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Understanding the Crisis: Bank Funding Structures as Source of Instability

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Preface

Understanding how banks fund themselves is of considerable importance. Leading up to the financial crisis banks became very dependent on short-term funding. Commercial paper, repos and wholesale funding markets gained considerable importance. What banks and policymakers have learned is that such dependence makes banks vulnerable to sudden-stops: investors may withdraw from these markets, and its availability may suddenly disappear. The overnight disappearance of access to these funding sources could induce acute liquidity problems. While a better capitalization of banks may help in mitigating this risk, and, indeed, this is the message of the previous contribution to this discussion series (see *Topics in Corporate Finance 23*), the funding models of banks deserve a deeper analysis.

The Amsterdam Center for Corporate Finance is delighted that Dr Tanju Yorulmazer—a former economist at the Federal Reserve Bank of New York and the Bank of England, and currently on the faculty of the University of Amsterdam—has been found to elaborate on these issues. Professor Yorulmazer is one of the foremost experts on bank funding models. In this contribution he elaborates on the sources of risk in the funding of banks, the fragility and disruptions in the various funding models, and the regulation that has been introduced to remedy potential problems.

We hope that this contribution to the ACCF *Topics in Corporate Finance* series helps in deepening our understanding of the intricacies of the financial system, and will play a fruitful role in policy discussions. As Amsterdam Center for Corporate Finance we hope that you enjoy reading it.

Arnoud W.A. Boot
Director ACCF

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Introduction and Overview

The financial crisis of 2007-2009 and the following European debt crisis mark the largest turmoil in financial markets since the Great Depression. During the financial crisis some of the world's largest and most prominent financial institutions failed or nearly failed, requiring unprecedented interventions and assistance from regulators such as extended access to lender-of-last-resort facilities, blanket debt guarantees, and injections of capital to mitigate distress. For example, for a brief period in 2009, Royal Bank of Scotland (RBS) was the largest bank by both assets and liabilities in the world. Table 1 summarizes the interventions and resolutions of major financial institutions that experienced difficulties.

The events of the crisis highlighted the fragility of many financial intermediaries including commercial banks, investment banks, and money market mutual funds (MMFs) as well as the strains in some market-based intermediation arrangements such as asset-backed commercial paper (ABCP). Gaining a better understanding of the sources of these difficulties is essential for understanding the determinants of financial (in)stability and should help in designing a more resilient financial system.

Chapter 1 discusses the risks that financial intermediaries face and reviews the literature on bank stability. The particular focus is on liquidity and the fragility of funding structures.

The actual experiences in the years leading up to the crisis and the disruptions during the crisis are analyzed in Chapter 2. Prior to the crisis, we observed shifts in activities to less regulated parts of the financial system, a globalization of financial intermediation and an increased reliance on wholesale funding. During the crisis many institutions experienced significant disruptions in their access to funding requiring extraordinary government interventions to mitigate distress in the financial system. We will discuss key developments in the funding markets and the (immediate) policy actions taken to alleviate the disruptions.

As a response to the crisis and the shortcomings of the regulatory system, major changes in the regulatory framework have been proposed (and introduced), including increases in capital requirements, the introduction of liquidity requirements, the designation of systemically important banks with a tailored regulatory regime, the introduction of stress tests as a periodic supervisory tool, and major changes in the lender-of-last-resort role of central banks. Chapter 3 discusses these developments.

Table 1: Some of the Largest Institutions that Failed and/or Received Government Support

