized interbank rates are analyzed empirically to determine what has driven interbank spreads higher. In particular, the question examined is whether the persistent, wide spreads over policy rates that have been observed reflect credit risk or other factors, and whether the underlying causes have changed over time. Third, structural changes influencing monetary transmission and the recent impact of elevated interbank spreads are described and empirically analyzed to test whether the interest rate channel of monetary policy has recently become less dependable. The final section identifies policy proposals to redress current interbank market pressures. In particular, a wide array of policies should aim at cross-market credit and liquidity issues, which have become intertwined during the current period of stress. This will entail central banks and other government entities rethinking their policy options.

The Microstructure of Bank Funding Markets

Term LIBOR and Euribor rates remain worthwhile as measures of a typical creditworthy bank's marginal cost of unsecured term funds in the wholesale money market, although volumes of unsecured term interbank lending have been shrinking as a proportion of short-term funding activity for many years. Nevertheless, given the huge outstanding amounts of derivative contracts and other financial instruments linked to term LIBOR and Euribor, these benchmark rates need to be maintained. Although the survey methodologies have been effective at eliminating most biases at the individual contribution level, proposals by the British Bankers' Association (BBA) to increase the number of sampled banks and introduce more aggressive scrutiny of individual bank contributions are welcome. However, the definition of LIBOR and Euribor in the calculation process should be amended to reflect bank unsecured term funding costs in wholesale money markets more generally, rather than just in the interbank market, to ensure that the indices remain representative of actual unsecured wholesale bank funding costs. Collection and publication of aggregate volume data would also help users to assess the reliability of term interbank rate fixings.

Interbank markets are integral to the functioning of many other financial markets, and so understanding the reasons for their disruption is important for relieving strains elsewhere in the financial system. They are especially tightly linked to interest rate derivatives (forwards, futures, and swaps), of which an estimated $400 trillion principal outstanding are LIBOR-related interest rate swaps (BBA, 2008a). In addition, interbank rates play key roles in capital markets more generally. For example, "credit" spreads on most fixed-income instruments are calculated from LIBOR- and Euribor-based interest rate swap curves to facilitate cross-market and cross-currency comparison given that issuers and investors use LIBOR-based derivatives to hedge and transform interest rate and currency risks (see Box 2.1).

Conceptually, large commercial banks fund their balance sheets in layers, starting with a capital base comprised of equity, subordinated debt, and hybrids of the two, plus medium- and long-term senior debt. The next layer consists of customer deposits—assumed to be "sticky" in most circumstances even though callable at little or no notice.[2] The final funding layer comprises various shorter-term liabilities such as commercial paper, certificates of deposit, repurchase agreements, swapped foreign exchange liabilities, and wholesale deposits. This layer is managed on a dynamic basis as its composition and maturity can change rapidly with cash flow needs and market conditions. Within this layer,

(EONIA) and Sterling Overnight Index Average (SONIA) are weighted-average rates of actual unsecured overnight rates by all banks surveyed for unsecured loans in euros and sterling, respectively.

[2]The embedded call option at par in a bank deposit makes banks vulnerable to deposit "runs" whereby depositors rush to withdraw deposits to avoid principal loss or being denied access through the bank's bankruptcy.

Box 2.1. Pricing and Hedging Role of Interbank Deposit-Related Derivatives

Until recently, marketable government securities were the pricing benchmarks for fixed-income transactions, primarily because of their large outstanding amounts and market liquidity. It was not until the early 1990s that potential benchmarks based on derivatives, such as interest rate swaps and futures, were liquid enough to be considered as viable alternatives.

There are several reasons why government bonds no longer serve as very useful benchmarks for anything other than the most commonly traded government securities:

- Government securities often enjoy a "flight to quality" during episodes of market stress (Fleming, 2000; McCauley, 2001).
- Many governments do not issue enough securities at the right maturities to be adequate for hedging purposes (Remolona and Wooldridge, 2003; Fleming, 2000).
- Even individual government securities issued by the same issuer, differing only by maturity date or even subtle contractual terms, are subject to idiosyncratic pricing (Duffee, 1996).

Note: John Kiff prepared this box.

As a result, interbank deposit-rate-based derivatives have become the preferred fixed-income benchmarking and hedging instruments, with U.S. corporate bonds being the exception. Not only are they more liquid than the alternatives, but long and short positions in these derivative markets are unrestricted, so the kinds of idiosyncrasies seen in securities markets are rare.

For some purposes, overnight index swap (OIS) rates may be more appropriate benchmarks, because they are more representative of risk-free rates, and they better reflect changes in policy rates (Goldman Sachs, 2008). However, shifting a legacy of over $400 trillion of instruments based on the London Interbank Offered Rate (LIBOR) would be a daunting operational task, and OIS benchmarks have their own downsides. For example, the overnight rates on which they are based can be subject to significant volatility, and benchmarks based on actual bank funding costs are the most appropriate when the marginal cost of bank funding is the relevant comparator. A likely outcome is that, as a greater credit and liquidity risk component has become evident in LIBOR and Euribor rates, parties to interest rate derivatives will more carefully consider various benchmark rates.

unsecured interbank funding has become a relatively small component of a typical large bank's short-term funding mix due to the regulatory capital charges associated with unsecured lending to other banks.[3]

For some time, the majority of the limited amount of unsecured interbank lending that does take place has been at maturities of one week or less, and predominantly overnight. This reflects general trends in money market activity. The European Central Bank euro money market survey (ECB, 2007) showed that in recent years the vast majority of transactions (about 70 percent) are overnight, while maturities of one month or less account for nearly all of them (about 95 percent) (Figure 2.1). Most bank short-term funding now comes from nonbank sources such as money market funds, securities lending reinvestment portfolios, and central bank foreign exchange reserves. However, these sources are increasingly switching to secured lending and derivatives-based structures—for example, lending overnight and

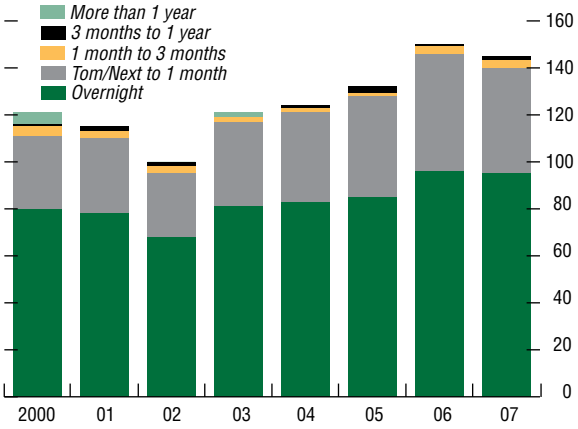
[3]Under Basel I, unsecured interbank deposits maturing within one year attracted a 20 percent risk-weighting for capital requirement purposes. Basel II uses ratings to determine risk weights. While the minimum weighting remains 20 percent, it can be higher for deposits of greater than three months' maturity. As a result, banks are encouraged to collateralize their exposures with bank counterparties or, if lending is unsecured, to do so at maturities of three months or less.

positioning for monetary policy actions with interest rate derivatives such as overnight index swaps (OIS).[4]

The relative paucity of interbank term lending means that LIBOR and Euribor "fixings" beyond a week or month's maturity may not represent actual transactions but rely instead on banks' assessments of their notional ability to borrow at those rates.[5] Although the integrity of the U.S. dollar LIBOR fixing process has been questioned by some market participants and the financial press, it appears that U.S. dollar LIBOR remains an accurate measure of a typical creditworthy bank's marginal cost of unsecured U.S. dollar term funding (Box 2.2). A BBA proposal to introduce more aggressive scrutiny of individual bank contributions is still welcome, as it should improve the accuracy of the LIBOR calculation by, potentially, expanding the panel of contributing banks, and increasing incentives to submit accurate funding rates while maintaining transparency (BBA, 2008a, 2008b).

In addition, consideration should be given formally to expanding the scope of the LIBOR and Euribor so that they represent unsecured term funding rates available to banks in wholesale money markets. This would ensure that they remain indicative of marginal unsecured bank funding costs, and would better reflect the range of funding sources that contributing banks actually consider when estimating their "interbank" funding costs. Broadening the meaning of these rates should not undermine the contractual

Figure 2.1. Unsecured European Bank Borrowing Volumes
(In euros; indexed to 2002:Q2 = 100)



Source: European Central Bank.
Note: Tom/Next is a transaction for settlement tomorrow and maturity the next day.

[4]An OIS exchanges the average realized overnight unsecured rate with a fixed interest rate over a specified term. Hence, the three-month OIS swap rate embodies the market's expectation of overnight rates over the next three months.

[5]For example, each day, just before 11:00 a.m. London time, each member bank of the BBA's LIBOR contributor panels for 10 different currencies submits the rate at which it could borrow funds in reasonable market size at various maturities (from overnight out to 12 months) in the interbank market. For each currency and maturity, the highest and lowest quartiles of rates are excluded and the rate is fixed at the simple average of the remaining contributions. Rate contributions are nonbinding, in that the banks are not obliged to prove that they did, or could, trade at the submitted levels.

Box 2.2. Is the LIBOR Fix Broken?

Market observers have been expressing concerns that some LIBOR contributors submit rates that are too low, particularly when they are facing liquidity constraints (Mollenkamp and Whitehouse, 2008). This is said to be driven by the requirement of the British Bankers' Association (BBA) that all rate submissions be published, and by the fact that banks facing liquidity strains may not want to reveal the higher market rates they are actually being offered.

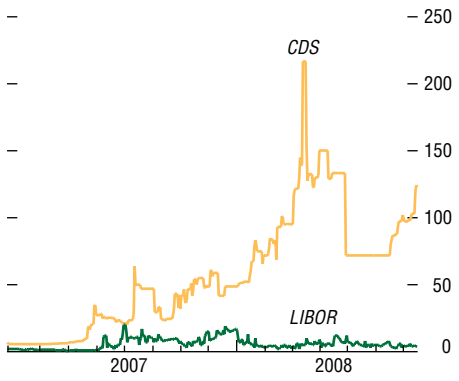
For example, between January and April 2008, the range of contributor bank short-term credit default swap (CDS) spreads far exceeded the range of three-month U.S. dollar LIBOR contributions as a spread over the three-month U.S. dollar overnight index swap (OIS) rate (a proxy for the effective "risk free" rate). Prior to August 2007, the two ranges fluctuated very closely together, but since then, and particularly since January 2008, the range of CDS spreads has been far wider than that of the LIBOR-OIS contribution spreads (see the first figure). However, contributing banks say that CDS spreads play little to no role in day-to-day short-term lending decisions per se.

In practice, outlier rate contributions have little impact on LIBOR fixings, because the lowest and highest are trimmed from the averaging calculation. However, if a downward bias in reported rates were to involve more banks, the median rate would provide a more accurate fixing in some situations. It has also been suggested that the LIBOR panel be expanded to minimize the impact of outliers and of contributors that may not be representative of banks that actually need funds in the relevant currency at the time of fixing. For example, European banks that are active in the London interbank market, but that book transactions at their continental head offices, could be included. Although JPMorgan (2008) suggests that the impact of such an expansion is likely to be marginal,[1] it is a welcome development that the BBA's committee overseeing the LIBOR setting process is to consider expanding the LIBOR contributor panels.

Even though volumes of unsecured term interbank lending have been shrinking for some years, the BBA has argued that the LIBOR remains reflective of the rate at which the panel banks could raise unsecured cash in the interbank lending markets. Also, LIBOR rates remain worthwhile as a measure of a typical creditworthy bank's marginal cost of unsecured funds, irrespective of source. For example, the second figure shows that various potential U.S. dollar three-month bank unsecured funding rates trade very closely to each other.

Note: John Kiff prepared this box.

Spread Between Highest and Lowest Three-Month U.S. Dollar LIBOR Contributions and Highest and Lowest Short-Term Contributor CDS Spreads
(In basis points)

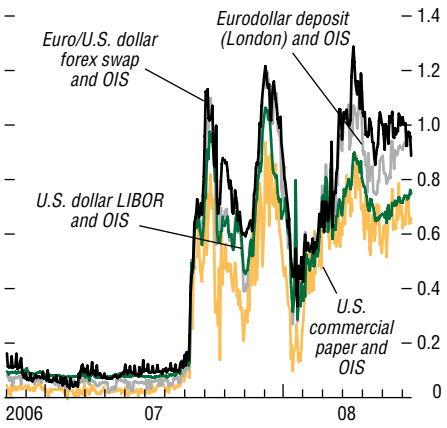


Sources: Bloomberg L.P.; and British Bankers' Association.
Note: CDS = credit default swap.

[1]JPMorgan (2008) compared three-month euro LIBOR to Euribor fixings, and found the difference to be statistically insignificant. The Euribor contributor panel is much broader than the BBA LIBOR panel (43 versus 16), and proportionally fewer observations are trimmed before averaging (the Euribor averaging calculation covers the middle 70 percent of contributions versus LIBOR's 50 percent).

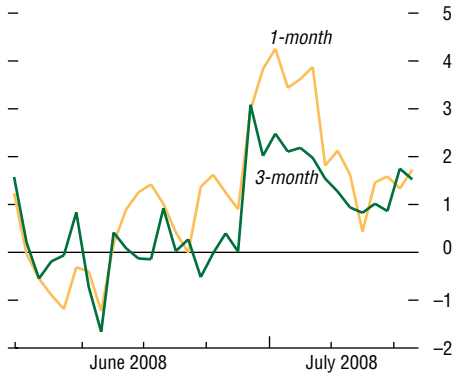
Box 2.2 ***(concluded)***

Selected Three-Month Spreads
(In percent)



Sources: Board of Governors of the Federal Reserve System; British Bankers' Association; and JPMorgan Chase & Co.
Note: OIS = overnight index swaps.

ICAP NYFR and BBA LIBOR Spread
(In basis points)



Sources: British Bankers' Association (BBA); and ICAP plc.

