Understanding and Measuring Liquidity Risk: A Selection of Recent Research

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- *During the financial crisis, many financial institutions saw significant declines in the liquidity of their assets and in their ability to fund themselves in wholesale funding markets.*
- *Recent research suggests that important causes behind declines in liquidity include uncertainty about fundamentals, fluctuations in margin requirements, and spillover effects between interconnected institutions.*
- *The recently announced new capital and liquidity rules for the banking sector, Basel III, should reduce the occurrence of financial crises. Higher capital requirements should lessen the need to raise margins, as well as decreasing the extent of network externalities. More stringent liquidity standards will promote the resilience of banks during stressed periods.*

The recent global financial crisis exposed major weaknesses in the functioning of the global financial system. Those weaknesses allowed a relatively small shock—the losses on U.S. subprime mortgages—to set in motion a chain of events that led to a major crisis in global financial markets. Significant declines in the market liquidity of assets and in the ability of financial institutions to fund themselves in wholesale funding markets were important channels for the transmission and, indeed, the magnification of this shock. A better understanding of the risks surrounding funding and market liquidity is therefore crucial for improving the stability of the financial system.

In this article, we review a selection of recent research on liquidity risk, including work by Bank of Canada staff. We also examine how financial market reforms, together with the new global regulatory reform package recently announced by the Basel Committee on Banking Supervision—Basel III—support the need to better manage liquidity risk.

We first present the findings of recent empirical studies that illustrate the important role that the decline in wholesale funding played during the financial crisis.[1] We then review two mechanisms behind the interaction of the wholesale funding available to financial institutions and the market liquidity of financial assets. This is followed by an examination of state-of-the-art quantitative models that help us better understand the impacts of the market liquidity of assets and the availability of wholesale funding on the stability of the financial system. We then summarize the implications of this recent research for financial system reforms, including Basel III, and present some conclusions.

1 Wholesale funding is defined as borrowing from other financial institutions and non-financial corporations.

Growth of Assets and Leverage at Financial Institutions

The losses on U.S. subprime mortgages that triggered the recent global financial crisis were much smaller than the losses associated with the subsequent declines in the prices of financial assets and the write-downs experienced by financial institutions. **Chart 1** illustrates that even investment-grade financial issuers had to pay historically high yields over the period. This increase in funding costs contributed to the failure of many notable financial institutions, including Bear Stearns and Lehman Brothers.

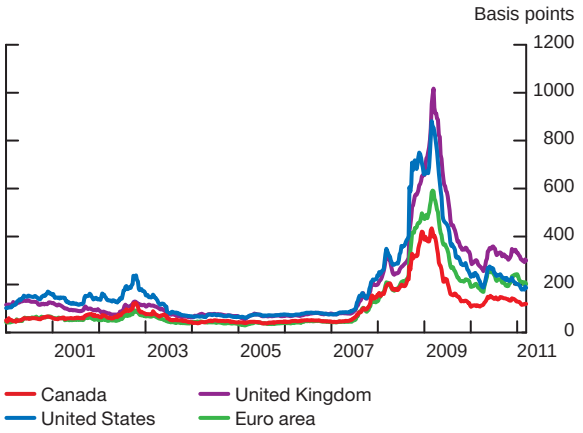
Recent empirical research suggests that one of the reasons behind the devastating effect of subprime losses was the high degree of leverage of certain U.S. and European financial institutions.[2] In particular, Adrian and Shin (2010) document a significantly positive correlation between asset growth and the growth of leverage at U.S. investment banks. Prior to the crisis, as asset prices rose, the balance sheets of investment banks expanded relative to their capital bases, meaning that they increased their leverage. But leverage quickly fell when the initial subprime-loan losses reduced the capital of U.S. investment banks: banks sold a higher proportion of assets than warranted by the decline in their capital. This behaviour is consistent with a vicious cycle, whereby a decline in asset prices (resulting from asset sales) reduces bank capital, causing more asset sales, which place more pressure on asset prices and further undermine bank capital. **Chart 2** shows that a positive correlation between asset growth and leverage growth also existed at Canadian banks over this period, but to a lesser extent than for U.S. investment banks.