Institution	Date	Resolution method/ support
ABN AMRO	Oct-2008	In October 2007, a consortium of the Royal Bank of Scotland Group, Fortis and Banco Santander, acquired the bank, in what was the world's biggest bank takeover. When RBS and Fortis soon ran into trouble, the Dutch government acquired the Dutch activities of Fortis (including the ABN AMRO assets that Fortis had acquired). RBS was rescued by the UK government.
ING Group	Oct-2008/Jan-2009	Received €10 billion capital injection from the Dutch Government (October 19). On January 26, 2009, the Dutch government further intervened by assuming 80% of the risk on ING's US investment portfolio in Alt-A mortgage securities.
Fortis	Oct-2008	Dutch government purchased the Dutch banking and insurance divisions for €16.8 billion including the assets of ABN AMRO held by Fortis. The Belgium government rescued what was left of Fortis and parts of it were sold to BNP Paribas.
Dexia	Sep-2008	Dexia received a capital injection of €6.4 billion (€3 billion from Belgium, €3 billion from France and €376 million from Luxembourg) and a state guarantee in order to regain access to wholesale funding markets. In 2011 it became a casualty of the sovereign debt crisis. The Belgium government bought Dexia Bank Belgium from Dexia Group. The bank continues under the name Belfius. The remaining part of Dexia Group is in (orderly) sell-off/liquidation.
Royal Bank of Scotland	Oct-2008	RBS has been rescued by the UK government with £45 billion of funds used for the bailout resulting in 79% state ownership.
Northern Rock	Sep-2007 to Feb-2008	In September 2007, the Bank of England provided a liquidity support facility. In February 2008, the bank was nationalized by the British Government.
Alliance & Leicester	Jul-2008	Acquisition by Banco Santander for £1.26 billion
Bradford & Bingley	Sep-2008	The UK government nationalized the institution on September 29, 2009, selling the savings unit and branches to Banco Santander.
HBOS	Sep-2008 to Jan 2009	Terms of a takeover by Lloyds TSB were agreed in September 2008. In October 2008, UK Treasury injected new capital amounting to £17 billion or a 43% equity stake the combined Lloyds TSB and HBOS. In January 2009, HBOS was acquired by Lloyds TSB.
UBS	Dec-2007 to Oct-2008	In December 2007, the bank received a capital injection from the Government of Singapore Investment Corporation. In October 2008, UBS sold CHF60 billion of its troubled assets to a special purpose vehicle acting as the "bad bank" entity, funded by a CHF6 billion capital injection by the Swiss government and a CHF54 billion loan from the Swiss National Bank.
Anglo Irish Bank	Jan-2009	Nationalized by the Irish Government
Allied Irish Bank	Feb-2009	Received capital injection of €3.5 billion
Bank of Ireland	Feb-2009	Received capital injection of €3.5 billion
Bankia SA	May-2012	The bank was partly nationalized through a €19 billion recapitalization by Spain.
Bear Stearns	Mar-2008	The bank was sold to JP Morgan Chase with assistance from the Federal Reserve in the form of a nonrecourse loan of $29 billion.
Lehman Brothers	Sep-2008	Lehman filed for chapter 11 bankruptcy. It was the largest bankruptcy filing in US history.
AIG	Sep to Nov-2008	On September 16, 2008, the Federal Reserve extended a credit facility of $85 billion, secured by stock in the form of warrants for a 79.9% equity stake. $40 billion of capital was injected under TARP.

Institution	**Date**	**Resolution method/ support**
Washington Mutual	Sep-2008	On September 25, 2008, WaMu was seized by the OTS and placed in receivership with the FDIC. The banking subsidiaries were sold to JPMorgan Chase, while the holding company filed for chapter 11 bankruptcy.
Citigroup Inc	Oct-2008 to Jan-2009	Received two capital injections through the Trouble Asset Relief Program (TARP): $25 billion in October 2008 and an additional $20 billion in January 2009.
Wells Fargo & Co	Oct-2008	Received $25 billion capital injection under TARP
State Street Corp	Oct-2008	Received $2 billion capital injection under TARP
Bank of America Corp	Oct-2008 to Jan-2009	Received two capital injections through the Trouble Asset Relief Program (TARP). $25 billion in October 2008 and an additional $20 billion in January 2009
JPMorgan Chase & Co	Oct-2008	Received $25 billion capital injection under TARP
Morgan Stanley	Oct-2008	Received $10 billion capital injection under TARP
Goldman Sachs Group	Oct-2008	Received $10 billion capital injection under TARP
Bank of New York Mellon	Oct-2008	Received $3 billion capital injection under TARP

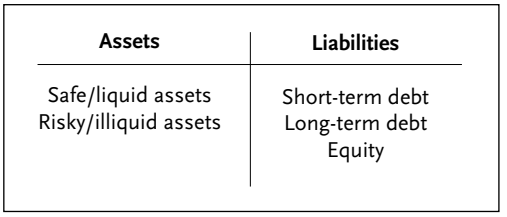
1 Bank Stability Explained

In this section, we provide a discussion of the risks banks face and a review of the literature on the stability of banks and the factors that contribute to bank stability. The key focus is on liquidity and the funding structure of banks.

1.1 The Risks Banks Face

Banks, and financial intermediaries in general, perform important roles such as channeling funds from savers to investors with profitable projects. Furthermore, they provide payment and liquidity services for their customers. In doing so, banks expose themselves to various risks. Below, we illustrate a simplified version of a bank's balance sheet.

Figure 1: Assets and Liabilities



On the asset side of the balance sheet, the bank has assets that are safe and liquid, but also assets that are risky and illiquid. The latter may suffer a discount when converted into cash in a short period of time. On the liability side, the bank finances itself with short-term debt, long-term debt and equity.

Risky assets such as mortgages or loans have an uncertain return, where the borrowers may default and the bank may not recover the full value. This exposes the bank to credit risk. Equity acts as a cushion to absorb the losses that may arise from risky assets.

When banks finance long-term investments, like mortgages, with short-term liabilities such as demand deposits or short-term wholesale funding, banks create a maturity mismatch. This exposes a bank to liquidity risk. In particular, when short-term creditors do not rollover their debt, the bank needs to come up with cash to make payments. First, it will use the short-term liquid assets. However, when these are not sufficient, the bank has to liquidate some or all of its illiquid assets. However, this may be costly since the bank may have to suffer a significant discount from selling illiquid assets. In extreme cases, the losses from liquidation can be so large that they can exhaust the equity of the bank, where liquidity risk can lead to the failure of the bank.

