CHAPTER 3

# MARKET AND FUNDING ILLIQUIDITY: WHEN PRIVATE RISK BECOMES PUBLIC

*The latest episode of financial turbulence has been marked by an extended and unusual period of illiquidity. This chapter explores the interrelationship between market and funding liquidity, and the role played by central banks in providing liquidity, both by examining recent events and through econometric analyses. New transmission mechanisms across markets and countries are evident, in part related to the recent proliferation of illiquid, hard-to-value structured credit products. Central banks have played a positive role in easing funding liquidity strains, though some have needed to adapt their operational procedures to do so. A key finding is that the private sector has increasingly relied upon the public sector for protection against liquidity shocks. Both sectors now need to re-examine how systemic liquidity risk management can be improved. Some tentative policy directions are proposed.*

The market turbulence that began in July 2007 stemmed initially from credit prospects deteriorating in U.S. subprime mortgages, but quickly spread to other markets. Growing uncertainty surrounding the valuation of structured credit instruments affected their liquidity, leading to difficulties in the asset-backed commercial paper (ABCP) market, where these instruments were partly funded. Illiquidity spread to the broader money markets as concerns grew over the extent of bank on- and off-balance-sheet exposures to these instruments, requiring bank rescues and capital injections.

The speed and extent of the transition from "market" illiquidity to "funding" illiquidity, and their subsequent interaction, was remarkable and required unprecedented intervention by mature market central banks to meet banks' liquidity needs.[1] As a result, important questions arise concerning the extent to which new financial instruments have increased the financial system's vulnerability to liquidity events and the adequacy of the tools central banks have at their disposal to address such disruptions. The episode also has important implications for the clarity of central bank communications when balancing their responsibilities for formulating monetary policy and protecting financial stability.

This chapter examines recent events and makes some recommendations for the future. The concepts of market and funding liquidity that are relevant for understanding the episode are examined first, along with how banks have managed liquidity risks in recent months. The

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[1]Market "illiquidity" arises when asset positions that are normally traded in reasonable size with little price impact can only be transacted at a substantial premium/discount, if at all. The concept is asset-specific. Funding "illiquidity" occurs when solvent counterparties have difficulty borrowing immediate means of payment to meet liabilities falling due. This concept is institution-specific. The former concept is a market-wide occurrence, whereas the latter applies to individual institutions, although a number can be affected simultaneously.

various ways in which market and funding liquidity can interact to cause self-sustaining "liquidity spirals" is then explained, including why such spirals may have become more prevalent. The response of central banks to the liquidity crisis, as well as their ability to address such disruption, is discussed in light of their operational frameworks. An empirical analysis suggests that liquidity transmission has been a key element during this period of stress and provides some evidence that certain types of central bank support can reduce the elevated volatility associated with these events. After identifying ways in which liquidity management has been deficient during this episode, the chapter concludes by proposing a set of reforms and policies to address these issues.

## The Nature of Market Liquidity Risks

During the period of stress that began in July 2007, "market liquidity"—the ease with which one can liquidate a position in an asset without appreciably altering its price—fell dramatically for a wide range of assets, reflecting both the characteristics of the markets in which these assets traded, and their specific characteristics (Box 3.1). Secondary market liquidity became extremely thin, most notably in markets for structured credit products—where securities were highly tailored to the needs of specific investors and, for the most part, were meant to be held to maturity. Moreover, since most trading took place in over-the-counter (OTC) markets, price reporting and a common venue to connect a wide variety of buyers and sellers were absent.

In other cases, traders attempted to hedge positions, meet margin calls, or realize gains in other safer or more liquid markets, transmitting demand for liquidity and the resulting volatility more widely. This demand for market liquidity migrated to robust trading platforms and easily valued securities, such as some highly liquid U.S. equities and Treasury securities. Robust price discovery mechanisms and the knowledge that even large trade sizes would be less likely to move prices appreciably attracted participants.

Market liquidity is often hard to measure precisely (Sarr and Lybeck, 2002). The interpretation of typical measures, such as bid-ask spreads and volumes, is more difficult during stressful periods, since they also reflect volatility and credit risks. In this latest event, anecdotal evidence suggests that the increased uncertainty and volatility, and higher default risks of potential counterparties, made posted bid-ask spreads in many instruments unreliable, as no trading took place at those prices.

Although recent developments would seem to make a strong case for amending market risk management procedures to take into account liquidity risk, doing so in the future will be challenging. One approach is to add a measure of liquidity risk to the value-at-risk measure, but this has proved difficult, especially given the absence of satisfactory measures of liquidity even in normal times (Box 3.2). Thus, financial firms have tended to use ad hoc approaches to control market liquidity risk, making their responses to crises difficult to anticipate.

## Funding Liquidity Risks

Events since July 2007 have demonstrated that funding liquidity risk is intimately related to market liquidity, potentially causing systemic difficulties. Funding liquidity risk captures the inability of a financial intermediary to service its liabilities as they fall due. It is intrinsic to financial intermediation where liabilities of shorter maturity are issued to finance longer-maturity assets with the intention of earning a yield premium, and is particularly relevant to commercial banks, whose core business historically has been to fund longer-term loans through short-term deposits. Moreover, funding liquidity difficulties can quickly result in insolvency if an illiquid firm is forced to sell assets quickly at fire-sale prices to raise cash, so reducing its capital.

### Complexities in Liquidity Risk Management

Measurement of a bank's vulnerability to liquidity risk is inherently difficult. For instance, demand deposits are usually stable sources of funding, but can quickly be lost in a bank run. Conversely, banks

### Box 3.1. The Determinants of Market Liquidity

A market is considered liquid if an investor has the ability to buy or sell a reasonable amount of an asset without appreciably affecting the price. In practice, there are a number of contributing elements to market liquidity:

- ***Information.*** Liquidity is enhanced if information about the asset's value is distributed roughly evenly between intermediaries and potential buyers and sellers. Wide bid-ask spreads quoted by intermediaries can reflect concerns over asymmetric information.
- ***Intermediaries.*** The existence of intermediaries such as brokers, specialists, locals, or market-makers that can provide ongoing price quotes, maintain an inventory of the asset, and perform timely execution of trades will add to market liquidity.
- ***Underlying funding of intermediaries.*** Those acting as market intermediaries and carrying inventories can be constrained in providing liquidity by their own capitalization and their ability to finance their trading positions (see fuller discussion in text).
- ***Trading venue.*** How buyers and sellers congregate, physically or electronically, can also affect liquidity. Formal exchanges that have well-established methods of recording and publishing prices can preserve liquidity in stress circumstances better than over-the-counter (OTC) markets, where buyers and sellers must find one another to trade—often through brokers—and traded prices may not be widely available.[1]
- ***Type of asset.*** Customized credit derivatives and collateralized debt obligations that are highly tailored to meet specific investor needs in the primary market are often illiquid in secondary markets. An investor wishing to unwind or modify a position may have to rely on the initial arranger of the transaction, who may not be willing or able to provide liquidity under stressed market conditions, or may do so only at a significantly discounted price.
- ***Size of tradable issue.*** The larger the asset size freely available to trade, the more liquid the asset is likely to be.

[1]Not all OTC markets are less liquid. U.S. Treasury securities and wholesale foreign exchange markets, where par amounts and securities traded are quite standardized, are examples of highly liquid OTC markets.

perceived to be safer during crises may actually attract deposits from competitors (Gatev and Strahan, 2006). Similarly, the degree to which a bank's liquidity commitments may be called in a crisis is difficult to judge ex ante and can depend on firm-specific or systemic liquidity conditions, and on the perceived reputational risk of exercising them.

Given the inherent complexity of managing liquidity risk, bank regulators have adopted a diverse approach. For example, some countries maintain multiple metrics to gauge bank liquidity, although most impose some type of minimum liquidity requirement (Box 3.3). Banks and regulators can legitimately differ over how long they believe that a bank should be able to rely on internal sources to meet its cash flow commitments. The longer a bank must be able to survive on its own, the more liquid assets it needs to hold, and the less efficient the banking system will be in providing maturity transformation services to the economy. Moreover, the systemic nature of much liquidity risk, and its "jump-to-crisis" fat-tailed distribution, also makes it very difficult to model funding liquidity risks so as to translate a given liquidity structure into a probability of default. Hence, banking regulators have yet to develop a liquidity equivalent to minimum capital requirements and have increasingly focused on the integrity of liquidity risk-management systems rather than specific liquidity ratios.

## Recent Trends in Banks' Liquidity Management: Undervaluing Access to Liquidity?

The trend among major global banks has been toward greater reliance on wholesale mar-

### Box 3.2. Liquidity-Adjusted Value-at-Risk: At the Forefront of Market Liquidity Risk Management?

Value-at-risk (VaR) measures have become a standard metric for assessing and managing market and credit risks (IMF, 2007). Standard VaRs are calculated by taking the mid-market prices of positions over a one-day time horizon—assuming positions can be closed out at such prices within a day. Consequently, asset liquidity risk is subsumed into market risk assuming normal market conditions.

For market positions where this was unlikely to be the case, "liquidity-adjusted" VaRs (L-VaRs) were conceived in the late 1990s to adjust for the likely liquidity of market positions. The L-VaR represents the maximum loss that could be incurred with a given probability if a position was closed out in alternative market circumstances.

There are several ways in which liquidity adjustments can be made to a VaR calculation (Bervas, 2006). At their simplest, they lengthen the assumed VaR holding period (e.g., to 10 days) to account for the longer period taken to close a position in less liquid markets, resulting in substantially higher L-VaRs and a very different ranking of position risk (Joint Forum, 2001, pp. 25–26).

Despite early progress, L-VaR measures have not become widespread due to:

- ***Data unavailability***. Market data on bid-ask spreads and turnover are not readily available, especially in over-the-counter markets.
- ***Methodological uncertainty.*** There is no agreed-upon standard way to calculate an L-VaR, even when bid-offer spread and turnover data are readily available.
- ***Rare but extreme nature of liquidity crises.*** Liquidity crises are extreme events that can only be accommodated through a "fat tail" and skewed probability distribution, as episodes of market illiquidity often coincide with declining fundamental asset values. VaR typically underestimates risks during systemic shocks. Also, at such times, counterparty risk usually rises and the gross, rather than hedged, trading position is at risk. Hence, an L-VaR will still underestimate exposures in a market liquidity shock.

In addition, systemic concerns would arise if L-VaR usage were to become widespread. For instance, a destabilizing feedback mechanism could develop if L-VaRs are used to set risk limits for traders or positions. If these reflect the latest market data, then a liquidity shock—manifested through a sharp increase in volatility, bid-ask spread widening, or a collapse in turnover—would raise the L-VaR and signal a reduction in position for a given risk appetite. If followed, this could raise volatility, search times, and L-VaRs, resulting in a vicious circle.[1]

[1]See Garleanu and Pedersen (2007). Chapter 2 of IMF (2007) describes how a similar mechanism can arise with standard VaR-based risk management.

ket sources of funding and a reduction in liquid asset ratios.[2] Notably, instead of retail deposits, banks are increasingly relying on interbank borrowing, short- and long-term debt (including securitized or collateralized funding), or the sale of marketable securities.[3]

[2]Cross-country time series data on bank liquidity ratios are difficult to compile due to differences in definitions, merger and acquisition activity, and database limitations. Figure 3.1 gives a cross-country comparison of deposit-to-asset ratios for the largest commercial banks from 2004 to 2006. Most display a slight fall in deposit ratios, with the exceptions of Belgium, Switzerland, and France. Japanese banks remain the most dependent on retail funding. Box 1.3 in Chapter 1 illustrates the recent decline in deposit-to-asset ratios of the 10 largest publicly quoted banks in Europe and the United States.

[3]Bradley and Shibut (2006) document how overall U.S. bank deposit liabilities fell from 93 percent of total liabilities in 1965 to stabilize at around 60 percent since 2000. The European Central Bank (2006) shows that the largest 500 European banks are becoming increasingly dependent on money market funding sources, although reliance on retail deposits has remained stable since 2000.

### Box 3.3. Standard Ways to Measure and Control Bank Liquidity Risks

Banks and regulators have devised a number of ways to quantify and manage the varied dimensions of funding liquidity risk. These include:

- ***Reserve requirements.*** These can include minimum holdings of physical cash, deposits at the central bank, and securities for use as collateral in central bank monetary operations.
- ***Liquidity ratios.*** Measures of liquid asset holdings relative to total assets or short-term liabilities.
- ***The degree of asset and liability cash flow mismatch.*** Projected payment inflows and outflows are placed into maturity brackets and limits are placed on the degree of mismatch. This can also be calculated by currency denomination and different parts of the bank's business.
- ***The degrees of diversification*** of borrowing facilities and contingent loan commitments.[1] These reduce a bank's dependence on borrowing from, or the potential requirement to lend to, any single counterparty.

In addition, banks protect themselves against liquidity risk by:

- Limiting the liquidity options that they implicitly write (e.g., deposit withdrawal maxima and notice periods on time deposits);
- Acquiring contingent credit facilities from banks and other lenders;
- Holding high-quality securities that can be borrowed against, or sold, quickly; and
- Gaining access to central bank liquidity facilities (given collateral of sufficient quality) either through standing monetary policy operations or emergency facilities.

[1]For a fee and/or a yield premium, banks and insurance companies commit to lend or contribute capital to another bank or client. In a systemic liquidity crisis, these commitments are more likely to be called on, making a bank's own liquidity position less certain. Conversely, smaller banks often make such arrangements with larger money center banks that have a wider range of liquidity sources. Such interlocking liquidity commitments increase banks' exposure to systemic risk (Gatev, Schuermann, and Strahan, 2006).