Empirical analysis by Damar, Meh and Terajima (2010), using Canadian data, finds that a bank's access to the markets for wholesale funding, which was severely impaired during the crisis (see **Chart 3**), contributed importantly to this positive correlation.

The findings of Damar, Meh and Terajima are consistent with the nature of wholesale funding, which allows banks to take on wholesale debt more quickly than deposits from households in normal times, but also allows the sources of wholesale funding to disappear more rapidly when a decline in asset prices impairs the capital of the borrowing financial institutions. Thus, when asset prices drop, financial institutions that rely heavily on wholesale funding need to be

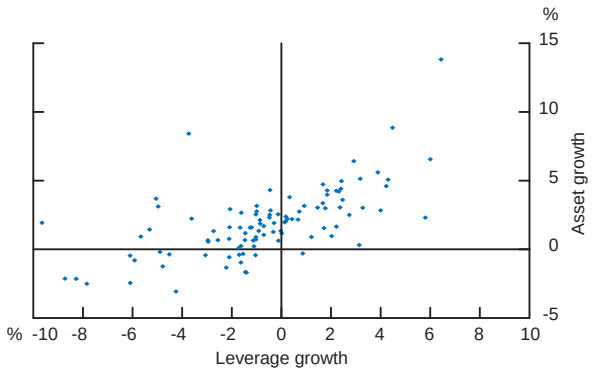
2 Leverage is the value of the assets held by a financial institution relative to its capital.

Chart 1: Yield spreads for investment-grade financial issuers



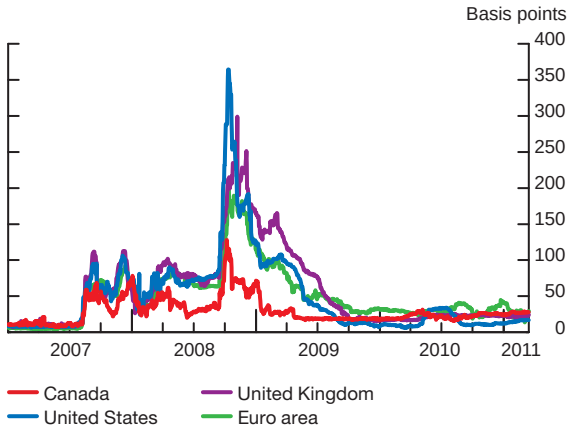
Sources: Bloomberg and Merrill Lynch Last observation: 23 March 2011

Chart 2: Growth in assets and leverage of major Canadian banks
1983—2009



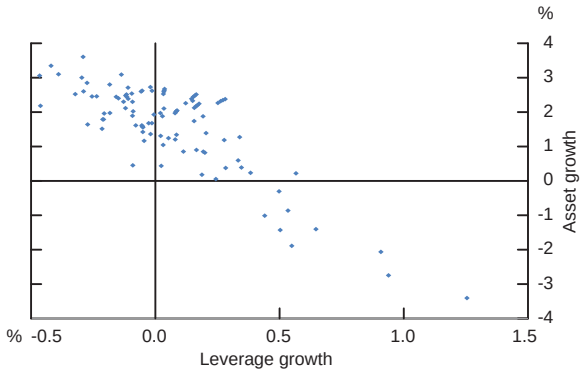
Sources: Office of the Superintendent of Financial Institutions and Bank of Canada calculations

Chart 3: Conditions in short-term funding markets[a]
Difference between 3-month interbank offered rates and their respective overnight index swaps



a. U.S. and U.K. LIBOR; EU EURIBOR; Canada CDOR
Source: Bloomberg Last observation: 15 March 2011

Chart 4: Growth in assets and leverage of Canadian households
1983—2009



Sources: Statistics Canada and Bank of Canada calculations

able to sell assets more quickly to reduce their liabilities (i.e., deleverage), generating a positive correlation between asset growth and leverage growth.[3] **Chart 4** supports Damar, Meh and Terajima, showing that the growth in leverage of Canadian households, who do not have access to wholesale funding, was negatively correlated with their asset growth over the same period.