In addition, the money market broker ICAP has recently introduced a more broadly defined measure of one- and three-month bank funding costs, and their fixings have differed little from U.S. dollar LIBOR fixings (see third figure).[2]

[2]ICAP asks banks to contribute their estimates of the rates at which prime banks would likely obtain funding (as opposed to what they themselves are funding at) as of 9:15 a.m. New York time. Any unsecured funding sources are covered, including interbank deposits, certificates of deposit, and commercial paper.

integrity of the trillions of LIBOR- and Euribor-indexed financial contracts, since this would better align the formal definition and procedures with how the rates are actually estimated.

The Causes of Elevated Interbank Spreads

The empirical results presented below provide evidence that the sustained strains in U.S. and European unsecured interbank markets have been driven by concerns about the distress risk of financial institutions (accounting for as much as 30 to 45 percent of the total variance). In the case of European banks, U.S. dollar liquidity pressures have also been important (representing up to an additional 30 to 35 percent of the variance). Once these factors are incorporated, other sources of stress in the markets are found to be relatively unimportant.

Although credit risk is theoretically distinguishable from liquidity risk, in practice these risks are intertwined, particularly during periods of stress. The empirical analysis suggests that high interbank rate spreads are due to banking sector distress risk, a term used here to represent both banks' credit and liquidity risks. Consequently, the results suggest that policies aimed at only

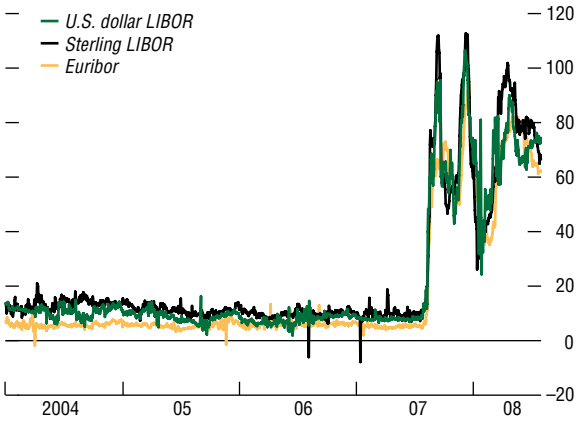
addressing market liquidity pressures may be ineffective, unless credit concerns are also addressed.

Interbank money markets have continued to show unabated signs of stress since the summer of 2007 (Figure 2.2). Not only the level, but also the volatility of these spreads has remained elevated. What has been driving elevated LIBOR-OIS spreads in recent months? Are these spreads driven primarily by liquidity factors or credit concerns in the interbank market?[6] Answers to these questions should allow central banks and other authorities to better calibrate their response to the ongoing crisis.

In principle, term LIBOR rates reflect the expected path of monetary policy, as well as a risk premium associated with credit, liquidity, and other risks.[7] However, the OIS rate embodies the market's estimation of the path of unsecured overnight rates, and so of policy rates in U.S. dollars, euros, and sterling. Hence, the LIBOR-OIS spread should strip out the effects of policy rate expectations, leaving a measure of interbank rate stress and credit concerns.

Several recent studies have attempted to separate the credit and noncredit components of LIBOR-OIS spreads.[8] However, they essentially focus on the role of the credit component measured by an aggregation of credit default swap (CDS) spreads among a collection of banks that are assumed to be independent of each other. The remaining noncredit component is typically *assumed* fully to represent liquidity risk. The

Figure 2.2. Spread Between Three-Month Uncollateralized Interbank Rates and Overnight Index Swaps
(In basis points)



Source: Bloomberg L.P.

[6]Earlier work on the transmission of liquidity shocks was presented in IMF (2008b) and further documented in Frank, González-Hermosillo, and Hesse (2008, 2008b).

[7]Although, for simplicity, most analyses assume that credit default swap (CDS) spreads primarily reflect credit risk, liquidity risks are also embedded in these spreads and it is difficult to disentangle them. There are two reasons for this. First, CDS are traded instruments so their prices contain a risk premium that reflects current market conditions, such as market volatility and investors' risk appetite. Second, banks' funding liquidity risk—the ease with which banks can raise funds—are likely to be also factored into their CDS.

[8]See Bank of England (2007); Taylor and Williams (2008a); Michaud and Upper (2008); Baba, Packer, and Nagano (2008); ECB (2008a); and Imakubo, Kimura, and Nagano (2008).

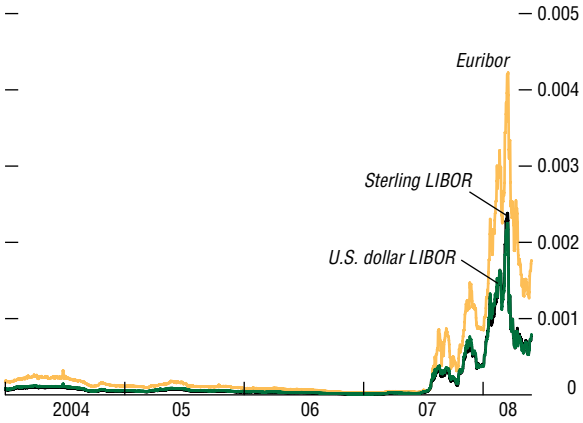
recent literature also finds conflicting evidence of the role of credit and liquidity risks in driving interbank lending spreads. For example, Michaud and Upper (2008) find that their measure of credit risk has little explanatory power for the day-to-day fluctuations in the premium. The Bank of England (2007) finds that while in the early stages of the crisis the spreads were more reflective of liquidity factors, a larger part of the move could be attributed to an increase in credit risk premia during the last months of 2007. Taylor and Williams (2008a) argue that counterparty risk between banks was largely responsible for the rise in the LIBOR-OIS spreads. In contrast, the ECB (2008a) assigns about 50 percent of the recent rise in interbank spreads to credit risk and assigns the remainder to liquidity risk.

This section attempts to refine these initial estimates for the U.S. dollar, Euribor, and sterling LIBOR rates less the OIS.[9] First, the joint probability of distress of the banking system, as a measure of systemic bank credit risk, is introduced (Figure 2.3). In addition, the remaining noncredit component is not *assumed* to be equivalent to a generic type of "liquidity" risk. Instead, a number of variables are used to proxy for different types of liquidity and volatility risk. Third, the estimation technique explicitly takes into account the observed time-varying variances in the variables that proxy for the risks, resulting in more precise estimates of the various components.

Turning first to the choice of variables:

- *Joint probability of distress.* The measure of systemic distress risk used is represented by the joint probability of distress (JPoD) of a group of systemically important banks corresponding to the group of banks that are contributors to each of the interbank rate fixings. The JPoD represents the probability of distress of all the banks in that group and, therefore, embeds banks' distress dependence.[10] Since the JPoD

Figure 2.3. Joint Probability of Distress: Selected Financial Institutions Participating in Interbank Panels



Sources: Bloomberg L.P.; and IMF staff estimates.

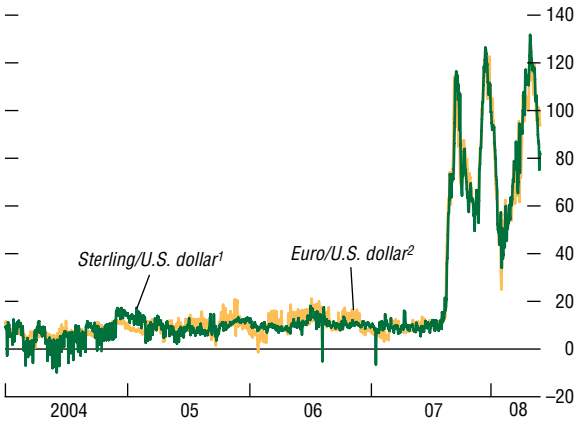
[9]The euro LIBOR and Euribor results are similar and, given the higher volumes of transactions in Euribor, only the Euribor results are reported.

[10]For further details, see IMF (2008b); Segoviano (2008); Segoviano, Goodhart, and Hoffmann (2006); and Segoviano and Goodhart (2008).

is constructed from individual banks' probabilities of distress, which are extracted from CDS spreads, JPoDs necessarily embody both credit and liquidity risks.

- *Collateralized bank funding market (repo spread).* Reflecting the fact that banks face a trade-off as they largely fund themselves in secured interbank markets, the degree of stress in the collateralized bank funding market is proxied by the spread between U.S. government-sponsored enterprises (GSE) debt three-month repo rates, and U.S. government collateralized repo rates. This spread is used as a proxy for global stress in secured interbank lending markets.
- *Market liquidity.* Market liquidity risk, measured by the spread between five-year on-the-run and off-the-run U.S. treasury notes, captures the flight to liquid assets. U.S. treasury notes are viewed by the markets as free of credit risk. However, periods of stress are often characterized by strong demand for the most liquid (on-the-run) U.S. treasury notes.
- *Market volatility.* Volatility risk in financial markets is proxied by the implied volatility in the S&P 500 (VIX), a measure often used to reflect investors' risk appetite.[11]
- *Interest rate volatility.* Another measure of volatility risk is uncertainty about the future path of interest rates, proxied by the implied volatility of swaptions (options to enter into an interest rate swap) with maturities between one and six months.
- *Forex swap.* The role of U.S. dollar liquidity pressures is also examined, as many European banks with U.S. dollar assets have faced difficulties funding these positions (see Box 2.3). U.S. dollar liquidity pressures are proxied by forex swap spreads, or the spread between the three-month pound sterling (or euro) and U.S. dollar forward rates, and the three-month U.S. OIS rate (Figure 2.4).[12]

Figure 2.4. Three-Month Forex Swap Spreads
(In basis points)



Sources: Bloomberg L.P.; JPMorgan Chase & Co.; and IMF staff estimates.
[1]Spread between sterling/U.S. dollar forex swap and 3-month U.S. dollar overnight index swaps.
[2]Spread between euro/U.S. dollar forex swap and 3-month U.S. dollar overnight index swaps.

[11]González-Hermosillo (2008) discusses the variables typically used to measure investors' risk appetite.

[12]A forex swap is a bilateral contract where different currencies are exchanged by combining foreign currency spot and forward contracts. Financial institutions with a need for foreign currency funds face a choice between

Box 2.3. The Federal Reserve's Term Auction Facility

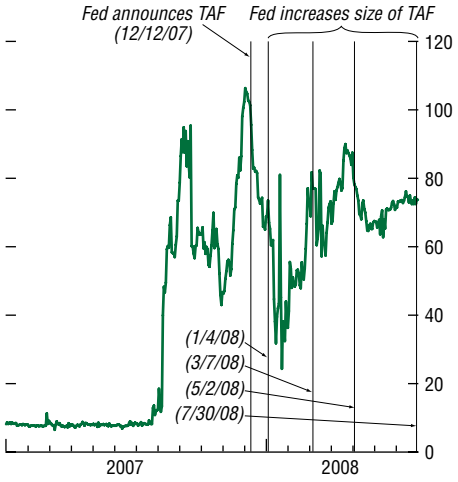
In December 2007, the Federal Reserve announced a temporary Term Auction Facility (TAF) that enabled U.S. banks to borrow for four weeks against the wider range of collateral permissible at the discount window.[1] This direct provision of term funding using an open auction process with a minimum interest rate removed the stigma associated with discount window access while preserving the anonymity of users.[2] By the end of June 2008, the amount of outstanding borrowing through the TAF was $150 billion (versus $14 billion at the discount window). U.S. dollars were also made available to European banks through foreign currency swap arrangements between the Fed and the European Central Bank (ECB) and Swiss National Bank.[3]

The initial TAF auctions were seemingly successful in reducing the spread between the three-month U.S. dollar LIBOR and overnight index swap rates (see first figure). However, uncollateralized term funding conditions deteriorated again in March, coinciding with problems at Bear Stearns, and despite some improvement have remained strained since then.

Despite an increase in the amounts allotted to the ECB's TAF auctions in May, auction demand for U.S. dollars from European banks has increased more rapidly (see second figure).

Impact of Term Auction Facility (TAF) on U.S. Dollar LIBOR Minus Overnight Index Swap Spread

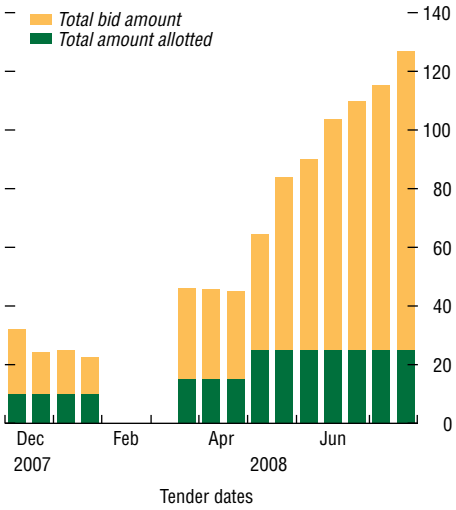
(In basis points)



Sources: Bloomberg L.P.; and Board of Governors of the Federal Reserve System.

European Central Bank: U.S. Dollar Term Auction Facility (TAF)

(In billions of U.S. dollars; 4-week tender)



Source: European Central Bank.

Note: This box was prepared by Brenda González-Hermosillo and John Kiff.

[1]The outstanding TAF balance was originally effectively capped at $40 billion, but it was increased in several steps to $150 billion in May 2008. On July 30, the Fed also announced that it would extend the maturity of some TAF auctions from the original four weeks to 12.

[2]In August, the Fed narrowed the spread between the discount and target Fed Funds rates from 100 to 50 basis points, and extended the term of the primary credit program to up to 30 days (from overnight). However, despite encouragement from Fed officials, banks remained reluctant to tap the facility, although its usage did increase somewhat after the Fed reduced the spread to 25 basis points in March 2008.

[3]The outstanding ECB and Swiss National Bank swap facilities were originally capped at $20 billion and $4 billion, respectively, but the caps were also increased in steps, and stood at $55 billion and $12 billion in August 2008.

This growing excess demand, and widening foreign currency (forex) swap spread (see Figure 2.4) suggests that the facility is serving a useful function but is yet to satisfy the strong demand for dollars arising from European banks bringing onto their balance sheets U.S. dollar-denominated assets that were previously in off-balance-sheet vehicles funded by asset-backed commercial paper and other means.