This trend has tended to raise funding liquidity risks. In principle, liquidity vulnerabilities could be reduced by issuing long-term notes, asset-backed securities (ABS), or covered bonds to match the associated asset's maturity, or by transfering its cash flows completely off balance sheet. However, in practice, much wholesale funding has been concentrated at shorter maturities requiring regular refinancing. Additionally, the maturity mismatch of a number of U.S. and European banks significantly increased as a result of the growth of off-balance-sheet bank conduits and structured investment vehicles (SIVs). These have held potentially illiquid longer-term securities, funded primarily through short-term ABCP and notes, sometimes without adequate capital charges to account for banks' contingent liquidity commitments.

Banks have an automatic incentive to economize on protection against funding liquidity risk. The higher return generally expected from longer maturity assets, the low frequency and systemic nature of liquidity crises combined with the limited liability of stockholders, deposit insurance, and the likelihood of central bank emergency operations, all encourage individual banks to underinsure against liquidity risk by holding insufficient liquid assets or liquidity facilities. This tendency explains prudential norms requiring minimum liquid-asset holdings and reserve requirements.

In an effort to raise the standards of bank liquidity risk management, the Institute of International Finance (IIF) published its *Principles of Liquidity Risk Management* in March 2007, which proved prescient in a number of respects (Box 3.4). The discussion appropriately high-

lighted the fact that standards of liquidity risk management and disclosure needed improvement, while raising concerns over the potential illiquidity of structured products and the growing reliance of firms on securitization and off-balance-sheet entities (e.g., conduits).

Subsequent events have shown where the IIF recommendations could have been taken further. In particular, the potential duration of a market stress event was underemphasized, while higher minimum holdings of cash assets by all firms would have eased systemic counterparty concerns.

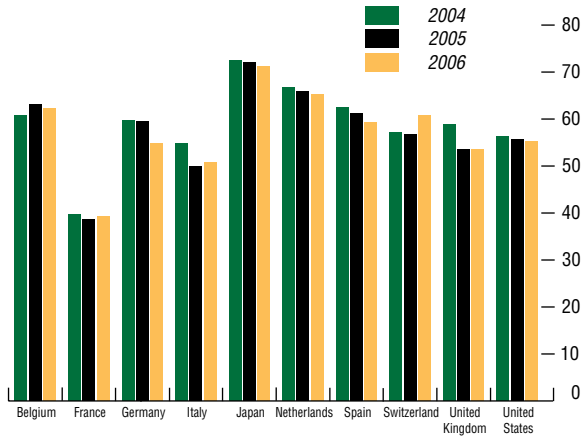
## Observations on Funding Liquidity Arising from Recent Events

Events since July 2007 have revealed weaknesses in funding liquidity management. First, banks tended to hoard liquidity during the period of systemic stress. This resulted from uncertainty over whether contingent loan facilities would be called, as well as concerns that loans in the securitization pipeline would need to be retained on balance sheets, and over counterparty credit risk.

Second, liquidity-stressed banks were reluctant to use central bank standing facilities or the discount window for reputational reasons. Instead, some banks relied on more expensive backup facilities or nontraditional sources of funding.[4]

Third, commercial and investment banks that relied on securitized and wholesale markets to fund their mortgage and corporate lending quickly became unable to dispose of their warehoused loans. This prompted the need for emergency assistance where contingent liquidity lines were inadequate (Northern Rock) or an

**Figure 3.1. Commercial Banks: Deposit-to-Asset Ratios**
*(In percent)*




Sources: ©2003 Bureau van Dijk Electronic Publishing-Bankscope; and bank annual reports.
Note: Asset-weighted deposit-to-asset ratios of banks with the equivalent of at least $200 billion of assets in 2006.

[4]For instance, Countrywide Financial called on its $11.5 billion of liquidity facilities in September 2007 and borrowed a further $22 billion from the Federal Home Loan Bank (FHLB) system during the third quarter of 2007. The $184 billion, or 29 percent, increase in FHLB advances in the third quarter of 2007 was funded primarily by an increase in discount notes (Federal Home Loan Banks, 2007; Bech, 2007).

### Box 3.4. Institute of International Finance Principles of Liquidity Risk Management

The Institute of International Finance published 44 recommendations as part of its *Principles of Liquidity Risk Management* in March 2007. The work constitutes a principles-based approach with which firms can comply, or explain why they have chosen not to. Throughout, the wide diversity of banks' approaches is recognized, reflecting different business models and circumstances. Few, if any, firms met all recommendations.

The principles focus on four areas where acceptable practice is defined:

- ***Governance and organization:*** Firms should define their liquidity risk appetite and publish their framework for controlling risk within those limits. The board of directors should have systems to monitor liquidity requirements and manage risk across subsidiaries and jurisdictions, consistent with the specified appetite.
- ***Measurement and control of liquidity risk:*** There is no single funding liquidity statistic that captures all aspects of a firm's risk, so a suite of measures is appropriate. Firms should develop diverse funding sources appropriate to their business model, have a range of assets against which they can borrow, and carefully model the retention of deposits and triggering of liquidity commitments.
- ***Stress testing:*** Liquidity needs should be modeled over a range of both firm-specific and market-wide stress events. When a reasonable stress test indicates a shortage of liquidity for the firm's risk appetite, business operations should be modified to address it.
- ***Contingency planning:*** Firms should maintain a minimum cushion of highly liquid assets and other contingency plans to prevent the escalation of liquidity concerns. Firms should not excessively rely on backup borrowing facilities in a crisis due to possible credit concerns from their counterparties. A firm may factor in the use of central bank emergency lending facilities to be used only in extreme circumstances.

The principles then derive implications for the official sector. In particular, the imposition of simple minimum liquidity requirements is rejected and national regulators are urged to assess a firm's cross-border liquidity management on a consolidated basis wherever possible. The principles call on central banks to expand and harmonize the pool of acceptable collateral, including less liquid securities, and provide greater clarity ex ante over their role and operating procedures as lenders of last resort.

The principles highlight two recent trends that add complexity to liquidity risk management:

- ***Increasing reliance on secured funding and securitization.*** Securities firms and large banks now rely on the ability to repo or securitize collateral and loans to manage liquidity, either to the market or central banks. Firms need to carefully consider the "haircuts" and discounts they charge others on such assets in normal and crisis conditions and the robustness of repo facilities.
- ***Complex financial instruments.*** Recording all the liquidity implications and contingent risks embedded in bespoke derivatives is now extremely complex; firms should not assume that even highly rated structured products will remain liquid in a crisis—the very opposite is possible due to their complexity; and the increasing use of off-balance-sheet conduits with contingent liquidity commitments from parent institutions means that greater attention needs to be paid to meeting these commitments in stress scenarios.

unanticipated expansion of balance sheets (e.g., holding of leveraged loans on the balance sheet).

Fourth, in one case, deposit insurance proved insufficient to prevent a retail deposit run. With regard to Northern Rock, the level of UK deposit insurance and the costs involved in gaining access to deposits gave retail depositors an incentive to run against an apparently solvent institution—a tendency encouraged by the ease of Internet withdrawals.

Fifth, disruption in the foreign-currency swaps market resulted in cross-border banks having some difficulty matching their available liquidity to meet payment requirements in specific

currencies. To ease cross-currency payment difficulties, the Federal Reserve (Fed), European Central Bank (ECB), and Swiss National Bank announced the use of their cross-currency swap facility in December 2007.

## Market and Funding Liquidity Dynamics

Recent events have highlighted anew the close interrelationship between market and funding liquidity. This section describes how this interconnectedness amplified market stress during the 2007 crisis and argues that this tendency seems to have become more pervasive.

### Mutual Reinforcement

The recent episode illustrates how shocks to funding liquidity can lead to runs on markets, and thus market illiquidity (Bernardo and Welch, 2004). Runs on markets can occur when there is an increased likelihood of a deterioration in funding conditions, leading to a simultaneous attempt to sell assets by a number of investors. Faced with the decision to sell immediately or wait, speculative investors have to take into account that they could be hit by an unexpected need to sell before asset values recover from fire-sale conditions. The risk of eventual forced selling at a lower price causes a rush to the exit.

The intensity of such an event will depend on several factors:

- ***Market-makers' absorptive capacity.*** Market runs become more likely as market-makers face limits to their capacity to absorb short-run pressures on prices through inventory adjustment. Market-makers' absorptive capacity, in turn, depends on the cost of funding their inventory, internal capital limits, and the presence of unconstrained speculative investors.[5]
- ***The trading venue.*** Some trading venues are more prone to market runs because they are less likely to ensure an orderly sequence of transactions. The uncertainty over one's "position" in the queue and the lesser ability to find the opposite side of the trade, as in many OTC markets, can greatly intensify the link from funding to market illiquidity.
- ***Direct links between funding instruments.*** Stress in specific funding markets may directly spill over to market illiquidity in related areas when the operations of financial intermediaries span multiple markets. In late 2007, European banks had difficulty obtaining dollar funding through foreign currency swaps, as the liquidity in underlying money markets dried up due to concerns over counterparty credit risk (Chavez-Dreyfuss, 2007).

Just as a lack of funding liquidity can impair smooth market functioning, market illiquidity can cause funding strains. Market illiquidity can severely impair a firm's ability to service its liabilities as they fall due by making it costly to liquefy existing assets through outright sales or repos; by making new funding sources inaccessible; by reducing a firm's perceived capital or the value of collateral against which it can borrow; and by raising general concerns over counterparty risk. These interactions became more important as the 2007 episode intensified, and operate through a variety of channels:

- ***Margin requirements.*** For speculative investors, margin requirements are sensitive to market liquidity. Larger price swings associated with market illiquidity lead to a re-assessment of volatility, feeding through to higher margin requirements and thus limiting speculative investors' leverage by inhibiting their ability to borrow. Such "margin spirals" were particularly visible in the subprime mortgage ABS market during the events surrounding the liquidation of hedge funds related to Bear Stearns Asset Management in July 2007 and other structured credit hedge funds in early 2008 (IMF, 2007, Chapter 1).
- ***Internal risk limits.*** For market-makers, funding constraints can result from internal risk

[5]More technically, it is the presence of time lags between the exit of market participants that face liquidity shocks and the entry of new market-making capacity that creates an incentive to run immediately.

limits, as decreasing market liquidity is often associated with a rise in volatility. This feeds through risk management systems to reduce risk capital allocated to market-making inventory and the ability to underwrite primary issues (e.g., the U.S. municipal bond market in early 2008).[6]

- ***Reduced market volume.*** As revenues from trading and market-making activities decline, a reduction in market volume limits the inflow of funding to investment banks and their ability to take risk.
- ***Trading losses.*** Trading losses associated with lower market liquidity may constrict an entity's ability to raise new funds through equity and debt markets.
- ***Inability to value assets.*** As clearly illustrated by the events surrounding the onset of the turmoil in July 2007, a lack of market liquidity can hamper asset valuations (see Chapter 2), inducing financial institutions to refuse to provide funding to each other due to concerns over counterparty credit risk. On August 9, 2007, the French bank BNP-Paribas announced that it would freeze withdrawals from three of its investment funds, stating that illiquidity in the respective markets prevented it from valuing assets.[7] Prompted by the announcement, financial institutions—particularly money market funds fearful of a sharp increase in redemptions—started to hoard term liquidity simultaneously, causing gridlock in funding markets.

As funding liquidity risk feeds market illiquidity and vice versa, mutually reinforcing dynamics, or "liquidity spirals," can emerge (Brunnermeier and Pedersen, forthcoming). As shocks to funding liquidity reduce the availability of funds to take positions, fire sales of assets contribute to market illiquidity, feeding back into funding liquidity, and so forth. Most importantly, liquidity dynamics may increasingly impact correlations between different assets—as increased margin calls in illiquid markets are met by sales of more liquid assets—potentially leading to similar dynamics in other markets (see the empirical section below).

[6]See Caballero and Krishnamurthy (2007). See Chapter 2 of IMF (2007) for a more general discussion of amplification effects resulting from internal risk limits.

[7]In its statement, the bank said: "The complete evaporation of liquidity in certain market segments of the U.S. securitization market has made it impossible to value certain assets fairly regardless of their quality or credit rating."

## Have Liquidity Spirals Become More Pervasive?

Have recent structural changes in financial systems made liquidity spirals more pervasive? Or at least do they change the nature of the underlying dynamics? Although the first question is difficult to answer, a number of factors suggest that this is so.[8] The changing dynamics can be seen in the following developments:

- The long-term shift from largely relationship-based toward more transactions-based business models resulting from the growth in securitized lending and credit risk transfer mechanisms. This has reduced the illiquidity of banks' asset holdings on average, but made access to liquidity more dependent on market conditions. In addition, it has increased the system's dependence on loan originators and securitizers who may not have direct access to central bank liquidity facilities.
- The emergence of new complex instruments that are difficult to value and appear prone to illiquidity in times of stress.
- The increasing dependence of market liquidity on hedge fund activity. While hedge funds have added generally to market liquidity, their increasing importance means that overall market liquidity often relies on their ability to leverage themselves, which is in turn affected by market volatility determining margining requirements.
- The low interest rate and favorable macroeconomic environment that spurred a

[8] In Persaud (2003), several contributors argue that adverse liquidity dynamics indeed have become more pervasive, and provide suggestive evidence to support this claim.

heightened risk appetite. This generated demand for more complex, higher-yielding assets without sufficient attention being paid to either the absorptive capacity of investors over the cycle, or the ways in which market participants can increase leverage using new and more opaque methods.