In addition, **Charts 1** and **3** show that Canada experienced a smaller rise in funding costs during the financial crisis than other developed countries. This results partly from the fact that while the correlation between asset growth and leverage growth at Canadian banks is positive, the *level* of leverage taken by Canadian banks prior to the onset of the crisis was substantially lower than that taken by U.S. investment banks and major European banks. In fact, Canadian banks were subject to leverage limits (the asset-capital multiple limit imposed by the Office of the Superintendent of Financial Institutions), while U.S. investment banks and most European banks were not. As a result, the leverage carried by Canadian banks prior to the crisis was significantly lower than that of U.S. investment banks, as well as that of major European banks.[4] This feature of Canadian banks likely contributed to the relative stability of the Canadian banking system during a crisis that rocked banking systems in the United States and Europe.[5]

Mechanisms behind Declines in Wholesale Funding

The previous section provided evidence which suggested that during the crisis, the banks most dependent on wholesale funding were required to undertake relatively more deleveraging. We now present various factors that help to explain the decline in bank's access to wholesale funding during the crisis. We focus on the roles of uncertainty about fundamentals, fluctuations in margin requirements, and network externalities.[6]

Uncertainty about fundamentals

Part of the decline in wholesale funding reflected the flight of institutional investors, who were no longer willing to supply funds to particular financial institutions. This flight of wholesale funds was an important contributor to the collapse of Bear Stearns, Lehman Brothers, Northern Rock and other institutions. Morris and Shin (2009) model the causes behind the disappearance of an institution's wholesale funding. They suggest a combination of investor concerns about the risk that an institution may become insolvent (i.e., uncertainty about its fundamental value), a decline in the market liquidity of the institution's assets, and the extent to which it relies on wholesale funding markets.

Their work shows that an otherwise solvent financial institution can be pushed into default if it is too dependent on short-term funding markets or if it is difficult to sell the institution's assets at fair prices; i.e., the market liquidity of the assets is low. For example, if the market liquidity of the assets falls, each lender becomes wary about the risk that the institution may have to sell assets at fire-sale prices as other lenders withdraw funding, and therefore pre-emptively cuts funding to that institution.

3 Adrian and Shin (2010) found no significant correlation between asset growth and leverage growth at U.S. commercial banks. The behaviour of Canadian banks lies between that of U.S. investment banks and that of U.S. commercial banks. This may partly reflect the fact that Canadian banks are more actively engaged in investment banking activities than U.S. commercial banks.

4 For example, the average leverage ratio for the Big Six Canadian banks, which incorporate investment-banking arms, was 20.8 in the first quarter of 2007, while that for U.S. investment banks was 25. The actual difference between Canadian and U.S. banks with large derivative activities was much larger than these numbers suggest, since the U.S. accounting standard (GAAP) allows derivatives to be netted. For example, Bordeleau and Graham (2010) show that the netting of derivatives by Deutsche Bank, which reports its balance sheet using both IFRS and U.S. GAAP for the period ending 31 December 2008, reduces its total assets by 50 per cent.

5 Some off-balance-sheet activities (such as liquidity facilities for securitization) are not included in the Canadian leverage ratio. However, Canadian banks were more restricted in these activities than banks in other countries since they were part of risk-weighted assets, and the floor on the Tier 1 capital ratio was higher in Canada than elsewhere. See, Crawford, Graham and Bordeleau (2009) for more details on the history of leverage regulation in Canada.

6 See Kirabaeva (2010–2011) for the role of serious information problems, such as adverse selection, during financial crises.

