CHAPTER 2

MARKET LIQUIDITY—RESILIENT OR FLEETING?

SUMMARY

Market participants in advanced and emerging market economies have become worried that both the level of market liquidity and its resilience may be declining, especially for bonds, and that as a result the risks associated with a liquidity shock may be rising. A high *level* of market liquidity—the ability to rapidly buy or sell a sizable volume of securities at a low cost and with a limited price impact—is important to the efficient transfer of funds from savers to borrowers and hence to economic growth. Highly *resilient* market liquidity is critical to financial stability because it is less prone to sharp declines in response to shocks. Market liquidity that is low is also likely to be fragile, but seemingly ample market liquidity can also suddenly drop.

This chapter separately examines the factors that influence the level of market liquidity and those that affect its resilience, and finds that cyclical factors, including monetary policy, play an important role. In particular, the chapter finds that only some markets show obvious signs of worsening market liquidity, although dynamics diverge across bond classes. However, the current levels of market liquidity are being sustained by benign cyclical conditions—and some structural developments may be eroding its resilience. In addition, spillovers of market liquidity across asset classes, including emerging market assets, have increased.

Not enough time has passed for a full evaluation of the impact of recent regulatory changes to be made. Reduced market making seems to have had a detrimental impact on the level of market liquidity, but this decline is likely driven by a variety of factors. In other areas, the impact of regulation is clearer. For example, restrictions on derivatives trading (such as those imposed by the European Union in 2012) have weakened the liquidity of the underlying assets. In contrast, regulations to increase transparency have improved the level of market liquidity.

Changes in market structures appear to have increased the fragility of liquidity. Larger holdings of corporate bonds by mutual funds, and a higher concentration of holdings among mutual funds, pension funds, and insurance companies, are associated with less resilient liquidity. At the same time, the proliferation of small bond issuances has almost certainly lowered liquidity in the bond market and helped build up liquidity mismatches in investment funds.

The chapter recommends measures to bolster both the level of market liquidity and its resilience. Since market liquidity is prone to suddenly drying up, policymakers should adopt preemptive strategies to cope with such shifts in market liquidity. Furthermore, because current market liquidity conditions can provide clues about the risk of liquidity evaporations, policymakers should also carefully monitor market liquidity conditions over a wide range of asset classes. The chapter does not, however, aim to provide "optimal" benchmarks for the level or resilience of market liquidity. Market infrastructure reforms (including equal-access electronic trading platforms and standardization) can help by creating more transparent and open capital markets. Trading restrictions on derivatives should be reevaluated. Regulators should consider using tools to help adequately price in the cost of liquidity at mutual funds. A smooth normalization of monetary policy in the United States is important to avoid disruptions in market liquidity in both advanced and emerging market economies.

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Introduction

Market liquidity—the ability to rapidly execute sizable securities transactions at a low cost and with a limited price impact—and its resilience are important for financial stability and real economic activity.[1] A lower level of market liquidity reduces the efficiency with which funds are intermediated from savers to borrowers, and can potentially inhibit economic growth. Market liquidity that is low is also likely to be fragile, that is, prone to evaporation in response to shocks. When liquidity drops sharply, prices become less informative and less aligned with fundamentals, and tend to overreact, leading to increased volatility. In extreme conditions, markets can freeze altogether, with systemic repercussions. Market liquidity is likely to be high if market infrastructures are efficient and transparent, leading to low search and transactions costs; if market participants have easy access to funding; if risk appetite is abundant; and when a diverse investor base ensures that factors affecting certain types of investors do not translate into broader price volatility.

The private provision of market liquidity may not be socially optimal, especially during stress periods. Market participants benefit from abundant and stable market liquidity because it makes transactions less costly and less risky. However, individual traders do not fully internalize the positive externalities for the whole financial system that their participation in the market entails—the more traders trade in a market, the more liquid it becomes. Moreover, because of the network nature of markets, effects tend to be self-reinforcing—high market liquidity tends to attract more traders and so forth. This creates scope for multiple equilibria with different degrees of liquidity (Buiter 2008). To alleviate these problems, in some markets, designated market makers have the obligation to provide liquidity in return for certain advantages.[2] However, in stress situations, other important market failures play a role. For example, market liquidity can be severely impaired as a result of asset price drops, margin calls, and induced fire sales and liquidity feedback loops.[3] Similarly, liquidity contagion across markets can occur.[4] The potentially dramatic effects of sharp declines in liquidity were evident in 2008, during the financial crisis, when market illiquidity amplified shocks originating elsewhere.[5]

Concerns about both a decline in current market liquidity, especially for fixed-income assets, and its resilience have risen lately. Events such as the October 2014 Treasury bond flash rally in the United States, or the April 2015 Bund tantrum in Europe, have reminded us that market liquidity is fickle and that market dislocations can occur even for some of the most liquid assets. Market participants in both advanced and emerging market economies have been expressing worries about a perceived decline in liquidity in a variety of markets. Associated with these worries are concerns about the resilience of market liquidity to larger shocks, such as a "bumpy" normalization of monetary policy in advanced economies. In this context, Chapter 1 of the April 2015 *Global Financial Stability Report* (GFSR) warned of the risk that liquidity could potentially vanish.

In recent years, important transformations in financial markets have had potentially conflicting effects on market liquidity. As banks have been changing their business models and shrinking their inventories, market-making services seem to have become concentrated in fewer clients.[6] In addition, regulations requiring banks to increase capital buffers and restrictions on proprietary trading may have led them to retrench from trading and market-making activities. The introduction of electronic trading platforms and the growing use of automated calculations for computerized trades may have made market liquidity less predictable.

Another key development has been the rise of larger but more homogeneous buy-side institutions, particularly investment funds.[7] Mutual funds have become

[1]Two alternative and widely used concepts of liquidity are funding liquidity—the ease with which financial intermediaries can borrow—and monetary liquidity, typically associated with monetary aggregates. See Box 2.1.

[2]See Bessembinder, Hao, and Lemmon (2011) for a theoretical discussion.

[3]See Brunnermeier and Pedersen (2009).

[4]Externalities caused by market illiquidity during stress periods are well documented in the literature. Specifically, readers can refer to Duarte and Eisenbach (2015) and the references therein.

[5]During the crisis, the effects of the uncertainty surrounding the valuation of asset-backed securities was most likely amplified by a dry-up in liquidity in some markets (Acharya and others 2009).

[6]An intermediary makes a market in a security when it stands ready to sell the instrument at the announced "ask" price and buy it at the announced "bid" price. Market making requires sufficient inventories of the security and large risk-bearing capacity. Under liquid market conditions, market makers (or dealers) execute financial transactions at low bid-ask spreads. See CGFS (2014) for additional explanations and the results of a survey of market participants.

[7]Buy-side institutions are asset managers and other firms that demand "liquidity services," that is, the immediate execution of trades. Sell-side institutions, including many banks, can trade at announced prices, thus providing immediate execution (Hasbrouck 2007).

Box 2.1. How Can Market Liquidity Be Low Despite Abundant Central Bank Liquidity?

As a response to the global financial crisis, several central banks adopted a variety of unconventional monetary policy measures that included asset purchases, or so-called quantitative easing (QE) measures, and the expansion in the availability of central bank liquidity to the financial sector through specific facilities. Various facilities included changes to eligible collateral against which the central bank would extend credit. As a consequence, bank reserves with central banks have soared. Despite this, fears about bouts of market illiquidity have increased. This box tries to explain this apparent contradiction.

Impact on market liquidity

It has long been argued that monetary policy affects market liquidity (Fleming and Remolona 1999). Traditional monetary policy expansions affect market liquidity by reducing the costs of market making and trading. The reduction in market-making costs may be greater if overall uncertainty is reduced. However, the unconventional measures taken by central banks after the global financial crisis have had additional effects on market liquidity. Overall, the above measures affect market liquidity of their targeted markets through the following channels:

The bank funding channel—Like other open-market operations, central banks' purchases of long-term securities increase bank reserves, and therefore funding liquidity. The improved funding liquidity of banks relaxes their funding constraints, making it easier to finance their inventories and thereby supporting market liquidity (Brunnermeier and Pedersen 2009).[1] Indirectly, banks' greater funding liquidity also allows them to continue or increase margin funding to traders or lending to other market makers, with positive effects on the liquidity of securities markets.

However, the link between monetary liquidity and market liquidity is not straightforward, and in recent years, banks have actually retrenched from repo markets. Market participants often attributed this to regulatory changes that have raised the cost of this activity for banks (ICMA 2014). More generally, however, banks may be reluctant to engage in repo or margin lending because of high aggregate uncertainty (Freixas, Martin, and Skeie 2011) or the need to self-insure against funding shocks (Ashcraft, McAndrews, and Skeie 2011).

The market functioning channel—Outright purchases by central banks directly affect the liquidity of the securities being bought by central banks by reducing search frictions that prevent investors from finding counterparties for trades (Lagos, Rocheteau, and Weill 2011).[2] In addition, the presence of a committed and solvent buyer in the market reduces the illiquidity risk for the target securities, and may therefore support market making in these securities and enhance market functioning. As a consequence, the liquidity premium—the compensation investors require to hold a security that cannot easily be sold at a fair market value—is reduced. This market-functioning channel only works for the duration of the QE program or if investors believe the central bank would intervene again in the market should the price of the securities drop too much (Christensen and Gillan 2015).

On the other hand, when certain assets become scarce as a result of central banks' purchases, search costs are raised and those assets' market liquidity is reduced. In particular, outright purchases of high-quality government debt securities may be reducing the total amount of collateralizable securities and contributing to reduced liquidity in repo markets (Singh 2013). Evidence presented in the chapter suggests that this effect may have recently become more important in the United States.

The risk appetite channel—Evidence indicates that accommodative monetary policy increases risk appetite (Bekaert, Hoerova, and Lo Duca 2013; Jiménez and others 2014). When market makers' appetite grows, they are more likely to hold inventories and facilitate trades. Similarly, increased risk appetite implies a higher propensity to engage in trades by other market participants.

Longer-term impact on the investor base and market structure

The prolonged period of easy monetary policies and low interest rates in advanced economies has likely induced a "search for yield" by investors seeking

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[1]For example, the report discusses the role of the European Central Bank's collateral eligibility framework.

[2]These frictions may include dealer failures, communications breakdowns, uncertainty about counterparties' abilities to fulfill trades, and informational asymmetries between dealers and traders. In extreme situations, such frictions may lead to considerable market illiquidity even when funding liquidity is high.

Box 2.1. *(continued)*

higher returns by investing in less-liquid and more risky bonds. Furthermore, it has also boosted the growth of open-end mutual funds and exchange-traded funds investing in longer-term assets while offering daily liquidity, potentially raising liquidity risk (GFSR October 2014, Chapter 2; GFSR April 2015, Chapter 3). Moreover, these developments have resulted in a more homogeneous, and partly more concentrated, ownership structure.

Other forces and overall effects

Overall, this chapter argues that monetary policy has had a positive impact on market liquidity in recent years. On the other hand, as discussed in the text, various structural changes have been working in the opposite direction, reducing market liquidity. The combination of these forces has yielded the mixed picture of market liquidity that we currently observe.

more important for financial intermediation while becoming more sensitive to redemption pressures, more prone to herd behavior (as documented in the April 2015 GFSR), and less likely to absorb order flow imbalances or to make markets. The behavior of hedge funds has become more comparable to that of mutual funds, the role of index-driven and benchmark-driven investment has grown, and the inclination of pension funds and insurance companies to act countercyclically may have declined (Chapter 1 of the October 2014 GFSR).

In addition, unconventional monetary policies involving protracted, large-scale asset purchases are likely to have affected market liquidity in contradictory ways. On the one hand, in some markets the policies have probably enhanced market liquidity by positioning the central bank as a predictably large buyer. On the other hand, the asset purchases have drastically reduced the net supply of certain securities available to investors. Moreover, easy monetary policies have induced a search for yield, prompting funds to invest in bonds with low market liquidity.

These developments call for a better understanding of the factors influencing market liquidity and its resilience, especially in bond markets. Bond prices strongly affect consumption and investment—and hence macroeconomic stability—through interest rate and wealth effects. Bond prices also affect financial stability through their pivotal role in the repo market and their connection to funding liquidity.[8] Moreover, evidence suggests that the bond market is the medium through which monetary policy affects the market liquidity of other asset classes (Goyenko and Ukhov 2009).

[8]Repo markets, for the purposes of this chapter, are considered pertinent mostly to funding liquidity and are not covered by the empirical analyses.

With a special focus on fixed-income assets, this chapter investigates the following questions:

- How has market liquidity evolved in key markets in recent years?
- How has the resilience of market liquidity evolved across markets?
- What factors have driven these developments?

The chapter tackles these issues in three stages, using novel approaches to analyze rich and highly granular data sets. First, the chapter discusses developments in key markets. Next, relying largely on event studies, it sheds light on the different effects of various factors on the level of market liquidity. Finally, the chapter (1) demonstrates that high liquidity can be fragile, and (2) shows how liquidity shocks propagate across markets.

The main findings are as follows:

- *Only some markets show obvious signs of worsening market liquidity.* The evidence, however, points to diverging dynamics across bond classes. Market liquidity indicators for high-yield and emerging market bonds have started to weaken relative to those for investment-grade bonds.
- *Benign cyclical conditions are masking liquidity risks.* Cyclical factors are among the most important drivers of liquidity, and changes in them can help predict shifts in liquidity regimes. Currently, many of these cyclical determinants—investor risk appetite, and macroeconomic and monetary policy conditions—are creating very benign market liquidity conditions, but they can turn quickly, and spillovers of weak liquidity across asset classes (including emerging market assets) have increased.
- *Regulatory changes are likely to have had mixed effects on market liquidity.* Reductions in market making appear to have harmed market liquidity, and banks

now seem to face tighter balance sheet constraints for market making compared with the precrisis period. Nevertheless, conclusive evidence regarding the role of regulation as the driver of this development is still lacking. Restrictions on derivatives trading imposed by the European Union (EU) also have weakened the liquidity of the underlying assets. In contrast, regulations to increase transparency have improved market liquidity by facilitating the matching of buyers and sellers and reducing uncertainty about asset values.

- *Changes in the investor base have likely increased liquidity risk.* Larger holdings by mutual funds, and a higher concentration of holdings among mutual funds, pension funds, and insurance companies, are associated with less resilient liquidity.
- *On balance, monetary policy has had a positive impact on market liquidity in recent years but may have increased liquidity risk*. Monetary policy helped relax funding constraints for financial intermediaries and heighten risk appetite, with important effects on market liquidity. However, outright purchases of some securities have reduced their supply; in the United States, this effect now seems to have started to dominate for those securities, to the detriment of their liquidity. Moreover, accommodative monetary policy has triggered a search for yield, with a rise in holdings of less liquid assets by funds and institutional investors.

The findings suggest the following policy recommendations:

- Policymakers should adopt preemptive strategies to deal with sudden shifts in market liquidity. Since current market liquidity conditions provide information about the risk of liquidity suddenly drying up, policymakers should monitor market liquidity conditions in real time and for a wide range of asset classes using transactions-based metrics.
- Since electronic trading platforms can facilitate the emergence of new market makers, asset managers and other traders should, in principle, have access to these platforms on equal terms.
- Trade transparency in capital markets and instrument standardization should be promoted to improve market liquidity.
- Given their negative effect on market liquidity, restrictions on derivatives trading, such as those implemented by the EU in 2012, should be reevaluated.
- Central banks should be mindful of the side effects on market liquidity arising from their policies on collateral and outright purchases of securities.
- Ways to reduce both liquidity mismatches and the first-mover advantage at mutual funds should be considered (April 2015 GFSR, Chapter 3).
- As the Federal Reserve begins to normalize its monetary policy, a smooth implementation will be critical to avoid disruptions of market liquidity, in both advanced and emerging market economies.

Market Liquidity—Concepts and Drivers

Concept and Measurement

Market liquidity is the ability to rapidly execute sizable securities transactions at a low cost and with a limited price impact. Market liquidity is different from the notions of funding liquidity (the ability by market participants to obtain funding at acceptable conditions) and monetary liquidity (typically used in relation to monetary aggregates). Despite their differences, these three concepts are related. Funding liquidity, for example, is typically a prerequisite for market liquidity, since market makers also use credit to maintain inventories. Market liquidity, for its part, tends to enhance funding liquidity because margin requirements depend on the ease with which securities can be sold (Foucault, Pagano, and Roell 2013). Monetary expansions ease funding conditions for banks, which in turn can facilitate market-making activities (see Box 2.1 for more details). However, the relationship between these three concepts is not one-to-one, and other factors play a role.

Two aspects of market liquidity must be considered: its level and its resilience. Low levels of liquidity may foretell low resistance to shocks. But measures of the level in normal times may be insufficient to assess the risk that a shock will produce if liquidity “freezes.” A well-known characteristic of market liquidity is that it can suddenly disappear during periods of market stress, causing asset prices to strongly overreact to unexpected events.