- The provision of emergency liquidity support, which remains tied to national currencies and payment systems, has not kept pace with the internationalization of financial institutions' treasury operations.
- The increasing importance of mark-to-market accounting, which has the potential to magnify liquidity dynamics through a variety of channels, including internal or external solvency constraints or risk limits that depend on the market value of assets (see Chapter 2).
- The increasing reliance on quantitative trading and risk management techniques, which often rely on a continuous availability of market liquidity. These may also have made the system vulnerable, since common responses to model signals can induce trading desks to withdraw simultaneously from certain markets.[9]

## Liquidity Dynamics Since July 2007: An Empirical Investigation

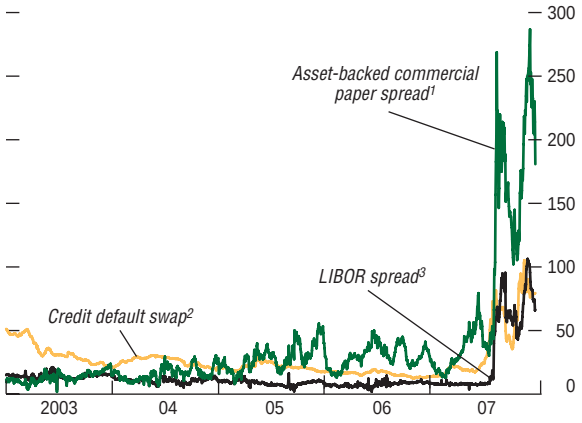
Having reviewed how market and funding liquidity can interact to cause systemic difficulties, we examine empirically how liquidity shocks were actually transmitted across financial markets and national boundaries during the 2007 crisis.[10]

In a first step, a parsimonious Generalized Autoregressive Conditional Heteroscedastic-

[9]An example of such dynamics was the behavior of so-called "quant" funds—hedge funds whose trading and investment strategies are tied to various quantitative models of market price behavior. In August 2007, as these funds attempted to hold on to their core strategies, they started liquidating assets in similar markets, collectively causing a transmission of market stress. See Khandani and Lo (2007).

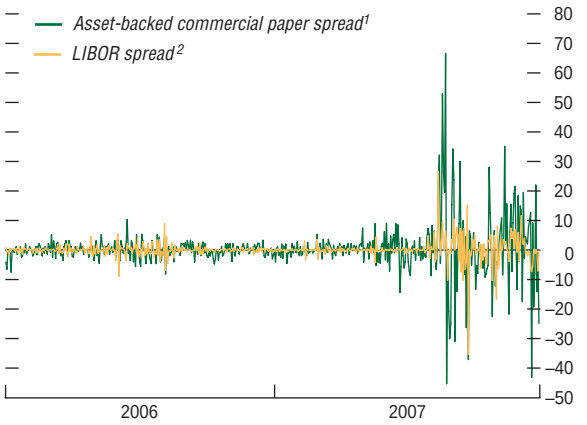
[10]See Annex 3.1 for technical details of the empirical analysis.

**Figure 3.2. Aggregate Bank Credit Default Swap Rate and Selected Spreads**
*(In basis points)*



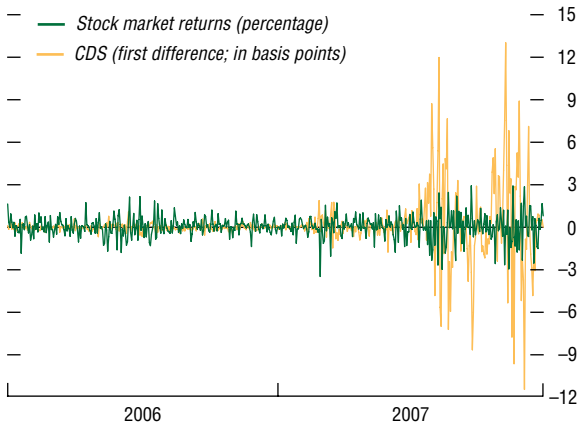

Sources: Bloomberg L.P.; and IMF staff estimates.
[1]Spread between yields on 90-day U.S. asset-backed commercial paper and on three-month U.S. Treasury bills.
[2]The unweighted daily average of the five-year credit default swaps for the following institutions: Morgan Stanley, Merrill Lynch, Goldman Sachs, Lehman Brothers, JPMorgan, Deutsche Bank, Bank of America, Citigroup, Barclays, Credit Suisse, UBS, and Bear Stearns.
[3]Spread between yields on three-month U.S. LIBOR and on the three-month U.S. overnight index swap.

**Figure 3.3. United States: Selected Money Market Spreads**
*(First difference; in basis points)*




Sources: Bloomberg L.P.; and IMF staff estimates.
[1]Spread between yields on 90-day U.S. asset-backed commerical paper and on three-month U.S. Treasury bills.
[2]Spread between yields on three-month U.S. dollar LIBOR and on the three-month U.S. dollar overnight index swap.

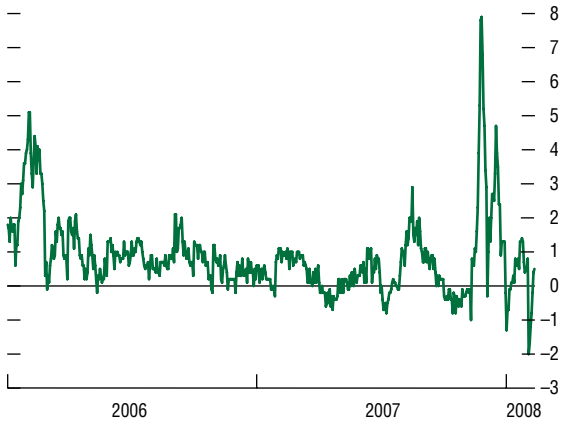
### Figure 3.4. United States: S&P 500 Stock Market Returns and Aggregate Bank Credit Default Swap (CDS) Rate




Sources: Bloomberg L.P.; and IMF staff estimates.
Note: CDS is calculated as an unweighted daily average of the five-year credit default swaps for the following institutions: Morgan Stanley, Merrill Lynch, Goldman Sachs, Lehman Brothers, JPMorgan, Deutsche Bank, Bank of America, Citigroup, Barclays, Credit Suisse, UBS, and Bear Stearns.

### Figure 3.5. On-the-Run/Off-the-Run Five-Year U.S. Treasury Note Spread

*(In basis points)*




Source: Bloomberg L.P.
Note: Spread between yields on five-year off-the-run and on-the-run U.S. Treasury notes.

ity (GARCH) model is developed to analyze potential transmission channels in U.S. financial markets, where the shocks originated. While the shocks derived from the subprime mortgage market, they were readily transmitted to the ABCP market, where funding liquidity pressures for SIVs and conduits developed. This ABCP link is measured by the spread between three-month ABCP rates and U.S. Treasury bill yields (Figure 3.2). Banks came under pressure to fund their sponsored SIVs and conduits, and they too faced funding liquidity pressures. This is captured by the spread between the three-month U.S. interbank LIBOR rate and the overnight index swap (OIS) rate (Figure 3.3). Amid higher uncertainty, market volatility increased (Figure 3.4) and investors shifted their positions to a highly liquid asset class (Figure 3.5). These risks are proxied by the S&P 500 index return and the five-year on-the-run versus off-the-run U.S. Treasury yield spread, respectively. Finally, the cost of insurance against default, measured by credit default swap spreads, of representative large complex financial institutions proxies for solvency risk (Figure 3.4). Thus, five variables are assumed to capture the key links that created systemic risks in financial markets.

The model is estimated in first differences using a Dynamic Conditional Correlation (DCC) GARCH model for the period from January 3, 2006 to December 24, 2007. The main findings are:

- A clear break in the time-varying correlation structure of the variables occurs at the end of July 2007, consistent with the onset of the financial turbulence (Figure 3.6).
- Measures of market and bank funding illiquidity become strongly intertwined during the crisis. Moreover, the underlying dynamics are characterized by strong correlation shifts over the crisis period. While average correlations after July do not increase markedly, two extreme jumps in the correlation measure are observed in August and toward the end of the year (Figure 3.6).
- Whereas solvency measures were relatively unconnected to other variables before the

subprime crisis, all liquidity-related variables become closely associated with market perceptions of insolvency risk.

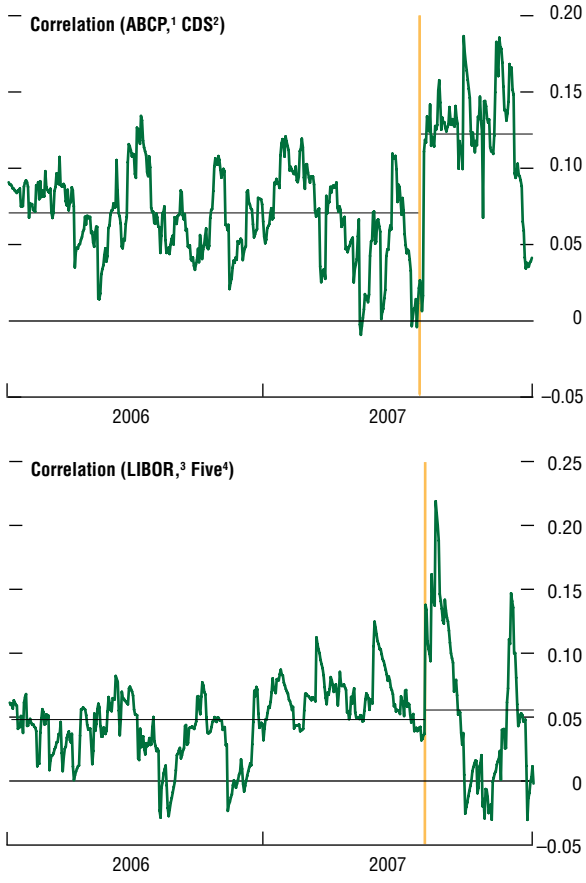
In a second step, the U.S. model is also extended to examine spillovers between U.S. and international money markets by adding similar funding spreads (LIBOR less the associated OIS rate) in Canada, the euro area, and the United Kingdom. The empirical results indicate that:

- The correlations between the U.S. funding liquidity measures (the ABCP and LIBOR spread), and the international LIBOR spreads in Canada, the euro area, and the United Kingdom are of relatively small magnitude and fairly stable before the subprime crisis. In contrast, correlations increase sharply during the crisis period (Figure 3.7).
- The correlation between international spreads and the U.S. LIBOR is more pronounced than the correlation between international spreads and the U.S. Treasury five-year on-the-run spread, suggesting that funding, more than market, illiquidity has been the important mode of transmission (Figure 3.7).
- Unlike the pre-crisis period, where interactions among the Canadian, euro area, and UK LIBOR spreads were limited, correlations rise sharply during the crisis period.

In a final step, the international model for advanced economies is extended to include some key emerging markets. Specifically, two measures of U.S. funding liquidity (one for the interbank money market and the other for funding liquidity in the ABCP market), as well as the five-year on-the-run spread measure of U.S. market liquidity, are linked to sovereign bond spreads and stock market returns in Brazil, Mexico, and Russia. The results indicate that:

- During the subprime crisis, a heightened interaction between the U.S. funding liquidity measures and stock markets is evident for all three emerging markets.
- The time-varying correlation between U.S. funding liquidity and sovereign bond spreads in Brazil, Mexico, and Russia becomes elevated.

**Figure 3.6. U.S. Model: Selected Implied Correlations from Dynamic Conditional Correlation GARCH Specification**




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

Note: The horizontal lines represent the arithmetic average of the correlations before and after the break in late July 2007.

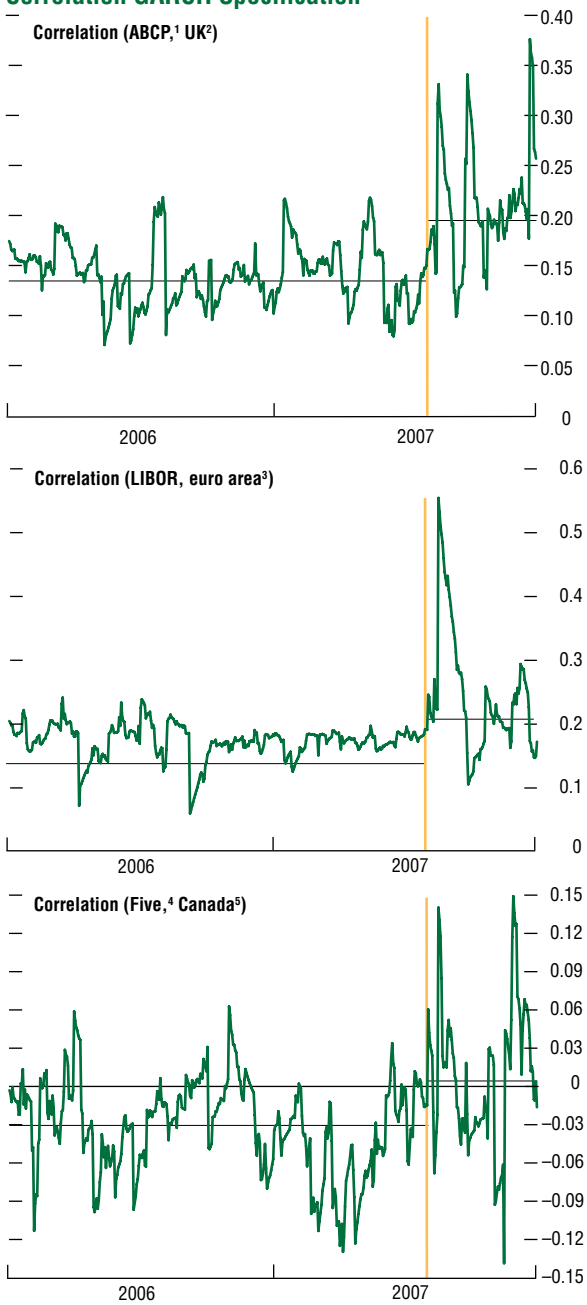
[1]Spread between yields on 90-day U.S. asset-backed commercial paper (ABCP) and on three-month U.S. Treasury bills.

[2]The unweighted daily average of the five-year credit default swaps for the following institutions: Morgan Stanley, Merrill Lynch, Goldman Sachs, Lehman Brothers, JPMorgan, Deutsche Bank, Bank of America, Citigroup, Barclays, Credit Suisse, UBS, and Bear Stearns.