Figure 2: Credit and Liquidity Risk

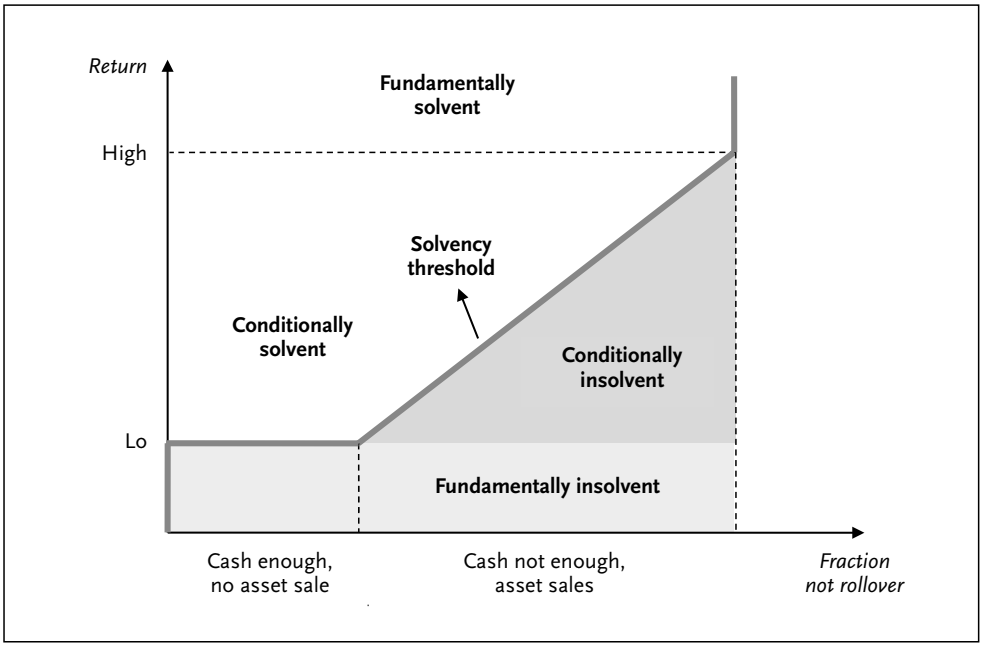


Figure 2 illustrates these risks. On the vertical axis we have the return from the risky assets, and on the horizontal axis we have the fraction of short-term creditors that do not roll over their debt. The gray line represents the solvency threshold for the bank, where the bank is insolvent (solvent) below (above) the gray line. When the return from the risky assets is low, the bank is insolvent even if all the short-term creditors roll over their debt, that is, the bank is *fundamentally insolvent*. When the return from the risky assets is high, the bank is solvent even if all the short-term creditors decide not to roll over their debt, that is, the bank is *fundamentally solvent*. For an intermediate range of returns the solvency of the bank depends on the fraction of short-term creditors that do not roll over. Note that the solvency threshold (gray line) is flat for small fractions of short-term debt holders that do not roll over since the bank has enough liquid assets to pay them and it does not need to liquidate any of the risky assets.

However, when liquid assets are exhausted, the bank has to liquidate some of the risky assets to pay short-term debt holders that do not roll over. These liquidations are costly and eventually eat up the bank's equity. Hence, for a higher fraction of withdrawals, the bank needs higher returns from the risky asset to stay solvent, that is, the solvency threshold is increasing in the fraction of short-term creditors that do not roll over. Hence, for an intermediate range of returns, solvency depends on the fraction of withdrawals. In particular, above (below) the solvency threshold, the bank has (does not have) sufficient returns from the risky assets to withstand withdrawals, that is, the bank is *conditionally solvent (insolvent)*.

In a technical appendix we present a formal derivation and analysis for these risks. Factors that affect bank solvency, such as equity, liquidity, liquidation values and the maturity structure of the bank, are analyzed formally there.

1.2 Review of the Literature on Bank Stability

We now review the literature on the stability of banks and other financial intermediaries, with a focus on their funding models and liquidity risk. We first discuss the standard framework used in the literature to analyze the fragility of financial institutions that perform maturity and liquidity transformation. Subsequently, we consider potential factors that amplify or mitigate such financial fragility.

1.2.1 Maturity Transformation and Illiquidity

We begin by describing the standard framework used in the literature—which is based on maturity transformation and the risk of a run and loss of significant funding sources—to think about the fragility of financial intermediaries.

One important role played by financial intermediaries is maturity and liquidity transformation, namely, issuing liquid, short-term liabilities while holding illiquid, longer-term assets. This arrangement allows investors to benefit from an intermediary's special skills in making high-return investments while maintaining the ability to shift funds to other uses, if needed. This flexibility is particularly valuable to investors who face significant uncertainty about the timing of their liquidity needs, because a financial intermediary can provide them with insurance against this uncertainty. However, as we discuss below, the role of financial intermediaries in providing liquidity creates fragility. In their seminal work, Bryant (1980) and Diamond and Dybvig (1983) provide a framework that illustrates the role of financial intermediaries in providing liquidity insurance, which has become the standard platform for studying financial fragility.