Can market liquidity be too high? It is difficult to envisage adverse effects of market liquidity in the absence of other major distortions. Higher market liquidity in general reduces volatility and speeds up information aggregation. Conceivably, high market liquidity levels that are largely driven by cyclical factors can foster the "illusion" of resilient market liquidity, inducing excessive risk taking (Clementi 2001). However, in this case it is the lack of resilience in market liquidity, rather than high market liquidity itself, that is harmful for financial stability. When investors are irrationally overconfident, in theory, high market liquidity could favor trading frenzies and amplify asset price bubbles (Scheinkman and Xiong 2003).[9] Yet, in general, it is easier to think of situations in which funding liquidity rather than market liquidity can be excessive. For example, high funding liquidity can lead financial institutions to take on excessive leverage, which can be detrimental to financial stability (Geanakoplos 2010).

A challenge for financial stability policy is to understand and attenuate the forces that, in the presence of a shock, can suddenly transform a state of high liquidity into one of low liquidity. Abundant and stable market liquidity has aspects of a public good—it benefits all the participants in the market and it is difficult to exclude participants from it; moreover, a sharp decline in market liquidity can adversely affect financial stability. These considerations suggest the potential for liquidity underprovisioning and imply a role for public policy in fostering sound market infrastructures and regulations to enhance liquidity. Moreover, the externalities associated with collapses in market liquidity and associated adverse feedback loops provide an argument for monitoring and managing the conditions that affect the resilience of market liquidity to financial shocks. In situations of stress, direct intervention may be needed. The chapter analyzes factors influencing the level of liquidity in the section on "Changes in Drivers of Market Liquidity—Empirical Evidence on Their Impact." The problem of predicting its resilience is examined in the section on "Liquidity Resilience, Liquidity Freezes, and Spillovers."

The level of market liquidity has many dimensions and cannot be captured by any single measure. However, depending on what dimension of market liquidity one is trying to assess—time, cost, or quantity—some measures are more informative than others. Some measures, such as imputed "round-trip costs," effective spreads (actual or estimated), and Amihud's (2002) price impact measure capture the cost dimension. Others, such as quote depth or dealer depth, capture the quantity dimension (see Table 2.1). This chapter emphasizes the following cost measures, which closely correspond to the definition of the level of market liquidity used in this chapter: the round-trip costs of trades (the cost of buying a security and immediately selling it), effective bid-ask spreads (actual or estimated), and price impact measures.[10]

General Drivers of Market Liquidity Levels and Resilience

The drivers of market liquidity levels and resilience comprise three broad categories (Figure 2.1). These include (1) the risk appetite, funding constraints, and market risks faced by financial intermediaries, all of which affect their inclination to provide liquidity services and correct the mispricing of assets by taking advantage of arbitrage opportunities; (2) search costs, which influence the speed with which buyers and sellers can find each other; and (3) investor characteristics and behavior reflecting different mandates, constraints, and access to information (Vayanos and Wang 2012; Duffie 2012).

- In recent years, structural developments, as well as monetary policy, have probably affected these fundamental drivers.
- Tighter funding constraints for trading—induced by changes in regulations and in business models—have arguably lowered dealers' risk-taking capacity or willingness to make markets and reduced banks' proprietary trading activities (CGFS 2014; Elliott 2015). Less market making impedes the matching of buyers and sellers, thereby increasing search costs.
- New regulations in major jurisdictions have also affected search costs both positively and negatively in various asset markets.[11] For instance, new trade transparency requirements probably reduced search costs, whereas the EU's ban on uncovered sovereign credit default swap (CDS) positions had the opposite effect.

[9]Asset price bubbles also occur in highly illiquid markets such as the real estate market (Shiller 2000).

[10]Some commonly used metrics can be misleading. Market turnover is a widely available quantity measure whose high readings during turbulent times are often taken to indicate high liquidity even though market liquidity at such times may, in fact, be very low (that is, transactions have a large price impact). For cost, quoted bid-ask spreads that are not based on actual transactions may not reflect the actual costs of trades.

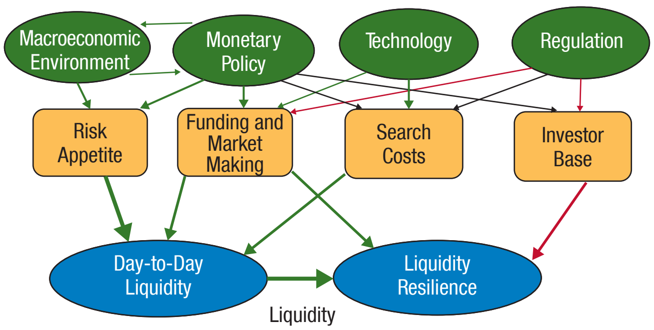
[11]For instance, since 2002 the United States has gradually increased posttrade transparency for corporate bonds by requiring the dissemination of trade information. Also in the United States, the Dodd-Frank Act of 2010 brought greater transparency to over-the-counter derivatives by mandating the disclosure of trades in swap data repositories. In 2017, the Directive on Markets in Financial Instruments (MiFID 2) regulation is scheduled to extend to fixed-income markets many of the pre-and posttrade transparency requirements that currently apply to equities.

Table 2.1. Liquidity Measures

Measures	Data Requirements	Calculation Method	Aspect of Market Liquidity
Bid-ask spread	Quotes	The quoted ask price minus the quoted bid price.	A measure of transaction costs. It shows how much a trader pays by buying and then immediately selling a given security.
Turnover	Volume data	Trade volume divided by market value of outstanding securities.	A measure of trading activity not necessarily related to market liquidity.
Roll's (1984) price reversal	Price data	Covariance between price change in time *t* and time *t*–1.	A measure of bid-ask spreads. It exploits the fact that buy and sell orders arrive randomly and force prices to bounce between ask and bid quotes. This generates a negative autocovariance of returns, under restrictive assumptions.
Corwin and Schultz's (2012) high-low spread	Price data	Nonlinear function of two-day high and low prices.	Similar to Roll's (1984) metric. It measures transaction costs by estimating a bid-ask spread when quote data are not available or unreliable. It uses information on intraday high and low prices.
Effective spread	Price and quotes data	The transaction price minus the quoted mid price (simple average of the best bid and ask quotes).	The actual, round-trip-equivalent, cost of trading to the liquidity demander. It captures how far away from the mid price trades are actually taking place.
Imputed round-trip cost	Price and volume data	The highest price of a security minus the lowest price of the same security with the same trade size within one day.	An indirect measure of the round-trip cost. Captures transaction costs in fixed-income markets by calculating how much it costs if a trader buys and sells the same security at the same day in the same amount. It is useful when there are no quoted prices available.
Price impact	Price and trading volume	Slope coefficient of a regression of price change on signed order flow (buyer-initiated trades minus seller-initiated trades).	A measure of market depth. It estimates the change in price for a given trading volume. In other words, it represents the marginal cost of trading an additional unit of quantity (Holden, Jacobsen, and Subrahmanyam, forthcoming).
Amihud's (2002) measure	Daily price and volume	Absolute daily return divided by daily volume.	A measure of market depth. It shows the daily price change associated with one dollar of trading. Market depth captures the quantity dimension of market liquidity, that is, the ease with which one can trade securities in large amounts.
Quote depth	Quotes	Total number of quotes or sum of quote sizes (total quantities dealers are willing to buy or sell at announced ask and bid prices).	A direct measure of market depth. It documents the depth of the order book and captures the quantity of securities for which dealers are willing to supply liquidity services.
Dealer count	Unique providers of quotes	Number of dealers quoting the security or showing some availability to trade.	An indirect measure of market depth that documents the number of dealer quotes we have on a given security. It also roughly captures the availability of market making.
Markit's liquidity score	Price and quotes data	An instrument-specific index of liquidity calculated by Markit that captures the following aspects: number of dealers; number of quotes; number of price sources; and bid-ask spreads. For bonds, it also takes into account the maturity and whether a benchmark yield curve with liquid bonds exists. For CDS contracts, it also includes volumes, number of price points, and index membership (for single-name CDS).	A composite measure of market liquidity. It provides an ordinal approximation of the many dimensions of liquidity based on observable bond and trade characteristics, with special emphasis on trade costs and data quality. According to Markit, it estimates market breadth—the number of participants in a market—and implied liquidity (useful when data are incomplete or securities do not trade often). A smaller value implies higher liquidity.

Source: IMF staff.
Note: CDS = credit default swap.

Figure 2.1. Drivers of Liquidity and Liquidity Resilience



Source: IMF staff.
Note: Green (red) arrows signify a positive (negative) effect. Black arrows signify an ambiguous or unknown effect. A thicker arrow suggests a stronger effect.

- The growth of electronic trading platforms should have, in principle, reduced search costs. But the implications of the associated advance of automated trades (algorithmic trading) are unclear. They are potentially adverse if such trading is mainly used to demand immediate liquidity or the algorithms are poorly designed. Conceivably, they may have increased the probability and severity of large market dislocations (Box 2.2; Laganá and others 2006).[12]
- Central banks' large-scale purchases of securities under unconventional monetary policy are likely to have affected market liquidity both positively and negatively—positively by relaxing funding constraints, reducing term and default premiums, and raising risk appetite; and negatively by reducing the supply of certain bonds and thereby raising search costs for market participants (Box 2.1). However, the search for yield in a low-interest-rate environment has likely spurred the demand for corporate bonds and stimulated an increase in the number of smaller issues, thus increasing search costs.

These issues are examined empirically in the "Changes in Drivers of Market Liquidity—Empirical Evidence on Their Impact" section.

Changes in other factors have potentially reduced the resilience of liquidity (Box 2.3), while the smaller role of highly leveraged financial intermediaries may have dampened the risk that liquidity might suddenly disappear.

- The growing role in bond markets of mutual funds that offer daily redemptions to retail investors, coupled with signs of increasing herding and concentration among market participants, has made market liquidity more vulnerable to rapid changes in sentiment (CGFS 2014; April 2015 GFSR, Chapter 3).
- This buildup of liquidity risk in the asset management industry was likely encouraged by accommodative monetary policy and the ensuing search for yield (Gungor and Sierra 2014).
- Similarly, the growth of index investors and the more widespread use of benchmarks are likely to have increased commonality in liquidity and thereby systemic liquidity risk.
- At the same time, hedge funds are said to have become more similar to mutual funds in their behavior (October 2014 GFSR, Chapter 1).
- Developments at hedge funds and traditional broker-dealers since the global financial crisis have likely moderated liquidity risk. Although these institutions may have reduced market making by paring back their leverage or their trading activities, they have also reduced the self-reinforcing link between leverage and market liquidity risk.[13]

The issue of predicting the risk of liquidity freezes is examined in the "Liquidity Resilience, Liquidity Freezes, and Spillovers" section.

Market Liquidity—Trends

This section examines the evolution of market liquidity for corporate and sovereign bonds with an emphasis on cost measures of liquidity. The precise choice of market liquidity measure varies according to data availability and market micro-structure; however, all measures try to approximate trade costs.[14]

Among major bond markets, only the U.S. Treasury market appears at first glance to have recently suffered a

[12]Compared with other asset classes, electronic platforms are not prevalent in the trading of corporate bonds (with a share between 10 percent and 20 percent) (McKinsey & Company and Greenwich Associates 2013). Hence, in this chapter, electronic trading does not receive as much attention as other drivers of market liquidity.

[13]See Acharya and Viswanathan (2011) for a theoretical explanation of the link between bank leverage, asset fire sales, and market liquidity spirals.

[14]For instance, for markets in which securities trade infrequently, such as the corporate bond markets, a measure such as Corwin and Schultz's (2012) estimated bid-ask spreads cannot be calculated.

Box 2.2. Electronic Trading and Market Liquidity

In the past few decades, electronic trading platforms have been introduced in a wide variety of markets. This box examines the potential benefits and costs of electronic trading platforms. Using the example from the over-the-counter (OTC) derivatives market, it argues that the introduction of electronic platforms is generally beneficial to market liquidity. However, some recent liquidity episodes also point to the potential vulnerabilities brought about by electronic trading, especially high-frequency trading.

Electronic trading platforms can potentially affect market liquidity in several ways. On the one hand, electronic trading can greatly facilitate matching between buyers and sellers. On the other hand, new trading strategies enabled by electronic trading platforms can potentially cause disruptions to market liquidity in the face of shocks.

Although studies of the impact of electronic trading on the market liquidity of corporate bonds are still scarce, in general they find it to be beneficial. The electronification of fixed-income markets makes it easier to match buyers and sellers by accessing a central limit order book on electronic trading venues. Hendershott and Madhavan (2015) find that electronic auction markets improve the liquidity of thinly traded corporate bonds (although the effects are larger for the most liquid ones). Furthermore, Chaboud and others (2014) find that, in the foreign exchange market, algorithmic trading enhanced price efficiency and average liquidity.

For securities that are originally traded in the OTC markets, the migration to electronic trading platforms can lead to a boost in trading volume and market liquidity, or improve price discovery (Zhu 2012). In the United States, the migration of several OTC derivatives contracts to electronic trading platforms started in October 2013, with the Commodity Futures Trading Commission (CFTC) authorizing the first Swap Execution Facility (SEF). Furthermore, effective in February 2014, the U.S. authorities mandated that all contracts that the CFTC has designated as "made available to trade" with U.S. counterparties be executed on a SEF or exchange market. The first wave of made-available-to-trade designations has focused on highly standardized and centrally cleared contracts, such as certain interest rate swaps and index-based credit default swaps (Figure 2.2.1). Once the implications of these developments

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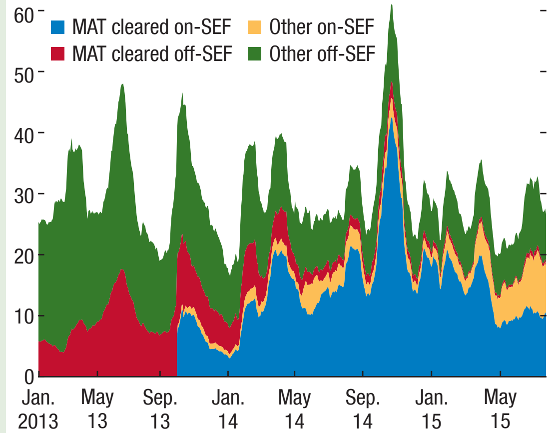
Figure 2.2.1. Trade Volume in U.S. Credit Default Swaps

The volume of trading in interest rate swaps in the United States has greatly increased since the introduction of SEFs.



Sources: ISDA-SwapsInfo; and IMF staff calculations.
Note: MAT = made available to trade; SEF = Swap Execution Facility.

for market liquidity in OTC derivatives become clear, important lessons may be drawn for the greater electronification and standardization of the corporate bond markets.

However, electronic trading platforms can also facilitate the growth of high-frequency trading (HFT) firms, with a potential negative impact on the resilience of liquidity. These firms are thought to have been one of the causes of the October 2014 flash rally episode in the U.S. Treasury market. Events such as this, and the May 6, 2010, flash crash in U.S. equity and equity futures markets, show how liquidity can evaporate very quickly even on the most liquid markets in the world and how the lack of liquidity can amplify shocks, resulting in heightened levels of volatility (see Easley, Lopez De Prado, and O'Hara 2011).

The structure of U.S. Treasury markets has experienced significant changes during the past decade, with a declining role for banks and a rise of HFT. The provision of liquidity changed because banks arguably now have less balance sheet space dedicated to market-making strategies, and HFT firms typically operate with very low capital. In normal times, liquidity is ample but when confronted with a shock, the market is more vulnerable because traditional and new market makers are unable or unwilling to provide liquidity.

Box 2.2. *(continued)*

On October 15, 2014, the U.S. Treasury futures market experienced one of the most volatile episodes of the past 25 years. A disappointing retail sales data release prompted hedge funds to reposition for a delayed Fed rate increase. As prices gradually rose, traditional market makers reduced their provision of liquidity, as shown by the steady decline in order book depth between 8:50 a.m. and 9:33 a.m. of that day (Figure 2.2.2[1]). At the same time, large volumes of algorithmic and other HFT activity were taking place. In the next 12 minutes, liquidity evaporated and a few large trades had a large enough impact on the market to set into motion the dynamics of the flash event. High trading volumes amid very low liquidity resulted in a feedback loop: HFT firms traded aggressively to reduce their risk but given that liquidity was low, the price impact of each trade increased volatility, leading to further trades (Bouveret and others, forthcoming).

A joint report by U.S. authorities (U.S. Department of the Treasury and others 2015) also emphasizes the predominance of HFT and the declining role of broker-dealers. During the flash dynamics, the share of trading done by HFT firms increased markedly to account for 80 percent of trading activity (compared with 50 percent on control days), as HFT firms aggressively bought during the price rise and sold during the decline.

[1]Figure 2.2.2 is available online as a PDF download at IMF.org and elibrary.IMF.org.

deterioration of liquidity (Figure 2.2, panel 2). Nevertheless, that market remains highly liquid compared with most other large markets, and estimated bid-ask spreads are close to their 2004 levels. In the bond markets of the United States, Europe, and emerging market economies, imputed round-trip costs (or similar metrics of liquidity) are generally below their 2007 levels.