[3]Spread between yields on three-month U.S. dollar LIBOR and on the three-month U.S. dollar overnight index swap.

[4]Spread between yields on five-year off-the-run and on-the-run U.S. Treasury notes.

**Figure 3.7. Advanced Economies Model: Selected Implied Correlations from Dynamic Conditional Correlation GARCH Specification**




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

Note: The horizontal lines represent the arithmetic average of the correlations before and after the break in late July 2007.

[1]Spread between yields on 90-day U.S. asset-backed commerical paper (ABCP) and three-month U.S. Treasury bills.

[2]Spread between yields on three-month pound sterling LIBOR and the UK three-month overnight index swap.

[3]Spread between yields on three-month euro LIBOR and the euro area three-month overnight index swap.

[4]Spread between yields on five-year off-the-run and on-the-run U.S. Treasury notes.

[5]Spread between yields on three-month Canadian dollar LIBOR and the Canadian three-month overnight index swap.

- For both the stock market and bond spread models, correlation magnitudes among the emerging countries examined is higher than with the U.S. funding liquidity during the sample period.

With market and funding liquidity risks increasingly intertwined, and their potential systemic consequences, central banks will likely need to reconsider their role and the instruments for intervention. The next section discusses this issue in the context of recent events, focusing on the ECB, the Fed, and the Bank of England.

## The Role of Central Banks During Periods of Market and Funding Illiquidity

Central banks assume a crucial role when market liquidity vanishes and funding strains imperil the viability of financial institutions. Their interventions typically are intended to address adverse dynamics described in the previous sections and prevent the collapse of financial intermediation. The central bank can provide funding liquidity to individual institutions and the market as a whole, either through market operations or bilateral arrangements. By signaling its willingness and ability to act decisively, the central bank's actions are intended to restore confidence in the system by avoiding fire sales of assets and supporting interbank lending.

Events since July 2007 have made the dual responsibilities of monetary policy execution and financial stability more challenging. During normal times, central banks provide sufficient liquidity to markets to set their policy interest rate on the expectation that (1) a reliable relationship links the target short-term rate and longer-term money market rates; and (2) counterparties effectively distribute liquidity to the wider market. But in mid-August 2007, the pattern of banks' liquidity demand changed—the short-term yield curve steepened and became more volatile, the gap between secured and unsecured rates widened, and the broader interbank market that distributed liquidity throughout the system was disrupted.

## Emergency Liquidity Support and the Stance of Monetary Policy

Communicating the distinction between monetary operations to provide general market liquidity and the stance of monetary policy has been difficult, partly as a consequence of the divergence in the tools and approaches used by different central banks. While the major central banks emphasized they would not adjust their monetary policy stance simply to improve market functioning, expectations to the contrary proved difficult to manage, in part because high and volatile term rates effectively tightened monetary conditions (Figure 3.8). In addition, the wider economic impact of the subprime mortgage crisis prompted a reappraisal of the appropriate monetary policy stance in some countries.

## Money Market Liquidity and Term Rates—Are Central Banks' Tools Sufficient?

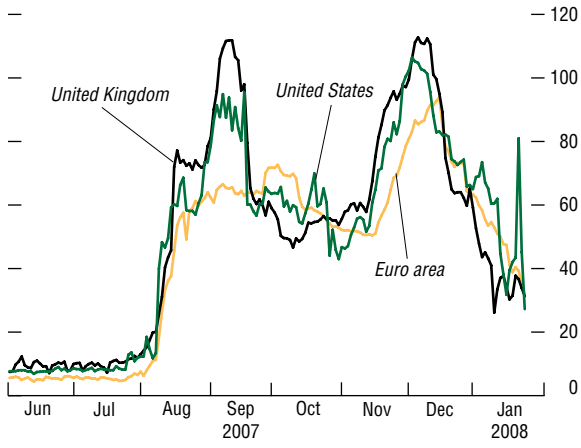
At the immediate onset of the crisis, there was a strong increase in demand for central bank liquidity (i.e., reserves at the central bank), but as the crisis unfolded, commercial banks desired increased liquidity beyond central bank balances. Initially, both the ECB and the Fed provided additional funds, while the Bank of England allowed banks' increased demand for reserves to be reflected in higher reserve targets.[11] As uncertainty over the financial soundness of counterparties increased, trading of unsecured term interbank funds dwindled because banks—and others—wanted to borrow long-term funds but lend only in the short term. Hence, term lending dried up for both counterparty credit and liquidity reasons, and longer-term yields rose sharply.

Central banks were able to increase the volume of longer-term refinancing to the market without expanding their balance sheets by withdrawing liquidity at other maturities or

[11]Under the Bank of England framework, banks set their own target for reserves before the start of a new maintenance period.

### Figure 3.8. Three-Month LIBOR to Overnight Index Swap Spreads

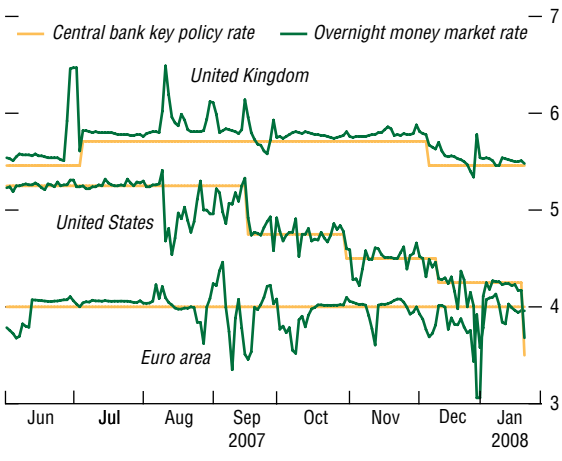
*(In basis points)*




Source: Bloomberg L.P.

### Figure 3.9. Central Bank Key Policy and Overnight Money Market Rates

*(In percent)*

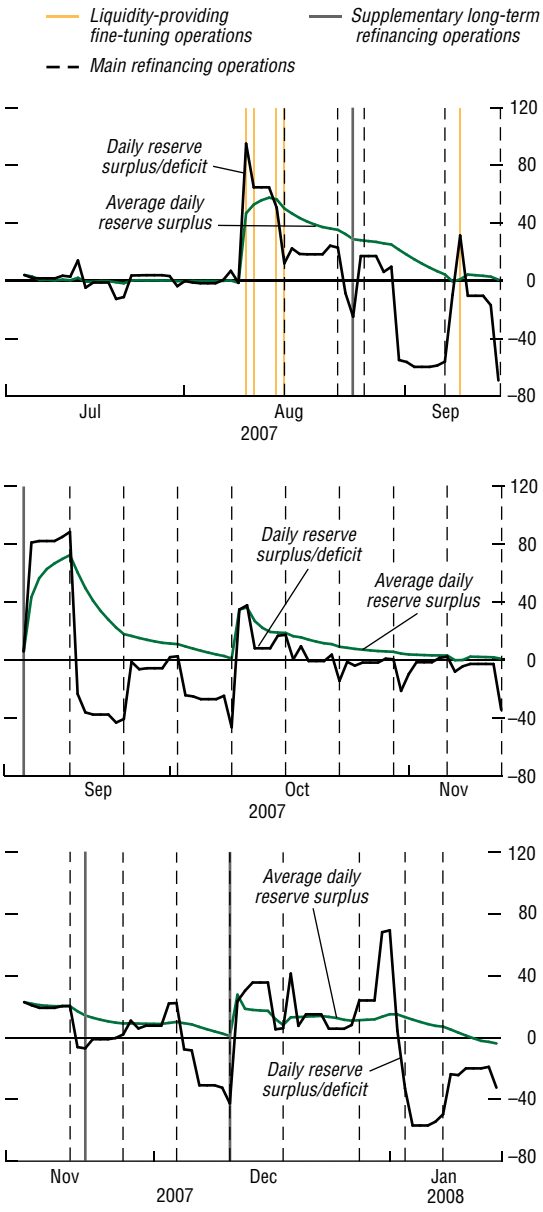



Source: Bloomberg L.P.

Note: Central bank key policy rates are the following: for the United States, federal funds target rate; for the United Kingdom, Bank of England's official bank rate; and for the euro area, main refinancing operation minimum bid rate.

Overnight money market rates are the following: for the United States, federal funds effective rate; for the United Kingdom, sterling overnight interbank average (SONIA); and for euro area, euro overnight interbank average (EURONIA).

**Figure 3.10. European Central Bank's Liquidity Provision and Reserve Holdings**
*(In billions of euros)*




Sources: European Central Bank; and IMF staff estimates.

Note: Liquidity-absorbing operations are not shown. Supplementary long-term refinancing operations (LTROs) are three-month liquidity-providing operations in addition to the regular LTRO, which is typically carried out once a month (not shown). For the weekly main-refinancing operations, only the ones in which the allotted amount exceeded the benchmark allotment (the amount banks would need to fulfill the reserve requirements, as projected by the ECB) by more than 1 billion euros are shown.

periods. This approach—accommodating more term lending while maintaining enough short-term lending at or around the policy rate to implement monetary policy—helped achieve the twin goals of executing monetary operations while addressing financial stability concerns (Figure 3.9). Moreover, systems that combined relatively large remunerated reserve cushions with a long reserve maintenance period (RMP) have provided considerable flexibility. For example, the large reserve requirements in the euro area (some 200 billion euros on average), together with a four- to five-week RMP, enabled the ECB to accommodate banks' desire to frontload reserve holdings toward the earlier phases of the RMP, when uncertainty was greatest (Figure 3.10). The ECB added large amounts of reserves early on in the RMP and it then drained the extra liquidity, so that banks ended the RMP with average daily reserve surpluses approaching zero.

Central banks have had to face a number of challenges in addressing financial system stress:

- They had to deal with the breakdown of standard distribution channels for liquidity, both nationally and internationally. This was because the provision of sufficient liquidity to a small group of intermediaries no longer guaranteed that it would either flow through the system, or to those in need of funding in specific currencies, as stress in money markets spread to foreign exchange swap markets.
- Some banks lacked direct access to open market operations (OMOs),[12] either because they did not belong to the list of eligible counterparties, or lacked the eligible collateral.
- Central banks had to project liquidity demands at different time horizons, as demand patterns changed rapidly and unexpectedly, and the impact of factors such as year-end effects became increasingly unpredictable.

[12]Open market operations—that is, purchases and sales of financial instruments in the open market at the policy rate—are central banks' principal tool for implementing monetary policy.

- They had to provide liquidity in support of unsecured term markets.

## Counterparties, Collateral, and Pricing

The reluctance of banks to make use of central banks' standing credit facilities raised operational challenges. In addition to short-term funding at the policy rate and longer-term OMOs at market or bid rates, all three central banks make available a standing credit facility or discount window, allowing approved banks to access funds at a rate above the policy rate. However, banks have been reluctant to use these facilities, not only because of the price, but because of a perceived stigma, since the facility is often accessed when an institution cannot find other sources of funding. This has been particularly important where differences between OMO and standing facility counterparty groups and eligible collateral were most pronounced (Box 3.5).[13]

Central banks modified their liquidity operations by way of the following measures in order to address this perceived stigma:

- The Fed narrowed the distinction between its OMO and standing facility operations by reducing the discount rate spread over the Fed funds target to 50 basis points. Use of this facility was notably higher in August-September and December 2007, but the amounts remained small. Many banks had recourse instead to the Federal Home Loan Bank system, using mortgage assets to obtain term funding at a rate midway between the Fed funds and discount rates, and without the perceived discount window stigma.
- In mid-December, the Fed announced a temporary Term Auction Facility (TAF) that made longer-term (four- to five-week) funds available to a wider range of potential borrowers (all standing facility counterparties) against the wider range of collateral usually permissible at the discount window. This direct provision of term funding through an open auction process with a minimum rate did not carry a stigma. The TAF was also linked through a foreign-currency swap operation with the ECB and the Swiss National Bank, allowing them to provide dollars to their much wider set of usual counterparties.
- The ECB extended the balance in the maturity of its operations. Already equipped with a very wide definition of acceptable collateral, the ECB's major challenge was the lengthening maturity profile of banks' liquidity needs.
- In the United Kingdom, the Bank of England was forced, by the rescue of Northern Rock, to accept collateral that fell outside its normal definition. But the bank subsequently chose to accept a broader range of collateral in some term operations open to all its counterparties.

While recent events have illustrated the benefits of a broad definition of eligible collateral, it also increases credit risk for central banks. The price of liquidity support ("haircuts" and discount rates applied to collateral that central banks accept) can help establish a floor for the value of a security, and effectively stem a market and funding liquidity spiral. However, accepting illiquid assets may encourage banks to retain tradable collateral to post with other counterparties, and to see the central bank as "lender of first resort." It is also likely to reduce incentives for banks to hold and provide top-rated securities, and to lead to a deterioration of the quality of collateral offered to the central bank. This approach runs the risk of "adverse selection"—the central bank is likely to accumulate inferior collateral—and may effectively establish the value of illiquid securities.[14]

[13]The differences between counterparty groups and eligible collateral for OMOs and standing facility are greatest in the United States. In the ECB and the Bank of England cases, most banks that do not normally access OMO funds directly had the option of participating in the main or longer-term OMOs, using the same collateral as they would use for standing facilities.

[14]In addition, if the central bank holds more collateral for its lender-of-last-resort activities, it must reduce other asset holdings; but if assets backing short-term lending undertaken to implement monetary policy become too small, or if the central bank cannot meet market demand for term lending, operations could lose their impact.