The effectiveness of the TAF in reducing interbank funding market strains has been intensely debated. There is, as yet, no consensus in the literature. Some find that the TAF has been effective in reducing spreads and dampening volatility (see Michaud and Upper, 2008; McAndrews, Sarkar, and Wang, 2008; Frank, Hesse, and Klueh, forthcoming; and Wu, 2008), whereas others find little impact (Taylor and Williams, 2008a, 2008b). As shown in this chapter, volatility in uncollateralized interbank funding rates reflects not only liquidity pressures, but also default risks and other factors. Moreover, identifying and untangling potential drivers of interbank liquidity conditions is empirically challenging, so it is not surprising that there is disagreement about the causes of elevated interbank rates. In particular, the TAF, with its currency-swap facility, was not designed to address uncertainty about the size of the banks' assets coming onto their balance sheets or potential counterparty risks, which is why the TAF has not been fully successful in eliminating interbank funding market strains.

However, banks are also likely to be facing other liquidity pressures that are difficult to measure directly. These include uncertainty relating to their own funding liquidity needs as they move off-balance-sheet positions onto their balance sheets, as well as uncertainty about asset valuation, particularly if others unwind similar positions at distressed prices. Banks may also hoard liquidity during periods of market stress as a mechanism to avoid potential signaling effects that they may be the ones in need of liquidity. These and other factors are captured by the unexplained component of the variation of interbank spreads, which is reflected in the residual of the model discussed below and described in Annex 2.1.

To examine these questions, a multivariate vector autoregression (VAR) and a structural VAR (SVAR) model are used based on a sample of daily data from January 1, 2004, through May 28, 2008. In using the VAR and SVAR frameworks, and in contrast with other approaches in the empirical literature that have examined interbank lending spreads, the model captures the observed time-varying volatility in the spreads highlighted by the data. The adoption of a time-varying volatility structure is consistent with the observation that the factors explaining the spread are not constant over the sample, but can change at each point in time.[13]

Empirical Results

In a standard VAR model, the variables are ordered to reflect the econometricians' views about the relative sequential influence of each of the variables. By contrast, the SVAR requires a more direct set of assumptions about the relationships among the variables. The benefits of this approach are that the assumptions are transparent, and that the restrictions about the

borrowing directly in the uncollateralized cash market for the foreign currency, or borrowing in another (typically domestic) currency's uncollateralized cash market and then converting the proceeds into a foreign currency obligation through a forex swap. For example, when an institution raises U.S. dollars via a forex swap using the euro as the funding currency, it exchanges euros for dollars at the spot rate, while contracting to exchange in the reverse direction at maturity at the forward rate.

[13]Further technical details of the model specification are provided in Annex 2.1.

Table 2.1. List of Restrictions Used in the Structural Vector Autoregression for Each LIBOR and Euribor Spread

	Market Volatility	Interest Rate Volatility	Market Liquidity	U.S. Dollar Liquidity	Credit	Distress	Residual
S&P 500 volatility index	X						
Swaption	X	X					
On/Off-the-run			X			X	
Currency/U.S. dollar swap			X	X		X	
Repurchase agreement					X	X	
Joint probability of distress					X	X	
LIBOR/Euribor	X	X	X	X	X	X	X

interactions among the variables can be made explicit and consistent with stylized facts.[14]

Thus, for each of the interbank lending markets, the associated SVAR model makes several assumptions about the relationships among the variables of interest (Table 2.1). For instance, the market volatility factor is assumed to affect the implied volatility from equity markets represented by the VIX and the implied volatility from swaption contracts. The volatility of the interest rate factor is applied to the implied volatility from the swaption and so on. Finally, the residual factor affects only LIBOR/Euribor, as it is assumed to be unrelated to the other variables, perhaps capturing bank-specific risks. All factors are designed to influence the unsecured interbank rates.

The empirical results suggest that the dominant influence on the movements in the variance of all three interbank rates arises from the proxy for systemic distress risk. For example, in the case of the three-month U.S. dollar LIBOR-OIS spread, the JPoD variable (the measure of systemic distress risk) reaches around 45 percent of total variance on April 2, 2008, shortly after the Bear Stearns' collapse.[15] In the past six months or so, until very recently, the systemic distress risk variable has accounted for the majority of the explained portion of the variance in the spread (Figure 2.5). In addition, the first hump in the JPoD contribution occurred much earlier, in late July 2007, when the markets first showed signs of significant stress. The role of the other variables is relatively small, but notably the repo spread began to show signs of stress in 2005 when the U.S. housing market began its recent downturn. After being important during much of 2005–06, the effects from forex swaps (dollar/euro) have been relatively small since mid-2007.

Similar results are found for the Euribor panel of banks, with systemic bank distress risk dominating the variance decomposition during the period around the Bear Stearns collapse. Importantly, the forex swap variable accounted for over 30 percent of the total variance at an earlier point of the crisis. U.S. dollar liquidity pressures have also become more important in recent months. The relative contribution of

[14]The variance decomposition reported is based on a one-day lag in order to reduce problems arising from time differences between U.S. and European markets. For robustness, various lags were examined. Additionally, two alternative SVAR specifications were modeled, as well as an unconstrained VAR model with a time-varying variance-covariance matrix, all of which gave similar results. Finally, various tests of over-identification of the restrictions were undertaken. Due to space constraints, only the results of the SVAR are presented here. See González-Hermosillo, Martin, and Segoviano (forthcoming) for details.

[15]The panels in Figure 2.5 are designed to show the percentage of the variance decomposition represented by each variable, adding up to 100 percent. The period before mid-2007 had a much smaller variance than during the crisis.

other factors is relatively small in comparison (Figure 2.5).

For the sterling LIBOR-OIS spread, the dominant variable is the forex swap spread, amounting to close to half the total LIBOR-OIS variance at times. The movements of the forex swap and systemic risk variables show collinearity as they are very similar. When the forex swap variable is omitted, the JPoD for the banks on the sterling LIBOR panel represents as much as 35 percent of the total variance during March 2008. The contributions from other variables are relatively small (Figure 2.5).

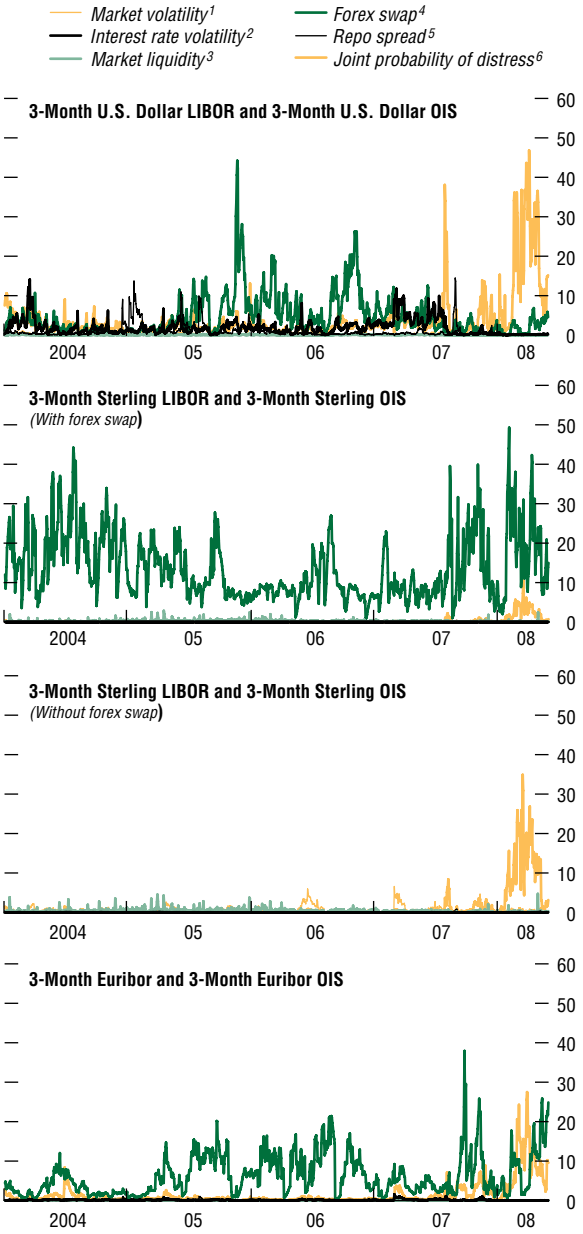
Implications for the Interest Rate Transmission Mechanism of Monetary Policy[16]

Structural changes in the financial sector appear not to have undermined monetary policy transmission over the past 25 years, but did set the stage for the alterations in the interest rate transmission mechanism beginning in the summer of 2007. The most germane structural changes were the emergence of near-banks, the shift of banks toward market financing, and the shortening of the term of market liabilities through the late-1990s.

Most importantly, empirical work indicates that the normal relations governing the pass-through of policy rates into the markets for short-term bank financing and for short- and long-term near-bank financing has become less reliable over the past year, particularly in the United States. The early stages of transmission have been impeded by (1) banks' higher dependence on short-term market financing and the dislocation of these markets, and (2) the increased importance of near-banks in the financial sector coupled with disruption to their financing. The alterations in the early stages of the transmission process mean that

[16]This section was developed in part based on discussions at the conference on "Challenges for Monetary Policy from Financial Innovation and Globalization" in January 2008 in Paris. See IMF (2008a).

Figure 2.5. Structured VAR Model: Variance Decomposition of LIBOR/Euribor Minus Overnight Index Swap (OIS) Spread
(In percent)



Source: IMF staff estimates.
[1]Implied volatility from S&P 500 equity index.
[2]Lehman Brothers swaption volatility index. Implied volatility of interest rate swaption with maturities ranging from 1 month to 6 months.
[3]Five-year on-the-run/off-the-run U.S. treasury note spread.
[4]Spread between 3-month euro/U.S. dollar and sterling/U.S. dollar forex and 3-month OIS.
[5]Spread between the yields on 3-month U.S. agency repo and 3-month U.S. treasury repo.
[6]Joint probability of distress of selected banks participating in U.S. dollar LIBOR, sterling LIBOR, or Euribor fixing.

changes in the policy interest rate are less likely to be reliably passed on to the middle and late stages. The results for borrower financing rates, which have thus far been less affected, need to be interpreted alongside other evidence (such as tighter lending standards and slower credit growth) that suggests that banks are reducing lending by cutting back loan originations rather than raising interest rates. The current re-intermediation process, whereby loans shift from lightly capitalized, market-funded "near-banks" back to more heavily capitalized banks, will add to the capital needs of the system and act as a drag on credit creation, possibly exaggerating the credit cycle.[17]

Structural Changes to the Financial System

This section examines the impact of structural changes in the financial sector and the current financial turmoil on interest rate transmission of monetary policy.[18] A change in the policy interest rate is transmitted in three stages:

(1) To the interest rates in money and other lender financing markets (early linkages);

(2) From lender financing interest rates to the funding costs and lending rates for household and business borrowers (middle linkages);[19] and

(3) From household and business financing costs to the ultimate policy objectives of price and output stability (final linkages) (IMF, 2006, 2008b; and Bhatia, 2007).

This section focuses on the early and middle linkages of interest rate transmission because they are easier to model empirically and insufficient time has passed to assess the impact of the current turmoil on the final linkages.

The structural changes in the financial sector over the past 25 years, which are described in the next section, may be altering monetary transmission by reshaping the traditional maturity transformation function of banks. And, at this crucial juncture in the business cycle, policymakers are acutely concerned about the implications of these structural changes for interest rate transmission and how they may have complicated the early linkages of transmission in the turmoil.

Against this backdrop, this section is concerned with two questions: How have the early and middle linkages of interest rate transmission been affected by financial sector structural changes over the past 25 years? And how is transmission being altered by the financial turmoil that began in the summer of 2007?

The analysis is primarily concerned with the United States, where structural changes have been most evident and monetary transmission seems to have been the most disrupted. The euro area and, to a lesser extent, Japan and the United Kingdom are also examined.

Implications of Structural Changes for Interest Rate Transmission

The main structural changes over the past 25 years are outlined below.

"Near-bank" financial institutions have gained a large share of financial intermediation. In the United States, near-banks (issuers of asset-backed securities [ABS] and other structured products, GSEs, finance companies, securities brokers and dealers, and funding corporations) now account for a large share of the financial sector (Figure 2.6). Banks' share of the financial sector declined through the 1980s and 1990s and leveled off thereafter. Meanwhile, the long-

[17]See IMF (2008e, Chapter 4) for further analysis of procyclical lending behavior.

[18]The main channels of monetary transmission are overlapping and shifting in line with changes in the financial system. (For a recent review of monetary transmission see Kuttner and Mosser, 2002.) *Interest rate channel* transmission begins with a change in the short-term policy rate that influences market interest rates, and, after some price stickiness, will raise the real rate of interest and the user cost of capital, thereby affecting aggregate demand, and so economic output and inflation. The other main channels are the *bank-lending channel* (Bernanke and Blinder, 1988), the *balance-sheet/financial accelerator channel* (Bernanke, Gertler, and Gilchrist, 1999), and the *expectations channel*. The interruption of monetary transmission during the recent financial turmoil is addressed in IMF (2008a) and Adrian and Shin (2008).