The level and resilience of market liquidity for higher-grade corporate bonds appears to be becoming increasingly stronger than that for lower grades. During the past year, quoted spreads of corporate bonds issued in emerging market economies have been rising faster than the spreads for those issued in advanced economies. For investment-grade corporate bonds, the short-term resilience of market liquidity—expressed as the pace at which the level of market liquidity recovers from bad news or unexpected events—seems to be improving faster than that for high-yield issues (Figure 2.3).[15]

Finally, the price impact of trades has risen in some markets. The price impact has increased for various European sovereign bonds and, to a lesser extent, for high-yield corporate bonds. An indication that large trades may now be harder to execute than 10 years ago is that the share of large transactions in trades involving U.S. corporate bonds has fallen (Figure 2.3).[16]

Changes in Drivers of Market Liquidity—Empirical Evidence on Their Impact

This section examines some of the drivers of the level of market liquidity. Because causality between drivers and market liquidity often goes both ways, most of the analyses rely on event studies. Although most (but not all) of the data pertain to securities issued or traded in advanced economies, many implications carry over to emerging market economies.[17]

When considering the extent to which changes in the various drivers have affected liquidity, it is typically difficult to sort out the direction of causality. Thus, the testing of the link between a change in a driver such as market making and a change in the level of market liquidity must take reverse causality into account—that is, the possibility that a change in liquidity can cause a change in the supposed driver. For example, market makers are more willing to provide liquidity services for securities that are more liquid. The approach taken here to overcome problems of reverse causality is to

[15]The speed at which liquidity recovers from small perturbations is calculated by regressing the daily changes in aggregate market liquidity on the lagged changes and the lagged level of liquidity. When the coefficient of lagged liquidity is closer to zero, the resilience of liquidity is estimated to be lower.

[16]Likewise, in the futures and equity markets, large trades are more expensive than smaller trades (Kraus and Stoll 1972), and the share of large trades has declined (see the statistics of the World Federation of Exchanges). But as in the corporate bond market, traders now avoid the higher cost of executing a large trade by exploiting technological improvements in risk management and trading platforms to break large trades into many small ones. Hence, the total cost of making what used to be a large trade has probably declined. In addition, the recent increase in corporate bond issuance also reflects a higher share of small issues.

[17]In addition, for the asset class featured prominently in the section—corporate bonds traded in the United States—some of the securities were issued by entities domiciled in emerging market economies.

Box 2.3. Structural Drivers of the Resilience of Market Liquidity

Several structural drivers have potentially affected the ability of market liquidity to withstand shocks. This box uses two event studies to analyze the contributions of market making, pretrade transparency, and the investor base to the behavior of corporate bond market liquidity in the face of a significant financial shock.

Impact of reduced market marking on liquidity resilience

During the "taper tantrum" episode of 2013, bonds for which there were fewer market makers saw the greatest deterioration of liquidity (Figure 2.3.1). The analysis is based on an examination of a large sample of corporate bonds from across the world, after controlling for various bond characteristics (see Annex 2.2 for details on the methodology). Accordingly, the presence of an additional dealer quoting a bond before the taper tantrum (April 2013) is associated with an improvement in that bond's performance relative to the sample average of roughly 15 percent. The same analysis also shows that higher-credit-quality bonds—thus with lower market-making costs—also experienced smaller declines in liquidity.

Issue size

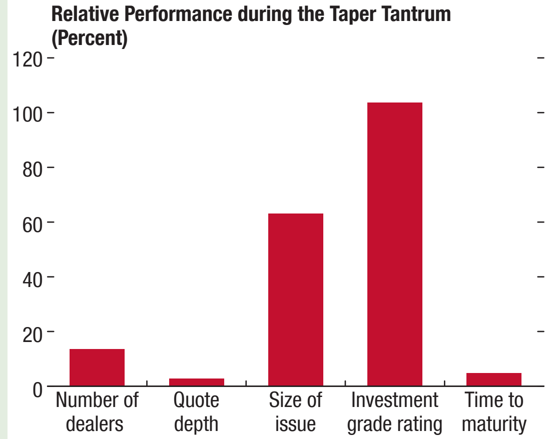
The combination of the proliferation of a variety of smaller issuances and the growth in riskier bonds is likely to have reduced the resilience of liquidity. Bond size or total amount issued by a borrower should be positively related to bond liquidity because larger issues are more likely to have a credit default swap or to belong to an index, or because of economies of scale in gathering information about credit risk. In fact, during the taper tantrum, everything else constant, the liquidity of larger issues exhibited greater resilience.

Trade transparency and liquidity resilience

Pretrade transparency—measured by the number of quotes—is positively related to the resilience of market liquidity.[1] Again for the taper tantrum, the market liquidity of bonds with better pretrade (or quote) transparency performed better than bonds with fewer advertised quotes (Figure 2.3.1). Although the result does not unequivocally establish causality,[2] it suggests that better dissemination of trading interest is associated with smaller declines in liquidity during periods of financial stress, in line with similar findings for the equity market (Boehmer, Saar, and Yu 2005).

Figure 2.3.1. Liquidity during the Taper Tantrum

Relative liquidity performance during the taper tantrum episode was better for bonds with more dealers, larger size, or better credit rating.



Sources: Markit; and IMF staff estimations.
Note: The figure shows the contribution of each factor to a nonfinancial corporate bond's liquidity performance during the taper tantrum episode. Liquidity is measured using Markit's liquidity score, which is a composite index of market liquidity. Solid columns mean statistical significance at least at the 10 percent level. See Annex 2.2.

Investor landscape and liquidity resilience

Empirically, larger holdings by mutual funds, in particular, open-end mutual funds, are associated with more severe liquidity declines during stress periods (Figure 2.3.2). When bonds were more heavily held by mutual funds before the financial crisis or the 2013 taper tantrum, liquidity (imputed round-trip costs) tended to decline more during the event.[3] The result is stronger if the measure of ownership concentration focuses on open-end mutual funds, which is consistent with the view that these funds have a more fickle investor base (Chapter 3 of the April 2015 GFSR). There is no evidence to support the notion that insurance companies or pension funds had a stabilizing impact on liquidity by acting as contrarian investors.

Finally, bond liquidity declines when ownership is more concentrated. During the global financial crisis of 2008, corporate bonds traded in the United States

This box was prepared by Luis Brandão Marques and Kai Yan.

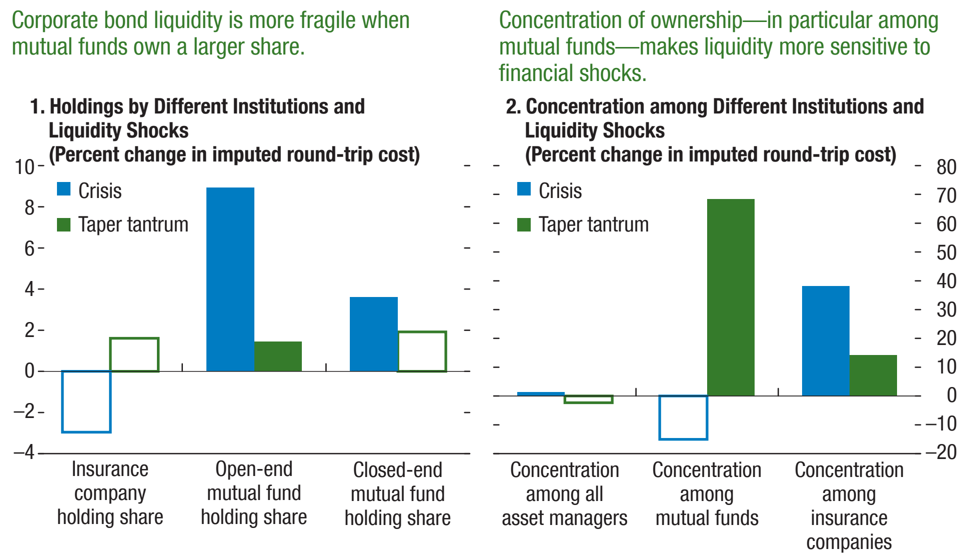
[1]Pretrade transparency refers to the dissemination of quotations or other indications of trading interest (Bessembinder and Maxwell 2008).

[2]It is possible that dealers refrain from posting quotes for bonds that they know to have low resilience.

[3]The hypotheses were tested using alternative measures of liquidity such as Amihud's (2002) price impact and Roll's (1984) price reversal, with qualitatively similar results.

Box 2.3. *(continued)*

Figure 2.3.2. Ownership and Market Liquidity



Sources: FINRA Trade Reporting and Compliance Engine; and IMF staff estimations.
Note: The charts show the estimated impact of ownership and ownership concentration on imputed round-trip costs for corporate bonds traded in the United States. A positive value signifies a decline in liquidity. Solid columns mean statistical significance at least at the 10 percent level. See Annex 2.2.

with more concentrated ownership by institutional investors (mutual funds, pension funds, and insurance companies) at the onset of the crisis (first quarter of 2008) experienced a significantly greater decline of liquidity during that year. Similarly, for the 2013 taper tantrum, bonds with more concentrated ownership among mutual funds also saw greater deterioration of liquidity.

use event studies, that is, to identify and examine events in which changes in potential drivers arise from sources independent of the state of liquidity.[18] The event studies are complemented by an econometric analysis of the role of cyclical drivers. The analyses do not, however, aim to quantify the net impact of all the discussed changes on market liquidity.

[18]The empirical work draws information on corporate and sovereign bonds from security-level data and from intraday transactions-level data in three data sets: (1) Financial Industry Regulatory Authority Trade Reporting and Compliance Engine, which covers about 140 million transactions on 100,000 corporate bonds traded in the United States since 2002; (2) MTS, which covers 120 million interdealer transactions in European sovereign bonds since 2005; and (3) Markit's GSAC and CDS databases, which provide liquidity metrics for a large number of bonds and CDS contracts. See Annex 2.1.

Event Studies of Market-Making and Funding Constraints

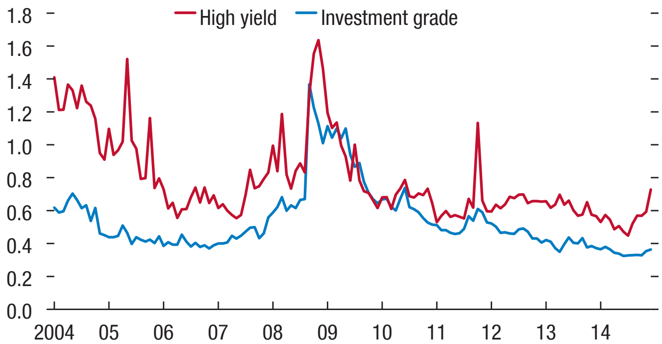
Evidence of reduced market making

Dealer banks in advanced economies show signs of being less active market makers in fixed-income securities (Figure 2.4, panels 3 and 4). In several advanced economies, bank holdings of corporate debt have declined (amid a large increase in total outstanding debt). The evidence on sovereign bonds is more mixed, however, with smaller holdings at U.S. banks and larger holdings at German banks. In addition, surveys by the Federal Reserve and the European Central Bank (ECB) suggest that market making has declined, mostly because of bank balance sheet constraints, internal charges to market making and trading, and regulatory reforms.

Figure 2.2. Trends in Bond Markets—Market Liquidity Level

Imputed round-trip costs for U.S. corporate bonds have declined...

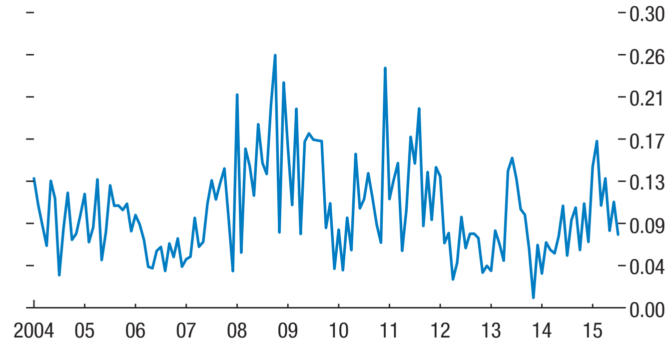
1. Imputed Round-Trip Cost, by Rating
(Percent)



Note: The figure shows the imputed round-trip cost of U.S. corporate bonds, by credit rating.

...while liquidity in the U.S. Treasury market has recently deteriorated.

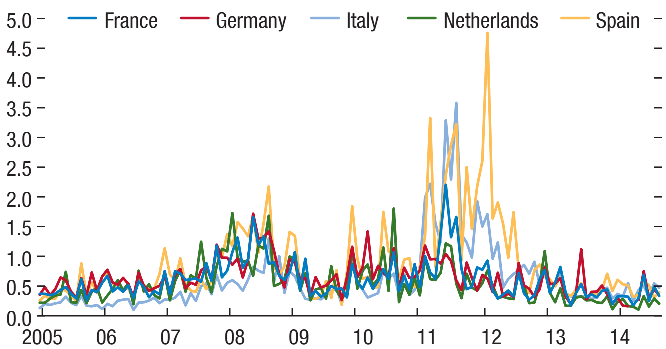
2. Estimated Bid-Ask Spreads for U.S. Treasuries
(Percent)



Note: Bid-ask spread, as a percent of price, for on-the-run 10-year U.S. Treasury bonds, estimated using the high-low spread suggested by Corwin and Schultz (2012).

Liquidity for European sovereign bonds appears to be similar to precrisis levels…

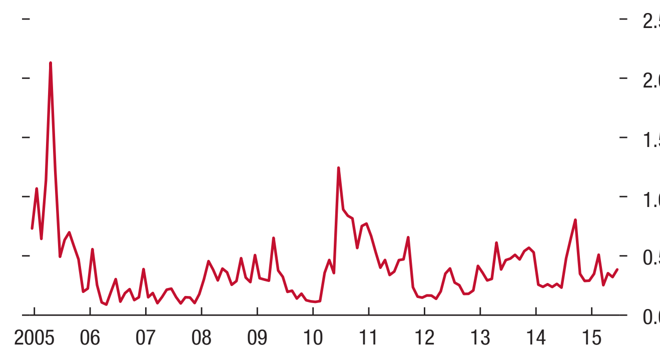
3. Effective Spread for European Sovereign Bonds
(Percent)



Note: The figure shows the effective spread of a two-year on-the-run government bond for the following countries: France, Germany, Italy, Netherlands, and Spain.

...and the liquidity of emerging market sovereign bonds has been stable.

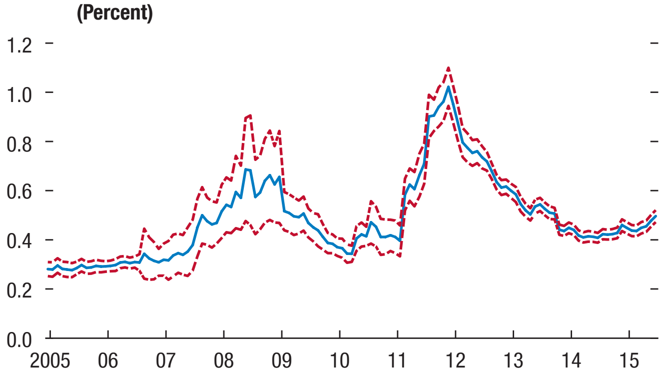
4. Estimated Bid-Ask Spread for Emerging Market Sovereign Bonds
(Percent)



Note: Bid-ask spread, as a percent of price, for local currency government bonds from Brazil, India, Indonesia, South Africa, and Turkey, with a maturity of at least five years, estimated using the high-low spread suggested by Corwin and Schultz (2012).

European corporate bonds are generally more liquid now...

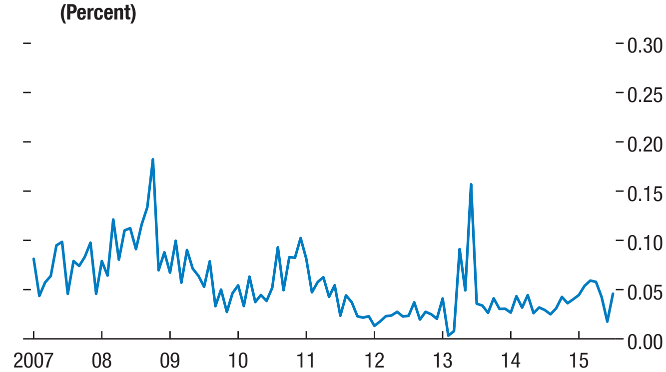
5. Bid-Ask Spreads for European Corporate Bonds
(Percent)



Note: The figure shows average bid-ask spreads for euro-denominated nonfinancial corporate bonds with a maturity greater than one year and all ratings from Belgium, France, Germany, Italy, Netherlands, and Spain. Dashed lines representing 95 percent confidence bands were added to account for increased sample coverage.

...as are Japanese government bonds.