### Box 3.5. Central Bank Counterparties

Many central banks do not deal directly with all commercial banks (and securities firms) in their open market operations (OMOs), largely due to the costs of establishing a repo operation. Provided sufficient competition between counterparties, liquidity should be smoothly onlent by OMO counterparties in response to market demand. However, in times of stress, the distribution function can break down, requiring the use of different operational instruments. Standing facilities are available to a wider group—normally all banks that hold transactions accounts at the central bank—but with the expectation that they will be used sparingly.

| | Federal Reserve | European Central Bank | Bank of England |
|---|---|---|---|
| | | Regular Open Market Operations | |
| Counterparties | 20 primary dealers | 300 to 500 banks (potentially 1,700) | About 40 banks and securities firms |
| Range of eligible collateral | Narrow | Wide | Intermediate |
| Pricing | Bid price; Fed funds rate as guideline | Bid price above minimum rate | Fixed price |
| | | Standing Facilities | |
| Counterparties | 7,500 credit institutions | 2,400 credit institutions | About 60 banks |
| Range of eligible collateral | Wide | Wide | Intermediate |
| Pricing | Fixed price | Fixed price | Fixed price |

## Cross-Border Issues

Stress in term funding markets inhibited activity in foreign-currency swaps, confronting central banks with additional challenges. Both U.S. and European-based lenders were reluctant to provide dollar term funds, due to both counterparty credit risk and liquidity concerns. As the term dollar money market dried up, particularly for loans to European institutions, so did the swaps market, as there was little underlying money market business to support.

The coordinated provision of term funding through the TAF by major central banks helped ease associated tensions. Providing U.S. dollars via the ECB and the Swiss National Bank, against banks' eligible collateral, facilitated European access to dollars. This cooperation was necessary to avoid complications to domestic monetary management. In particular, if central banks had acted directly, this could have affected monetary conditions in the home currency, potentially altering the euro/dollar exchange rate.

## Central Banks' Response to Liquidity Strains Since July 2007: An Empirical Investigation

An econometric evaluation of the impact of central banks' emergency response to liquidity stress yields further insights into the underlying dynamics and the effectiveness of alternative policy tools. To this end, the volatility of euro and U.S. dollar term spreads is modeled using both a univariate GARCH specification and a Markov regime-switching approach with low-, medium-, and high-volatility "regimes" (Annex 3.1) (Hamilton and Susmel, 1994). A range of maturities for the dependent variables is considered, all based on changes in the spread between LIBOR and overnight interest rates swaps.[15]

To proxy the amount of "extra" liquidity injections used as intervention variables, the

[15]The reported results refer to three-month LIBOR spreads.

chosen measures should aim at capturing injections over and above the neutral level needed to just fulfill reserve requirements, any additional operations that provide extraordinary liquidity to deal with market stress, and, more broadly, the surprise element associated with the actions.

For the ECB, we employ a range of intervention measures, such as a variable that quantifies liquidity injections through supplementary long-term refinancing operations (LTROs) and, for main refinancing operations (MROs), a variable based on the MRO allotment exceeding the ECB's benchmark amount.[16]

For the Fed, we use the difference between actual repurchase agreements outstanding and estimates of the amount of repurchase agreements that would have been necessary to achieve neutrality with respect to fulfilling banks' needs over a reserve maintenance period.[17]

The results of both the GARCH and the Markov regime-switching approach are consistent with the analysis above and broadly support the policy recommendations summarized in the next section. In particular, additional term lending and the joint central bank response announced on December 12, 2007 were instrumental in reducing stress, conceptualized as a combination of spread levels and volatility:

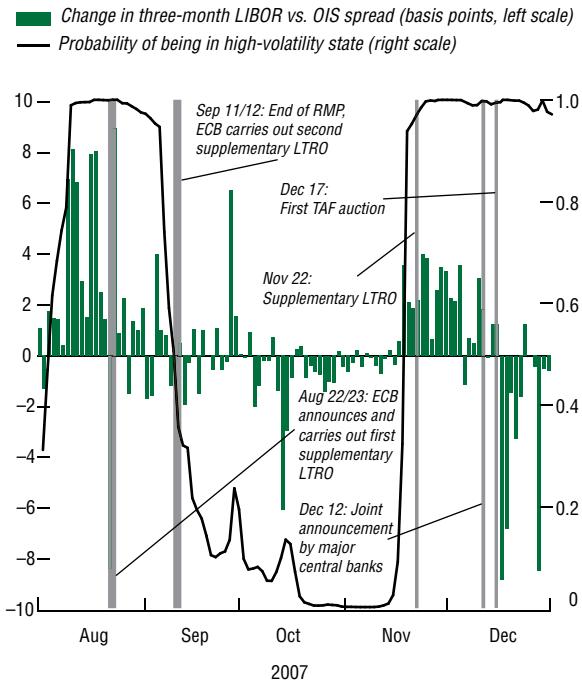
- While GARCH results for most of the ECB intervention variables are inconclusive, there appears to be a statistically robust and significant volatility-reducing effect in the case of the ECB's supplementary LTRO.[18]
- This is confirmed by the result from the Markov regime-switching model for the euro LIBOR spread (Figure 3.11). The probability of being in a state of very high volatility starts

[16]The benchmark allotment is the ECB's projection of the liquidity provision needed to smoothly fulfill reserve requirements.

[17]The estimates were provided by Wrightson ICAP.

[18]For both the ECB and U.S. GARCH models, the effect on the level of the benchmark rate is not economically very large. For instance, if the difference between actual and neutral repurchase agreements in place increases by $25 billion, this would result in a contemporaneous decrease of the three-month spread by four basis points.

**Figure 3.11. Euro Area: Selected European Central Bank Policy Actions and Term Funding Stress**



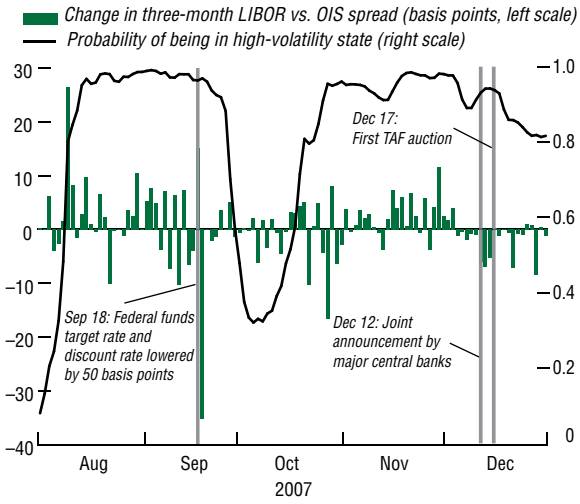

Sources: Bloomberg L.P.; and IMF staff estimates.

Note: The green bars represent the change in the spread between three-month euro LIBOR and three-month euro overnight index swap, measured in basis points. These data are used in the estimation of a three-state Markov Switching ARCH model. The black line provides the subsequent probability of being in the highest volatility regime, which is determined by the variation in the LIBOR spread. The probabilities of being in the medium- and low-volatility states are not shown here. The gray bars indicate selected major central bank interventions. OIS = overnight index swap; RMP = reserve maintenance period; ECB = European Central Bank; LTRO = long-term refinancing operations; TAF = Term Auction Facility.

to decline on the day following the announcement of the first LTRO on August 22, 2007, and falls below the 50 percent margin by the end of the respective reserve maintenance period on September 11.[19]

- When year-end effects start to surface in mid-November, volatility as assessed by the regime switching model for the euro-LIBOR spread again increases markedly. Spread levels decrease only after the joint announcement of various central banks on December 12, 2007.[20]
- According to GARCH estimations, the Fed's interventions via additional repurchase agreements appear to have had a significantly negative contemporaneous effect on dollar spread levels and volatilities. The level effect, however, is largely offset by a rebound on the next day, and both effects are sensitive to the chosen lag structure.
- From the Markov regime-switching model for U.S. data, it is clear that the system transitions from a high- to a medium-volatility state toward the end of September 2007, following the reduction of the federal funds target rate on September 18 (Figure 3.12). After returning to stress levels shortly thereafter, the joint announcement of major central banks, and of the TAF auction, are followed by both a compression of the spread, and a continuous yet incomplete reduction in the probability of being in the high-volatility state.

**Figure 3.12. United States: Selected Federal Reserve Policy Actions and Term Funding Stress**




Sources: Bloomberg L.P.; and IMF staff estimates.
Note: The green bars represent the change in the spread between three-month U.S. LIBOR and the three-month U.S. overnight index swap, measured in basis points. These data are used in the estimation of a three-state Markov Switching ARCH model. The black line provides the subsequent probability of being in the highest volatility regime, which is determined by the variation in the LIBOR spread. The probabilities of being in the medium- and low-volatility states are not shown here. The gray bars indicate selected major central bank interventions. OIS = overnight index swap; TAF = Term Auction Facility.

## Recommendations to Enhance Liquidity Risk Management

Events since July 2007 have illustrated how liquidity risk impacts the stability of the global financial system and suggest important lessons for market participants and policymakers.

[19]Smoothed probabilities exceeding a value of 0.5 indicate that the data generating process is in that respective volatility regime.

[20]As a period of large increases in the spread is followed by a period of large decreases, volatility is not affected in a statistically significant way.

### Market Participants

For market participants, the ongoing crisis provides important lessons on managing market liquidity risk, though final conclusions will require further analysis. For example:

- Firms need to factor in more severe liquidity gapping and correlation jumps in their market risk models and stress tests, making sure that these are well tailored to firms' particular circumstances and positions.
- Where market liquidity can be measured robustly, a liquidity adjustment to market risk measures can be helpful, and its disclosure can usefully focus attention on liquidity risk, especially in "normal" conditions.[21] However, stress tests are better suited to examine the firm's potential exposures in extreme liquidity events, and recent turbulence has demonstrated that such tests should include a scenario where market liquidity is under strain for many months.
- The demonstrated links between market and funding liquidity suggest that there is a need for greater transparency regarding market liquidity management practices, including the models used for valuing structured products (and their liquidity assumptions).
- Margin requirements and pricing in financial markets—including for OTC derivatives—need to give greater weight to market liquidity risk, including considering longer-term measures of liquidity risk over the cycle and less sensitivity to the most recent time period.

There are similarly important lessons to be drawn regarding funding liquidity risk, including:

- Greater transparency is needed regarding commercial bank liquidity management policies and practices, including liquidity risk appetite, funding sources, liquidity commitments (especially to off-balance-sheet entities), maturity mismatches, contingency plans, and assumptions made over deposit withdrawal prospects.
- More severe stress testing of funding liquidity should be adopted, taking into account the possible closure of multiple wholesale markets (both secured and unsecured) and widespread calls on liquidity commitments, taking into account commitments to off-balance-sheet entities. These stress test results and the underlying assumptions should be publicly available.
- Cross-border banks should take greater account of multi-currency funding liquidity shocks, taking into consideration the need to manage liquidity mismatches in each operating currency and the potential for stress in the foreign-currency swaps markets.
- Banks' reliance on highly structured securities, especially holdings of their own securitized assets, to generate collateral for secured funding have proven problematic. Illiquidity and volatility in these markets have coincided with interbank market disruption resulting in banks facing a correlated liquidity squeeze on both their repo-able assets and wholesale funding.

### Financial Regulators and Supervisory Authorities

In view of the under-insurance of large banks to the risk of liquidity shocks revealed by the 2007–08 crisis, there is now a case to consider tougher liquidity risk management standards. Recent experience and empirical work presented here illustrates that high levels of risk-weighted capital—well in excess of regulatory minima—did not prevent systemic liquidity concerns. The heightened price volatility of the value of complex assets held by banks, combined with opacity over these exposures, meant that capital adequacy margins quickly came into question. In such an environment, where formal liquidity risk management techniques are still somewhat underdeveloped and, where available, difficult to calibrate to extreme liquidity events, more traditional means of reducing liquidity risks may be warranted to protect interbank markets from

[21]For example, the Counterparty Risk Management Policy Group II (2005, p. 34).

these systemic risks (United Kingdom Financial Services Authority, 2007). For example, increased holdings of liquid assets would help to share the burden of liquidity disruptions with central banks and reduce the moral hazard that results from the expansion by central banks of acceptable collateral during crises.

Possible regulatory steps that could be considered include (1) raising minimum liquid asset requirements in the form of holdings of reliably liquid and collateralizable assets; (2) stricter limits on maturity mismatches in bank's asset/liability structures; and (3) tighter rules governing diversification of funding sources and the ability to survive a funding market disruption.

The Basel Committee is currently reviewing liquidity risk regulation and management, and has so far confined its considerations to qualitative issues (Box 3.6). As ever, care will be needed should this work be extended to a more rules-based approach. First, it would be difficult to define a single norm that applies well to banks with very different business models, such as predominantly wholesale- or retail-financed banks (Joint Forum, 2001). Moreover, if very costly liquidity requirements are imposed, supervisors will need to take into account the incentives for banks to circumvent them, including via off-balance-sheet entities and other counterparties, and the welfare loss from increasing the cost of financial intermediation. In addition, regulators will need to be careful to recognize that excessive stringency of norms can exacerbate crises by creating too strong an incentive to hoard liquidity in times of stress. These considerations point to bank supervisors formulating guidance more along the lines of Pillar 2 of the Basel framework to raise standards of liquidity risk management, rather than initially tightening minimum quantitative requirements for liquid asset holdings. Neither existing best practices for liquidity risk management promoted by the IIF, existing guidance from the Basel Committee, nor the work of the Joint Forum appear to have been widely applied to date, and supervisors will need to devise better ways to ensure that progress toward best practices is achieved.