[19]Business borrowers in this section refers to nonfinancial businesses.

term growth of GSEs, ABS issuers, and broker dealers accelerated around 2000 (Box 2.4). Then, around 2003, GSE and bank shares of the mortgage market shrunk rapidly as other near-bank entities, market-financed ABS issuers, and finance companies grew. In the euro area, the shift from traditional banks to other intermediaries has been more moderate than in the United States and the United Kingdom. The majority of "other intermediaries" in the euro area are mutual funds that function as investment vehicles for households and insurance corporations, holding shares and other securities. Corporate financing through debt securities is relatively limited, and the recent increase in home mortgages appears to have been mainly supplied by commercial banks.[20]

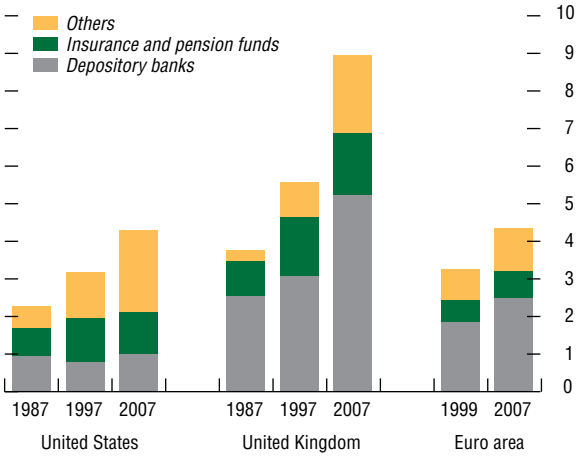
Banks have been shifting away from deposits to less reliable market financing. "Core deposits" dominated U.S. banks' liabilities in the past, but have been gradually replaced by other "managed liabilities" (Figure 2.7).[21] At the same time, near-banks—which are entirely market financed—have grown sharply. This is related to the "originate-to-distribute" financing model that relies heavily on sound short-term market liquidity management. Euro area and U.K. banks also rely more on market financing than in the past, as in the United States. Similarly, the share of deposits by households (defined roughly the same as U.S. core deposits[22]) has been gradually declining over time, while deposits held by nonfinancial corporations, other financial intermediaries, and nonresidents have

[20]ECB (2008b) suggests that statistical differences in the share of monetary financial institutions' (MFI) financing derived from households among the euro area, the United Kingdom, and the United States are partly the result of respective accounting and statistical treatments. For example, European accounting rules have largely prevented MFIs from removing securitized loans from their balance sheets, thereby making MFIs' assets larger relative to U.S. counterparts.

[21]U.S. "core deposits" are defined as the sum of checkable deposits and low value time and saving deposits, which includes some (checkable) deposits from businesses.

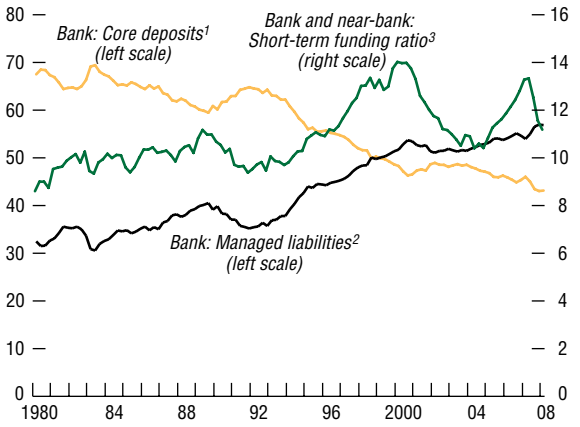
[22]The euro area and U.K. equivalents of core deposits are specified as deposits by households only.

Figure 2.6. Selected Countries: Size of Financial Assets
(In multiples of GDP)



Sources: U.S. Board of Governors of the Federal Reserve System; U.K. Office of National Statistics; European Central Bank; and IMF staff estimates.

Figure 2.7. United States: Structural Changes in Financial Sector Liabilities
(In percent of total liabilities)



Sources: U.S. Board of Governors of the Federal Reserve System; and IMF staff estimates.
[1]Core deposits: checkable deposits, and small time and savings deposits.
[2]Managed liabilities: total liabilities less core deposits.
[3]Ratio of banks' and near-banks' funding through Fed Funds, security repo agreements, and commercial paper, vis-à-vis total liabilities.

Box 2.4. Breakdown of the Financial Sector for Monetary Transmission Analysis

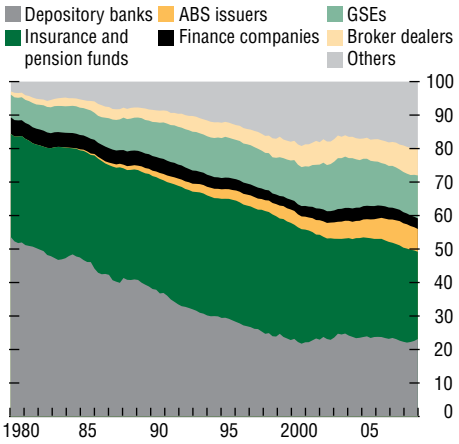
For purposes of this analysis of monetary transmission, the financial sector can be divided into banks and near-banks (see figure).

Banks. Traditionally collected short-term deposits and transformed into long-term loans, but more recently have moved to greater reliance on market financing.

Near-banks. Similar to banks on the asset side but dissimilar in financing. In the U.S. flow of funds tables, near-banks comprise the following entities:

- *Asset-back security (ABS) issuers,* which typically are private bank-controlled conduits that securitize mortgages and consumer credits, and are financed by ABS and asset-backed commercial paper (ABCP), which in turn are held by a variety of investors including banks, life insurance companies, mutual funds, and foreign entities. ABS issuers are very similar in terms of assets but mainly issue bonds and differ from banks on the liability side.
- *Government-sponsored enterprises (GSEs) and GSE pools,* which finance home mortgages through issuing agency- and GSE-backed securities that banks, foreign investors, and many other sectors purchase. These entities largely benefit from the information collection specialization of banks and hold similar assets to banks, but are financed mainly by long-term bonds.
- *Finance companies,* which are similar to banks on the asset side but are market-financed and relatively small.
- *Securities brokers and dealers,* which are largely investment banks that finance their traded assets by security repo agreements and other types of credit that are advanced again by banks, money market mutual funds, and, especially in recent years, foreign entities. The information collection skills of these brokers and dealers are different from those of banks and their role in monetary transmission is related to security transactions and their role as market-makers. This group also includes funding corporations, which are funding subsidiaries of foreign financial institutions, nonbank financial holding companies, and custodial accounts associated with security lending. Their funding is obtained mainly from commercial paper markets.

United States: Breakdown of Financial Sector
(In percent of total assets)



Source: U.S. Board of Governors of the Federal Reserve System.
Note: Government-sponsored enterprises (GSEs) include agency- and GSE-backed mortgage pools. Broker dealers include funding corporations. ABS = asset-backed security.

Note: Mark Stone and Seiichi Shimizu prepared this box.

steadily increased.[23] In addition to these "managed deposits," financing through repurchase agreements and issuance of debt securities, both in domestic and foreign markets, have expanded, indicating that European banks are also increasingly exposed to developments in money markets. At the same time, the share of household deposits for Japanese banks has been stable and even increasing over time. This may

[23]For example, deposits by nonresidents recently accounted for 46 percent of U.K. bank liabilities.

partly reflect the prolonged low interest environment since the late-1990s.[24]

Until recently, bank liability maturities had shortened and become more volatile. The short-term markets became more important for banks and near-banks through the mid-1990s as a more flexible way to manage their asset and liability structures. An "aggregate short-term funding ratio" for the United States comprising commercial paper, Fed Funds, and security repo agreements of banks and near-banks shows an upward trend through 2000, with a subsequent large swing (Figure 2.7). Banks in the United Kingdom have also tapped an increased share of funding through repo agreements through 2004.[25] However, short-term market financing costs are more volatile than the traditional main financing source of core deposits. The interest rate on checkable deposits is relatively stable compared with rates on federal funds and repurchase agreements and time deposits, and the liability share of checkable deposits has fallen.

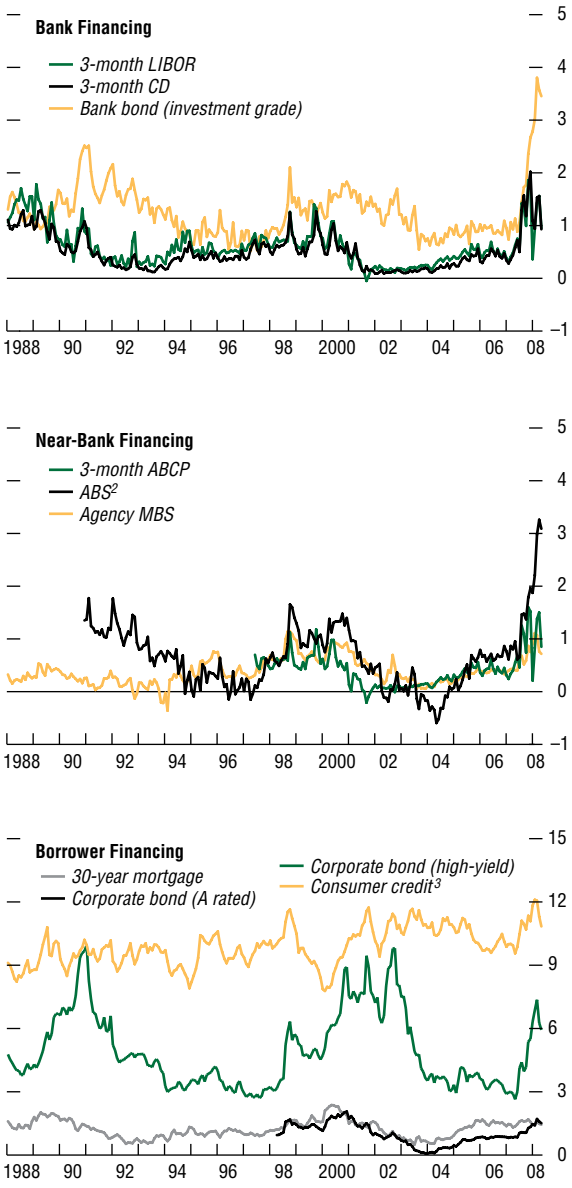
Implications of the Current Financial Turmoil for Interest Rate Transmission

The dramatic alteration in the interest rate transmission mechanism brought on by the market turbulence that erupted in July 2007 can be seen in the changing costs and composition of bank and near-bank financing (IMF, 2008c, Chapter 3). In the United States, interest rate spreads and the volatility of banks' short-term financing rose to levels exceeding

[24]In addition, limited subprime exposure has sheltered Japanese banks from the balance sheet and funding difficulties experienced by U.S. and European banks (IMF, 2008d).

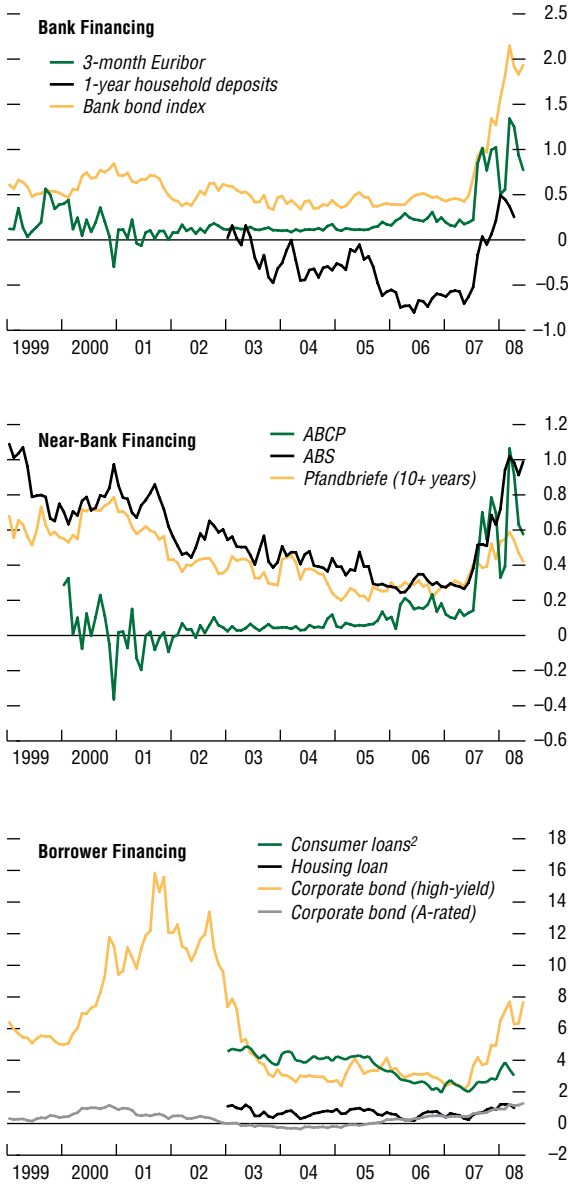
[25]Data show a fairly low and stable share of repo funding in the euro area. This is mostly because noneuro repo funding is apparently not included. According to the latest European repo market survey conducted by the International Capital Market Association, the outstanding volume of repo in Europe increased from 924 billion euros as of June 2001 to 3,153 billion euros as of end-2007, equivalent to 7 percent and 14 percent of MFI liabilities, respectively (see International Capital Market Association, 2008).

Figure 2.8. United States: Selected Interest Rate Spreads[1]
(In percent)



Sources: Bloomberg L.P.; and Merrill Lynch.
Note: ABCP = asset-backed commercial paper; ABS = asset-backed security; CD = certificate of deposit; MBS = mortgage-backed security.
[1]Spread over treasury securities of comparable maturity.
[2]Merrill Lynch fixed ABS index.
[3]Credit card (accounts assessed) interest rate.

Figure 2.9. Euro Area: Selected Interest Rate Spreads[1]
(In percent)



Source: Eurpean Central Bank.
Note: ABCP = asset-backed commercial paper; ABS = asset-backed security.
[1]Spread over government securities of comparable maturity.
[2]Consumer credit (over 1 year and up to 5 years) rate as reported in the ECB Monthly Bulletin.

those of previous downturns (Figure 2.8, top panel), immediately raising marginal financing costs and probably, in effect, cutting off some banks from the markets. The overall short-term funding ratio for banks and near-banks declined sharply beginning in the second half of 2007 (Figure 2.7). Banks' financing from the Fed Funds and repo markets declined from the third quarter of 2007. Similarly, security brokers and dealers reduced funding from repo markets in line with attempts to deleverage, while customer lending associated with security transactions increased and the issuance of asset-backed commercial paper (ABCP) contracted significantly.

Banks and near-banks were compelled to tap longer-term financing, notwithstanding the higher costs. The spreads over treasury securities of comparable maturities of long-term bank financing instruments shot up to levels far above previous cyclical highs (Figure 2.8, middle panel). In the United States, Federal Home Loan Bank advances were another important source of mortgage-related financing for banks.