6. Estimated Bid-Ask Spreads for Japanese Government Bonds
(Percent)



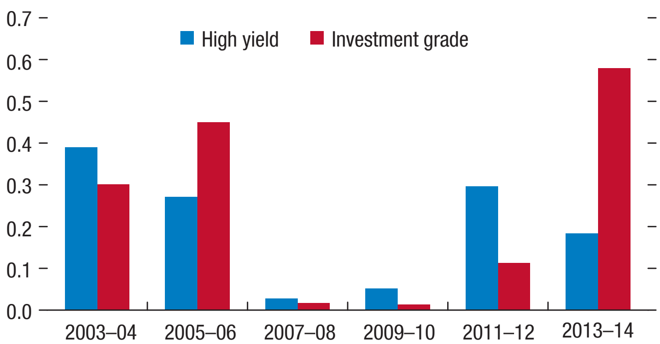
Note: Bid-ask spread, as a percent of price, for on-the-run 10-year Japanese government bonds estimated using the high-low spread suggested by Corwin and Schultz (2012).

Sources: Bloomberg, L.P.; FINRA Trade Reporting and Compliance Engine; MTS; and IMF staff calculations.

Figure 2.3. Bond Market Liquidity—Bifurcation and Price Impact of Transactions

The short-term resilience of liquidity has moved in opposite directions for investment-grade and high-yield U.S. corporate bonds.

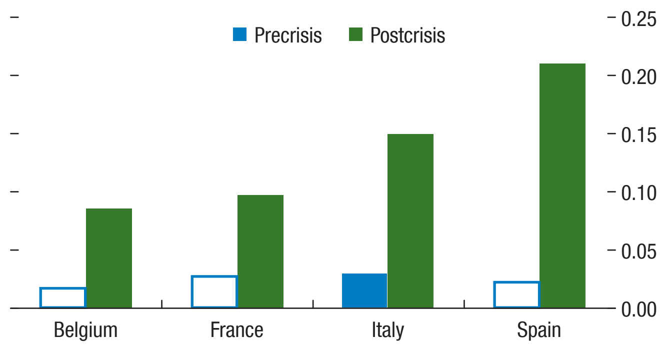
1. Liquidity Mean Reversion Coefficient (Regression coefficient)



Note: The figure shows the coefficients of mean reversion of a measure of market liquidity—imputed round-trip cost—for corporate bonds by credit rating.

The price impact of trades has risen in some European countries.

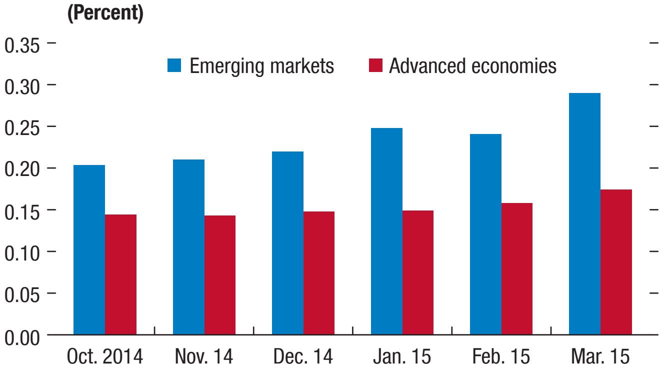
2. Price Impact Coefficient, Five-Year Sovereign Bonds (Coefficient for €100 million in volume; percentage points)



Note: The figure shows the estimated price associated with a €100 million purchase of a five-year on-the-run government bond for the following countries: Belgium, France, Italy, and Spain. Solid bars indicate that the impact is statistically significant at least at the 10 percent level.

Quoted bid-ask spreads have increased faster for emerging market bonds in recent months.

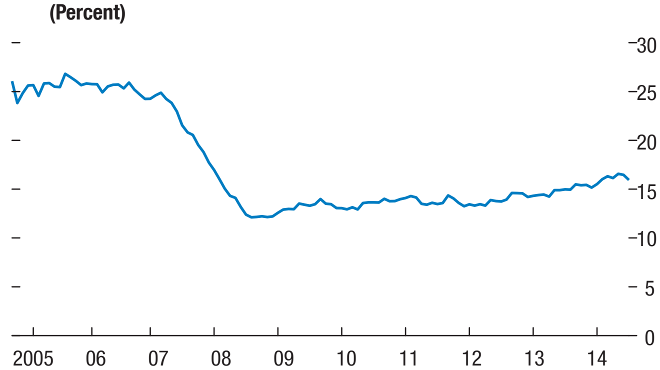
3. Bid-Ask Spreads for Investment-Grade Corporate Bonds (Percent)



Note: The figure shows the average bid-ask spread as a percent of bond par value.

Larger trades are less frequent than before the crisis.

4. Large Transactions in the U.S. Corporate Bond Market (Percent)



Note: The figure shows the fraction of large trades in the U.S. corporate bond market as a percent of total transactions. A large trade is defined as larger than $1 million.

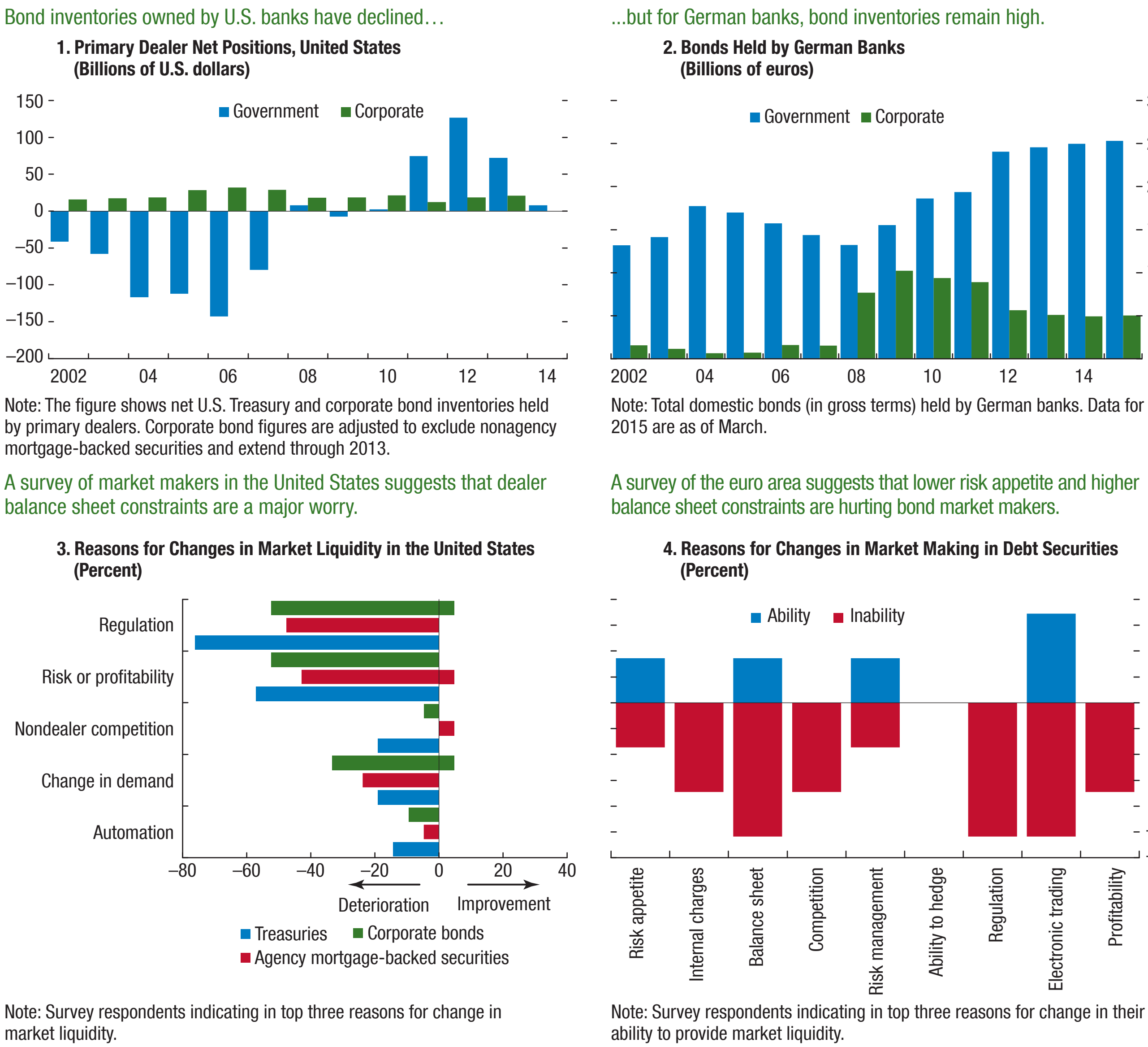
Sources: Bloomberg, L.P.; Markit; MTS; Thomson Reuters Datastream; and IMF staff calculations.

Impact of reduced market making

Can reduced market making adversely affect market liquidity? When dealers face constraints in the amount of balance sheet space they can allocate to corporate bonds, market liquidity for those assets deteriorates. To overcome the problem of two-way causality, episodes around U.S. Treasury auctions are examined. When the U.S. Treasury auctions its debt securities, primary dealers must bid for some of the issuance. Assuming that their balance sheet space allocated to fixed-income securities is limited, the auction becomes an exogenous shock to their market-making ability in other markets. In fact, there is evidence that dealers take into their inventory an important share of the issuance, that it takes them several weeks to unload these holdings, and that they mostly do not hedge against them with futures (Fleming and Rosenberg 2008).[19] The analysis in this chapter, based on daily data from 2002 to 2014, shows that on the day after a Treasury auction, aggregate

[19]The dates of the auctions are predictable, but their outcomes are not. See also Duffie (2012) for further considerations and Annex 2.2 for details on the data and method.

Figure 2.4. Trends in Market Making



Sources: Deutsche Bundesbank; European Central Bank Survey on Credit Terms and Conditions in Euro-Denominated Securities Financing & OTC Derivatives Markets, December 2014; Federal Reserve Bank of New York; Federal Reserve Senior Credit Officer Opinion Survey on Dealer Financing Terms, June 2015; Haver Analytics; and IMF staff calculations.

market liquidity drops by nearly 13 percent in high-yield bonds but negligibly for investment-grade bonds (Figure 2.5).[20] The same analysis shows that the effect of this measure of banks' balance sheet space has significant explanatory power after 2010, but none for the period before the financial crisis (between 2002 and 2006). This finding suggests that banks now may face tighter balance sheet constraints for market making compared with the precrisis period.

Monetary policy and market making

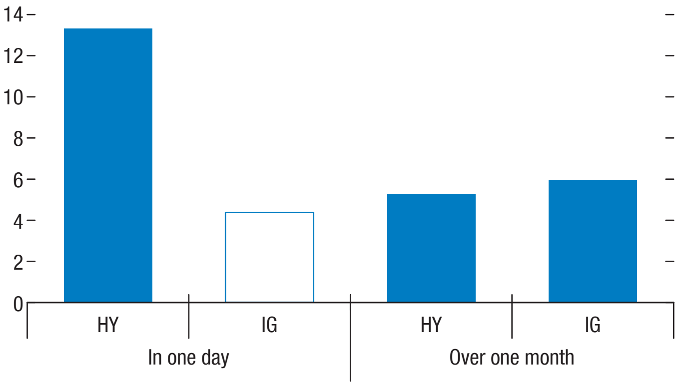
An analysis of changes in collateral policies supports the notion that central banks can improve liquidity by facilitating market making. One way central banks can relax market makers' funding constraints for certain securities and thereby improve the market liquidity of those assets is to include the instruments in the list of eligible collateral for repurchase operations (repo).

[20]When monthly averages are used instead of daily data (to reduce noise in the data) the statistical significance is increased for both investment-grade and high-yield bonds, but the effects are estimated to be smaller, suggesting they are temporary in nature. See Annex 2.2.

Figure 2.5. Dealers' Balance Sheet Space

U.S. Treasury debt auctions briefly reduce primary dealers' balance sheet space. As a result, aggregate market liquidity drops for corporate bonds.

U.S. Treasury Auctions and Change in Corporate Bond Liquidity
(Percent increase in imputed round-trip costs)

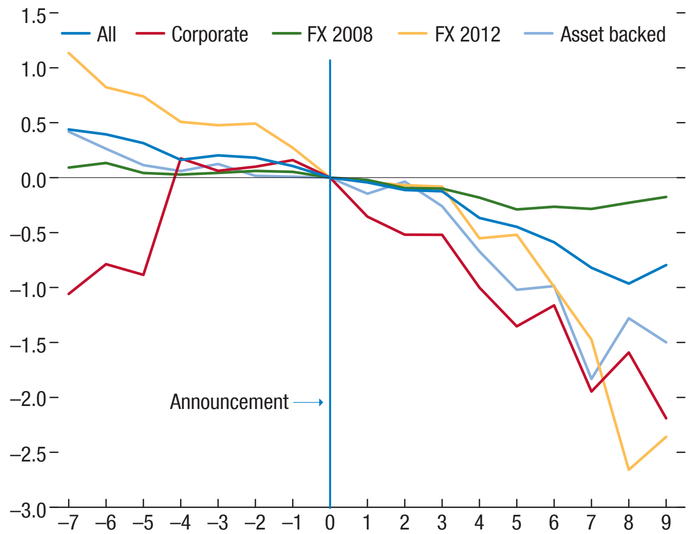


Sources: FINRA Trade Reporting and Compliance Engine; U.S. Treasury Department; and IMF staff estimates.
Note: The figure shows the estimated increase in imputed round-trip costs of corporate bonds, in one day (or one month) with one debt auction by the U.S. Treasury. See Annex 2.2 for details. HY = high-yield corporate bonds; IG = investment-grade corporate bonds. Solid bar indicates that the impact is statistically significant at the 10 percent level.

Figure 2.6. Central Bank Collateral Policies

Increasing the range of assets eligible to be posted as collateral for central bank credit increases market liquidity.

Market Liquidity and Collateral Eligibility
(Percent change in median bid-ask spread)



Sources: Bloomberg, L.P.; European Central Bank; and IMF staff estimates.
Note: The figure shows the percent change in liquidity for bonds that become eligible as collateral, before and after the announcement. The frequency is daily, and liquidity is measured by quoted bid-ask spreads. See Annex 2.2 for details. FX = foreign currency.

Doing so lowers the cost of holding the instrument as a liquidity buffer asset and can also stimulate issuance in the primary market. To assess the impact of changes in the collateral framework, the analysis focuses on a series of events in which the ECB broadened the eligibility of collateral either by reducing the rating threshold for securities issued in euros, or by accepting securities issued in U.S. dollars, British pounds, and Japanese yen.[21]

When a bond is included in the ECB's list of eligible collateral for credit operations, the liquidity of the security improves (Figure 2.6). For instance, when the ECB in 2008 started accepting European bonds issued in foreign currencies and lower-rated bonds, bid-ask spreads fell by as much as 0.35 percentage points following the announcements. The impact was even larger for decisions lowering the rating threshold.[22] Although the increase in liquidity is persistent for at least the first two weeks, these announcements did not seem to have had a permanent impact on bonds' liquidity.

Event Studies of Search Costs

Impact of trade transparency

Some studies find that a rise in trade transparency has a small positive effect on bond market liquidity, but for most other assets the literature suggests a negligible or ambiguous effect. On the one hand, greater trade transparency should improve market liquidity because it increases competition, facilitates the valuation of assets, helps enforce rules against unfair trading practices, and improves risk sharing among dealers. On the other hand, increased transparency may erode the willingness of market makers to carry large inventories because it hampers their ability to unwind large positions.[23] Empirical work on posttrade transparency

[21]The authors thank the ECB/DGM/MOA for providing data on eligible securities.

[22]This may be explained by the fact that, relative to securities with a higher rating and denominated in other currencies, securities with lower ratings are less liquid to begin with, because some investors have strict investment guidelines regarding the rating of assets in which they may invest.

[23]Increased trade disclosure may discourage market making because dealers will not be able to unwind their positions after a large trade. Once a large trade becomes public information, other traders will be able to predict the market maker's behavior and extract price concessions. The same reasoning applies to equity markets and has ultimately led to the growth of "dark pools"—registered stock trading systems in which the size and price of trades are not disclosed to other participants.

(the disclosure of completed trades) in corporate bonds finds either a positive effect or no effect on price discovery, liquidity, and trade activity (Bessembinder and Maxwell 2008). However, some studies of the equity markets find that pretrade transparency (disclosure of the limit-order books and quotes) reduces liquidity in the equity market (Madhavan, Porter, and Weaver 2005).

For corporate bonds traded in the United States, enhanced transparency has had a positive impact on liquidity—especially for large transactions of lower-rated bonds. Again, the U.S. corporate bond market provides a suitable event study: the Financial Industry Regulatory Authority (FINRA) started collecting data on all bond transactions in 2002 but disseminated that information only gradually. The event study here examines the reaction around four dissemination phases to test whether liquidity improved after transactions data became public (see Annex 2.2 for details).[24] In the first two phases (2a and 2b), the bonds for which transactions data were disseminated were of higher credit quality (at least BBB rating), whereas those in the fourth phase (3b) were speculative grade. Contrary to expectations and views expressed by market participants, the study finds that when the data for large transactions of bonds of lower credit quality were released (phase 3b), market liquidity improved significantly (Figure 2.7).[25] The result suggests that, in this instance, the improvement in price discovery caused by transparency outweighed the potential costs for market makers.