In the Diamond-Dybvig model, there are three dates, and depositors are initially uncertain about the date at which they will want to consume. Each depositor will turn out to be either the "early" type, who wants to consume in the interim date, or the "late" type, who wants to consume in the final date. On the initial date, the bank invests the resources collected from the depositors into a long-term asset. This asset yields a return of $R > 1$ at the final date for each unit invested. However, there is a cost to liquidate the asset early. If the asset is liquidated at an interim date, it yields a return of one per unit invested. Although each depositor is uncertain as to when she will need to consume, the fraction of depositors who will want to consume early is known by the bank. By pooling the funds it collects, the bank can insure depositors against their liquidity-preference shocks. In fact, the bank can achieve an efficient allocation of resources in this environment by offering a contract that promises depositors a consumption level of c_1 if they withdraw in the interim period, and a consumption level c_2 if they withdraw in the final period. These values are chosen so that $1 < c_1 < c_2 < R$ holds. This arrangement is preferred by depositors because it provides them with

an opportunity to better smooth their consumption, compared with what they could achieve on their own[1].

Notice that this arrangement is self-enforcing in the following sense. A depositor who is the early type will always prefer to withdraw in the early period and receive c_1, while a depositor who is the late type will prefer to withdraw in the late period and receive c_2 as long as she is confident the bank will have the necessary funds available. When all late-type depositors wait until the late period to withdraw, the bank can indeed afford to pay c_2 to each of them, which justifies their decision to wait.

There is, however, another possible outcome. If patient depositors become nervous about the bank's ability to pay them in the late period, they may choose to withdraw in the early period. This outcome resembles a *run* on the bank, which causes all assets to be liquidated early and leaves each depositor with only one unit of consumption. Note that this outcome is also self-enforcing, in the sense that it is rational for each depositor to withdraw in the interim period because she correctly anticipates that the bank will run out of funds by the late period. This outcome is strictly inferior to the "good" outcome described above and can be viewed as a coordination failure among depositors.

Diamond and Dybvig (1983) view this multiplicity of equilibria as capturing, in a stylized way, the inherent fragility of financial intermediaries.[2] If, for whatever reason, depositors and other investors become nervous that the bank will fail, their actions will tend to make this belief self-fulfilling.[3] Their model does not address the question of what events might cause depositors' beliefs to shift and, hence, trigger a run. In the next section, we provide a short discussion on the different views about the origins of bank runs that have emerged in the literature.

1.2.2 What Causes Runs: Credit Risk, Liquidity Risk or Both?

While the inherent fragility of bank deposits can result in depositor runs and liquidation, what triggers these runs? According to one view, bank runs can be triggered by anything that causes depositors to become pessimistic, including what might be called "mass hysteria" (Kindleberger, 2000). The Diamond-Dybvig model is consistent with this view, since it does not offer a theory of what triggers a crisis. The shift in depositors' beliefs is typically modeled as resulting from exogenous random events (often labeled "sunspots").

The historical evidence, however, indicates a significant correlation between bank runs and the current condition of particular sectors, or of the economy as a whole. Gorton (1988) conducts an empirical analysis using US data from the late nineteenth and early twentieth centuries to investigate the origins of banking panics and finds a close relation between the occurrence of banking panics and the overall state of the economy. Calomiris and Gorton (1991) use a larger data set and find similar evidence. In

1 A depositor who invests funds directly in the long asset would consume 1 if she turns out to be the early type and R if she is the late type. The arrangement here is strictly preferred by the depositor as long as her coefficient of relative risk aversion is greater than 1.

2 Also see Ennis and Keister (2009) for a model of runs as a multiple-equilibrium phenomenon. Some studies take a different approach, however, in which a bank run occurs with positive probability in the unique equilibrium. See, for example, Postlewaite and Vives (1987), Chari and Jagannathan (1988) and Goldstein and Pauzner (2005).

3 This basic framework can also be extended to study issues related to secured funding, as in Martin, Skeie and Von Thadden (2010).

parallel with this historical evidence, another view of the origins of bank runs claims that these runs are natural consequences of the business cycle and that they are information driven. If there is adverse information about the banks' prospects, depositors anticipate the difficulties banks may face in honoring their promised payments so they may choose to withdraw their funds. Therefore, bank runs are essentially triggered by adverse news about the soundness of banks. This view of bank runs has been modeled by Allen and Gale (1998).[4]

Morris and Shin (2009) reconcile two different views on the origins of bank runs. In particular, they distinguish between and try to measure three distinct types of risk: (1) *insolvency risk*, the conditional probability of default due to deterioration in asset quality if there is no run by short-term creditors; (2) *total credit risk*, which is the unconditional probability of default due to either a (short-term) creditor run or (long-run) asset insolvency; and (3) *illiquidity risk*, which is the difference between the first two, specifically, the probability of a default due to a run when the institution would otherwise have been solvent. An important contribution of Morris and Shin (2009) is to define clear measures of these different types of risk. Furthermore, they also discuss how the three kinds of risk vary with different features of a bank's balance sheet. In particular, they show that illiquidity risk is (1) decreasing in the "liquidity ratio," the ratio of realizable cash on the balance sheet to short-term liabilities; (2) increasing in the "outside option ratio," a measure of the opportunity cost of the funds used to roll over short-term liabilities; and (3) increasing in the "fundamental risk ratio," a measure of ex-post variance of the asset portfolio.