Funding stresses exerted downward pressure on bank lending even as lenders faced increasing demand for commercial and industrial loans, as nonfinancial corporations drew down previously established credit lines (Federal Reserve Board, 2008). According to the Federal Reserve's Senior Loan Officer Opinion Survey, banks significantly and quickly tightened lending standards for most categories of loans (see Chapter 1). However, neither bank lending rate spreads over treasury securities nor corporate bond yield spreads have risen to date above levels previously experienced during economic downturns, suggesting that credit tightening is in the form of quantity rather than price adjustment (Figure 2.8, bottom panel).

Thus far, the upshot of the market turmoil has been an expanding role for banks at the expense of near-banks. Near-banks are more vulnerable to funding illiquidity and have stopped gaining market share in relation to the banks. This is partly explained by the contrac-

tion of ABS and ABCP issuance, reflecting banks bringing the associated assets onto their balance sheets (IMF, 2008c, Chapter 2).

In the euro area over the past year, interest rate spreads for both lender and borrowing financing display patterns similar to the United States, indicating that other monetary systems may have suffered a similar alteration to the normal interest rate transmission process (Figure 2.9). Banks have tried to secure more stable financing through deposits with an agreed maturity as well as debt securities, and near-bank financing spreads have widened, although they account for a smaller share of the financial system. Household mortgage loan growth has abated in line with the ongoing trend since 2006, but credit growth to nonfinancial corporations has remained robust.

Empirical Analysis

The empirical analysis below aims to gauge the impact of structural changes in the financial sector on interest rate transmission in the past and during the current time of stress. The specific questions examined are:

(1) Have structural changes in the financial sector over the past 25 years undermined or enhanced interest rate transmission?[26]

(2) How has the recent market turmoil affected the markets crucial for interest rate transmission?

Interest rate transmission in the United States and the euro area is modeled here in a system of simultaneous regression equations comprising the effective policy rate and a market interest rate or yield.[27] The policy rates are the actual Fed Funds rate for the United States and the Euro Overnight Index Average (EONIA) for the euro area, and the market interest rates or yields comprise (1) lender financing interest rates and yields (three-month LIBOR, the investment-grade bank bond yield, the ABS yield, and the mortgage agency bond yield); and (2) borrower financing rates and yields (the mortgage rate and high-yield corporate bond yields).

The regressions are estimated using monthly data from the initial date of data availability to end-June 2008, using an approach aimed at distinguishing between the short- and long-term effects of changes in monetary policy rates on market rates (in terms of direction, timeliness, and magnitude).[28] The estimated equations model the contemporaneous monthly change in the market rate as dependent on its previous changes and on past changes in the overnight unsecured rate, and any deviation from the long-run equilibrium (with the core deposit ratio of the banking sector as an unreported control variable). The impact of the policy rate on each market rate is the focus, as opposed to direct estimation of the potential variables that explain the market rate itself.[29] This approach facilitates the analysis of shifts in interest rate transmission as well as cross-market comparisons.

The results suggest that interest rate transmission from the Fed Funds or EONIA to market rates has operated broadly as expected over the past 25 years (Tables 2.2 and 2.3).[30] The long-term pass-through is

[26]The empirical literature has generally concluded that over the last several decades the interest rate pass-through has probably strengthened while other transmission channels may have weakened (Kuttner and Mosser, 2002).

[27]The technical details are presented in Annex 2.2.

[28]Specifically, a two-dimensional Vector Error Correction Mechanism (VECM) model with a three-period lag structure is estimated. The cointegration vector represents a possible linear combination of each interest rate pair, which establishes a long-term relation towards which convergence occurs over time (Banerjee and others, 1993; Granger, 1986; Hendry and Juselius, 2000).

[29]For instance, with elevated commodity prices, measures of inflation expectations may be expected to influence market rates. However, market implied inflation expectations in advanced economies have, until recently, remained relatively stable (compared with emerging economies), indicating that their influence on monetary policy transmission has been limited.

[30]Kok Sørensen and Werner (2006) found that, in the euro area, rates on mortgage loans and time deposits adjust more efficiently than rates on consumer loans and checking deposits.

Table 2.2. Static Vector Error Correction Mechanism (2, 3) Estimation with Variable Controls: United States

Fed Funds Rate vis-à-vis:	*Long-Term Pass-Through* Cointegration factor coefficient	*Short-Term Pass-Through* Fed Funds At 1-month coefficient	Fed Funds At 2-month coefficient	*Direction of Causality* Modified GG score	Adj. R^2
		Lender Financing Rates (Banks)			
Three-month LIBOR rate					
Entire sample: 1/1985–6/2008	**–1.48*** **	**0.06*** **	**–0.05***	**–1.00[1]**	**0.05**
Period I: 1/1985–12/1991	–1.13***	0.34	0.05	–1.00[1]	0.05
Period II: 12/1991–9/2000	–0.11	0.42	0.15	0.72[1]	0.43
Period III: 9/2000–12/2004	–6.30***	0.04	–0.30	–0.66[1]	0.19
Period IV: 12/2004–6/2008	–1.17***	1.27***	–0.11	–1.00[1]	0.56
Bank bond yield					
Entire sample: 12/1987–6/2008	**–1.25*** **	**0.06**	**–0.05**	**–1.00[1]**	**0.07**
Period I: 12/1987–12/1991	–0.50**	0.14	–0.02	–0.71[1]	0.23
Period II: 12/1991–9/2000	4.27***	0.17	–0.04	1.00[1]	0.15
Period III: 9/2000–12/2004	–0.42	0.05	–0.27*	–0.01[1]	0.12
Period IV: 12/2004–6/2008	6.26	–0.46**	0.17	1.00	0.27
		Lender Financing Rates (Near-Banks)			
Asset-backed security (ABS) yield					
Entire sample: 11/1987–6/2008	**–1.45*** **	**0.06**	**–0.07**	**–1.00[1]**	**0.10**
Period I: 11/1987–12/1991	–3.33***	–0.17	–0.91	–1.00[1]	0.83
Period II: 12/1991–9/2000	–1.23***	0.06	0.03	–1.00[1]	0.07
Period III: 9/2000–12/2004	–1.43***	0.18	–0.28	–1.00[1]	0.25
Period IV: 12/2004–6/2008	8.43*	–0.16	–0.30	1.00[1]	0.25
Agency mortgage-backed security (MBS) yield					
Entire sample: 1/1985–6/2008	**–1.66*** **	**0.04**	**0.00**	**–1.00[2]**	**0.09**
Period I: 1/1985–12/1991	–2.46***	–0.01	0.00	–1.00[1]	0.16
Period II: 12/1991–9/2000	–1.14***	0.09	–0.01	–1.00[1]	0.11
Period III: 9/2000–12/2004	–0.98***	0.09	–0.08	–1.00[1]	0.10
Period IV: 12/2004–6/2008	–2.47***	0.03	–0.06	–1.00[1]	0.31
		Borrower Financing Rates			
30-year mortgage loan rate (fixed)					
Entire sample: 1/1985–6/2008	**–2.35*** **	**0.02**	**–0.05**	**–1.00[1]**	**0.23**
Period I: 1/1985–12/1991	–1.16***	0.03	–0.12	–1.00[1]	0.31
Period II: 12/1991–9/2000	–1.66***	–0.12	0.09	–1.00[1]	0.16
Period III: 9/2000–12/2004	–0.24	–0.12	–0.18	–0.03[2]	0.37
Period IV: 12/2004–6/2008	–6.42***	0.05	0.07	–1.00[1]	0.20
Corporate bond (high-yield)					
Entire sample: 12/1987–6/2008	**0.43***	**–0.09**	**0.01**	**–1.00[1]**	**0.11**
Period I: 12/1987–12/1991	0.48**	–0.04	0.01	–0.22[1]	0.26
Period II: 12/1991–9/2000	0.25	0.23	0.70	0.23[2]	0.15
Period III: 9/2000–12/2004	0.11	0.65	–0.44	–1.00[1]	0.14
Period IV: 12/2004–6/2008	1.14*	–0.13	0.70**	0.77[1]	0.49

Note: The modified GG score is between –1 and 1, where –1 means that the Fed Funds rate leads the market rate perfectly whereas +1 means the opposite (Jobst, 2006; Gonzalo and Granger, 1995). The superscript "1" indicates that the parameter associated with causality in the GG score is statistically significant. A superscript "2" indicates both the parameter associated with causality and the one associated with the adjustment to the long-run equilibrium are statistically significant. *,**, and *** indicate statistical significance at the 10, 5, and 1 percent level.

measured by the cointegration factor, which measures the speed with which deviations from long-run relationships return to normal. These factors are mostly stable over time and are close to unity for all market interest rates (with the exception of high-yield bonds). This indicates a smooth long-run transmission of policy rate changes to market interest rates. Further, over the long run, the three-month U.S. dollar LIBOR and Euribor rates have a more stable and reliably estimated relation with the policy rate compared with other lender financing rates (Figures 2.10 and 2.11).

Table 2.3. Static Vector Error Correction Mechanism (2, 3) Estimation with Variable Controls: Euro Area

EONIA Rate vis-à-vis:	*Long-Term Pass-Through* Cointegration factor coefficient	*Short-Term Pass-Through* EONIA At 1-month coefficient	At 2-month coefficient	*Direction of Causality* Modified GG score	Adj. R^2
		Lender Financing Rates (Banks)			
3-month Euribor rate					
Entire sample: 12/1998–6/2008	**–0.97*** **	**0.21*** **	**0.20*** **	**–0.53[1]**	**0.22**
Period II: 12/1998–9/2000	–1.13***	0.00	–0.01	–1.00[1]	0.54
Period III: 9/2000–12/2004	–1.03***	0.16	–0.01	–0.94[1]	0.22
Period IV: 12/2004–6/2008	–3.29***	0.02	0.23*	0.10[2]	0.53
Bank bond yield					
Entire sample: 12/1998–6/2008	**–1.14*** **	**0.08**	**0.06** **	**–0.97[1]**	**0.08**
Period II: 12/1998–9/2000	3.64***	0.12	0.10	1.00[2]	0.60
Period III: 9/2000–12/2004	–1.43	0.00	–0.01	–1.00[1]	0.10
Period IV: 12/2004–6/2008	–0.20	–0.07	–0.15	–0.25[1]	0.28
		Lender Financing Rates (Near-Banks)			
Asset-backed security (ABS) yield					
Entire sample: 12/1998–6/2008	**–1.17*** **	**0.06**	**0.10**	**–1.00[1]**	**0.05**
Period II: 12/1998–9/2000	3.35***	0.16	0.11	1.00[2]	0.66
Period III: 9/2000–12/2004	–1.40***	–0.03	–0.03	–1.00[1]	0.08
Period IV: 12/2004–6/2008	–0.82***	0.00	0.06	–1.00[1]	0.15
Pfandbriefe (German covered bond) yield					
Entire sample: 12/1998–6/2008	**–1.44*** **	**0.07**	**–0.06**	**–1.00[1]**	**0.08**
Period II: 12/1998–9/2000	2.01***	0.16	–0.17	1.00[1]	0.69
Period III: 9/2000–12/2004	–2.09***	–0.02	–0.01	–1.00[1]	0.12
Period IV: 12/2004–6/2008	–1.45***	0.02	–0.04	–1.00[1]	0.28
		Borrower Financing Rates			
Housing loan rate (ECB)					
Entire sample: 2/2003–6/2008	**–0.64*** **	**0.10** **	**0.04**	**–1.00[2]**	**0.41**
Period II: n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Period III: 2/2003–12/2004	0.36	0.18*	0.29***	–0.81[1]	0.63
Period IV: 12/2004–6/2008	–1.37***	–0.06	–0.12**	0.05[1]	0.63
Corporate bond (high-yield)					
Entire sample: 12/1998–6/2008	**–0.24*** **	**–0.51**	**–0.32**	**–0.93[1]**	**0.15**
Period II: 12/1998–9/2000	–0.90***	–0.15	–0.36	–1.00[1]	0.59
Period III: 9/2000–12/2004	–0.24***	–0.57	–0.38	–0.96[1]	0.19
Period IV: 12/2004–6/2008	0.13	–1.45**	–0.62	–1.00[1]	0.35

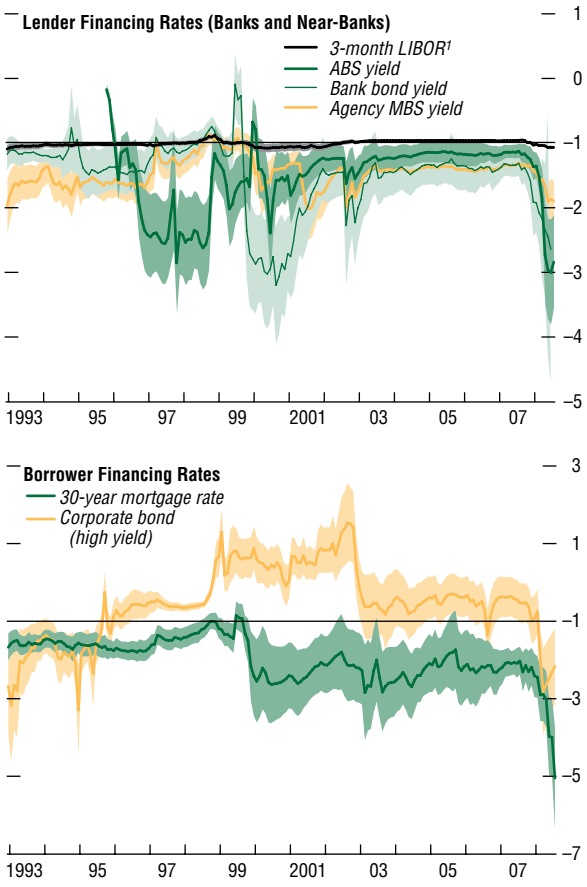
Note: EONIA = Euro Overnight Index Average; Euribor = Euro interbank offered rate; ECB = European Central Bank. The modified GG score is between –1 and 1, where –1 means that the effective European Central Bank policy rate (EOCNIA) leads the market rate perfectly whereas +1 means the opposite (Jobst, 2006; Gonzalo and Granger, 1995). The superscript "1" indicates that the parameter associated with causality in the GG score is statistically significant. A superscript "2" indicates both the parameter associated with causality and the one associated with the adjustment to the long-run equilibrium are statistically significant. *,**, and *** indicate statistical significance at the 10, 5, and 1 percent level.