Impact of the EU ban on uncovered credit default swaps

The EU's ban on indirect short selling of sovereign debt via uncovered sovereign credit default swaps (SCDS) reduced the liquidity of those assets (Figure 2.7). Beginning November 1, 2012, the EU banned uncovered CDS positions in EU sovereign debt and required disclosure of short positions in European sovereign bonds. Such restrictions reduce the ability of investors to find counterparties for trades and the ability of market makers to hedge. An analysis of a sample of SCDS contracts shows that in the three months after the ban, EU SCDS contracts became substantially less liquid.[26]

The EU's ban also reduced liquidity in the European sovereign bond market. This chapter compares liquidity—as measured by quoted bid-ask spreads—for a sample of sovereign bonds three months before and after the ban. The findings indicate that liquidity in EU sovereign bonds declined after the ban. The decrease in liquidity for sovereigns was larger for countries with low credit risk (that is, low CDS spreads). Thus, the negative effect on liquidity in the derivatives market (for uncovered CDS on sovereign bonds) spilled over to the cash market (for the sovereigns themselves). The result is in line with predictions from Chapter 2 of the April 2013 GFSR and findings in ISDA (2014), and it is consistent with studies that find a detrimental effect on liquidity and price discovery from temporary bans on short selling in equity markets (Boehmer, Jones, and Zhang 2013; Beber and Pagano 2013).[27]

Monetary policy and scarcity effects

Quantitative easing in the United States at first improved liquidity in the market for mortgage-backed securities (MBS), but then degraded it (Figure 2.8). Since November 2014, Federal Reserve purchases on the secondary market have had a detrimental effect on market liquidity. The effect indicates that the scarcity associated with large central bank purchases then dominates any positive effects (Box 2.1). The magnitude of the impact is, however, relatively small, suggesting that any adverse effects on market liquidity represent a small cost of quantitative easing. The results also point to the increasing importance of capital market depth and liquidity for monetary policy operations in a low-interest-rate environment.[28]

[24]FINRA is the nongovernmental U.S. organization that self-regulates securities firms. The data dissemination dates for the four phases studied are March 3, 2003 (phase 2a); April 14, 2003 (phase 2b); October 1, 2004 (phase 3a); and February 7, 2005 (phase 3b). Data were graciously provided by FINRA.

[25]Asquith, Covert, and Pathak (2013) report similar findings for turnover and price dispersion; and Edwards, Harris, and Piwowar (2007) find a reduction in trading costs after dissemination. See Bessembinder and Maxwell (2008) for a survey of results.

[26]The results show that liquidity decreases significantly for SCDS contracts affected by the ban, relative to other SCDS, when measured by Markit's composite liquidity indicator, market depth, number of valid quotes, and number of dealers quoting the contract. Results on quoted bid-ask spreads estimate a decline that is not statistically significant. See Annex 2.2.

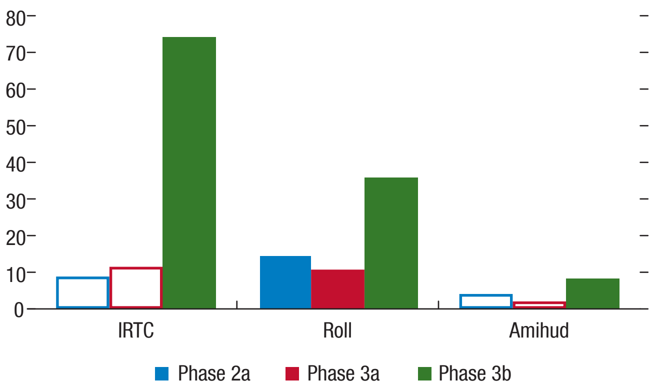
[27]However, ESMA (2013b) does not find a significant impact on SCDS or sovereign bond market liquidity and ESMA (2013a) estimates a decline in SCDS bid-ask spreads.

[28]Gagnon and others (2011) report that in the early stage of the Federal Reserve's large-scale asset purchase programs, older and less liquid Treasury securities were trading at a negative premium compared with more recently issued Treasury securities. Prices went up and yield spreads narrowed after the Federal Reserve started purchasing such bonds. Similarly, Krishnamurthy and Vissing-Jorgensen (2012) find evidence of a decrease in the spread between agency and Treasury bonds' yields, a proxy for the liquidity premium, following

Figure 2.7. Regulation and Market Liquidity: Two Examples

Enhanced posttrade transparency, in some cases, improves market liquidity.

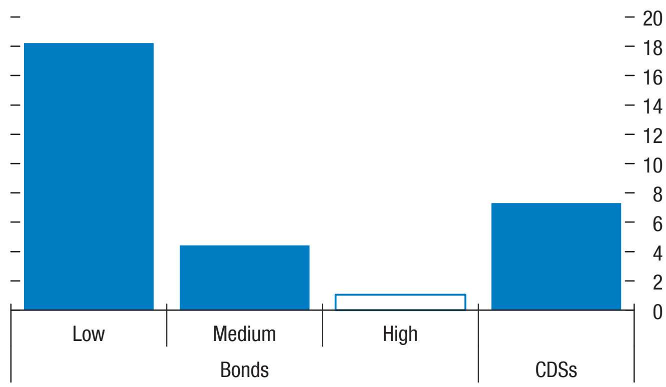
1. Liquidity Improves with Transparency (Percent improvement in liquidity measure)



Note: The figure shows estimated change in liquidity three months before and after trade dissemination. Dissemination dates are March 3, 2003 (phase 2a); April 14, 2003 (phase 2b, not shown); October 1, 2004 (phase 3a); and February 7, 2005 (phase 3b). A positive value means improved liquidity. Solid columns mean statistical significance at least at the 10 percent level. See Annex 2.2 for details. Amihud = Amihud's (2002) price impact; IRTC =imputed round-trip cost; Roll = Roll's (1984) price reversal.

The European sovereign CDS ban was followed by a deterioration in the liquidity of EU sovereign CDSs and bonds.

2. Decrease in Liquidity due to EU Uncovered CDS Ban (Percent deterioration in liquidity)



Note: The figure shows the estimated deterioration in liquidity in sovereign bonds and sovereign CDS contracts that can be attributed to the EU ban on uncovered CDS on EU sovereign debt. The effect for bonds is broken down according to the credit risk of the issuer: low, medium, and high signify CDS spreads around the 25th, 50th, and 75th percentiles. Solid columns mean statistical significance at least at the 10 percent level. See Annex 2.2 for details. CDS = credit default swap.

Sources: FINRA Trade Reporting and Compliance Engine; Markit; and IMF staff estimations.

Investor base

Empirical evidence indicates that the decline in the heterogeneity of the investor base may have contributed to a deterioration in liquidity. It is difficult to test for this effect because, when market liquidity deteriorates for a particular asset, some holders may decide to sell it. To overcome this problem, the exercise examines an exogenous shock to demand for some corporate bonds that may have affected banks' willingness to invest.[29] According to a rule adopted in the United States in June 2012 and made effective in January 2013, banks would have to decide for themselves whether a security is investment grade rather than use credit agency ratings. Because U.S. commercial banks are prohibited from investing in below-investment-grade bonds, the rule narrowed the investor base for bonds at the low end of the rating agencies' investment grade (BBB– for Standard & Poor's ratings). In turn, the narrowing of the investor base should raise dealers' inventory costs for those bonds and reduce market making. Indeed, data indicate that the effect took place at the time of the announcement, with the liquidity of BBB– bonds subsequently deteriorating relative to other bonds.

In sum, changes in market making, market structure, regulation, and monetary policy in recent years have had an impact on market liquidity. The observed decline in market making has probably contributed to the reduction in market liquidity in some market segments. Enhanced transparency regulations appear on net to have boosted market liquidity, whereas restrictions on CDS in the EU seem to have reduced it. On the whole, monetary policy in recent years is likely to have had a positive impact on market liquidity. The proliferation of small issuances has likely lowered liquidity in the bond market.

Econometric Evidence for Risk Appetite and Other Cyclical Drivers

How much has market liquidity been affected by cyclical factors in the postcrisis period? A linear regression

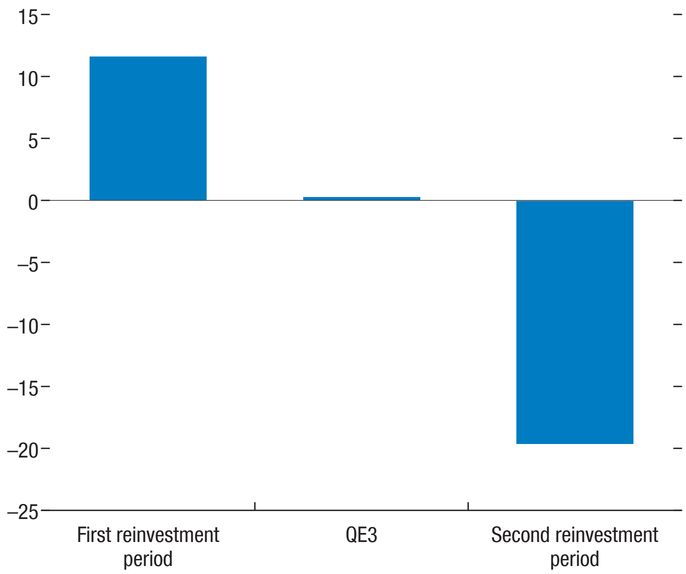
the Federal Reserve's purchases of agency mortgage-backed securities. The liquidity premium of the securities not targeted by quantitative easing was not affected.

[29]The exercise uses the change in regulation only as an example of an exogenous shock to the investor base and should not be understood as a quantification of the positive or negative effects of this aspect of the Dodd-Frank Act.

Figure 2.8. Fed Purchases and Mortgage-Backed Securities Liquidity

Outright purchases improved liquidity of MBS during the first reinvestment program (October 2011–November 2012), had no effect during QE3 (December 2012–October 2014), and was recently decreasing market liquidity (November 2014–March 2015).

Impact of Fed Purchases on MBS Liquidity
(Percent of improvement in imputed round-trip cost)

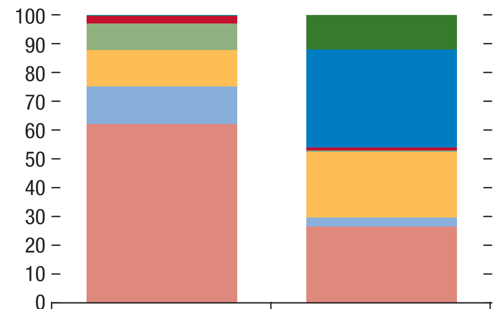


Sources: Federal Reserve Bank of New York; FINRA Trade Reporting and Compliance Engine; and IMF staff estimates.
Note: The figure shows the estimated improvement in liquidity (reduction in round-trip costs) in MBS securities per billion dollars of securities purchased by the Federal Reserve. The effect is normalized by the average imputed round-trip cost in the sample. Solid columns mean statistical significance at least at the 10 percent level. See Annex 2.2 for details. Fed = Federal Reserve; MBS = mortgage-backed security; QE = quantitative easing.

Figure 2.9. Main Drivers of Market Liquidity

Risk appetite has been the main driver of investment-grade U.S. corporate bond market liquidity since 2010, whereas funding liquidity seems more important for high-yield bonds.

Contributions to Market Liquidity of U.S. Corporate Bonds
(Percent)



	Investment grade	High yield
Bank holdings	0.1	11.9
Commodity prices	0.3	34.2
Business conditions	2.6	1.0
U.S. monetary policy	9.0	0.5
Funding liquidity	12.8	22.9
Credit spread	13.0	3.1
VIX	62.1	26.5

Source: IMF staff estimates.
Note: The figure and table show the unique contribution of each variable (normalized by total unique contributions) in predicting the variance of aggregate market liquidity by type of bond since 2010. R^2 for investment grade = .79 and R^2 for high yield = .42. See Annex 2.2 for details. The decomposition follows the commonality coefficients approach described in Nathans, Oswald, and Nimon (2012). VIX = Chicago Board Options Exchange Market Volatility Index.

model of market liquidity for both high-yield and investment-grade U.S. corporate bonds since 2010 is used to examine this question. This approach does not, however, overcome the problem of two-way causality. The model includes the credit spread as a proxy for credit conditions; the TED spread (difference between the three-month London interbank offered rate based on the U.S. dollar and the three-month T-bill secondary market rate) as a measure of funding liquidity; corporate bond holdings by large commercial banks as a proxy for inventories; the estimated shadow monetary policy rate for the United States; commodity price changes as a control for the volatility of some important underlying assets; and the Chicago Board Options Exchange Volatility Index (VIX) as a measure of overall uncertainty, which is negatively related to risk appetite.

Risk appetite and funding liquidity seem to be the main drivers, but indirectly the results point to an important role for monetary policy. In fact, the combined contribution of the TED spread, the VIX, and unconventional monetary policy account for most of the liquidity behavior of investment-grade bonds and, to a lesser extent, of high-yield bonds (Figure 2.9). For investment-grade bonds, the cyclical factors explain almost 80 percent of the total variation of aggregate market liquidity, whereas for high-yield bonds the model explains slightly more than 40 percent.

Liquidity Resilience, Liquidity Freezes, and Spillovers

The chapter so far has examined the extent to which changes in various market conditions in recent years *may have eroded the market liquidity of securities, especially bonds. Such erosion has negative implications for the efficiency of capital allocation and for economic growth. From a financial stability point of view, however, the main concern about liquidity is not its level but the risk of disruptive drops in liquidity ("freezes") across markets, and policymakers can help reduce the risk of such events and mitigate their severity if they occur.*

This section provides empirical evidence on structural and cyclical factors associated with the resilience of liquidity to shocks. It briefly discusses event studies to examine the role of structural factors and then implements an econometric approach ("regime switching") to measure the likelihood that aggregate market liquidity suddenly evaporates.[30] *Although the focus is on corporate bonds traded in the United States, European sovereign bonds and the foreign exchange market, including emerging market currencies, are also examined. The section ends with an analysis of spillovers of liquidity freezes.*

Liquidity Regimes and Resilience

Structural factors

Various structural factors are associated with the degree of liquidity resilience in markets. The analysis shows that a lower presence of market makers, a broader range of smaller and more risky bonds, large mutual fund holdings, and concentrated holdings by institutional investors are all associated with higher vulnerability of liquidity to external shocks (see event studies in Box 2.3). Higher leverage at financial firms and their greater use of short-term funding are typically associated with higher liquidity risk (Acharya and Viswanathan 2011). But the feedback loops between leverage and market illiquidity may have been weakened by the postcrisis decline in capital market participation by banks and hedge funds (Figure 2.10). Unfortunately, data limitations prevent a quantitative assessment of these factors and their overall impact from being made.

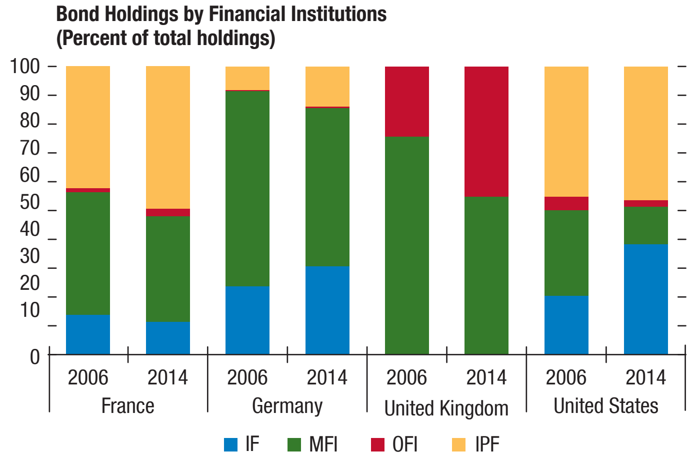
Cyclical factors

Empirically, market liquidity tends to abruptly switch between different states (Figure 2.11; Flood, Liechty,

[30]In this section, aggregate market liquidity is defined as a measure of market liquidity averaged across all securities in an asset class.

Figure 2.10. Financial Sector Bond Holdings

Bond holdings by investment funds have been growing in various advanced economies.