1.2.3 Fragility of Wholesale Funding

While most retail deposits are demandable upon request, they usually constitute a more stable form of funding for banks compared with funding in wholesale markets. Many countries have deposit insurance, up to certain limits, that add to the stability of retail deposits as a source of funding. Furthermore, some academic studies show that switching and search costs lead depositors to change banks infrequently, which adds to the stability of retail deposits. Kiser (2002) uses survey data on households' decisions to change or remain with their checking or savings account providers to show that the distribution of household tenure is wide, and that about a third of households have never changed depository institutions.[5] However, one has to keep in mind that deposit insurance may be an important factor contributing to the stickiness of retail deposits.

4 Although the business cycle view of bank runs has strong empirical support, there are also instances where healthy banks experienced runs. Saunders and Wilson (1996) examine deposit flows in 163 failed and 229 surviving banks over the Depression era of 1929-33 in the United States. In 1929 and 1933, they find evidence of "flight to quality," in which withdrawals from failed banks were associated with deposit increases in surviving banks. However, they observe a decrease in deposits in both failed and surviving banks for the period 1930-32. One possible explanation for these events is that the depositors may not have accurate information about each bank and may base their decisions on publicly available information such as the overall state of the economy or even the number of recent bank failures. Therefore, imperfect information can lead to runs on healthy banks. Ennis (2003) offers a different interpretation, arguing that the observed correlation between runs and economic fundamentals does not imply that healthy banks are immune to runs.

5 Gondat-Larralde and Nier (2006) use data for current account switching behavior for the United Kingdom. The data imply that a representative current account holder would only change banks every ninety-one years. Also see Kim, Kliger and Vale (2003) for a study on Norway.

Funding from wholesale markets, especially when it is short term, is usually considered more flighty since it is typically not insured and subject to rollover risk (Acharya, Gale, and Yorulmazer, 2011).[6] Furthermore, runs in the wholesale market can be destructive and costly socially. Huang and Ratnovski (2011) point to that issue. On the one hand, wholesale funding allows sophisticated financiers to monitor banks—disciplining bad banks, but refinancing good ones. On the other hand, in an environment with a costless but noisy public signal on bank project quality, short-term wholesale financiers have lower incentives to conduct costly monitoring and may instead withdraw funds based on negative public signals, triggering inefficient liquidations too often.

1.2.4 Potential Frictions in Interbank Markets

Interbank markets, where banks lend to and borrow from other banks, help banks coinsure against liquidity shocks. It may be the case that in certain states, some banks experience high liquidity shocks while other banks experience liquidity surpluses. By lending and borrowing in the interbank market, banks may coinsure against liquidity shocks (Allen and Gale, 2000 and Leitner, 2005).[7] Goodfriend and King (1988) argue that with sophisticated interbank markets, a solvent bank that needs liquidity will always get it from the interbank market and therefore will never be illiquid. They argue that because of the existence of efficient interbank markets, central banks can provide sufficient liquidity via open market operations, and the interbank market will allocate the liquidity among banks.

Although the interbank market may perform these very important roles in many cases, there may be potential failures, too. The following discussion investigates these potential market failures and the cases in which the interbank market may not work as efficiently as required.

Asymmetric information

When interbank participants see that a bank wants to borrow, they may not know the exact reason. For example, it may be the case that the bank wants to borrow for liquidity reasons or because the bank is insolvent. Therefore banks may not be willing to take the risk and may decide not to lend. Because of this information asymmetry, a solvent bank may not get funding from the interbank market.

One possible solution to asymmetric information is to borrow against collateral (Bester, 1985). However, Flannery (1996) argues that while other market participants may know the value of the bank's portfolio as a whole, they may not have adequate information about the individual assets in the portfolio. If market participants do not have sufficient resources to purchase the whole portfolio, rather only a small proportion of it, they may fear that they end up purchasing the lowest quality assets.

6 Goldsmith-Pinkham and Yorulmazer (2010) analyze the role of excessive reliance on wholesale funding during the Northern Rock episode.

7 In addition, banks monitor each other through lending and borrowing relations in the interbank market (Rochet and Tirole, 1996). While monitoring can be very costly (or not feasible) for dispersed depositors, cross-holdings may provide banks with incentives to monitor each other's activities (peer monitoring), which can be a crucial disciplining device that influences banks to run their affairs in a more prudent way.