The findings of Morris and Shin are consistent with the complex securitization of subprime-mortgage loans as a cause of the decline in wholesale funding during the crisis. While the initial increase in delinquent subprime-mortgage loans raised concern about the solvency of some financial institutions, the securitization that distributed that delinquency risk to various asset-backed securities (ABS) made it difficult to identify the actual locations of the risk. This led to a significant decline in the liquidity of the ABS market and in wholesale funding for the financial institutions holding those assets.[7]

Margin spirals and wholesale funding

When buyers purchase securities they can use their assets as collateral for the purchase. The difference between the collateral value of the asset and the purchase price is the margin—the portion paid for with the buyer's own capital. The margin required is thus akin to the buyer's leverage capacity. The margin requirements for various securities increased sharply during the crisis, as shown by **Table 1** from the report of the Committee on the Global Financial System (CGFS 2010).[8]

Margin requirements for various securities increased sharply during the crisis

Regarding the effect of increased margin requirements, Brunnermeier and Pedersen (2009) illustrate that a small negative shock to asset prices can trigger a large decline in wholesale funding through the tightening of margin requirements for investment banks. Their work shows that an increase in asset sales that lowers asset prices can make investors wary about the risk of further price declines. To cover this risk, the suppliers of wholesale funds to investment banks require them to hold more capital in support of their asset positions (i.e., they raise the margin requirements), resulting in a decline in the banks' wholesale funding. This reduces the capacity of investment banks to absorb an excess supply of assets and increases their need to deleverage, leading to further asset sales, a further decline in asset prices, and even larger increases in margin requirements, again reducing the banks' wholesale funding.[9] This margin spiral likely contributed to the substantial increase in margin requirements along with the large depreciation in asset prices observed during the crisis.[10]

Credit risk, liquidity risk and network effects

The amount of risk in the financial system as a whole (system-wide risk) can be thought of as the combined impact of the different types of financial and economic risks. Recent Bank of Canada research (Gauthier, He and Souissi 2010; Gauthier, Lehar and Souissi 2010) builds on some of the theoretical literature described above to develop quantitative models for measuring system-wide risk.[11] Different types of risks are integrated into a network of bilateral exposures between banks, through which one bank's default can cause otherwise solvent banks to default as well.

Gauthier, He and Souissi (2010) incorporate the possibility of the disappearance of wholesale funding (à la Morris and Shin) into a stress-testing framework for Canadian banks. They find this channel to be a potentially important contributor to system-wide risk as illustrated by **Chart 5**: The likelihood of important losses in a stylized banking system increases substantially when network effects and liquidity risk are considered relative to consideration of only credit risk.

Their framework can also be used for policy analysis. To evaluate the trade-offs between the regulatory standards for capital and liquidity proposed in Basel III, the authors conduct simulations under a severe, but plausible, macroeconomic scenario for different combinations of banks' liquid asset holdings, capital, and short-term funding. One of their findings is that increasing capital alone is more effective at reducing solvency risk than liquidity risk.

7 See Gorton (2009) for more details on the complexity of the securitization process and Krishnamurthy (2010) for a review of the developments in debt markets during the crisis. Also, see Tomura (2010) for a model illustrating that the inability of outsiders to evaluate the quality of an asset leads to undervaluation of the asset in the market, and Fontaine and Garcia (2009) for a measurement framework of the effect of funding-liquidity conditions on bond prices.

8 The data were gathered through bilateral interviews with various market participants, including banks, prime brokers, custodians, asset managers, pension funds and hedge funds.

9 Shleifer and Vishny (1997) use a simple model to illustrate that margin requirements for arbitragers prevent corrections of mispricing in asset markets. Their model illustrates how a decline in asset prices because of random trading by uninformed traders is amplified through withdrawal of funding by investors and fire sales of assets by arbitragers. Allen and Gale (2005) show how a small shock causes a large change in asset prices when the prices are determined by the amount of cash held by arbitragers.

10 See Brunnermeier (2009) and CGFS (2010) for more details on margining practices during the crisis.

11 A *Bank of Canada Review* article providing more details on this work is planned for later this year.

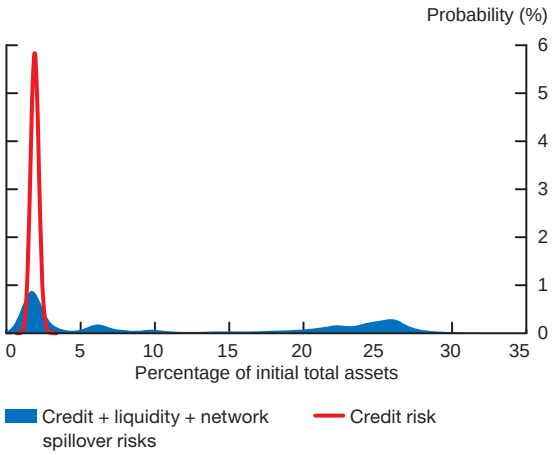
Table 1: Typical margins on term securities financing transactions (per cent)