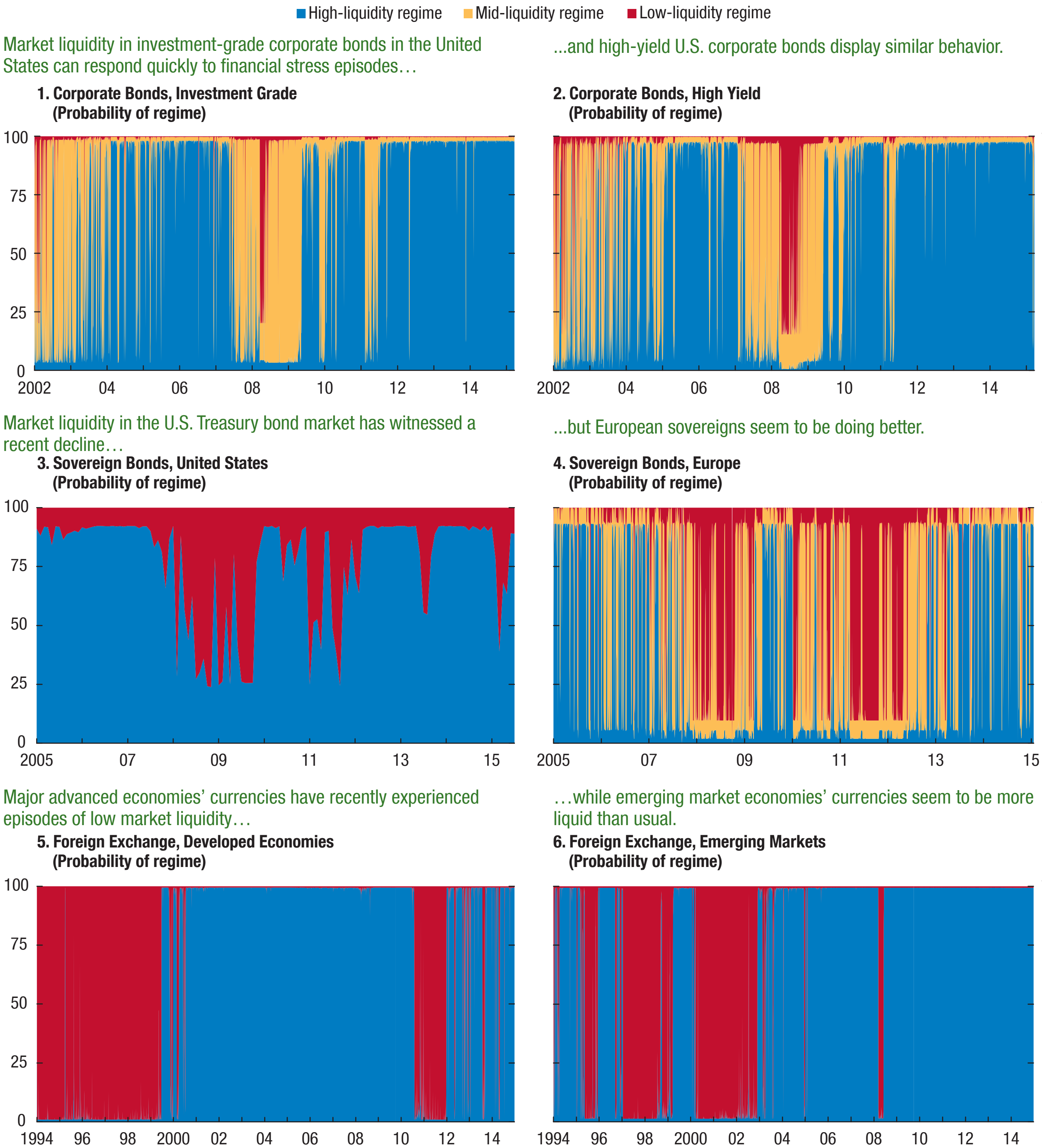
Sources: European Central Bank; Board of Governors of the Federal Reserve System; and IMF staff calculations.
Note: Bond holdings in European countries refer to long-term debt securities; bond holdings in the United States refer to corporate and foreign bonds. Data for the United Kingdom do not discriminate among nonbank financial institutions. IF = investment funds excluding money market mutual funds (MMMFs); IPF = insurance and pension funds; MFI = monetary financial institutions (including MMMFs and, for the United States, securities brokers and dealers); OFI = other financial institutions.

and Piontek 2015). To study the importance of cyclical factors for the resilience of market liquidity, a regime-switching model is used in which liquidity may take on two or more regimes (for example, low, medium, and high). In this approach, the resilience of liquidity is measured by the one-day-ahead or one-month-ahead probability of a given market being in a low-liquidity regime. The model uses aggregate measures of market liquidity for corporate bonds traded in the United States, U.S. Treasury bonds, European sovereign bonds, and foreign currencies (Figure 2.11).[31]

To some extent, liquidity resilience in the corporate bond market can be predicted by cyclical factors

[31]Figure 2.11 shows estimates of one-day-ahead probabilities of a given market being in the low-liquidity regime, except U.S. Treasury bonds for which, because of data constraints, one-month-ahead probabilities are presented. The determination of such regimes is, however, asset specific. In other words, the regimes are not comparable across assets but only depict the estimated state of market liquidity in one day or one month's time relative to the asset's historical behavior. For instance, the liquidity of currencies has improved compared with the levels in the late 1990s. In particular, the average frequency of developed economies' currencies being in the low-liquidity regime declined from greater than 99 percent during 1995–99 to 34 percent in the past five years. See Annex 2.3 for details.

Figure 2.11. Probability of Liquidity Regimes



Sources: Bloomberg, L.P.; FINRA Trade Reporting and Compliance Engine; MTS; Thomson Reuters Datastream; and IMF staff estimates.

Table 2.2. Determinants of Low-Liquidity Regime Probability in the U.S. Corporate Bond Market

	One-Day Ahead		One-Month Ahead	
	U.S. Corporate Bonds		U.S. Corporate Bonds	
	Investment Grade	High Yield	Investment Grade	High Yield
U.S. Business Conditions	.	–**	–**	–**
VIX	+***	+***	.	.
Moody's Credit Spread	+***	+***	+***	.
TED Spread	+***	+***	.	.
Dealers' Holdings	…	…	–***	–***
Treasury Auctions	.	.	+**	+**
Fed Quantitative Easing	–**	.	–**	.

Sources: Board of Governors of the Federal Reserve System; FINRA Trade Reporting and Compliance Engine; Haver Analytics; Thomson Reuters Datastream; the United States Department of the Treasury; and IMF staff calculations.
Note: The table shows the estimated sign of ordinary least squares (OLS) estimates of a regression of the probabilities of being in the low-liquidity regime on a set of macroeconomic and financial variables for both investment-grade and high-yield corporate bonds. When the estimate is not statistically different from zero, a "." is used. "…" means the variable in the first column was not included. See Annex 2.3 for details on methodology and data. ***, **, * denote significance at the 1, 5, and 10 percent levels, respectively.

(Table 2.2).[32] These factors include business conditions, financial volatility, and risk appetite (as measured by the VIX); the price of credit risk; and, to some degree, monetary policy measures. The current level of liquidity also matters for liquidity resilience.[33] The analysis summarized in Table 2.2 shows that high-yield bonds seem to be especially sensitive to business conditions and credit market developments, whereas unconventional monetary policy only affects the liquidity of investment-grade bonds.[34] However, an analysis of the response of market liquidity to changes in the VIX over time does not suggest that liquidity is now more sensitive to financial volatility compared with the precrisis period.

Evidence from the U.S. bond market indicates that when inventories at dealers are low or when dealers' ability to make markets is impaired, aggregate liquidity is more likely to drop sharply. Measures of dealers' inventories or of their ability to make markets are empirically associated with liquidity regimes. For instance, the ratio of total corporate securities to commercial banks' total assets is negatively associated with a low-liquidity regime in the corporate bond market. Similarly, when funding liquidity is low (that is, when the TED spread is high), the probability of the corporate bond market being in a low-liquidity regime increases (Table 2.2).

In the markets for foreign exchange and European sovereign bonds, business conditions in key advanced economies seem to be the main drivers of liquidity regimes (Table 2.3). The resilience of liquidity of foreign exchange markets in emerging market economies and smaller advanced economies seems to be driven by external conditions, and does not appear to depend on business conditions in those markets. This dependence on external conditions may be due to the fact that these markets are strongly influenced by global investors. Overall, unconventional monetary policy measures by advanced economy central banks have had a positive impact on the liquidity resilience of foreign currency markets, including those in emerging markets.[35]

Given that the VIX is still at historical lows, the picture of benign market liquidity conditions may be deceiving. Cyclical factors like global uncertainty and risk aversion can change quickly, for example, as a result of a "bumpy" normalization of U.S. monetary

[32]The results on liquidity regimes presented in this section rely on measures of the cost dimension of market liquidity such as imputed round-trip costs, Corwin and Schultz's (2012) high-low spread, quoted bid-ask spreads, or effective spreads. However, for U.S. corporate bonds, results were tested using alternative measures of liquidity such as Amihud's (2002) price impact and Roll's (1984) price reversal, with qualitatively similar results. The estimates for U.S. Treasury bonds and foreign currencies suggest only two regimes instead of three.

[33]Bao, Pan, and Wang (2011) also find that normal-time liquidity can help predict crisis-time liquidity.

[34]Although the VIX plays a broader role, its significance in this estimation is consistent with the finding that it is a key driver of mutual fund redemptions (see the April 2015 GFSR, Chapter 3)—and large mutual fund holdings are associated with higher liquidity risk (Box 2.3).

[35]The behavior of equity markets is not analyzed here, but Flood, Liechty, and Piontek (2015) also identify three liquidity regimes for those markets and similar determinants for the probability of them being in a low-liquidity state.

Table 2.3. Determinants of Low-Liquidity Regime in the Foreign Exchange and European Sovereign Bond Markets

	FX Markets			European Sovereign Bonds
	Major AEs	Other AEs	EMs	Euro-6
U.S. Business Conditions	.	–***	–***	.
Major AE Business Conditions	–***	–**	–**	–***
Other AE Business Conditions	…	.	…	…
EM Business Conditions	.	.	.	…
VIX	+***	.	.	+***
Moody's Credit Spread	–***	+***	+***	.
Domestic Short-Term Interest Rate	–***	.	.	+*
Fed Quantitative Easing	–*	.	.	.
Major AE Quantitative Easing	.	–**	–***	.

Sources: Board of Governors of the Federal Reserve System; FINRA Trade Reporting and Compliance Engine; Haver Analytics; Thomson Reuters Datastream; the United States Department of the Treasury; and IMF staff calculations.
Note: The table shows the estimated sign of ordinary least squares (OLS) estimates of a regression of the probabilities of being in the low-liquidity regime on a set of macroeconomic and financial variables in the foreign currency and European sovereign bond markets. When the estimate is not statistically different from zero, a "." is used. "…" means the variable in the first column was not included. Major advanced economies (AEs) = euro, Japanese yen, Swiss franc, and British pound. Other AEs = Australian dollar, Canadian dollar, Danish krone, New Zealand dollar, Norwegian krone, and Swedish krona. Emerging markets (EMs) = Brazilian *real*, Indonesian rupiah, Indian rupee, Russian ruble, South African rand, and Turkish lira. Euro-6 = Belgium, France, Germany, Italy, Netherlands, and Spain. ***, **, * denote significance at the 1, 5, and 10 percent levels, respectively. FX = foreign exchange.

policy, unexpected developments in the euro area, or geopolitical events. To illustrate, should the VIX, the TED spread, and other cyclical factors (excluding monetary policy variables) deteriorate in the same way they did between December 2006 and August 2008, the probability of the U.S. corporate bond market switching from a high-liquidity to a low-liquidity regime would rise to about 75 percent for investment-grade bonds and 96 percent for high-yield ones.

The fact that investors require higher returns on illiquid assets only during periods of stress indicates that they pay little attention to the possibility that liquidity can suddenly vanish during normal times (Table 2.4). In principle, when holding securities, investors require compensation for different types of risk, including the risk of sharp drops in liquidity. However, in the U.S. corporate bond market, bond returns react to liquidity shocks only when volatility is high and returns are low (that is, stress periods), and not in tranquil periods.[36] This suggests that during periods in which liquidity is abundant, investors tend to neglect the risk that liquidity may suddenly vanish. Moreover, the chapter finds significant evidence that illiquidity shocks from the equity market spill over to the high-yield market and cause bond returns to fall.

[36]In principle, only large, systematic, and persistent shocks to liquidity should be priced (Korajczyk and Sadka 2008). Conceivably, such shocks are more frequent in the low-liquidity regime.

Table 2.4. Bond Returns and Liquidity Risk

	Investment Grade	High Yield
Constant Parameters		
Term Spread	+	+
Moody's Credit Spread	+*	+*
Equity Illiquidity	–	–*
Regime-Switching Parameters		
Regime 1 (tranquil period)		
Bond Illiquidity	+	–
Regime 2 (stress period)		
Bond Illiquidity	–***	–***

Source: IMF staff estimates.
Note: The table shows the estimated sign of the coefficients of a regression of monthly corporate bond excess returns (relative to 30-day U.S. Treasury bills) on the term spread, credit spread, and illiquidity measures for the equity and bond markets. The latter is based on imputed round-trip costs averaged across all securities. Equity illiquidity is based on the measure proposed by Corwin and Schultz (2012). The regression coefficients for the bond illiquidity measure are allowed to vary according to a regime-switching regression, while the rest are assumed constant. See Annex 2.3 for details. *, **, and *** signify statistical significance at the 10, 5, and 1 percent levels, respectively.

Spillovers

Market illiquidity and the associated financial stress can spill over to other asset classes. Liquidity shocks may propagate to other assets, including those with unrelated fundamentals, for a variety of reasons. These reasons include market participants' need to mark to market and rebalance portfolios, which can affect their ability to trade and hold other assets. The propagation of liquidity shocks (known as liquidity spillovers) could be amplified when market participants are highly leveraged. In addition, when asset fundamentals are correlated, spillovers can be larger: investors may perceive a sharp price correction in certain assets as conveying information about the valuations of their own securities. As a result, they may start fire sales and cause liquidity to freeze up.

Empirically, liquidity spillovers are larger during stress periods, and spillovers have become more prevalent in recent years. When returns are low and more volatile, liquidity shocks tend to propagate from one asset class to others. A measure of liquidity spillovers over several asset classes, including emerging markets equities, shows considerable time variation—but spillovers have become more frequent since the crisis (Figure 2.12).[37] This increase in frequency is in line with concerns expressed about rising comovements in prices across asset classes (April 2015 GFSR, Chapter 1). Furthermore, total liquidity spillovers across assets rise in periods of financial market stress (that is, when asset returns are low, volatile, and display significant comovement). See Annex 2.3 for details on the methodology.

Although common factors may play a role in the comovement of liquidity across asset classes, shocks often propagate from the investment-grade bond market to other markets. Statistical analysis of temporal spillover patterns (so-called Granger causality) suggests that liquidity shocks to investment-grade bonds significantly affect liquidity in other asset classes but that those bonds' liquidity is not much affected by that of other classes. This outcome suggests that monitoring investment-grade corporate bonds as a source of liquidity spillovers should be part of the market surveillance toolkit.

Summary of Findings on Liquidity Resilience, Liquidity Freezes, and Spillovers

Market liquidity can quickly disappear when volatility increases or funding conditions deteriorate, and monitoring day-to-day liquidity conditions has merit. In fact, having high liquidity today, all else equal, reduces the probability of being in a low-liquidity regime tomorrow, with the associated systemic stress repercussions. Dealers' inventories and their overall balance sheet capacity are negatively associated with illiquidity spells. The regime-switching approach used in this chapter also finds that unconventional monetary policy can reduce the likelihood that markets will be in a low-liquidity regime. Furthermore, liquidity risk seems to be priced only in periods of financial stress.

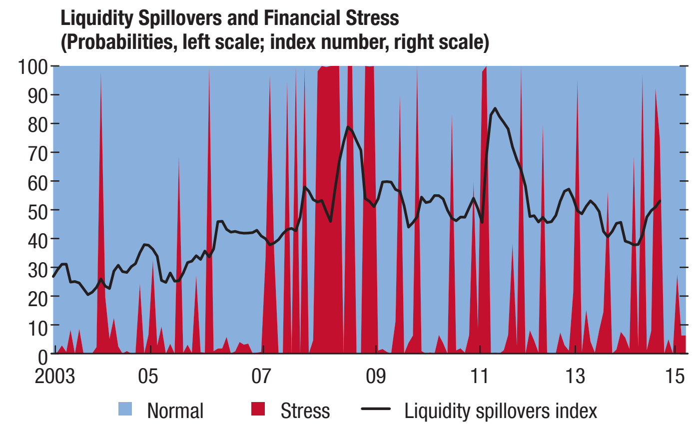
Liquidity comovement across asset classes has increased in recent years. Spillovers are particularly pronounced during periods of financial stress. In those periods, asset returns are low and volatile, and the comovement of liquidity across asset classes is stronger. Even though common factors may generate some of these liquidity spillovers, shocks often originate in investment-grade bonds traded in the United States.

Policy Discussion

Market liquidity is prone to sudden evaporation, and the private provision of market liquidity is likely to be insufficient during stress periods; hence, policymakers need to constantly monitor liquidity developments and have a preemptive strategy in place to confront episodes of market illiquidity. Monitoring market

Figure 2.12. Liquidity Spillovers and Market Stress

Liquidity spillovers across asset classes seem to intensify in periods of financial stress.