### Monetary Authorities

While central bank actions have prevented wider damage to the financial system, significant and sometimes ad hoc changes to operational frameworks were required, suggesting that policymakers had not always been well prepared for the extraordinary events that took place. Central banks have begun to discuss necessary adjustments, not only with respect to crisis management arrangements, but also monetary policy frameworks and market operations more broadly. In their attempts to learn the lessons of the recent turmoil, central banks should actively explore the scope for convergence of practices, in particular in the areas of counterparty selection, eligible collateral, and the appropriate mix between short-term and longer-term refinancing operations. Against this backdrop, key lessons from recent events (as well as from earlier episodes of large-scale central bank interventions, such as the Bank of Japan's experience toward the end of the 1990s),[22] include the following:

- Standing facilities work well in normal circumstances, when their use is infrequent and very short-term, but they are not designed to cope with generalized market problems, especially when a stigma is attached to their use.
- In a crisis, it is expedient for the central bank to be able to operate with a wide range of counterparties and collateral that provides banks with broad access to liquidity and releases more liquid collateral for interbank usage, and that these be in place and tested before a crisis strikes. However, central banks face difficult trade-offs when widening the pool of counterparties and collateral that they deal with. First, widening the range of instruments can reduce the incentive for banks to hold, and if necessary, provide to the central bank, high-quality collateral. In particular, in stressful times, banks will naturally be inclined

[22]Apart from supporting our main conclusions with respect to collateral and counterparty eligibility, the Japanese experience highlights the importance of a comprehensive exit strategy that ensures a timely reactivation of interbank markets.

### Box 3.6. Liquidity Regulation and the Basel Process

The work of the Basel Committee on Banking Supervision in the area of supervision of bank liquidity has taken on greater importance in the context of recent market events.

Solvency and liquidity are complementary and mutually reinforcing supervisory concerns—illiquid banks can progress rapidly to insolvency, while banks perceived to be insolvent are denied funding liquidity. The committee is well known for its work establishing a regulatory capital framework (Basel I and II), and its work on liquidity has focused on developing high-level principles of good practice—an approach that the banking industry has also favored. This outcome resulted from the need for supervisors to coordinate their approaches with national central banks in their role as liquidity providers, as well as to coordinate with national approaches to deposit insurance and bank resolution, resulting in a wide range of practices for measuring, managing, and supervising liquidity risks among committee members. Moreover, the comfortable liquidity environment of the past decade and the committee's focus on finalizing capital requirements for credit, market, and operational risk within the Basel II framework, resulted in liquidity risk receiving less attention than other types of risk.

A 1992 Basel Committee paper, "A Framework for Measuring and Managing Liquidity," first assembled the practices followed by major international banks in one framework (BCBS, 1992). This was intended primarily as summary guidance for banks and was largely silent on supervisory standards. In 2000, this paper was significantly updated in "Sound Practices for Managing Liquidity in Banking Organizations," which laid much greater emphasis on liquidity management as a vital element of banks' overall risk management practices (BCBS, 2000). Its key elements were also incorporated through a stand-alone principle in the 2006 revision of the Basel "Core Principles for Effective Banking Supervision"—the accepted minimum requirements for sound banking supervision (BCBS, 2006). In the same year, the Joint Forum representing banking, securities, and insurance standard setters also released a paper on funding liquidity risk management, "The Management of Liquidity Risk in Financial Groups," based on a survey of practices followed by major conglomerates (Joint Forum, 2006). While not aiming to identify best practices or make recommendations, it informed the continuing work of standard setters regarding liquidity management.

With work on Basel II largely completed, the committee established a Working Group on Liquidity in late 2006 to review liquidity supervision practices in member countries and others, as well as banks' liquidity management practices. The group also assessed the preliminary lessons and implications arising from market turmoil that began in mid-2007. These include issues related to stress testing, contingency funding plans, off-balance-sheet activity and contingent commitments, balance sheet management and internal transfer pricing, capital, and cross-border issues and exchange of information. As a result of its findings, discussed in "Liquidity Risk: Management and Supervisory Challenges" published in February of this year (BCBS, 2008), the working group has started a fundamental review of the committee's 2000 guidance and a consultative document is expected to be issued in 2008. While minimum quantitative standards for liquidity akin to Pillar 1 (minimum capital requirements) of the Basel II framework are not on the committee's agenda, its review of the 2000 guidance will seek to strengthen global standards for liquidity regulation, supervision, and risk management.

Note: This box was prepared by Aditya Narain.

to provide their lower-quality collateral, exposing the central bank to greater credit risk. Hence, it is important that the collateral pricing policy be reviewed periodically to ensure that it provides banks with sufficient incentive to hold and post more liquid and better-

quality collateral, thereby limiting credit risk to the central bank and the emergence of "eligibility premiums." Second, maintaining a wide group of counterparties may be administratively inefficient in normal times; but widening the pool at short notice may be operationally difficult to manage, and send a signal that certain institutions, with newly acceptable collateral, are receiving preferential treatment.

- Having in place operational procedures to address changes in banks' demand for liquidity at different maturities can be a powerful tool to ease money market strains. However, altering the maturity profile of central bank operations has to be complemented with a communications strategy encompassing both entrance to and exit from the market, so as to not weaken monetary policy implementation and normal interbank market functioning.
- Preemptive planning is needed to ensure that central banks can effectively coordinate and communicate how emergency liquidity provision interacts with the broader macroeconomic policy mandate. In particular, central banks need to be able to explain what impact additional emergency liquidity will have on monetary conditions and the circumstances that would permit, and the mechanisms that would be used for, liquidity withdrawal.
- Coordination with international counterparts on emergency operations, liquidity arrangements for cross-border banking groups, and emergency foreign-currency swaps should be furthered, including preparing the operational requirements for managing currency liquidity across borders. The case could be considered for an international securities depository that would provide international banks with greater flexibility to post collateral across a range of currencies and central banks.

Defining the optimal approach to monetary policy implementation in light of recent events will take time, particularly when applying lessons from mature to emerging markets. Over the medium run, however, converging to best practices will allow central banks to avoid gaps in the international management of systemic liquidity needs, communicate more easily with markets and the public, and more clearly distinguish financial stability concerns from monetary policy implementation. Communication alone, however, will not suffice to address the incentive problems resulting from a partial transfer of illiquidity tail risks to central banks. As central banks increase their readiness to address these problems, financial regulation will have to focus its attention on limiting the system's inherent tendency to reduce liquidity buffers in the upswing.

Recent events have attested to the crucial role of central banks as ultimate providers of liquidity, highlighting the need to review both their role in national and international financial arrangements, and as guarantors of both macroeconomic and financial stability. There is a need to regularly examine the relationship between these twin responsibilities. This should involve a fresh look at required adjustments to the institutional framework for financial supervision and regulation. No matter what type of financial stability arrangements are in place in a country, the central bank needs to be provided with sufficient information about the liquidity and solvency risk profiles of individual, systemically important institutions to further the goal of assuring the smooth functioning of the payment system, as well as money and interbank markets.

### The Role of the International Monetary Fund

Lastly, the recent liquidity crisis offers some useful lessons to the IMF. In particular, it appears that the IMF could test systemic liquidity risk more stringently during Financial Sector Assessment Program (FSAP) assessments and bilateral surveillance. The IMF's FSAPs already include a review of systemic liquidity management practices, including adherence to the relevant Basel banking supervision "core" principle for liquidity management (BCBS, 2006, Principle 13). In addition, where interbank data are available, a systemic liquidity stress test is conducted. However, there is room to increase the sophistication and extent of liquidity stress testing.

Similarly, there is room for the IMF to more actively promote best practices for financial crisis management and monetary policy emergency operations. This has become an increasing focus of IMF FSAP assessments, but greater efforts will be made to learn lessons from these exercises and apply them more effectively in the IMF's bilateral and multilateral policy advice.

## Conclusion

This chapter has explored the interrelationship between market and funding liquidity—two concepts of liquidity that have taken on new meaning since mid-2007. The relationship between market and funding risks has changed along with market practices for managing risk, and detrimental "liquidity spirals" may be more pervasive than before. The recent episode has raised important and very difficult issues about how "liquidity" is managed—both in private financial institutions and in the public sector. The chapter has attempted to shed some light on how, generally, funding liquidity risk is shared between the private and public sectors, and how the cost of insurance against liquidity events appears to have shifted from the private toward the public sector. The renewed focus on this balance of risks will likely bring forth additional analysis about how the incentives of both sides have influenced their decisions. Careful consideration will need to be given to these incentives in order to improve policies to reduce systemic liquidity risks in the years to come.

## Annex 3.1. Liquidity Dynamics Since Summer 2007

The recent period of stress in global financial markets raises important questions, two of which are examined empirically below: How were liquidity shocks transmitted across financial markets and national boundaries during the 2007 crisis? And to what extent, if any, did the policy interventions of the Fed and the ECB contribute to stabilizing term funding markets, particularly at one- and three-month maturities?

As discussed earlier, conceptually, a number of links are likely to have been established during the recent period of turbulence, either through increased market illiquidity, funding illiquidity, or solvency risks. This annex analyzes the relative strength of these linkages based on a simple reduced-form econometric model.[23] In particular, a parsimonious multivariate GARCH model is estimated to evaluate the transmission of liquidity shocks during the recent period of financial stress. This allows for the modeling of the heteroscedasticity exhibited by the data, in addition to interpreting the conditional variance as a time-varying risk measure.

The data chosen for the model are motivated by the following observations. During normal periods, market illiquidity shocks tend to be temporary, as they create opportunities for traders to profit and, in doing so, provide liquidity and contribute to the price-discovery process.[24] However, during periods of financial stress, several mechanisms may amplify and propagate liquidity shocks across financial markets, creating systemic risks. These mechanisms can operate through direct linkages between the balance sheets of financial institutions, but also indirectly through asset prices and spreads as described above.[25] Asset price movements are set in motion when financial institutions face marked-to-market price declines. As a consequence, they start to deleverage their positions and curtail lending. If the value of their assets is significantly affected, financial institutions can also see their creditworthiness deteriorate and risk of default increase. As a result, linkages can be established through the interaction of market and funding illiquidity shocks and default risks, creating systemic pressures.

After analyzing the events in U.S. financial markets, where the shocks originated, a GARCH

[23]For further details, see Frank, González-Hermosillo, and Hesse (forthcoming).

[24]These collective "traders" include hedge funds, proprietary trading desks, and market-makers.

[25]Models examining these connections include Adrian and Shin (2007), Cifuentes, Shin, and Ferrucci (2005), and Brunnermeier and Pedersen (forthcoming).

model is used to examine international linkages across advanced economies and key emerging markets. Finally, the role of central bank policy actions during the period of turbulence is assessed. The results suggest that the correlations between the variables under examination increased sharply and in somewhat unexpected ways, and that policy interventions had some success in stabilizing financial markets.

## U.S. Model

The model uses a system of five variables to summarize key linkages, across various U.S. financial markets, acting as proxies for overall market liquidity, funding liquidity, default risk, and attitudes toward risks. While the shocks originated in the subprime mortgage market, they were readily transmitted to the ABCP market. The turbulence in ABCP reflects the funding illiquidity experienced by SIVs and conduits resulting from concerns about the increasing market illiquidity risk of the underlying structured credit securities as they became difficult to value. The ABCP link is measured by the spread between three-month ABCP rates and U.S. Treasury bill yields (Figure 3.3).

As the problems with SIVs and conduit facilities spread, banks came under increasing pressure to fund those that they had sponsored. Uncertainties with respect to the magnitude of the problem for individual institutions and treasurers' concerns about future funding needs were quickly reflected in unsecured longer-term funding markets. As a proxy of these funding liquidity pressures, the second variable examined in the system is the spread between the three-month U.S. interbank LIBOR rate and the overnight index swap (Figure 3.3).

As turbulence in markets heightened, financial markets more generally showed signs of stress. Volatility increased, reflecting higher uncertainty, and many investors shifted their positions to the safest and most liquid asset classes.[26] As such, the third variable, the variance of returns in the S&P 500 stock market index, proxies market volatility and uncertainty (Figure 3.4).[27] The fourth variable is the spread between the five-year on-the-run and off-the-run U.S. Treasury notes as a measure of overall market liquidity pressures (Figure 3.5).[28] Finally, the cost of insurance against default—credit default swap spreads—of several representative large complex financial institutions is used to proxy the default risk of financial institutions.[29] It also increased sharply during the crisis (Figure 3.4).

In sum, five variables in the system are assumed to capture the key links that created systemic risks in financial markets:[30]

[26]Market participants often equate an increase in market volatility with a diminished risk appetite of investors.

[27]Market volatility is often proxied by the Chicago Board of Options Exchange Volatility Index (VIX), which measures the implied volatility priced into S&P 500 equity index options. This variable was not chosen because the model used to estimate the transmission, a multivariate GARCH model, is based on a volatility estimate, and so using VIX would represent examining the volatility of a volatility measure.

[28]The "on-the-run" Treasury note is usually the most recently issued of a particularly liquid maturity and is used for pricing other assets. An on-the-run note becomes "off-the-run" when a new note is issued in that maturity bracket. Other alternative measures of overall market liquidity were also examined, including the spread between the 10-year and the two-year on-the-run and off-the-run U.S. Treasury securities, and the spread between the 10-year U.S. Treasury bond and other less liquid maturities. Overall, the findings were broadly in line with the five-year, on-the-run spread. Fleming (2003) notes that the various measures are imperfect proxies of U.S. Treasury market liquidity, but that the five-year and the two-year note spreads showed the biggest increase during the 1998 Long-Term Capital Management crisis in response to a desire for investors to move to the most liquid assets. The high demand for two- and five-year Treasury notes for potential repurchases suggests this variable may capture some funding liquidity as well as market liquidity.

[29]This variable was created by taking the unweighted daily average of the five-year credit default swaps *(cont.)* for the following institutions: Morgan Stanley, Merrill Lynch, Goldman Sachs, Lehman Brothers, JPMorgan, Deutsche Bank, Bank of America, Citigroup, Barclays, Credit Suisse, UBS, and Bear Stearns.