The results for the short-run pass-through coefficients are more mixed. The one- and two-month pass-through estimates vary widely, and in most cases are not statistically significant, indicating that the initial impact of changes in the policy rate takes more than two or three months to take effect.

Another method to assess whether the overnight rate is transmitted to other market rates is to look at lead-lag relations. The application of the modified Gonzalo-Granger (GG) (1995) score of adjustment coefficients gauges the direction of causality between the various interest rate pairs.[31] The generally negative

[31]The modified GG-test measure of the error correction coefficients on the first and second lags in a regression gauges how much each interest rate contributes individually to the differential price discovery and how quickly deviations from their long-run equilibrium will be eliminated. A negative GG score means that an increase in the interest rate differential will initiate an adjustment in the market interest rate.

Figure 2.10. Dynamic Vector Error Correction Mechanism (VECM) (2,3) Estimation of the U.S. Fed Funds Rate and Market Rates—United States
(Coefficient value)



Source: IMF staff estimates.
Note: Sample time period: 1/31/1985–6/30/2008. VECM (2,3) eight-year rolling window estimation results of the cointegration coefficients (with 90 percent confidence band) denoting the long-term equilibrium relation between level changes in the effective U.S. Federal Funds rate and selected market rates of lenders and borrowers (with seasonal control). A coefficient value of "–1" indicates a stable long-term equilibrium relation of the policy rate and the selected market rate, whereas deviations from this value indicate a breakdown in the relation. The dates in the charts refer to the end dates of the rolling window. ABS = asset-backed security; MBS = mortgage-backed security.
[1]The error bands for the 3-month LIBOR rate are very tight (between 1.6 percent and 7.6 percent of the coefficient value) and have thus been suppressed from the figure for clarity.

GG scores (close to unity) suggest that (in this model specification) the policy rate almost always leads the market rate—a good indication of normal transmission processes.

Impact of Structural Changes in the Financial Sector on Interest Rate Transmission

Rolling window estimates of long-run pass-through (gauged by the cointegration factors) between market rates and policy rates show generally stable interest rate transmission for the three-month LIBOR and Euribor rates up to the summer of 2007 (Figures 2.10 and 2.11).[32] The absolute value of the cointegration coefficient is rarely less than one and varied considerably during the 1990s, but stabilized beginning in the early 2000s in both economies at the same time as these markets deepened. The estimated long-term interest rate pass-through for the near-bank U.S. agency mortgage-backed security (MBS) yield and the Pfandbriefe yield has stabilized beginning only in the early 2000s.

Not surprisingly, borrower financing rates generally have a less stable relationship with the policy rate. Mortgage rates have a cointegration factor lower than –1 for much of the period in both the United States and euro area, perhaps because banks feel the need to increase their lending rates more than the Fed Funds or EONIA rates to compensate for attracting a riskier class of borrowers. As expected, the long-term impact of policy rate changes is the weakest and least stable for high-yield corporate bonds.

Impact of Recent Market Disruption on Interest Rate Transmission

Market disruptions since the summer of 2007 appear to have been more severe for the United States compared with the euro area. In the United States, rolling window forecasts of the market rates based on the historical trend over the past 15 years are fairly accurate prior to the

[32]Rolling window regressions move the estimation period ahead by one month, allowing assessment of the stability of the estimated relations.

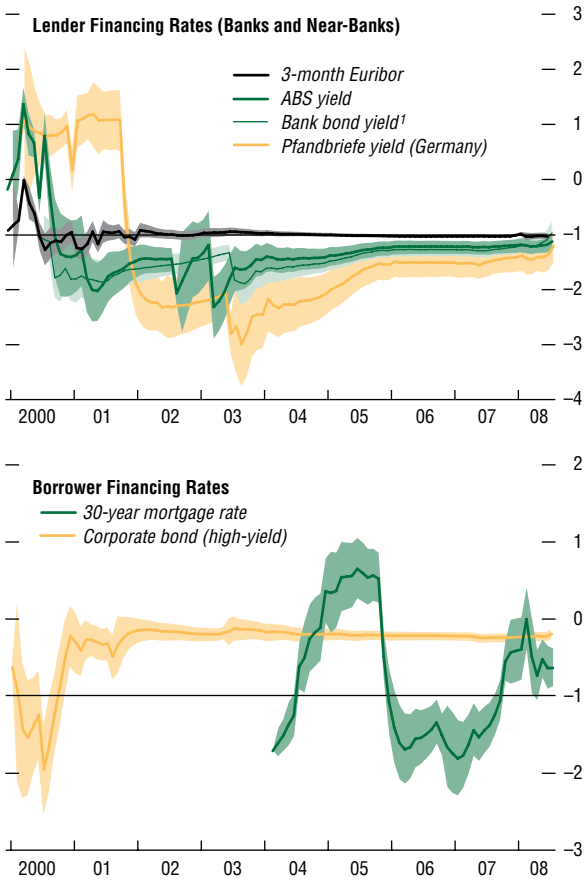
summer of 2007 (Figure 2.12).[33] However, from mid-2007 the forecast errors for the three-month LIBOR jumped substantially at the same time as the extraordinary increase in money market spreads and the collapse of the structured credit market in response to subprime mortgage market distress (Figure 2.13).[34] The larger forecast errors for the near-bank financing rates (ABS and U.S. agency MBS yields) and a widening of forecast confidence intervals after the summer of 2007 is evidence of a dramatic alteration in the predictability of interest rate transmission. These results suggest that the early linkages of interest rate transmission in the United States have been impeded by the financial turmoil. At the same time, forecasts of borrower financing rates have not been significantly altered to the same degree as lender financing markets thus far, but forecast accuracy appears to have decreased after the crisis.

Monetary transmission in the euro area appears to have suffered from a similar—but smaller—degree of uncertainty in the pass-through of policy rates to short-term lender financing rates (Figure 2.14). Similar to the United States, longer-term financing rates continue to show unstable forecasts, and deviations from actual rates reveal that policy rates have become disconnected over the past six months. The gradual movement of credit creation from near-banks back to banks does not seem to have, as yet, translated into significantly higher retail borrowing rates, perhaps reflecting the smaller role of near-banks in the euro area. The relatively reliable forecasts of mortgage rates may be due to euro area banks' lower dependence on money markets (as well as alternative sources of

[33]These forecasts are derived as out-of-sample estimates of the market rate in the next month based on the VECM model parameters over an eight-year (six-year) rolling window of preceding observations of U.S. (euro area) data.

[34]Note that the large over-prediction in January 2008 for the bank and near-bank financing rates in the United States is a result of the dramatic cut of the Fed Funds (target) rate from 4.25 to 3 percent and should be excluded from our general assessment of forecast accuracy.

Figure 2.11. Dynamic Vector Error Correction Mechanism (VECM) (2,3) Estimation of the EONIA Rate and Market Rates—Euro Area
(Coefficient value)

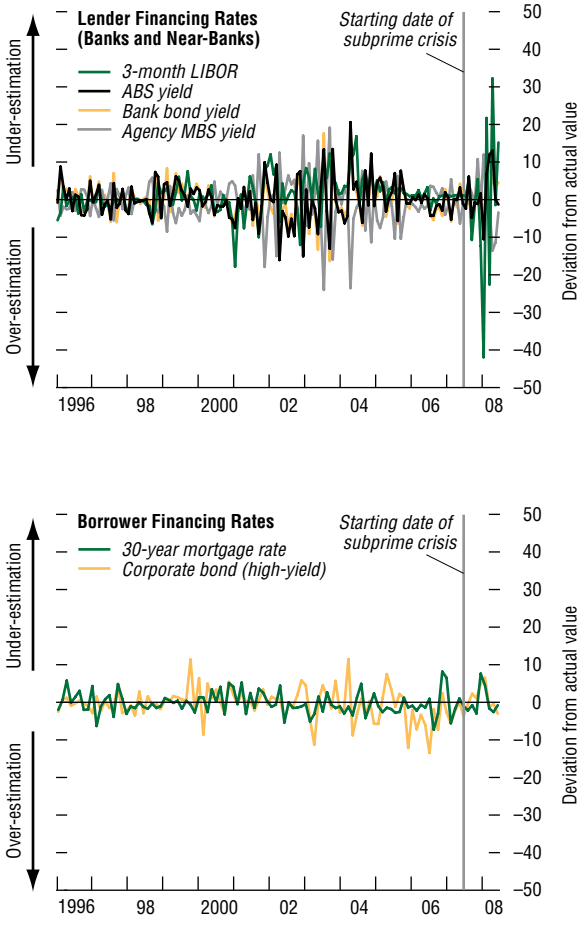


Source: IMF staff estimates.

Note: EONIA = Euro Overnight Index Average. Sample time period: 1/31/1985–6/30/2008. VECM (2,3) six-year rolling window estimation results of the cointegration coefficients (with 90 percent confidence band) denoting the long-term equilibrium relation between level changes in the effective European Central Bank policy rate (EONIA) and selected market rates of lenders and borrowers (with seasonal control). A coefficient value of "–1" indicates a stable long-term equilibrium relation of the policy rate and the selected market rate, whereas deviations from this value indicate a breakdown in the relation. The dates in the charts refer to the end dates of the rolling window. ABS = asset-backed security.

[1]The data series of bank of bank bond yields starts in June 1992.

Figure 2.12. Summary Chart: Accuracy of Forecasts—U.S. Model, 1996–2008
(In percent)



Source: IMF staff estimates.
Note: Forecast error represents deviation (in percent) of dynamic (out-of-sample) Vector Error Correction Mechanism (2,3) forecast estimate from actual market rates (based on eight-year rolling window, starting in January 1988). The estimation algorithm includes the change of core deposits of commercial banks as seasonal control variable. ABS = asset-backed security; MBS = mortgage-backed security.

funds via the covered mortgage bond market). Corporate bond yields are mostly underpredicted since the summer of 2007.

The relatively stable relationship between borrower financing rates and the Fed Funds rate should not be seen as evidence of unimpeded monetary transmission. First, separate regressions suggest that the sensitivity over the past 25 years of the mortgage rate to changes in the Fed Funds rates is largely explained by the indirect effect of policy rate changes operating through the LIBOR rate rather than by the direct effect of the policy rate on the mortgage rate.[35] Thus, the early linkages of interest rate transmission from the Fed Funds rate to the mortgage rate seem to be historically strong. By contrast, in the euro area, the indirect effect of the EONIA on the mortgage rate is much less apparent. Second, stricter overall lending standards as well as shrinking issuance in high-yield and structured credit markets indicate that lenders are tightening credit availability by adjusting quantities rather than prices. In this light, overall monetary transmission—including through channels other than interest rates—may be constrained.

Policy Recommendations

This chapter has shown that the persistence of disturbances in money and related financial markets that began in the summer of 2007 appears to be impeding interest rate transmission. The increased complexity, depth, and interconnectedness of these markets means that measures to help restore normal market conditions necessarily cover a wide policy spectrum. Below are recommendations aimed at alleviating the strains in U.S. and European interbank markets.

The following recommendations concern interbank rate setting and use:

[35]A three-equation model (not reported) of the mortgage interest rates was estimated including bank financing rates (LIBOR and the three-month Euribor, in addition to the policy rates).

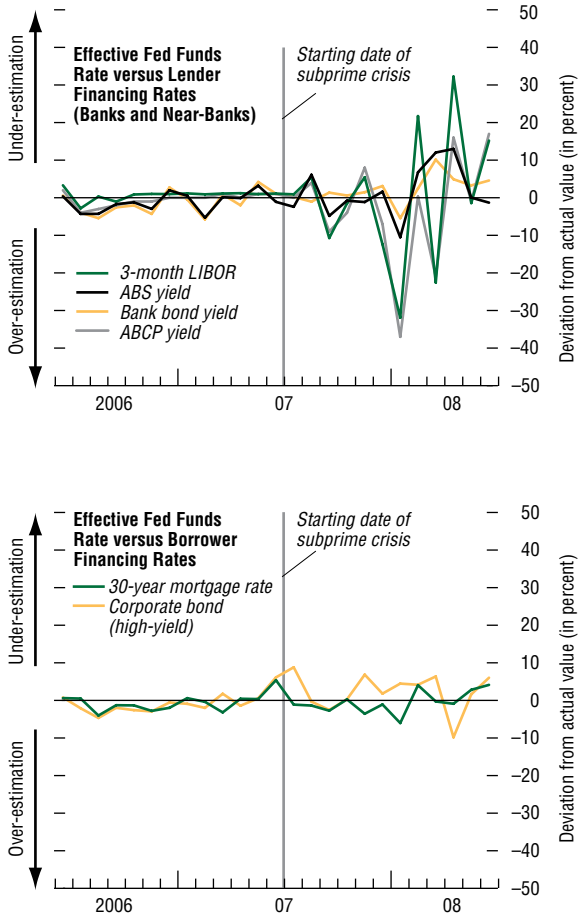
- *Improve infrastructure in funding markets.* Although transaction volumes in the London and euro area term interbank markets on which LIBOR and Euribor calculations are based have shrunk to negligible levels, they remain worthwhile measures of banks' marginal funding costs and there is no systematic evidence that published rates are biased. However, greater confidence in the representativeness of the calculated rates would be achieved by expanding their scope to encompass banks' unsecured term funding costs in wholesale money markets more generally, rather than just in the interbank market, and by publishing aggregate volume data.[36]
- *Allow markets to choose own benchmark.* Official policies to encourage a switch to the use of OIS rates, rather than LIBOR or Euribor rates, are not warranted. Although OIS rates are more representative of credit risk-free rates and the expected path of policy rates, shifting an estimated legacy of over $400 trillion notional outstanding of LIBOR-based instruments would be a daunting operational task. In addition, LIBOR remains the appropriate benchmark rate for contracts needing to reflect marginal bank funding costs. Hence, counterparties to interest rate derivatives should use whichever benchmark (LIBOR/Euribor or OIS) is most appropriate to their needs. While an active OIS market provides useful information about market expectations to policymakers, no formal policy action is justified.