	June 2007			June 2009		
	Prime counterparty	Non-prime counterparty	Unrated[a]	Prime counterparty	Non-prime counterparty	Unrated[a]
G-7 government bonds						
Short-term	0	0	0.5	0.5	1	2
Medium-term	0	0	0.5	1	2	3
U.S. agencies						
Short-term	1	2	3	1	2	3
Medium-term	1	2	3	2	5	7
Pfandbrief[b]	0	0	1	1	2	8
Prime MBS						
AAA-rated	4	6	10	10	20	30–100
AA- and A-rated	8	12	25	100	100	100
Asset-backed securities	10	20	20	25	50	100
Structured products (AAA)	10	15	20	100	100	100
Investment-grade bonds						
AAA- and AA-rated	1	2	5	8	12	15
A- and BBB-rated	4	7	10	10	15	20
High-yield bonds	8	12	20	15	20	40
Equity						
G-7 countries	10	12	20	15	20	25
Emerging economies	15	20	35	20	25	40

a. Hedge funds and other unrated counterparties
b. Pfandbrief is covered interest-bearing bonds issued by German banks under the Pfandbrief Act.
Source: CGFS (2010, 2)

A different version of the same stress-testing framework (Gauthier, Lehar and Souissi 2010) focuses on the market-liquidity risk arising from endogenous fire sales of assets (i.e., the sale of assets at a price below their fundamental value) by troubled financial institutions. The authors find that such a channel of contagion can also have important system-wide effects.[12] This framework was one of those used by the Financial Stability Board and the Basel Committee in their recent international study to assess the longer-run macroeconomic benefits and costs of higher capital and liquidity standards (Basel Committee on Banking Supervision 2010a).[13]

Chart 5: Distribution of total system loss



Source: Bank of Canada calculations

12 The integration of the asset-fire-sale component into the network model is an extension of the work by Cifuentes, Ferrucci and Shin (2005) in which banks are assumed to be equally risky. In contrast to that work, Gauthier, Lehar and Souissi (2010) assume a more realistic world in which banks have various risk profiles, and calibrate the model so that the equilibrium price of a bank's illiquid assets is a decreasing function of its riskiness. This reflects the fact that riskier assets are less liquid in a crisis period.

13 Both studies also show that limiting analysis to traditional interbank lending may seriously underestimate spillover risks, since the size of off-balance-sheet exposures has increased steadily over the past decade, and other types of on-balance-sheet exposures may also be important.

Implications of Financial System Reform

Banking sector regulation

In December 2010, in response to the weaknesses revealed by the 2007–09 financial crisis, the Basel Committee announced new capital and liquidity rules for the banking sector—Basel III.[14] Here, we discuss some of the measures in Basel III in light of the research described previously, as well as other recent Bank of Canada research, highlighting the importance of capital and liquidity standards in reducing the extent of liquidity risk.

Capital standards

A higher and better-quality capital base: Basel III requires banks to hold higher capital than the previous framework, Basel II. The new regulatory capital must also be of better quality, since its predominant form is common equity, which is tangible, loss-bearing capital.[15] Higher and better-quality regulatory capital under Basel III will reduce the scope for amplification of shocks through the various mechanisms described above: more capital and, hence, less leverage reduces the extent of deleveraging needed in times of stress, the likelihood of runs by creditors, the need to increase margin requirements, and the extent of negative spillover of a bank's fragility to other banks through interbank financial obligations. This expectation is consistent with the experience in Canada, where, as summarized by Carney (2010b), banks were already required to hold higher and better-quality capital than Basel II and remained remarkably stable during the financial crisis.