Sources: Bloomberg, L.P.; FINRA Trade Reporting and Compliance Engine; Thomson Reuters Datastream; and IMF staff estimates.
Note: The figure shows (1) the monthly average of an index of liquidity spillovers (measured as in Diebold and Yilmaz 2014) across the following asset classes: U.S. equities; U.S. Treasuries; U.S. high-yield corporate bonds; U.S. investment-grade corporate bonds; European equities; emerging market equities; and an index of liquidity in the foreign exchange market; and (2) probabilities of being in a low-return and high-volatility regime as given by a Markov-Switching Bayesian vector autoregression model of monthly returns for the same asset classes as in (1).

[37] The asset classes are equities in the United States, the EU, and emerging market economies; U.S. Treasury bonds; high-yield and investment-grade corporate bonds traded in the United States; and an index of market liquidity for the four major currency pairs (the U.S. dollar paired with the British pound, the euro, the Japanese yen, and the Swiss franc). The analysis controls for common factors.

liquidity conditions using transactions-based measures, especially in the investment-grade bond market, should be part of regular financial sector surveillance. Although current levels of market liquidity are not clearly and significantly lower than they were before the crisis, that appearance may be an artifact of the extraordinarily accommodative monetary policies of key central banks.[38] The risk of a sudden reduction in market liquidity has been heightened by the larger role of mutual funds and by other structural changes combined with the impending normalization of monetary policy in advanced economies.

Regulatory changes aimed at curbing risk taking by banks can impair their capacity to make markets, but the evidence so far is not sufficient to support revisions to the regulatory reform agenda. Indeed, the reforms have made the core of the financial system safer. The empirical findings of this chapter suggest that constraints on dealers' balance sheets may impair market liquidity, and that these constraints have become tighter—but it is difficult to link such developments to specific regulatory changes. In particular, not enough time has passed to assess the impact of many Basel III innovations, such as the leverage ratio requirement, the net stable funding ratio, the increase in capital requirements, and restrictions on proprietary trading by banks.[39] Finally, independently of regulations, traditional market makers have also changed their business models by moving from risk warehousing (acting as dealers) to risk distribution (acting as brokers), in part because of technological changes and more efficient balance sheet management (see Goldman Sachs 2015).[40] These developments should continue to be monitored.

Trade transparency, standardization, and the use of equal-access electronic trading could dampen the impact of reduced market making at banks. For a variety of reasons, traditional market makers may have reduced their presence in the marketplace, but the emergence of new players and trading platforms may help fill the void. For example, in the United States, the standardization that will come from moving most index-CDS trading to swap execution facilities (Box 2.2) should enhance liquidity by introducing incentives for market-making activities and enhancing transparency.

Important obstacles to trade automation and the emergence of new market makers remain. New U.S. regulations for over-the-counter (OTC) derivatives markets require that trading platforms provide impartial and open "all-to-all" access. However, some interdealer platforms have resisted inviting nondealers to participate or have required high fees, which may act as a barrier to entry for alternative market makers.[41]

Smooth normalization of monetary policy is crucial. Given the empirical results on the direct and indirect effects of monetary policy on liquidity, it is important that normalization of monetary policy avoid disruptive effects on market liquidity. The empirical results on the effects in MBS markets suggest that liquidity in these markets will likely vary according to the modalities of the normalization (for example, whether it involves outright sales or simply allowing the securities in possession of the central bank to mature). Similarly, a "choppy" normalization process may lead to a sudden drop in risk appetite, with ensuing adverse effects on market liquidity. Although data constraints prevent a more in-depth evaluation of the market liquidity of emerging markets assets from being undertaken, the findings for emerging market foreign currency markets suggest that monetary policy actions in advanced economies greatly affect their resilience.

These general observations and the empirical results discussed in the chapter suggest the following policy options for strengthening market design, enhancing the role of central banks, improving

[38]The long period of monetary accommodation by major central banks has further discouraged dealers from market making or risk warehousing. In a low-volatility and low-risk environment, it is often most profitable to act as a broker since the premium paid to warehouse risk is correspondingly low.

[39]As argued by banks, it is possible that by linking capital requirements to all assets irrespective of risk, the Basel III leverage ratio requirement has lowered the attractiveness of high-volume, low-margin activities such as market making and collateralized lending. The net stable funding ratio, once fully implemented, could also have an adverse impact on market making by raising the relative cost of short-term repo transactions. The rise in capital requirements may also encourage banks to operate closer to the minimum required capital levels and, hence, render them unable or unwilling to take large trading positions.

[40]Banks' changes in their business models following the financial crisis have also led them to focus more on their most profitable activities. Since market making is a high-volume, low-profit activity, banks have been reconsidering their presence in fixed-income and credit markets.

[41]Some platforms are reportedly insisting on posttrade identification of counterparties—even for centrally cleared trades—on order book trades, to which nondealers object because of the potential for information leakage.

financial market regulation, and reducing market liquidity risks.

On market microstructure design:

- *Reforming the design of markets should be encouraged.* Objectives would include creating incentives for instrument standardization,[42] designing circuit breakers based on liquidity conditions rather than prices, and enhancing transparency.
- *Open access to electronic platforms should become the norm.* The analysis of the introduction of electronic platform trading of OTC derivatives underscores the importance of product standardization and of equal access to trading venues to allow buy-side firms to act as alternative market makers. However, the introduction of electronic platforms can attract new players, such as high-frequency trading firms, to the market, whose impact still needs to be further understood.
- *Restrictions on the use of financial derivatives should be reevaluated.* The analysis of the after-effects of the EU ban on uncovered CDS confirms the view expressed in the April 2013 GFSR that regulations on derivatives can distort markets and reduce liquidity in the associated cash market.

On the role of central banks:

- *Central banks should take into account the effects on market liquidity when making policy.* For example, to counteract the potential scarcity created by large-scale asset purchases, central banks could set up securities-lending facilities.
- *Central banks and financial supervisors should routinely monitor market liquidity in real time across several asset classes, but especially in the investment-grade bond market.* They should use a wide range of market liquidity measures with an emphasis on metrics derived from transactions-level data.
- *In periods of financial market stress, central banks could use various instruments, including their collateral policies, to enhance market liquidity*. In particular, they can do so by accepting, with appropriate haircuts, a wide range of assets as collateral for repo transactions.

[42]The standardization of bond terms and conditions, such as call options and coupon and maturity payment dates, would reduce the effective dimensions of the market. Moreover, larger and more frequent borrowers could issue bonds in larger sizes and reopen old issues. See BlackRock (2014).

On the regulation and supervision of financial intermediaries:

- *Liquidity stress testing for banks and investment funds should be conducted taking into account the systemic effects of market illiquidity.* Liquidity stress testing can incorporate the externalities created by illiquid market conditions such as asset fire sales and funding risks (Box 2.4, and Chapter 3 of the April 2015 GFSR).
- *Liquidity mismatches in the asset management industry should be mitigated.* Liquidity mismatches characterize funds that invest in relatively illiquid and infrequently traded assets but allow investors to easily redeem their shares. The evidence presented in this chapter reinforces the recommendation of the April 2015 GFSR to consider the use of tools that adequately price in the cost of liquidity, including minimum redemption fees, improvements in illiquid asset valuation, and mutual fund share-pricing rules.

Conclusion

Even seemingly plentiful market liquidity can suddenly evaporate and lead to systemic financial disruptions. Therefore, market participants and policymakers need to set up policies in advance that will maintain market functioning during periods of stress. For example, the return to conventional monetary policy by the key central banks will inevitably boost volatility as market price discovery adjusts to new monetary conditions. The smooth adjustment of asset prices to their new equilibrium levels will require ample levels of market liquidity. In contrast, a low-liquidity regime would be more likely to produce market freezes, price dislocations, contagion, and spillovers.

This chapter explores developments in market liquidity and the role of liquidity drivers, with a focus on bond markets (Table 2.5). Structural changes, such as reductions in market making, appear to have reduced the level and resilience of market liquidity. Changes in market structures—including growing bond holdings by mutual funds and a higher concentration of holdings—appear to have increased the fragility of liquidity. At the same time, the proliferation of small bond issuances has likely lowered liquidity in the bond market and helped build up liquidity mismatches in investment funds. Standardization and enhanced transparency appear to improve securities liquidity.

Overall, current levels of market liquidity do not seem alarmingly low, but underlying risks are masked by unusually benign cyclical factors. On the one hand,

Box 2.4. Market Liquidity and Bank Stress Testing

Market illiquidity episodes can become systemic events when banks' balance sheets become impaired. Therefore, bank stress testing should take into account scenarios of market liquidity shocks. This box describes a stylized agent-based model approach to dynamic macro stress testing that can be used to obtain a prediction of market behavior under stress and simulate its impact on credit provision and economic growth.

Liquidity crises in one market can become systemic macroeconomic crises by damaging banks' balance sheets. When a market suddenly becomes illiquid, investors will require higher returns on their assets. As a result, asset prices of that market can drop dramatically. If banks own a large amount of assets in that market, a liquidity shock in that market can affect bank solvency, tightening bank regulatory constraints and limiting access to funding markets. Facing weakened balance sheets, banks react by unwinding their portfolio at distressed prices, withdrawing liquidity from financial intermediaries, or cutting back credit to the real economy, with negative consequences for financial stability and economic growth.

Building an integrated stress test for solvency and market liquidity is challenging. This is in part due to the difficulty in defining possible channels through which these interactions can occur. In addition, from a methodological point of view, it is difficult to analyze the effect of high-frequency changes in market liquidity with low-frequency information on bank solvency.

The model described here is an attempt to provide a stylized stress-testing framework of solvency and liquidity incorporating the interactions between banks, asset managers, and equity investors. The mechanism through which agents interact with one another is threefold. First, both banks and asset managers participate in the securities market to purchase or sell assets.[1] Second, banks can lend to each other in the credit markets. Third, banks interact with investors in equity markets through capital injections or withdrawals. The shock on market liquidity comes from redemption pressures on asset managers. Banks are value investors, that is, they buy undervalued assets, and are subject to regulatory constraints. In normal times, their behavior stabilizes markets. But a large market liquidity shock reduces their capital buffers, weakens their balance sheets, and tightens regulatory constraints. Banks react by re-optimizing their balance sheets, thereby becoming positive feedback traders, amplifying market shocks, and constraining credit supply.

The model analyzes a baseline scenario and a market liquidity shock (Figure 2.4.1). It is calibrated on two levels. The micro approach works to individually calibrate agents to their specific behavior rules, reflecting heterogeneous optimization problems. The macro approach parameterizes the global variables shared by agents to fit the aggregate variable outcomes of all the agents' behaviors. In the baseline scenario, initial low credit growth depresses real GDP growth, increases credit risk and risk-weighted assets, lowers maximum available leverage, and erodes banks' capital adequacy ratios. As banks optimize over their credit supply, GDP growth recovers, asset prices return to fundamentals, banks' capital adequacy ratios increase, and the economy transitions toward the steady state.

In the market liquidity shock scenario, redemption pressures force asset managers to unwind their holdings of securities. This market shock generates a drop in asset prices and an abrupt surge in market volatility, which triggers a funding shock, morphs into a credit shock that softens GDP growth, and erodes banks' capital ratios.

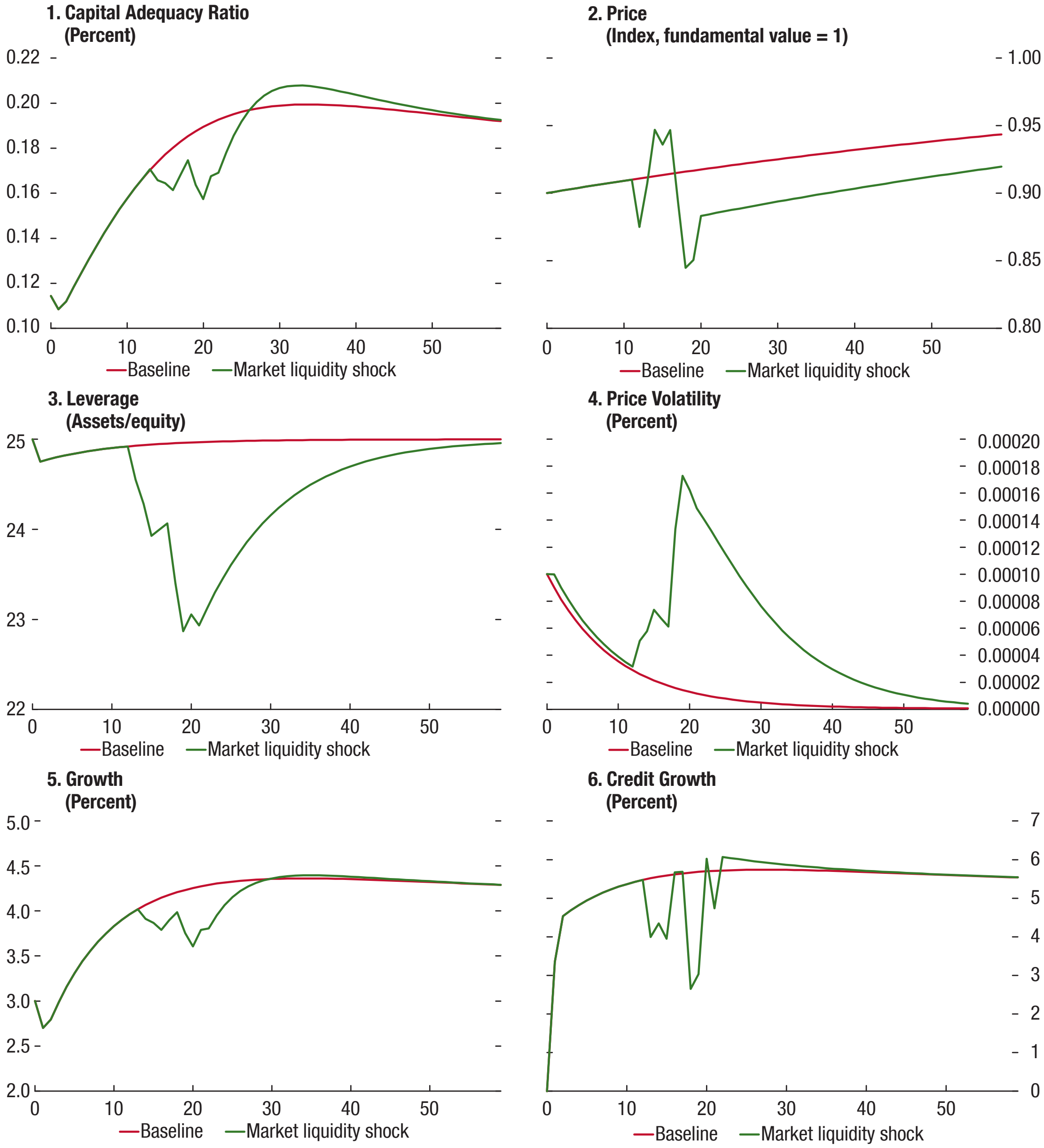
Overall, the model shows the mechanism through which a market liquidity event amplifies, spreads, and outlives the initial shock, affecting financial stability. Banks' deleveraging contributes to a downward spiral in asset prices triggering a fire sale mechanism, which further erodes their balance sheet capacity, weakens their capacity to sustain markets and provide credit, and depresses GDP growth. Banks' soundness, credit provision, and GDP growth remain subdued for a prolonged period because of feedback effects between the banking sector and the real economy.

The box was prepared by Laura Valderrama.

[1]The model does not focus on high-quality liquid assets.

Box 2.4. *(continued)*

Figure 2.4.1. Stress Test of the Financial System and the Real Economy



Source: IMF staff estimates.

Note: This figure illustrates the dynamics of the banking sector, the securities market, and the real economy under a baseline scenario and a market liquidity shock scenario. The following variables are shown: *Capital adequacy ratio* of the banking system subject to a risk-based capital regulatory framework. *Price* reflects the market price of securities with a fundamental value of 1. *Leverage* denotes the equilibrium leverage of the banking system under a time-varying market-funding constraint that is tighter the higher the asset price volatility. *Price volatility* shows the volatility of the security, which follows a stochastic process with an autoregression coefficient of 0.9. *Growth* denotes GDP growth. *Credit growth* represents aggregate credit growth. The dynamics of the system are triggered by initial subdued credit growth at $t = 0$. Low initial credit growth depresses real GDP, increases credit risk, pushes up risk-weighted assets, lowers maximum available leverage, and erodes banks' capital adequacy ratios. As banks optimize credit supply, GDP growth recovers, asset prices trend up toward fundamentals, banks' capital adequacy ratios increase, and the economy shifts toward a steady state. The market liquidity shock is prompted by redemption pressure mounting on asset managers who are forced to sell their asset holdings over the time period t from 12 to 20. Asset managers' impaired liquidity leads to higher asset price volatility (market shock), decreases banks' maximum allowable leverage (funding shock), leads to a credit squeeze (credit shock), and depresses GDP growth (macro shock).

current liquidity levels partly reflect important cyclical drivers of liquidity, monetary accommodation, and risk appetite that are in a supportive phase: monetary policy is unusually benign, and investors in most advanced economies currently have a high appetite for risk. On the other hand, they are concealing the buildup of structural fragilities that can bring them down. When the cyclical factors at some point reverse—most likely in conjunction with the normalization of monetary policies in advanced economies—the resulting exposure to the underlying fragilities can produce a sudden deterioration in market liquidity and an increase in liquidity spillovers across asset classes. This chapter has made some progress toward a framework that helps anticipate these risks.