The following recommendations are based on the empirical analysis of the factors driving interbank spreads:

- *Attention to both credit and liquidity strains.* Wide interbank spreads appear to have been primarily driven by systemic distress risk—a combination of credit and liquidity risk repre-

[36]The BBA has announced that it will be seeking to expand the number of banks it surveys for its rate fixings. The need for such expansion has been underscored since mid-September, when the spreads between various unsecured funding rates widened significantly.

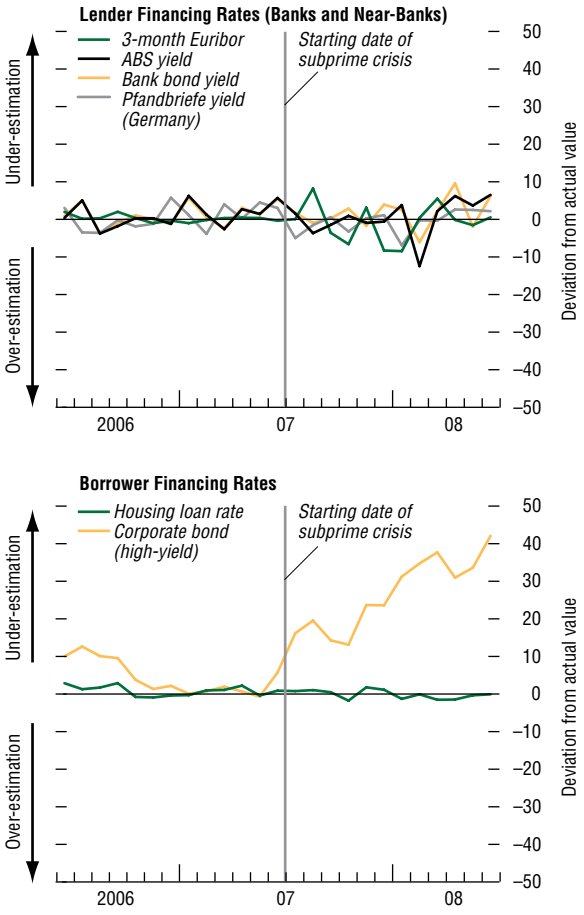
Figure 2.13. Summary Chart: Accuracy of Forecasts—U.S. Model, 2006–08
(In percent)



Source: IMF staff estimates.

Note: Forecast error represents deviation (in percent) of dynamic (out-of-sample) Vector Error Correction Mechanism (2,3) forecast estimate from actual market rates (based on eight-year rolling window, starting in May 1988). The estimation algorithm includes the change of core deposits of commercial banks as seasonal control variable. ABS = asset-backed security; ABCP = asset-backed commercial paper.

Figure 2.14. Summary Chart: Accuracy of Forecasts—Euro Area Model, 2006–08
(In percent)



Source: IMF staff estimates.
Note: Forecast error represents deviation (in percent) of dynamic (out-of-sample) Vector Error Correction Mechanism (2,3) forecast estimate from actual market rates (based on six-year rolling window, starting in May 1999). The estimation algorithm includes the change of core deposits of commercial banks as seasonal control variable. ABS = asset-backed security.

sented in an interdependent measure derived from CDS spreads of major banks. Hence, to relieve interbank funding stresses, policies should aim at jointly addressing credit and liquidity issues.

- *More transparency to remove uncertainty.* To this end, regulators and supervisors can facilitate the reduction in uncertainty surrounding the assessment of credit risk by market participants. For example, they could move to standardize and improve the disclosure of off-balance-sheet items; increase the transparency of the valuation of collateral; and require better disclosure of the maturity structure of liabilities and of the liquidity management practices of major financial institutions (IMF, 2008c). Although such steps would not remove counterparty credit concerns, they would help address some of the uncertainty about the health of some banks' balance sheets.

The severe alteration in the reliability of interest rate transmission during the past year, as evidenced by the empirical results for bank and near-bank financing rates, demonstrates the interconnections between the various financial market rates that serve as the early and middle linkages of monetary transmission. Policies to restore these linkages are complex and interconnected and encompass central bank liquidity management, financial institution and market oversight, systemic crisis management, the monetary policy framework, and even fiscal policy. In this light, the aims and instruments of policy measures should be specified as transparently as possible to foster effectiveness, accountability, and credibility.[37] Such policy measures include:

- *Indirect money market support.* The disturbances of markets in securities used as collateral—such as the GSE securities and ABS markets—can spread to the repo markets for which they serve as collateral. Thus, central banks should have a broad mandate and strategy to take measures to restore the functioning

[37]This discussion draws on Chailloux and others (2008), and IMF (2008e).

of markets indirectly necessary for smooth monetary transmission. In the United States, the Federal Reserve introduced the TAF (as well as other facilities, including the Term Securities Lending Facility [TSLF] and the Primary Dealer Credit Facility [PDCF]), which indirectly undertook significant market risk from $29 billion of securities owned by Bear Stearns, and was given the capacity to lend against collateral to the largest GSEs. The Special Liquidity Scheme announced by the Bank of England in April 2008 also serves as indirect money market support by exchanging treasury bills for other types of securities used as collateral.[38] Circumstances permitting, the design of such interventions should be considered ahead of time and incorporated into central bank contingency planning and crisis simulations. Clear exit criteria for extraordinary interventions should be in place to help address moral hazard and limit the degree to which intervention substitutes for regular market functioning in the long term.

- *Oversight of bank liquidity management.* The latest disruptions to interbank funding markets, and the resulting increased dependence on overnight and short-term liquidity, justify an escalation in the oversight of bank liquidity management. In particular, supervisors and central banks should ensure that stress testing is rigorous and includes scenarios involving sustained market-wide shocks and possible spillovers; that current elevated operational risks are being addressed; and that financial institutions' liquidity buffers and contingency plans are robust and comprehensive.[39] Access to emergency central bank liquidity facilities should be granted only in extreme scenarios to ensure that banks do not become overly dependent on central bank support during periods of liquidity stress.
- *Oversight of near-banks.* Actual and potential liquidity support to near-banks (primary dealers, GSEs) justifies stronger oversight of them by the central banks providing such liquidity. Efforts in this direction are under way, though in some cases assuring compliance with supervisory recommendations may entail legislative change. The U.S. Securities and Exchange Commission and the Federal Reserve recently agreed to a memorandum of understanding under which they will freely share information and analysis pertaining to the financial conditions of U.S. investment banks. Further, the Federal Reserve has been given a consultative role in the supervision of the housing GSEs. The U.K. Treasury proposed broadening the mandate of the Bank of England over systemic financial stability, including the establishment of a financial stability committee.
- *Central bank cooperation.* The importance of U.S. dollar liquidity pressures for Euribor spreads, suggested by the empirical results, highlights the global integration of funding markets and the importance for central banks of the spillover of shocks from one county to another. More frequent cooperation and communication between central banks, including information sharing, becomes ever more important in a crisis (see IMF, 2008c, Chapter 3).
- *Fiscal costs.* Central bank losses that could result from their absorption of credit risk in liquidity crises should ultimately be borne by the government to protect the balance sheet of the central bank, so reinforcing its independence while fostering transparency and political accountability for taxpayers' interests.[40] Crisis

[38]The TSLF, introduced in March 2008, involves the Federal Reserve swapping government securities with primary dealers for illiquid collateral-serving securities for extended periods. The PDCF, also announced in March 2008, gives primary dealers access to Fed discount window liquidity against a wide pool of collateral. The Special Liquidity Scheme announced by the Bank of England in April 2008 plays a role similar to that of the TSLF in exchanging risky collateral for government securities, but for terms of up to three years.

[39]Good practices for liquidity risk management are outlined in the *Principles of Liquidity Risk Management* published by the IIF (2007) and the draft of the *Principles for Sound Liquidity Risk Management and Supervision* of the Basel Committee on Banking Supervision (2008).

[40]For instance, there should be a mechanism to transfer the substantial credit risk incurred by the Federal

management can also be facilitated through close cooperation between the government's debt manager and the central bank if additional government collateral is required.

- *Communication*. During a period of stress, central banks need to provide more information about market conditions than in normal times, including details on monetary operations, to maintain functioning markets and to facilitate transmission. In particular, information may need to be delivered more frequently, including between regular meetings of the monetary policy committee. Separating measures aimed at price stability from those in support of market liquidity can be especially challenging when money market conditions are stressed but inflation is on the rise.[41] Further, there should be a more explicit discussion of the uncertainties pertaining to the impact of financial stress on monetary transmission in order to prepare the public and markets for unforeseen changes in the policy stance necessitated by systemic developments. Indeed, monetary policymakers should consider whether the market turbulence, and the resulting rise in the cost of bank capital, changes their estimation of the neutral policy rate.

Conclusions

Short-term funding markets in mature economies have been under stress for an extended period despite extraordinary policy interventions by central banks to widen the availability of secured liquidity. Although interbank lending is no longer the principal source of bank term funding, wide spreads are not simply arising from the method for calculating interbank rates and are principally driven by concerns about banks being in significant distress, with U.S. dollar liquidity strains also representing a significant factor in the euro money market. Further, evidence of disruptions to bank and near-bank financing markets indicates that the transmission of policy interest rate changes are less certain and reliable. Policy interventions to further broaden access to emergency liquidity may continue to contain systemic risks but are unlikely to resolve the crisis until broader policy measures are implemented.

Annex 2.1. Empirical Framework: The Causes of High Interbank Spreads[42]

This annex explains the variables used in the Structural Vector Autoregression (SVAR) model, which is used to estimate the components of the various LIBOR spreads, and the technical rationale for undertaking this modeling technique. The variable used in the SVAR model to proxy bank distress risk is relatively new and has been adapted to assess the joint risk of distress in a number of the banks included in the LIBOR and Euribor panels. The construction of this variable is described first, followed by the SVAR model.

Joint Probability of Distress

The measure of systemic distress risk used here is represented by the joint probability of distress (JPoD) of a group—portfolio—of systemically important banks. The JPoD represents the probability that all the banks in the group experience distress, and embeds banks' distress dependence. This is based on the fact that banks are usually connected—either directly, through the interbank deposit market and joint participation in syndicated loans, or indirectly, through lending to common sectors or engaging in similar proprietary trades. Banks' distress dependence tends to rise in times of stress, since the fortunes of banks decline concurrently through either spillovers and contagion after idiosyncratic shocks (direct links) or through negative systemic shocks (indirect links). Therefore, in

Reserve to support the Bear Stearns takeover to the U.S. Treasury.

[41]For the ECB, this challenge is discussed in González-Páramo (2007).

[42]See González-Hermosillo, Martin, and Segoviano (forthcoming) for a more detailed presentation of this framework.

such periods, the banking system's JPoD may experience larger and nonlinear increases than those experienced by the probabilities of distress (PoDs) of individual banks. Consequently, it becomes essential for the proper measurement of systemic distress risk to incorporate banks' distress dependence.

In modeling the JPoD, we follow Segoviano and Goodhart (2008). Thus, first, we conceptualize the banking system as a *portfolio* of banks. Then, we infer from credit default swap (CDS) spreads the PoDs of the individual banks comprising the portfolio. Subsequently, using such PoDs as inputs (exogenous variables), and employing a novel nonparametric methodology—the Consistent Information Multivariate Density Optimizing (CIMDO) methodology—we derive the banking system's multivariate density from which the JPoD is estimated.[43]

The banks' distress dependence embedded in the JPoD captures the linear (correlation) and nonlinear dependencies among the banks in the portfolio, and allows for these to change throughout the economic cycle. These are key advantages over traditional risk models, the majority of which incorporate only correlations, and assume them to be constant throughout the economic cycle.[44]

The Vector Autoregression Framework

A vector autoregression (VAR) framework was specified to decompose the variance of LIBOR spreads into the contributions of various factors characterizing the LIBOR market. In specifying the VAR, the factors are characterized to have General Autoregressive Conditional Heteroscedasticity (GARCH) volatility specifications to capture the empirically observed volatility in the spreads.[45] In identifying the structural shocks, two types of specifications are adopted: (1) a recursive identification; and (2) a structural VAR.

Model Specification

As previously discussed, the factors driving the movements in LIBOR spreads broadly encompass volatility, credit, and different types of liquidity risks, as well as idiosyncratic risk. Systemic distress risk is measured by the JPoD of the various groups of banks—effectively, portfolios of banks—participating in the setting of the LIBOR and Euribor rates.[46] Finally, the contribution of idiosyncratic shocks represents the residual part of the variance that is not explained by the other measures of risk.

In specifying the VAR, separate models are adopted for each of the three LIBOR spreads and Euribor spreads. The full set of seven variables, denoted by y_t below and associated with the LIBOR and Euribor spreads, is given in Table 2.4.

Consider the following dynamic structural model of y_t:

$$B_0 y_t = B_1 y_{t-1} + B_2 y_{t-2} + \ldots + B_k y_{t-k} + u_t, \qquad (1)$$

where the B_i $(i = 0,1,\ldots,k)$ are matrices of structural parameters with B_0 having coefficients of 1 down the main diagonal to represent the usual normalization, k represents the order of the

[43]The CIMDO methodology is a nonparametric approach to model densities based on cross-entropy (Segoviano, 2006).

[44]The distress dependence embedded in the JPoD is characterized by the CIMDO-copula (Segoviano, 2008). The structure of linear and nonlinear dependencies among the assets in a portfolio can be represented by copula functions. Our approach infers copulas directly from the joint movement of individual banks' PoDs. This is in comparison with traditional approaches, in which parametric copulas have to be chosen and calibrated explicitly—usually a difficult task, especially with limited available data.

[45]The adoption of a time-varying volatility structure means that the variance decompositions are no longer constant over the sample, but can change at each point in time as a result of changes in the conditional variance.

[46]The 16 banks participating in the British Bankers' Association's LIBOR fixings are listed at www.bba.org.uk, and the 43 banks in the Euribor panel are listed at www.euribor.org. For the Euribor panel, only 15 banks were considered for the construction of the JPoD due to constraints in the availability of CDS data.