Hence, information asymmetry may lead to a lemons problem, in which the bank may try to keep the high-quality assets in its portfolio while liquidating the bad ones quickly. As a result, when loans are sold or borrowed against, they may not generate their full value in the interbank market.

Banks may exploit other banks' liquidity needs

In a situation where some banks need liquidity, the cash-rich banks may try to take advantage of the cash-stricken ones. If the number of banks who are subject to the liquidity shock is large, banks with excess liquidity may exert market power and charge higher than competitive interest rates on interbank loans (Donaldson, 1992). Furthermore, cash-rich banks may even refuse to lend in order to force cash-stricken banks to sell their assets at fire-sale prices so that they can acquire those assets at cash-in-the-market prices and make windfall profits (Acharya, Gromb, and Yorulmazer, 2012).[8]

Banks may free-ride on liquidity

Holding liquid assets may have an opportunity cost in terms of foregone higher returns from illiquid assets. In the presence of an interbank market, banks may rationally choose to hold lower levels of the liquid asset and may rely on other banks' liquid asset holdings. Bhattacharya and Gale (1987) build a model of interbank coordination where individual banks that are subject to liquidity shocks can insure each other against these shocks through a borrowing-lending mechanism designed by the central bank—the "discount window."

However, in the presence of informational asymmetry among banks, where the composition of liquid and illiquid assets in each bank's portfolio and the size of the liquidity shock each bank faces is private information, such a mechanism may fail to perform efficiently and banks may have an incentive to under-invest in liquid assets. Banks will rely on the interbank market for their liquidity needs and will free-ride on the common pool of liquidity so that even in the presence of an interbank market, there might be liquidity shortages at the aggregate level. Similar arguments have been made by Repullo (2005) in the context of a lender of last resort (LoLR), where banks can have incentives to hold low levels of liquidity and rely on the LoLR for liquidity.

Liquidity hoarding

Inefficiencies may arise if banks do not hold sufficient levels of liquidity; however, another reason that interbank markets may not function efficiently is that banks may hoard liquidity rather than lend it to each other (Diamond and Rajan, 2011; Gale and Yorulmazer, 2013). This can be caused by credit risk associated with the borrowing banks. Furthermore, it may arise from a precautionary motive in which banks prefer to hold on to cash if they are worried about future liquidity shocks and their access to markets when they need the liquidity, as well as the speculative

8 See also Diamond and Rajan (2011) and Gale and Yorulmazer (2013) for models that feature a speculative motive in which banks do not lend with the expectation of potential future profits from fire sales.

motive in which they prefer to carry cash to take advantage of potential fire sales in the future.[9]

Contagion through interlinkages

While the interbank market can act as a device for coinsurance against uncertain liquidity shocks and provide incentives for peer-monitoring, it can also serve as a channel through which problems in one bank can spread to other banks with significant contagion effects (Allen and Gale, 2000).[10] Thus, while interlinkages can act as shock absorbers and allow risk sharing among banks for random liquidity shocks, they can also act as shock transmitters and lead to the spreading of losses through the banking system, resulting in contagion.[11]

1.2.5 Liquidity and Fire-Sale Externalities

When a firm experiences financial difficulties and needs to sell assets, it is likely that other firms operating in the same industry would experience similar problems or may not have enough resources to purchase these assets (Shleifer and Vishny, 1992).[12] This, in turn, can result in fire sales, in which the prices of the assets fall below their fundamental value. Furthermore, the prices are determined by the amount of available cash to purchase those assets, resulting in cash-in-the-market prices (Allen and Gale, 1994; 1998).[13] What may be of particular interest in the case of banks is that bank loans are usually specific arrangements between the bank and the borrower and may not be easily marketable.[14]

Fire sales can create externalities, in which an agent liquidates assets and the resulting fire-sale prices can have adverse effects on agents with similar asset holdings and can lead to further fire sales and further disruptions. Cifuentes, Ferrucci, and Shin (2005) build a model of the interbank market, where banks are subject to regulatory solvency constraints, and sales by distressed institutions depress the market price for assets. An initial shock may force some banks to liquidate some of their illiquid assets to satisfy the regulatory solvency constraints. Marking-to-market of the asset book can induce a further round of endogenously generated sales of assets, depressing prices further and inducing further sales.

9 Malherbe (2014) studies a model in which markets may be illiquid because of adverse selection. Anticipating a market "dry-up," agents engage in liquidity hoarding that worsens the adverse selection problem and makes the market dry-up more severe. Also, see Chapter 7 of Holmström and Tirole (2011), which uses the model described in Malherbe (2014). There is substantial evidence that banks did in fact build up cash positions during the recent crisis (Acharya and Merrouche, 2013; Heider, Hoerova and Holthausen, 2008; Ashcraft, McAndrews and Skeie, 2011). Afonso, Kovner and Schoar (2011) document that while rates spiked and terms became more sensitive to borrower risk, borrowing amounts remained stable in the US federal funds market during the Lehman episode. They argue that it is likely the market did not expand to meet the additional demand, which is consistent with hoarding.