The chapter offers five main policy recommendations:

- During normal times, policymakers should ensure through preventive policies that liquidity is resilient. Moreover, they need to monitor liquidity developments with a policy strategy in hand to deal with episodes of market illiquidity.
- Market infrastructure reforms (equal-access electronic trading platforms, standardization) should continue with the goal of creating more transparent and open capital markets.
- Trading restrictions on derivatives should be reevaluated.
- In the process of normalization of monetary policy in the United States, good communication and attention to liquidity developments across markets will be important to avoid disruptions in market liquidity in both advanced and emerging market economies. Central banks should take market liquidity into account when conducting monetary policy.
- Regulators should develop measures to reduce liquidity mismatches and the first-mover advantage at mutual funds.

Table 2.5. Summary of Findings and Policy Implications

Characteristics	Markets	Findings	Tentative Policy Implications
	Improving the Level of Liquidity		
Transparency	U.S. Corporate Bond	Posttrade transparency is beneficial to market liquidity.	Promote posttrade transparency.
Cost of Holding Inventory	U.S. Corporate Bond	Increase in dealers' inventory costs or reduced balance sheet space decreases their ability to provide market liquidity.	Encourage entry of new market makers by promoting standardization and equal access to trading venues.
Central Bank Purchases	U.S. MBS	Central bank purchases, over time, degrade market liquidity for the underlying asset.	Take into account market liquidity when implementing monetary policy.
Short-Sell Ban	CDS	Short-sell bans decrease market liquidity.	Consider revoking the ban.
	Improving the Resilience of Liquidity		
Ownership by Mutual Funds and Concentration of Ownership	U.S. Corporate Bond	Ownership by mutual funds and concentration makes market liquidity evaporate more quickly during severe market downturns.	Contain liquidity risks associated with mutual fund ownership and redemption pressures.
Collateral Eligibility	European Sovereign Bond	Including an asset as eligible for collateral temporarily increases market liquidity.	During crisis, support market liquidity of certain markets by including the assets in collateral pools.
Cyclical Factors, including Monetary Policy	U.S. Corporate Bond; U.S. and EU Sovereign Debt; FX	Explains most of the behavior of the level of liquidity and an important part of the resilience of liquidity, when taken in conjunction with funding liquidity and risk appetite.	Reversal of current monetary stance should pay special attention to the possibility of a rapid deterioration of market liquidity.
Liquidity Regimes	U.S. Corporate Bond; U.S. and EU Sovereign Debt; FX	Market liquidity evaporates during crises.	Have a preemptive strategy to deal with liquidity dry-ups. Monitor liquidity in real time.
Liquidity Spillovers	U.S. Corporate Bond; U.S. Sovereign Debt; EME, EU, and U.S. Equity; FX	Market liquidity spillovers across asset classes increase in periods of financial stress and are now more elevated than before the financial crisis.	Monitor liquidity over a wide range of asset classes.

Source: IMF staff

Note: CDS = credit default swaps; EME = emerging market economy; EU = European Union; FX = foreign exchange; MBS = mortgage-backed securities.

Annex 2.1. Data and Liquidity Measures

The analyses in this chapter—both the ones at the security level and the aggregate ones—use several data sets:

- *U.S. corporate bond data*—The TRACE (Trade Reporting and Compliance Engine) data set contains trade-by-trade analysis for corporate bonds, structured products, and agency bonds traded in the United States since 2002.
- *Global corporate, agency, and sovereign bonds*—The Markit GSAC data set contains quote-by-quote information on four categories of bonds around the world (government, sovereign, agency, and corporate). The data set contains more than 40 percent of observations denominated in developing economy currencies and quote-level information for more than 950,000 bonds. The analysis uses the time periods of April–September 2013 and October 2014–March 2015 to document the "taper tantrum" and recent liquidity events.
- *European sovereign bonds*—The MTS data set contains the top of the order book for all European sovereign bonds traded on the MTS platform from 2005 to 2014. The MTS platform is an interdealer trading platform that trades more than 1,100 government bonds in 18 countries. For each security, the chapter observes quote-by-quote information of the top three bid and ask prices, as well as trades, generating more than 30,000 observations on an average day.
- *Over-the-counter derivatives*—High-level trading volume data were retrieved from the International Swaps and Derivatives Association *SwapsInfo* portal (http://www.swapsinfo.org). Credit default swap liquidity metrics, such as bid-ask spreads and number of quoting dealers, were retrieved from Markit (http://www.markit.com).
- *Quoted spreads and prices*—Information was also gathered on daily bid, ask, high, and low prices on bonds from Thomson Reuters Datastream and Bloomberg, L.P. for a series of bonds, currencies, and stocks, as well as transaction volumes, whenever available.
- *Ownership by institutional investors*—The data are sourced from Thomson Reuters eMaxx data set, which contains each institutional investor's holdings of different fixed-income securities at the quarterly frequency. The sample covers 2008 and 2013.

Annex 2.2. Event Studies of Market Liquidity

The methodology employed in the event studies described in this chapter uses two main approaches: (1) a differences-in-differences approach using panel data and (2) simple cross-section regressions. The first approach can be implemented when it is possible to identify a specific change in regulation or policy that may have affected the behavior of a group of investors or financial intermediaries (the treatment group), while leaving the other group unaffected (the control group). The approach uses the following generic specification:

$$LIQ_{it} = \beta_0 + \beta_1 D_i + \beta_2 T_t + \beta_3 D_i \times T_t + \varepsilon_{it}$$

where the effect of a given determinant is measured with a dummy variable D_i, which takes value one if security i is affected by it, and zero otherwise, multiplied by another dummy variable T_t, which takes value one after the regulatory or policy change is either announced or implemented. The coefficient of interest is β_3, which can be interpreted as the impact the regulatory change has on the treatment group, after removing all the possible aggregate trends that affect both the treatment and the control groups. The equation is estimated using panel fixed effects and robust standard errors. The approach is used to estimate the effect of the following episodes:

- *Increasing posttrade transparency*—Between 2003 and 2005, FINRA forced the disclosure of bond trades of different types of corporate bonds: March 3, 2003 (phase 2a), April 14, 2003 (phase 2b), October 1, 2004 (phase 3a), and February 7, 2005 (phase 3b).
- *Ban of uncovered European sovereign CDS*—The analysis estimates the impact of the November 2012 EU ban by measuring liquidity of about 80 sovereign CDS contracts three months before and after its approval (from August 1, 2012 to January 31, 2013). The metrics used are quoted bid-ask spreads, market depth, number of dealers quoting the CDS, number of quotes, and Markit's liquidity score. The analysis is repeated using quoted bid-ask spreads for roughly 3,400 sovereign bonds from a variety of countries (including EU countries). Since credit risk may be an important time-varying determinant of bond liquidity, the chapter uses a specification with an interaction of the treatment effect with the value of the issuer's CDS spread between May and July 2012.[43]

[43] The CDS spread is in logarithms because the effect of credit risk is likely not linear and the variable has fat tails.

- *Investor base and U.S. corporate bond liquidity*—The security-level analysis compares the imputed round-trip cost of U.S. corporate bonds rated as BBB–, relative to that of other bonds, six months before and after the adoption by the Office of the Comptroller of the Currency of a rule removing references to credit agency ratings as a standard for investment grade.
- *Outright purchases and MBS liquidity*—The analysis displayed in Figure 2.8 follows Kandrac (2014). The dependent variable is the imputed round-trip cost calculated using security-level TRACE data for 30-year MBS and the explanatory variable is the dollar value of outright purchases of each security, as reported by the Federal Reserve Bank of New York. The controls also include issuance and distance to coupon, sourced from JP Morgan.

The cross-section approach uses the following specification:

$$\Delta LIQ_i = \delta_0 + \delta_1 X_{i,-1} + \mathbf{z}_i \Gamma + u_i,$$

where X_i is the value of the variable of interest before liquidity is affected by an exogenous shock (such as the global financial crisis or the taper tantrum), $\mathbf{z}_i$ is a set of additional controls, and ΔLIQ_i is the change in liquidity of security *i* during the episode under consideration. The coefficient of interest is δ_1 and is estimated using a pooled ordinary least squares regression. Statistical inference is based on robust standard errors. The approach is used to study the following:

- *Ownership composition and concentration*—The study focuses on corporate bond liquidity and relates it to the types of investors and their concentration, as reported by eMaxx. It controls for ratings, age, total issue amount, and other bond-level characteristics.
- *Greater pretrade transparency and other bond characteristics*—The study measures the contribution to the change in liquidity of the number of dealers (pretrade transparency), issue size, credit rating, quote depth, time to maturity, and number of issues by the same issuer.

The impact of changes in the collateral framework is assessed by looking at changes in the bid-ask spread for aforementioned securities, available from Bloomberg, L.P. The analysis focuses on a series of events in which the ECB broadened the eligibility of collateral either by reducing the rating threshold for securities issued in euros (October 15, 2008, for all securities except asset-backed securities, and December 8, 2011, June 20, 2012, and July 9, 2014) or by accepting securities issued in U.S. dollars, British pounds, and Japanese yen as collateral (October 15, 2008, and September 6, 2012).

The analysis of the impact of market making on market liquidity uses time-series regressions of aggregate liquidity for U.S. corporate bonds on the frequency of U.S. Treasury auctions—an instrument for dealers' ability to make markets. The following equation is estimated for investment-grade and high-yield corporate bonds at the daily and monthly frequencies:

$$LIQ_t = \gamma_0 + \gamma_1\, Auction_{t-1} + \Gamma_2 X_{t-1} + \nu_t$$

where *Auction* is a dummy variable that equals one in any day when there is at least one U.S. Treasury auction, and zero otherwise. *X* denotes a set of macroeconomic and financial variables as specified in Annex 2.3 except for the variable *Dealer's inventory*. The monthly variables are constructed by averaging the daily values over the month, including the dummy. The coefficient of interest is γ_1. The effect in a day is computed by dividing the γ_1 from daily regressions by the average imputed round-trip cost. The effect over one month is computed by dividing the γ_1 from monthly regressions first by 30 and then by the average imputed round-trip cost. A similar specification is used in Figure 2.9, where imputed round-trip costs are regressed on the lagged VIX, credit spread, TED spread, business conditions index, commodity prices, and commercial bank holdings of corporate bonds, as well as on the U.S. shadow policy rate (sourced from Leo Krippner's webpage at the Reserve Bank of New Zealand).

Annex 2.3. Markov Regime-Switching Models for Market Liquidity and the Liquidity Premium

Data for U.S. corporate bonds and European sovereign bonds suggest the existence of three liquidity regimes—low, intermediate, and high liquidity. The probabilities of being in each of the three distinct liquidity regimes (low, intermediate, and high) for U.S. corporate bonds or European sovereign bonds are estimated using a Markov regime-switching model:

$$LIQ_t = \alpha_0^k + \varepsilon_t^k, \qquad \text{(A.2.1)}$$

where *LIQ* is the liquidity measure at either daily or monthly frequency, and *k* indicates the liquidity regime. The model allows both the level and the volatility of liquidity to change among the regimes and is estimated by the maximum likelihood method. Three trade-based measures are used to measure the market liquidity of U.S. corporate bonds: the imputed round-trip cost (IRTC), the Amihud measure, and the Roll measure.[44]

[44]All liquidity measures are available at a monthly frequency. The IRTC is also available at daily frequency. Results based on the Amihud and Roll measures are similar to those based on IRTC.

For European sovereign bonds, equally weighted effective spreads are used (aggregated over six euro area sovereign bonds—Belgium, France, Germany, Italy, Netherlands, and Spain).

A similar regime-switching behavior is also identified in the foreign exchange and U.S. Treasury bond markets, but only two regimes are found. Model (A.2.1) is estimated using equally weighted bid-ask spreads (normalized by mid prices) in three currency aggregates: the major advanced markets (euro, British pound, Japanese yen, and Swiss franc), other advanced markets (Australian dollar, Canadian dollar, Danish krone, New Zealand dollar, Norwegian krone, and Swedish krona), and emerging markets (Brazilian *real*, Indonesian rupiah, Indian rupee, Russian ruble, South African rand, and Turkish lira). For U.S. Treasury bonds, the Corwin and Schultz (2012) measure is used.

The probability of being in the low-liquidity regime can be explained by a set of lagged macroeconomic and financial variables. Following Acharya, Amihud, and Bharath (2013), we apply a standard logit transformation to the probability:

$$\log\left(\frac{Probability + c}{1 - Probability + c}\right)$$

where c is a constant added to accommodate the cases in which $Probability$ = 1 or 0. The explanatory variables are as follows:

- *Citigroup economic surprise index*—Measures the actual outcome of economic releases relative to consensus estimates at the daily frequency.
- *Business condition index*—Real business conditions are tracked using Aruoba, Diebold, and Scotti's (2009) index of business conditions at the monthly frequency.
- *VIX*—The Chicago Board Options Exchange Volatility Index, which measures the market's expectation of stock market volatility over the next month.
- *Commodity price inflation*—The daily (monthly) percentage change in the commodity price index from the Commodity Research Bureau for the daily (monthly) regressions.
- *Moody's credit spread*—The yield spread between Moody's Baa- and Aaa-rated corporate bonds.
- *TED spread*—The difference between the three-month London interbank offered rate (LIBOR) based on the U.S. dollar and the three-month T-bill secondary market rate (orthogonalized with respect to the credit spread).
- *Unconventional monetary policy*—The number of positive minus negative announcements by the Federal Reserve of large-scale asset purchases during the previous 30 days. The monthly variable is constructed by averaging the daily values over the month.
- *Dealers' inventory*—Dealers' inventory is approximated by the U.S. commercial banks' holdings of total corporate securities in percent of their total assets.
- *U.S. Treasury auctions*—A dummy variable that equals one if there is a U.S. Treasury auction in any day. The monthly variable is constructed by averaging the daily values over the month.

The analysis estimates the liquidity premium for investment-grade and high-yield bond returns using the following Markov regime-switching model as in Acharya, Amihud, and Bharath (2013).

- Investment grade-bond returns (in excess of the 30-day T-bill return):

$$r_{IG,t} = \beta_{IG,0} + \beta_{IG,1} TERM_t + \beta_{IG,2} CREDIT_t + \beta_{IG,3} Sillq_t + \beta^s_{IG,4} Billq_{IG,t} + \varepsilon^s_{IG,t}$$

- High-yield bond returns (in excess of the 30-day T-bill return):

$$r_{HY,t} = \beta_{HY,0} + \beta_{HY,1} TERM_t + \beta_{HY,2} CREDIT_t + \beta_{HY,3} Sillq_t + \beta^s_{HY,4} Billq_{HY,t} + \varepsilon^s_{HY,t}$$

- Regime-dependent variance-covariance matrix:

$$\Omega_s = \begin{pmatrix} \sigma^2_{IG,s} & \rho_s \sigma_{IG,s} \sigma_{HY,s} \\ \rho_s \sigma_{IG,s} \sigma_{HY,s} & \sigma^2_{IG,s} \end{pmatrix}, \qquad \text{(A.2.2)}$$

where s is the regime, r_{IG} and r_{HY} are the returns on Barclay's investment-grade and high-yield corporate bond indices in excess of the 30-day T-bill return. $TERM$ is measured by the difference between the monthly 30-year Treasury bond yield and one-month T-bill yield. $CREDIT$ is Moody's credit spread measure. $Sillq_t$ is a liquidity risk measure of the stock market based on Corwin and Schultz (2012). $Billq_{IG}$ and $Billq_{HY}$ are liquidity risk measures of investment-grade and high-yield corporate bonds, respectively, based on imputed round-trip costs, and their coefficients are assumed to differ across regimes.[45] Liquidity risk is measured by the residuals of autoregressive models of the liquidity measures.

The spillover analysis calculates an index of market-wide liquidity spillovers and relates it to regimes of high asset-returns volatility and comovement. Financial market stress is identified by running a regime-switching Bayesian vector autoregression (VAR) for monthly returns of equities in advanced and emerging market economies, U.S. and European sovereign bonds, high-yield and investment-grade corporate bonds, and com-

[45]Allowing stock market liquidity risk to change across regimes does not qualitatively change results.

modities. Market liquidity spillovers are measured by decomposing the generalized forecast error variance for a VAR of liquidity measures in a 200-day rolling window and then calculating for each day the total contribution of each asset class to the other asset classes' market liquidity. See Diebold and Yilmaz (2014).

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