Table 2.4. List of Variables Used in the Vector Autoregressions

Variable	U.S. Dollar LIBOR	Euro LIBOR	Sterling LIBOR	Euribor
Volatility_Market	VIX	VIX	VIX	VIX
Volatility_Interest Rates	Implied volatility from swaption	Implied volatility from swaption	Implied volatility from swaption	Implied volatility from swaption
Liquidity_Market	On/Off–the-run	On/Off-the-run	On/Off-the-run	On/Off-the-run
Liquidity_U.S. dollar	Euro/U.S. dollar forex swap	Euro/U.S. dollar forex swap	Pound sterling/ U.S. dollar forex swap	Euro/U.S. dollar forex swap
Interbank_Secured	Repo	Repo	Repo	Repo
Systemic Distress	JPoD (portfolio of banks setting the U.S. LIBOR)	JPoD (portfolio of banks setting the euro LIBOR)	JPoD (portfolio of banks setting the U.K. LIBOR)	JPoD (portfolio of banks setting the Euribor)
Interbank_Unsecured	LIBOR (U.S.)	LIBOR (Euro)	LIBOR (U.K.)	Euribor

Note: VIX = S&P 500 volatility index; JPoD = joint probability of distress; Euribor = Euro Interbank Offered Rate.

lags, and u_t is a vector of independent structural disturbances with the property

$$E[u_t] = 0,\ E[u_t u_t'] = H_t,\ E[u_t u_s'] = 0,\ t \neq s. \qquad (2)$$

The matrix H_t is a time-varying diagonal matrix where the diagonal terms have univariate GARCH (1,1) representations:

$$h_{i,t} = \delta_i + \alpha_i u_{i,t-1}^2 + \beta_i h_{i,t-1}. \qquad (3)$$

When embedded into the VAR, the GARCH variable framework implies that the variance-covariance matrix of the VAR disturbances is time-varying, but unlike the structural disturbances in equation (2), this matrix is not necessarily diagonal, in which case the volatilities of all factors have an effect on all variables in the VAR.

The model is estimated using maximum likelihood methods, by maximizing the conditional log-likelihood with respect to the unknown parameters $\{B_0, B_1,\ldots,B_k, \delta, \alpha, \beta\}$.

The dimension of the model is represented by N, where $N = 7$.

Recursive Identification

In identifying the structural shocks, first, a recursive identification is adopted. This is standard in the VAR literature. Let B_0 in equation (1) be lower triangular, in which case its inverse is also lower triangular and is given by:

$$L = B_0^{-1}. \qquad (4)$$

For the $N = 7$ variate model, L is represented as:

$$L = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ l_{2,1} & 1 & 0 & 0 & 0 & 0 & 0 \\ l_{3,1} & l_{3,2} & 1 & 0 & 0 & 0 & 0 \\ l_{4,1} & l_{4,2} & l_{4,3} & 1 & 0 & 0 & 0 \\ l_{5,1} & l_{5,2} & l_{5,3} & l_{5,4} & 1 & 0 & 0 \\ l_{6,1} & l_{6,2} & l_{6,3} & l_{6,4} & l_{6,5} & 1 & 0 \\ l_{7,1} & l_{7,2} & l_{7,3} & l_{7,4} & l_{7,5} & l_{7,6} & 1 \end{bmatrix} \qquad (5)$$

In choosing the ordering of the variables, the LIBOR is chosen last so that all factors have an instantaneous effect on the LIBOR, as given by the last rows in equation (5).

The ordering of the recursive identification is to a certain extent arbitrary.

Structural VAR

The full structural VAR is given by specifying the following restrictions given by the L matrix below.[47]

$$L = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{2,1} & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & a_{3,6} & 0 \\ 0 & 0 & a_{4,3} & 1 & 0 & a_{4,6} & 0 \\ 0 & 0 & 0 & 0 & 1 & a_{5,6} & 0 \\ 0 & 0 & 0 & 0 & a_{6,5} & 1 & 0 \\ a_{7,1} & a_{7,2} & a_{7,3} & a_{7,4} & a_{7,5} & a_{7,6} & 1 \end{bmatrix} \qquad (6)$$

[47]See Table 2.1 for the associated list of restrictions used in the structural VAR for each LIBOR and Euribor spread.

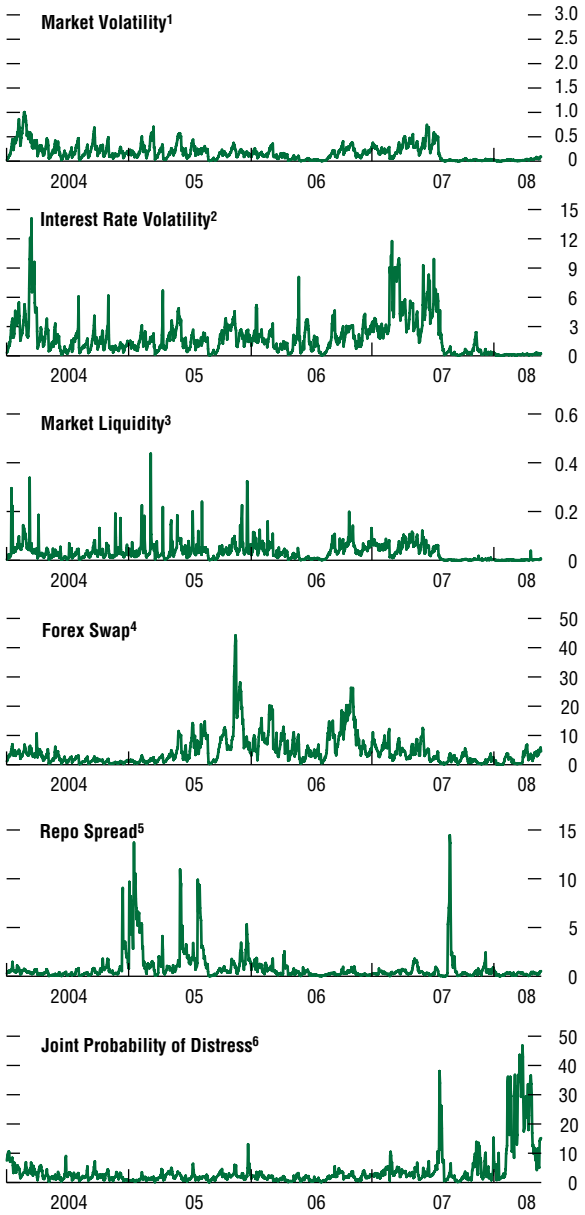
This suggests the following interpretations for the structural factors following Table 2.4. The volatility factor is assumed to affect VIX and Swaption. The volatility of interest rates factor hits the Swaption. The market liquidity factor affects the on-the-run/off-the-run treasury note spread and the forex swap. The U.S. dollar liquidity factor affects the forex swap. The credit factor impacts the Repo and JPoD variables. The distress factor affects the credit variables (Repo and JPoD) and the liquidity variables (on-the-run/off-the-run and forex swap). Finally, the idiosyncratic or residual factor only hits the LIBOR/Euribor and represents the effects not captured by the factors described above. Notice that all factors are designed to impact the LIBOR/Euribor, as given by the last row in the *L* matrix.

For example, the structural VAR results for the U.S. dollar LIBOR-overnight index swap (OIS) spread are depicted in more detail in Figure 2.15. The results suggest that the JPoD has been the dominant factor explained by the model since the onset of the current crisis, peaking at around 45 of the total variance in the spring of 2008. Interestingly, the first hump in the JPoD contribution occurred much earlier, in July 2007, when it contributed to more than 30 percent of the LIBOR-OIS variance. The role of the other variables has been relatively small during the crisis period. Notably, however, the repo spread began to show signs of stress in 2005 when the U.S. housing market began its recent downturn. In contrast with the Euribor fixing, the effect from the dollar/euro forex swap has been relatively small during the current crisis.

Annex 2.2. Empirical Framework: Monetary Transmission

As one measure of monetary policy transmission (and interest rate elasticity) over time, we adopt a restricted VAR framework in the form of a simple Vector Error Correction Mechanism (VECM). In general, the VECM specification defines the long-term consistency of joint dynamics of endogenous variables within

Figure 2.15. Decomposition of Spread Between Three-Month U.S. Dollar LIBOR and Overnight Index Swaps
(In percent)



Source: Bloomberg L.P.; and IMF staff estimates.
[1]Implied volatility from S&P 500 equity index.
[2]Lehman Brothers swaption volatility index. Implied volatility of interest rate swaption with maturities ranging from 1 month to 6 months.
[3]Five-year on-the-run/off-the-run U.S. treasury note spread.
[4]Spread between 3-month euro/U.S. dollar forex swap and 3-month U.S. overnight index swaps.
[5]Spread between the yields on 3-month U.S. agency repo and 3-month U.S. treasury repo.
[6]Joint probability of distress of selected banks participating in U.S. dollar LIBOR fixing.

a linear system of simultaneous equations. If the variables share at least one cointegration vector—which means that there is one long-term stable relation between them—we restrict their long-run behavior to converge to their cointegrating relationship while allowing the model to accommodate a wide range of short-term random disturbances (Johansen, 1991; Johansen and Juselius, 1990). The cointegration restriction shows the scale and direction of short-term adjustments needed to restore the long-term equilibrium relation.

The degree of cointegration is reflected in the specification of the error correction term, which is defined by past deviations from the long-run equilibrium through a series of partial short-run adjustments of level changes over the sample time period. These adjustments represent intertemporal corrections that indicate the short-term lead-lag relation of the endogenous variables.[48]

The VECM model used for this chapter defines the long-run intertemporal relation between the policy rate and selected market rates of lenders (banks and near-banks) and borrowers (households and nonfinancial corporates) in both the United States and the euro area. The model estimates show the direction of causality (and its significance) between changes in the policy rate and market rates over the short run and the nature of their long-term relation in response to unanticipated interest rate shocks.

For the United States, we pair the monthly average effective Fed Funds rate (as a proxy for the official policy rate, or "target rate") with several financing rates (e.g., three-month LIBOR rate for unsecured interbank lending, asset-backed commercial paper and certificate of deposit rates, and yields of either bank-issued bonds or asset-backed securities) and borrower rates (e.g., corporate bond yield, 30-year mortgage rate, and consumer loan rates). Analogously, for the euro area, the effective policy rate of the European Central Bank (ECB), the Euro Overnight Index Average (EONIA), is matched with market rates for both financiers and borrowers.[49]

The two-dimensional VECM model,

$$X_t, = C + \Lambda(\underbrace{i_t - \alpha - \beta_2 r_t}_{CE}) + \sum_{j=1}^{p} \Phi X_{t-j} + \Xi_t Z_t + E_t, \quad (7)$$

is specified with the endogenous data vector $X_t = (\Delta i_t, \Delta r_t)'$ consisting of the effective Fed Funds rate (or the EONIA rate for the euro area), i_t, and the selected end-of-month market interest rate, r_t, at first differences. All endogenous variables are cointegrated at the same order and are stationary in differences.[50] The endogenous variables have one cointegration equation at a statistical significance level below 5 percent according to the Unrestricted Cointegration Rank Test (MacKinnon, Haug, and Michelis, 1999). The model has a uniquely defined cointegration equation ordered such that the Fed Funds rate coefficient is set to one. The estimated parameter coefficients of short-term dynamics are represented by the (2 x 2) matrix Φ of jointly dependent past X_t values.[51] C is a (2 x 1) vector of constants c_1 and c_2. Ξ is the (2 x 1) parameter coefficient vector of the core deposit rate[52] as contemporaneous seasonal control variable. E_t is the (2 x 1) vector of non-

[48]For instance, an integrated variable, $I(1)$, is typically one exhibiting trending behavior, with a differenced series showing mean-reverting behavior.

[49]Instead of using the ECB interest rate on the main refinancing operations, which changes only infrequently, as the effective policy rate in the euro area, we used the EONIA, which is the interest rate the ECB tries to align with the rate of open market operations.

[50]The classical Augmented Dickey-Fuller (Dickey and Fuller, 1979, 1981) and Phillips-Perron (1988) unit root tests suggest that all endogenous variables are stochastic with a constant forecast value and time-varying autocovariance. Although the cointegration restriction of VECM does not require level stationarity of the constituent time series (unlike VAR), it implies difference stationarity of each time series regardless of the individual degree of integration.

[51]The simple lag structure has been optimized based on the Akaike criterion over all iterative estimation steps.

[52]The core deposit ratio is defined as the sum of checkable deposits and savings deposits held by banks in the United States/euro area as a share of total liabilities each month.

autoregressive and heteroscedastic normal i.i.d. residuals.

The cointegration equation (with rank order of one and constant drift) restricts the long-run behavior of the two level series of vector X_t to converge to a common, long-term trend subject to the short-term impact of interest rate shocks. The short-term adjustment factors λ_1 and λ_2 of (2 x 1) vector Λ correct these deviations against the long-term trend and indicate the short-term lead-lag relation of the endogenous variables. We compute the modified Gonzalo and Granger (GG) score $(\lambda_1 - \lambda_2)/(|\lambda_1| + |\lambda_2|)$(Jobst, 2006) as an indication of the direction of causality, with –1 implying that the Fed Funds rate (or the EONIA rate for the euro area) leads the market rate perfectly and +1 implying the reverse.

In the chapter, we focus primarily on the market rate equation of our VECM specification, where the contemporaneous monthly change of the selected market rate, r_t, is modeled as dependent on its previous changes, past changes of the policy rate, i_t, and any deviation from the long-run relation. The model is estimated both statically for nonoverlapping sample periods and dynamically over an eight-year rolling window with monthly updates based on a heteroscedasticity-consistent coefficient covariance matrix (White, 1980). There is a particular focus on the evolution of the cointegration coefficients. Over a relatively long span of data, Monte Carlo simulation of possible interest rate paths confirms that these coefficients can reasonably be interpreted as "long-term elasticities" of selected market rates to changes in the policy rate.[53]

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[53]We recognize that for short samples it is possible for cointegration analysis to indicate that a long-run relation can be found when in fact there is only a cyclical relation.

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