10 Also, see Nier, Yang, Yorulmazer and Alenton (2007) for an analysis of contagion through interlinkages.

11 A series of empirical papers, Sheldon and Maurer (1998) for Switzerland, Furfine (1999) for the United States, Upper and Worms (2000) for Germany, and Wells (2002) for the United Kingdom, to cite only a few, analyze the potential for failures resulting from these interlinkages.

12 Also, see Williamson (1988). There is strong empirical support for this idea, as shown, for example, by Pulvino (1998) for the airline industry, and by Acharya et al. (2007) for the entire universe of defaulted firms in the United States over the period 1981 to 1999 (see also Berger et al., 1996, and Strömberg, 2000).

13 Also, see Allen and Gale (2004a; 2004b; 2005). These ideas have been further developed by Bernardo and Welch (2004) and Morris and Shin (2004) to explain financial market runs. Brunnermeier and Pedersen (2005) use similar arguments to investigate strategic behavior among traders.

14 See James (1991) for evidence.

Therefore, contagious failures can result from small shocks through asset prices. Even though the origin of the initial failures can be insolvency, through depressed asset prices, the initial effect can be magnified and spread to the rest of the system (Diamond and Rajan, 2001a; 2001b; Gorton and Huang, 2004; Allen and Gale, 2004a; 2004b; 2005, to cite a few).

1.3 Conclusions

Maturity mismatching introduces liquidity risk in banking. If short-term funding cannot be rolled over, illiquid assets may have to be liquidated at a cost and bank failure may occur. This issue introduces not just fragility in banking, but also coordination problems and externalities in the industry at large. We have highlighted that bank runs may come about even on healthy banks: excessive withdrawals may trigger costly liquidation and become a self-fulfilling spiral bringing down such banks. This highlights a coordination problem: if depositors could coordinate they would have no incentive to run on a healthy bank.

Externalities come about when, for example, a bank liquidates assets to meet deposit withdrawals, but these asset sales depress asset prices that may cause problems in other banks (which in turn might be forced to liquidate assets causing a true fire sale). In that case, a cascading effect may come about affecting the industry at large. What this points at is that the concept of liquidity is an intriguing one: liquidity problems can be self-fulfilling (see the comments on bank runs) and liquidity easily creates externalities across institutions.

2 The Financial Sector Before the Crisis and Disruptions During the Crisis

This chapter discusses actual experiences in the years leading up to the crisis and the disruptions during the crisis. Prior to the crisis, we observed important changes in the financial sector such as shifts in activities to less regulated parts of the financial system, a globalization of financial intermediation and an increased reliance on wholesale funding. Also leverage went up. As subsequent events showed, the financial sector had become more fragile, and this became most apparent in the funding of financial institutions. During the crisis many institutions experienced significant disruptions in their access to funding requiring extraordinary government interventions to mitigate distress in the financial system.

We will analyze the various markets and institutions that experienced significant disruptions during the crisis along with the responses of policy makers to mitigate the resulting disruptions.

2.1 Changes in the Financial Sector Before the Crisis[15]

Here, we look at some of the changes that have taken place in the financial sector in recent decades, and how these changes have affected the stability of financial intermediation and the effectiveness of the policies in place. For example, some activity has shifted to less regulated parts of the financial system, which has likely weakened the effectiveness of existing regulations. Furthermore, some of the changes in the funding structure of financial intermediaries, for example, dependence on short-term wholesale funding, may have increased the fragility of the financial system.

2.1.1 Banks Became More Levered

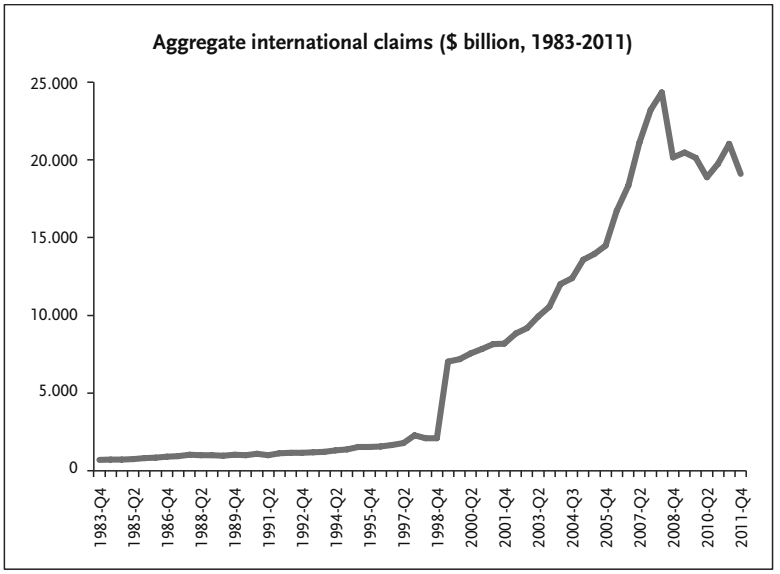
Equity capital can act as a buffer against losses and can induce prudent risk management by increasing banks' "skin in the game" (Gale, 2004). One interesting observation is the historical decline in commercial banks' equity as a percentage of assets in the United States, as illustrated by Berger, Herring and Szegö (1995) for the period 1840-1993. In 1840, equity funded more than 50% of banks' assets, whereas the ratio fell steadily for about a century and settled in the 6 to 8% range from the mid-1940s to the 1990s. Hence, through time banks became more levered.