[30]The data examined in this model clearly constitute a simplification of the dynamics that may occur during periods of stress. For example, in practice, the widening of the ABCP and LIBOR-OIS spreads could also potentially reflect an unobserved component that represents changes in the perceived credit risk of the collateral backing ABCP, and in the perceived credit risk of banks.

*abcp* = ABCP—U.S. Treasury bill (ABCP funding liquidity)
*LIBOR* = LIBOR—OIS (bank funding liquidity)
*five* = five-year on-the-run vs. off-the-run U.S. Treasury notes (market liquidity)
*ret* = S&P 500 returns (volatility)
*CDS* = credit default swap spreads for financials (solvency risk).

### *Empirical Results*

The data sample begins on January 3, 2006 and ends on December 24, 2007, although the final week of 2007 is omitted in order to avoid end-of-year effects in the strained interbank money markets.[31] The model was estimated using a DCC GARCH specification by Engle (2002), which allows the conditional variance and covariance to be time-varying risk measures.[32] By directly parameterizing the conditional correlations and accounting for their potential time variation, this model is best interpreted as a generalization of the Constant Conditional Correlation specification suggested by Bollerslev (1990).

The DCC GARCH model is estimated using first differenced data, as augmented Dickey-Fuller tests indicate that the ABCP, LIBOR and CDS spreads exhibit nonstationarity during the second half of 2007.

Prior to July 2007, there is evidence of only limited implied correlations between the variables in the system. During the crisis period, correlations become more important and their magnitudes increase sharply. In particular, there is a more pronounced interaction between market and funding liquidity (Figure 3.13). In addition, solvency considerations, measured in terms of CDS spreads, also become significant, whereas they were relatively unconnected to the other variables before the subprime crisis, suggesting that concerns about solvency arose as liquidity difficulties increased, and indicating funding illiquidity as a source of difficulty. As the representative set of graphs in Figure 3.13 illustrates, a clear break in the time-varying correlation structure of the variables is observed at the end of July 2007, consistent with the onset of the financial turbulence.

## Advanced Economies Model

As described above, the initial U.S. subprime mortgage shock also affected financial intermediaries abroad, many of whom funded structured securities with ABCP. This was most clearly the case for Canadian financial intermediaries, but also for many entities in Europe. As such, a multivariate DCC GARCH model is used to examine the spillovers between U.S. and international money markets.

Three potential links are examined. The first one reflects the potential link between U.S. funding liquidity pressures, proxied by the three-month U.S. LIBOR rate over the OIS rate, and funding pressures in Canada, the euro area, and the United Kingdom, proxied by three-month LIBOR rates relative to the overnight index swaps in each zone. The second link addresses the potential relationship between U.S. ABCP and international interbank spreads. Finally, the third potential spillover is captured by the overall U.S. market liquidity measure, proxied by the spread between the five-year, on-the-run versus the five-year, off-the-run U.S. Treasury notes, and the LIBOR spreads in the various countries.

### *Empirical Results*

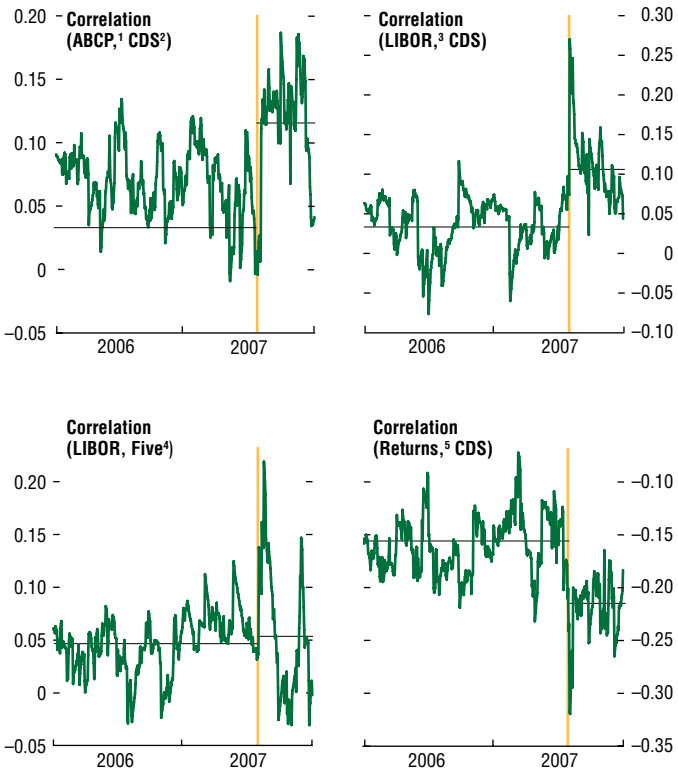
The correlations between the U.S. funding liquidity measures (ABCP and LIBOR spread)

Similarly, CDS prices and the credit premia implicit in LIBOR rates may also partly reflect additional compensation for market participants' risk appetite and overall uncertainty in the markets. Disentangling these components is difficult, since they are nonobservable and can be time-varying. Michaud and Upper (2008) find that credit risk measures have little explanatory power for the day-to-day fluctuations in the LIBOR-OIS spread. However, the Bank of England (2007) notes that credit concerns since October 2007 appear to account for a more significant portion of LIBOR spreads.

[31]The estimation was also conducted from 2003 onward, and the findings did not change appreciably, indicating that the low volatility in U.S. markets during 2006 does not bias the results.

[32]This model avoids the criticism that tests of contagion are biased when the heteroscedasticity of the returns is not modeled explicitly (Forbes and Rigobon, 2002).

**Figure 3.13. U.S. Model: Implied Correlations from Dynamic Conditional Correlation GARCH Specification**




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

Note: The horizontal lines represent the arithmetic average of the correlations before and after the break in late July 2007.

[1]Spread between yields on 90-day U.S. asset-backed commercial paper (ABCP) and on three-month U.S. Treasury bills.

[2]The unweighted daily average of the five-year credit default swaps (CDS) for the following institutions: Morgan Stanley, Merrill Lynch, Goldman Sachs, Lehman Brothers, JPMorgan, Deutsche Bank, Bank of America, Citigroup, Barclays, Credit Suisse, UBS, and Bear Stearns.

[3]Spread between yields on three-month U.S. LIBOR and on the three-month U.S. overnight index swap.

[4]Spread between yields on five-year off-the-run and on-the-run U.S. Treasury notes.

[5]S&P 500 stock market returns.

and the international LIBOR spreads in Canada, the euro area, and the United Kingdom, are all of relative small magnitude and fairly stable before the subprime crisis. Figure 3.14 shows some of the time-varying conditional correlations, for instance, between the U.S. LIBOR spread and those in the United Kingdom and euro area, as well as between the U.S. ABCP spread and the LIBOR spreads in the United Kingdom and Canada.

During the crisis period, the correlations between U.S. funding liquidity and international LIBOR spreads increase sharply. The elevated implied correlation between the U.S. ABCP spread and the Canadian LIBOR spread during the crisis period possibly reflects the transmission of the U.S. subprime mortgage and ABCP shock to Canadian financial institutions (Figure 3.14).The correlation between international spreads and U.S. LIBOR is more pronounced than the correlation between international spreads and the U.S. Treasury five-year, on-the-run spread. Overall, this is consistent with market participants' views that funding, more than market illiquidity, has been the important mode of transmission of shocks across countries. Finally, unlike the pre-crisis period, when there were limited interactions between the Canadian, euro area, and UK LIBOR spreads, those interactions become more important during the crisis period.

## Emerging Markets Model

The international model for advanced economies discussed above is extended to include some key emerging markets.[33] Specifically, two measures of U.S. funding liquidity (one for the interbank money market and the other for funding liquidity in the ABCP market), as well as the five-year, on-the-run spread measure of U.S. market liquidity, are linked to the bond spreads and stock market returns in Brazil, Mexico, and Russia. This is done across each of the two asset

[33]The computational demands of the multivariate DCC GARCH model restricts the number of countries that can be examined.

classes across countries in order to capture any potential differences between them. The sovereign bond spreads are measured by JPMorgan's Emerging Market Bond Index Plus (EMBI+) for each country, and the stock market returns are calculated from the respective local stock market indices in domestic currency.

### *Empirical Results*

During the subprime crisis, a heightened interaction between the U.S. funding liquidity measures and the stock markets is evident for all three markets (Figure 3.15).[34] Correlation changes are most pronounced between the U.S. LIBOR spreads and the Mexican stock market returns, as well as the U.S. ABCP spreads and the Mexican and Russian bond spreads. Similarly, it is found that the time-varying correlation between U.S. funding liquidity and the bond spreads in Brazil, Mexico, and Russia rises. It is also noteworthy that, for both the stock market and bond spreads models, the correlation magnitudes among the emerging countries examined here are higher than with the U.S. funding liquidity measures during the sample period. Co-movements among emerging countries have increased in recent years and became more pronounced during crises. The findings from introducing the U.S. market liquidity variable, the five-year, on-the-run spread, were inconclusive.[35]

## European Central Bank and Fed Interventions

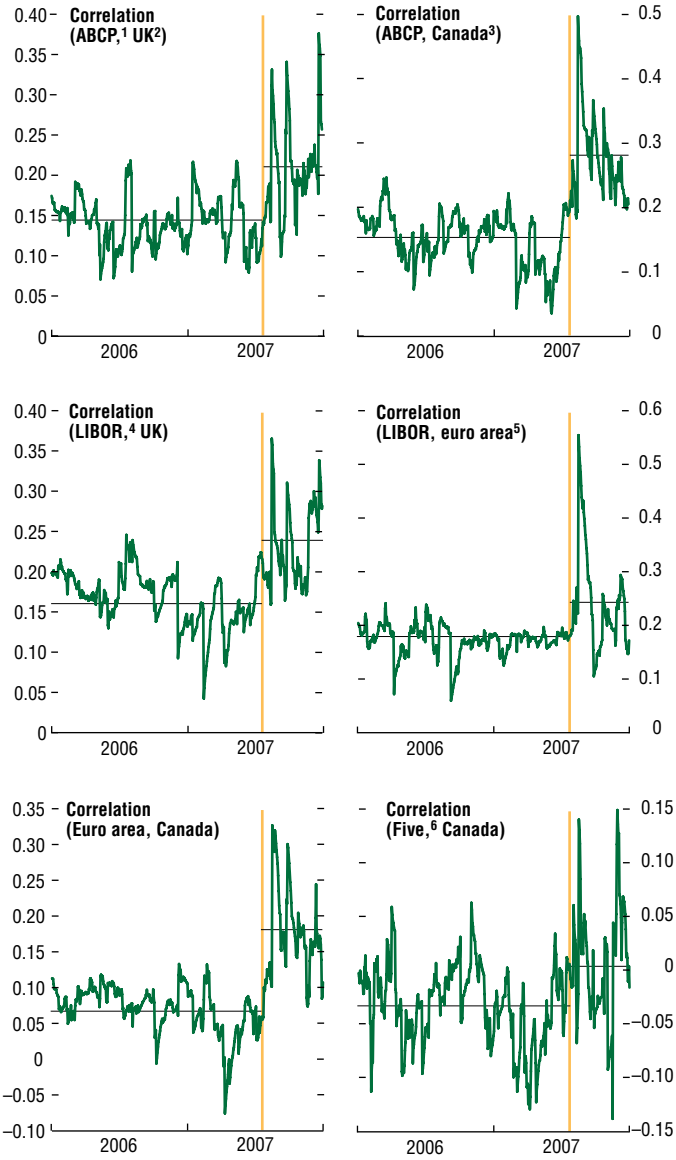
To assess the impact of the emergency response of central banks, two methods were used.[36] First, a univariate GARCH model is estimated for both the U.S. Fed and the ECB for a sample period ranging from July 26 to Decem-

[34]The other period of recent increased correlation between the various measures of U.S. funding and market liquidity shocks and emerging markets examined occurs on February 28, 2007, following a sharp correction in China's Shanghai stock market.

[35]Similarly inconclusive results were obtained from the U.S. two-year and 10-year on-the-run spreads.

[36]See also Frank, Hesse, and Klueh (forthcoming).

**Figure 3.14. Advanced Economies Model: Implied Correlations from Dynamic Conditional Correlation GARCH Specification**




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

Note: The horizontal lines represent the arithmetic average of the correlations before and after the break in late July 2007.

[1]Spread between yields on 90-day U.S. asset-backed commercial paper (ABCP) and three-month U.S. Treasury bills.

[2]Spread between yields on three-month pound sterling LIBOR and the UK three-month overnight index swap.