More capital and, hence, less leverage reduces the extent of deleveraging needed in times of stress

A countercyclical capital buffer: Beyond making the global system look more Canadian, Basel III introduces an important innovation for flexible capital standards. While Basel II set a constant minimum requirement for the risk-weighted capital-asset ratio of each bank, under Basel III national authorities can increase the minimum capital requirements for banks in their jurisdiction if they judge that aggregate credit growth is excessive and associated with a buildup of system-wide risk in their jurisdiction. This "countercyclical capital buffer" will require banks to increase their capital base during economic booms—when risk from the perspective of an individual bank is perceived to be low and risk at the system level is likely to be increasing—and allow them to draw down this capital buffer when conditions are weak (Arjani 2009; Chen and Christensen 2010). Such a buffer should help to counteract a buildup of leverage at financial institutions and resulting rises in asset prices during excessive asset-market booms, and should consequently reduce the likelihood of a financial crisis caused by the subsequent deleveraging and its negative externality to asset prices and bank capital. This hypothesis is supported by the model developed by Tomura (2010), which indicates that the dynamics of such a minimum bank capital requirement will prevent the disappearance of wholesale funding over the regular business cycle, where there is no disruption in the market liquidity of assets.[16]

Tomura's model also suggests an additional linkage between the market liquidity of assets and the countercyclical capital buffer. The model indicates that a decline in the market liquidity of assets because of difficulty in evaluating asset quality increases the minimum bank capital required to prevent bank runs. This result suggests that, even though banks may not be able to draw down a capital buffer in such a situation, a prior buildup of bank capital under the countercyclical capital buffer should reduce the occurrence of bank runs.

Leverage ratio: Along with the risk-based minimum capital requirement, banks will be required to satisfy a leverage limit based on the ratio of Tier-1 regulatory capital to their total assets, including selected off-balance-sheet commitments.[17] This leverage ratio is

14 See Basel Committee on Banking Supervision (2010b) for more details.

15 Under the new framework, regulatory capital at a bank consists of two Tiers: Tier 1 and Tier 2. Common Equity Tier 1 must be at least 4.5 per cent risk-weighted assets (RWAs), Tier 1 Capital (Common Equity Tier 1 + Additional Tier 1) must be at least 6 per cent RWAs, and Total Capital (Tier 1 + Tier 2) must be at least 8 per cent RWAs, at all times. In addition, each bank is restricted from paying out dividends when the difference between its Common Equity Tier 1 capital and the regulatory requirement (4.5 per cent) falls below 2.5 per cent RWAs, so that its retained earnings increase its Common Equity Tier 1 capital. See Basel Committee on Banking Supervision (2010b) for more details.

16 Meh and Moran (2010) analyze a different reason for a countercyclical capital buffer because of volatile bank-asset values. In their model, banks are essential to the economy since they monitor borrowers on behalf of depositors. But since their monitoring effort is not observable, banks must finance part of their lending to borrowers through their own capital to commit to efficient monitoring services. The authors show that when banks suffer unexpected loan losses, their capital-adequacy ratios decrease, since the scarcity of bank capital gives banks a greater incentive to monitor borrowers during such an episode.

17 The Basel Committee on Banking Supervision will test a minimum Tier-1 leverage ratio of 3 per cent during the parallel-run period from1 January 2013 to 1 January 2017.

intended to prevent an excessive buildup of leverage in the banking sector by introducing a safeguard against model risk and measurement error in the risk-based capital framework. A simple, transparent indicator of leverage will thus provide a useful backstop to such frameworks. This measure will also help contain the impact on the financial cycle of the interactions between leverage and asset growth that amplifies asset-market booms and subsequent financial crises, as described above. As already mentioned, a regulatory limit on leverage is already in place in Canada, and Canadian banks carried significantly lower leverage ratios than U.S. investment banks and major European banks before the recent financial crisis. This feature of Canadian banks likely contributed to the relative stability of the risk-averse Canadian banking system.

Liquidity standards

To reduce liquidity risk along with solvency risk, Basel III will supplement the capital standards with two new liquidity standards. One is a measure of whether banks have enough unencumbered liquid assets to cover cumulative net outflows over a 30-day horizon (the Liquidity Coverage Ratio). The second is a more structural measure requiring banks to maintain a certain level of stable funding that depends on the liquidity of their assets and the size of their off-balance-sheet exposures over a one-year horizon (the Net Stable Funding Ratio).[18] These new standards aim to promote the resilience of banks during stressed periods when the market liquidity of assets and wholesale funding for financial institutions decline.[19] The research summarized previously makes it clear that such measures should help to reduce the likelihood of institutions finding themselves caught short in terms of liquidity and thus the occurrence of financial crises.

These new standards aim to promote the resilience of banks during stressed periods

Financial market reforms

To maintain the stability of the whole financial system, it is important to ensure continuous operations of key financial markets, so that banks and other firms can have access to funding when necessary. Here, we discuss some of the recent proposals for financial market reform to increase the robustness of financial market infrastructure.

Central counterparties

The network effects measured by Gauthier, He and Souissi (2010) and Gauthier, Lehar and Souissi (2010) demonstrate the potential importance of bilateral exposures among banks in the transmission and amplification of risks. The benefits traditionally associated with central counterparties (CCPs)[20] include reduced counterparty credit risk and reduced potential for the transmission of stress through the financial system (Chande, Labelle and Tuer 2010). For example, in the case of a default by one system participant, the standardized procedures of a CCP can contribute to the orderly closing out of that participant's positions, thus eliminating the chance of a fire sale and reducing spillovers to other markets (Carney 2010a). The development of CCPs should therefore improve the resilience of the financial system, given that CCPs are designed to be risk proofed and thus robust in the presence of financial stress. For this reason, the Bank of Canada is supporting the development of a domestic CCP for Canadian-dollar repos, which will be provided by the Canadian Derivatives Clearing Corporation. The Bank is also working with its domestic partners to develop similar infrastructure for over-the-counter (OTC) derivatives markets.[21]

Through-the-cycle margins

As described earlier, a spiral of tightening margin requirements and declining asset prices destabilized the financial system during the 2007–09 crisis. In response, the Committee on the Global Financial System (2010) published a set of recommendations for preventing such a spiral in the future. One of these recommendations is to make the supervisory margin requirements on securities-financing transactions (such as repos, securities lending and OTC derivatives) relatively stable through the cycle (i.e.,

18 The Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) will be implemented following an observation period during which the Basel Committee on Banking Supervision will monitor implications of these standards for financial markets, credit extension and economic growth, addressing unintended consequences as necessary. The LCR, including any revisions, will be introduced on 1 January 2015. The NSFR, including any revisions, will move to a minimum standard by 1 January 2018 (see Basel Committee on Banking Supervision 2010b for more details).

19 See Northcott and Zelmer (2009) for further discussion on the system-wide effects of liquidity standards.

20 A CCP is a financial market infrastructure that interposes itself between two parties in a trade.

21 See Wilkins and Woodman (2010) for more detail on how to strengthen the resilience of OTC derivatives markets.

introducing so-called through-the-cycle margins).[22] These margin requirements would take into account the volatility of asset prices over a long historical period that includes stressed market conditions, thereby avoiding a substantial decline in margins during economic expansions and a significant increase during stressed periods, such as that observed in the crisis.[23]

Conclusions

One of the forces set in motion by the initial losses on subprime-mortgage loans was a significant decline in the market liquidity of assets and in wholesale funding for financial institutions. This article has summarized selected examples of recent research that clarify the role of liquidity in destabilizing the financial system and has shown how the implications of this work support the recently announced package of reforms to the rules governing bank capital and liquidity.

Although recent research has greatly advanced our understanding of liquidity and its role in the financial system, such efforts should continue. Further research would provide insights for the ongoing improvement of policies and would help to improve the Bank's capacity to contain the emergence of serious system-wide risks.

In particular, we need to keep improving our ability to measure incipient risks to market liquidity and bank funding. The research summarized in this article will be an important building block for further progress in this area.

22 The report also recommends the introduction of CCPs; timely updates of margin requirements in order to avoid large, discrete margin calls; the development of best practices for securities lending; and the collection of information on credit terms.

23 For details, see Longworth (2010) and Kahmi (2009).

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