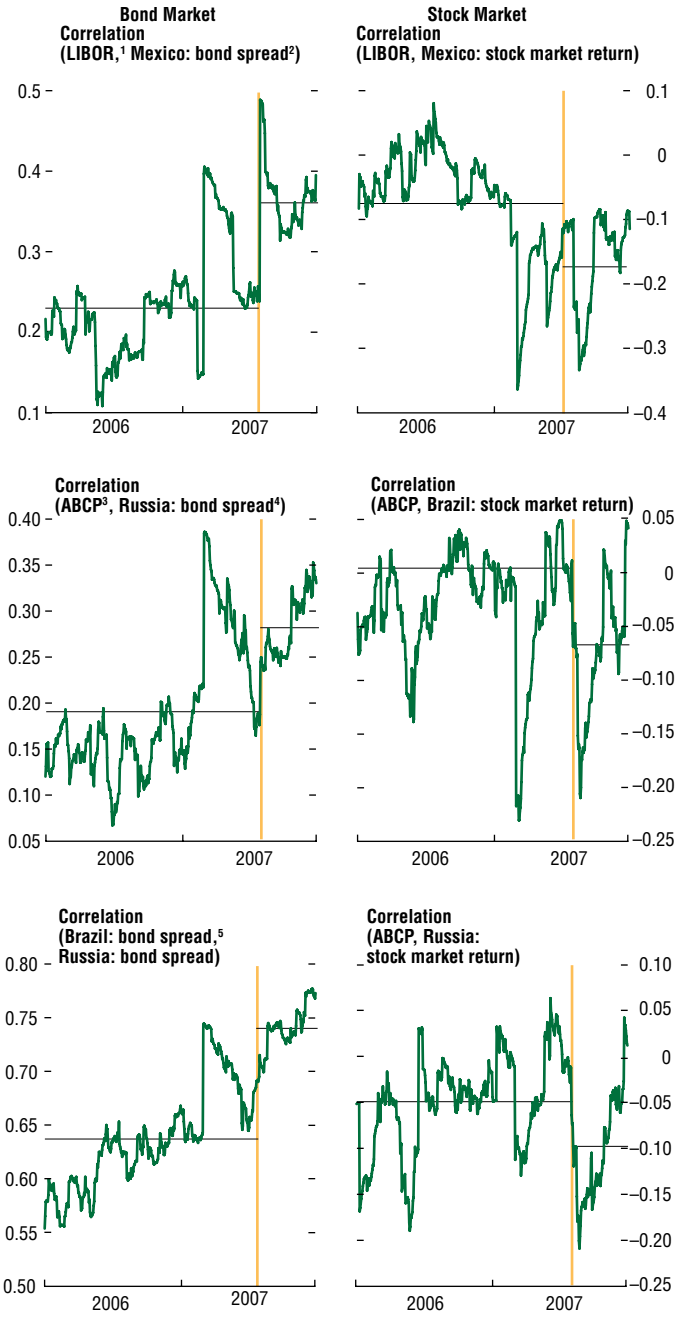
[3]Spread between yields on three-month Canadian dollar LIBOR and the Canadian dollar three-month overnight index swap.

[4]Spread between yields on three-month U.S. dollar LIBOR and the three-month U.S. overnight index swap.

[5]Spread between yields on three-month euro LIBOR and the euro area three-month overnight index swap.

[6]Spread between yields on five-year off-the-run and on-the-run U.S. Treasury notes.

**Figure 3.15. Emerging Markets Model: Implied Correlations from Dynamic Conditional Correlation GARCH Specification**




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

Note: The horizontal lines represent the arithmetic average of the correlations before and after the break in late July 2007.

[1]Spread between yields on three-month U.S. dollar LIBOR and on the three-month U.S. dollar overnight index swap.

[2]JPMorgan's EMBI+ Mexico sovereign spread.

[3]Spread between yields on 90-day U.S. asset-backed commercial paper (ABCP) and on three-month U.S. Treasury bills.

[4]JPMorgan's EMBI+ Russia sovereign spread.

[5]JPMorgan's EMBI+ Brazil sovereign spread.

ber 24, 2007.[37] Second, a three-state Markov regime-switching model (Hamilton and Susmel, 1994) for the volatility of term spreads is implemented, and is used to compare regime transitions with central bank intervention dates.[38]

To proxy the amount of "extra" liquidity injections used as intervention variables in the GARCH model, differences in operational frameworks among central banks have to be taken into account. Conceptually, the measures should aim at capturing injections over and above the neutral level needed to just fulfill reserve requirements. Also important are operations that provide extraordinary liquidity to deal with market stress and, more broadly, the surprise element of a particular intervention.

For the ECB, we first employ a variable quantifying liquidity injections through longer-term refinancing operations (LTROs) that had been carried out in addition to those implemented regularly on a monthly schedule. Second, for main refinancing operations (MROs), a variable based on the MRO allotment exceeding the ECB's benchmark allotment is used.[39]

For the Fed, we use the difference between actual repurchase agreements outstanding and estimates of the amount of repurchase agreements that would have been necessary to achieve

[37]A GARCH framework is used to disentangle level and volatility effects of LIBOR spreads, as both can have an impact on financial institutions' funding conditions. At the same time, it is worth mentioning that the results are only indicative, as our approach does not take into account that intervention amounts themselves are likely to be determined endogenously. In particular, central banks might react to an expected increase in money market stress by raising their respective interventions, which then occur jointly with a potentially strong increase in the observed spreads.

[38]To capture the fact that during a crisis central bank operations may encompass multiple objectives (steering very short-term interest rates *and* supporting the smooth functioning of markets more broadly), a range of dependent variables were considered, all based on changes in the spread between LIBOR and overnight interest rate swaps for different maturities and currencies.

[39]The benchmark allotment is the ECB's projection of the liquidity provision needed to smoothly fulfill reserve requirements.

neutrality with respect to fulfilling banks' needs over a reserve maintenance period.[40]

The explanatory variables only proxy certain aspects of the responses of the ECB and the Fed. For example, the GARCH model cannot be expected to fully capture changes in the ECB's broader strategy of communication and liquidity provision through the maintenance period, factors that have been perceived to have contributed to the leveling off of euro LIBOR spreads between August and November 2007. Similarly, for the Fed, the choice of approach and sample period implies that the GARCH estimation takes into account neither TAF operations nor other operational adjustments. To address these shortcomings, the results from the GARCH model are complemented with a more heuristic approach based on a Markov regime-switching Autoregressive Conditional Heteroskedasticity (ARCH) specification. This model is used to determine the probability of being in a low-, medium-, or high-volatility state.[41] Changes in these probabilities are then compared with those of major central bank announcements or interventions.

Figures 3.11 and 3.12 and Table 3.1 summarize the results. As explained in the main text, the findings indicate that additional term lending, the joint central bank response announced on December 12, as well as the actual implementation of the TAF, were instrumental in reducing stress levels, conceptualized as a combination of spread levels and spread volatility.

**Table 3.1. Impact of Central Bank Interventions on LIBOR-OIS Spreads**

| | Three-Month LIBOR-OIS Spreads | |
|---|---|---|
| | Level | Volatility |
| ECB supplementary LTRO (L1) | –0.54 | –12.27*** |
| ECB supplementary LTRO (L2) | 0.10 | –8.66* |
| Fed repurchase agreements exceeding neutral | –0.16** | –2.69*** |
| Fed repurchase agreements exceeding neutral (L1) | 0.33*** | 1.18 |
| Fed repurchase agreements exceeding neutral (L2) | 0.06 | –0.01 |

Source: IMF staff estimates.

Note: The table reports coefficient signs of intervention variables from a GARCH specification. *** indicates significance at the 1 percent level; **(*) indicates significance at the 5 (10) percent level. The model is computed using Bollerslev-Wooldridge robust standard errors. L1 and L2 refer to lag lengths. The sample is from July 26 to December 24, 2007. OIS = overnight index swap; ECB = European Central Bank; LTRO = long-term refinancing operation.

## References


Adrian, Tobias, and Hyun Song Shin, 2007, "Liquidity and Leverage" (New York: Federal Reserve Bank of New York). Available via the Internet: http://www.ny.frb.org/research/economists/adrian/LiquidityLeverage25Sep2007.pdf.

Bank of England, 2007, "Markets and Operations," *Bank of England Quarterly Bulletin - Q4,* Vol. 47, No. 4.

Basel Committee on Banking Supervision (BCBS), 1992, "A Framework for Measuring and Managing Liquidity" (Basel: Bank for International Settlements, September). Available via the Internet: http://www.bis.org/publ/bcbs10b.pdf.

———, 2000, "Sound Practices for Managing Liquidity in Banking Organizations" (Basel, Bank for International Settlements, February). Available via the Internet: http://www.bis.org/publ/bcbs69.pdf.

———, 2006, "Core Principles for Effective Banking Supervision" (Basel, Bank for International Settlements, October). Available via the Internet: http://www.bis.org/publ/bcbs129.pdf.

———, 2008, "Liquidity Risk: Management and Supervisory Challenges" (Basel, Bank for International Settlements, February). Available via the Internet: http://www.bis.org/publ/bcbs136.htm.

Bech, Morton L., 2007, "The Federal Home Loan Bank System: The Lender of Next to Last Resort?" New York Federal Reserve Board Conference Presentation, December 13. Available via the Internet: http://www.newyorkfed.org/research/conference/2007/liquidity/FHLB_LiquidityConference.pdf.

Bernardo, Antonio E., and Ivo Welch, 2004, "Liquidity and Financial Market Runs," *Quarterly Journal of Economics,* Vol. 119 (February), pp. 135–58.


[40]The estimates were provided by Wrightson ICAP.

[41]Smoothed probabilities exceeding 0.5 indicate that the data-generating process is in that respective volatility regime.

Bervas, Arnaud, 2006, "Market Liquidity and Its Incorporation into Risk Management," *Banque de France Financial Stability Review,* No. 8 (May), pp. 63–79.

Bollerslev, Tim, 1990, "Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized ARCH Model," *Review of Economics and Statistics,* Vol. 72, No. 3, pp. 498–505.

Bradley, Christine M., and Lynn Shibut, 2006, "The Liability Structure of FDIC-Insured Institutions: Changes and Implications," *FDIC Banking Review,* Vol. 18, No. 2, pp. 1–37.

Brunnermeier, Markus, and Lasse Pedersen, forthcoming, "Market Liquidity and Funding Liquidity," *Review of Financial Studies.*

Caballero, Ricardo J., and Arvind Krishnamurthy, 2007, "Collective Risk Management in a Flight to Quality Episode," NBER Working Paper No. 12896 (Cambridge, Massachusetts: National Bureau of Economic Research).

Chavez-Dreyfuss, Gertrude, 2007, "Lingering Money Market Gloom Dims FX Swaps Outlook," Reuters, November 28.

Cifuentes, Rodrigo, Hyun Song Shin, and Gianluigi Ferrucci, 2005, "Liquidity Risk and Contagion," *Journal of the European Economic Association,* Vol. 3 (April–May), pp. 556–66.

Counterparty Risk Management Policy Group II (CRMPG II), 2005, "Toward Greater Financial Stability: A Private Sector Perspective" (July 27). Available via the Internet: http://www.crmpolicygroup.org/docs/CRMPG-II.pdf.

Engle, Robert, 2002, "Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models," *Journal of Business & Economic Statistics,* Vol. 20 (July), pp. 339–50.

European Central Bank (ECB), 2006, *EU Banking Structures* (Frankfurt: European Central Bank, October). Available via the Internet: http://www.ecb.int/pub/pdf/other/eubankingstructures2006en.pdf.

Federal Home Loan Banks (FHLB), 2007, "Combined Financial Reports," Office of Finance (various issues). Available via the Internet: http://www.fhlbof.com/specialinterest/financialframe.html.

Fleming, Michael, 2003, "Measuring Treasury Market Liquidity," *Federal Reserve Bank of New York Economic Policy Review,* Vol. 9 (September), pp. 83–108.

Forbes, Kristin, and Roberto Rigobon, 2002, "No Contagion, Only Interdependence: Measuring Stock Market Comovements," *Journal of Finance,* Vol. 57 (October), pp. 2223–261.

Frank, Nathaniel, Brenda González-Hermosillo, and Heiko Hesse, forthcoming, "Global Transmission of Liquidity Shocks: Evidence from the 2007 Subprime Crisis," IMF Working Paper (Washington: International Monetary Fund).

Frank, Nathaniel, Heiko Hesse, and Ulrich Klueh, forthcoming, "Term Funding Stress and Central Bank Interventions During the 2007 Subprime Crisis," IMF Working Paper (Washington: International Monetary Fund).

Garleanu, Nicolae B., and Lasse Pedersen, 2007, "Liquidity and Risk Management," NBER Working Paper No. 12887 (Cambridge, Massachusetts: National Bureau of Economic Research).

Gatev, Evan, Til Schuermann, and Philip E. Strahan, 2006, "How Do Banks Manage Liquidity Risk? Evidence from the Equity and Deposit Markets in the Fall of 1998," in *The Risks of Financial Institutions,* ed. by Mark S. Carey and René M. Stulz (Chicago: University of Chicago Press).

Gatev, Evan, and Philip E. Strahan, 2006, "Banks' Advantage in Hedging Liquidity Risk: Theory and Evidence from the Commercial Paper Market," *Journal of Finance,* Vol. 61 (April), pp. 867–92.

Hamilton, James D., and Raul Susmel, 1994, "Autoregressive Conditional Heteroskedasticity and Changes in Regime," *Journal of Econometrics,* Vol. 64 (September-October), pp. 307–33.

International Monetary Fund (IMF), 2007, *Global Financial Stability Report,* World Economic and Financial Surveys (Washington, October).

Institute of International Finance, 2007, *Principles of Liquidity Risk Management* (Washington, March).

Joint Forum, 2001, *Multidisciplinary Working Group on Enhanced Disclosure Final Report* (Basel: Bank for International Settlements).

———, 2006, "The Management of Liquidity Risk in Financial Groups" (Basel, Bank for International Settlements, May). Available via the Internet: http://www.bis.org/publ/joint16.pdf.

Khandani, Amir E., and Andrew Lo, 2007, "What Happened to the Quants in August 2007?" MIT Working Paper (Cambridge, Massachusetts: Massachusetts Institute of Technology, November 4). Available via the Internet: http://web.mit.edu/alo/www/Papers/august07_2.pdf.

Michaud, François-Louis, and Christian Upper, 2008, "What Drives Interbank Rates? Evidence from the

LIBOR Panel," *Bank for International Settlements Quarterly Review* (March), pp. 47–57.

Persaud, Avinash D., ed., 2003, *Liquidity Black Holes: Understanding, Quantifying and Managing Financial Liquidity Risk* (London: Risk Books).

Sarr, Abdourahmane, and Tonny Lybek, 2002, "Measuring Liquidity in Financial Markets," IMF Working Paper 02/232 (Washington: International Monetary Fund).

United Kingdom Financial Services Authority, 2007, "Review of the Liquidity Requirements for Banks and Building Societies," Discussion Paper No. 07/7 (London, December).