2.1.2 Globalization of Financial Intermediation

Another factor is the globalization of banking. Figure 3, taken from Cetorelli and Goldberg (2012), shows the aggregate international claims of Bank for International Settlements (BIS) reporting country banks, where international claims comprise both cross-border claims and local foreign claims. The increase in the aggregate international claims shows clearly the globalization trend in the banking industry.

15 The discussion in this section builds in part on Yorulmazer (2014a).

Figure 3: Aggregate International Claims of BIS Reporting Country Banks



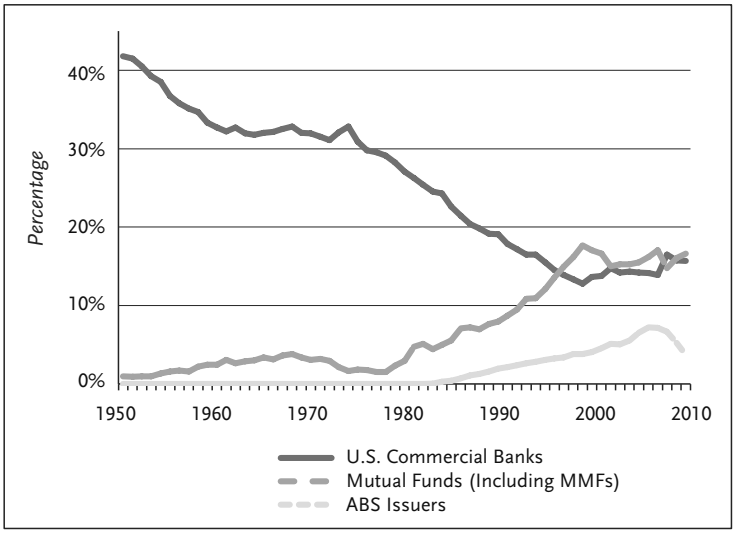
Source: Cetorelli and Goldberg (2012)

2.1.3 Financial Intermediation Became Less Bank-Centric

An additional interesting development in the financial sector is the shift from bank-based activities to market-based activities. The following discussion is mostly based on Adrian and Shin (2009) and Cetorelli, Mandel and Mollineaux (2012).

Figure 4 shows the trend for banks' share of financial sector assets since the 1950s. The chart also illustrates the growth of nonbank intermediaries that compete with banks on both sides of the balance sheet. For instance, on the liability side, mutual funds and, more recently, money market mutual funds (MMFs) have grown substantially. Similar trends are observable for entities that may compete with banks on the asset side, such as asset-backed securities (ABS) issuers lately.

Figure 4: US Commercial Banks, Mutual Funds (Including MMFs), and ABS Issuers as a Share of Total US Financial Assets



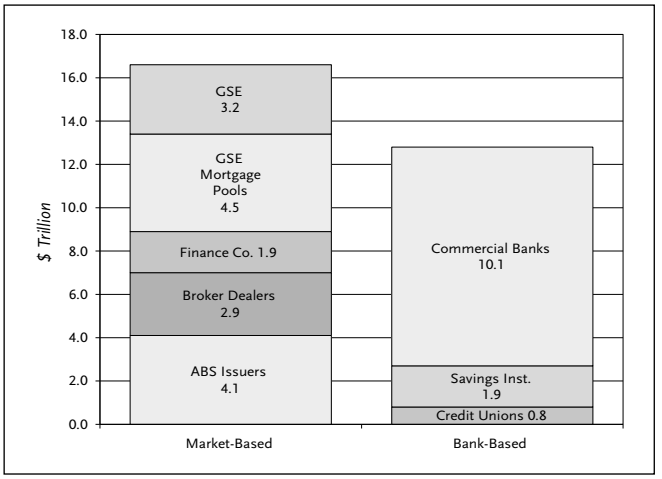
Source: Federal Reserve Flow of Funds

Before the financial crisis, the integration of banking with capital markets was an important trend in the financial system. The growing use of capital markets to supply credit was particularly important, especially in the United States. While banks were traditionally the dominant suppliers of credit, their role has been increasingly supplanted by market-based institutions—especially those involved in the securitization process.

Figure 5, taken from Adrian and Shin (2009), compares total assets held by banks with the assets of securitization pools or at institutions that fund themselves mainly by issuing securities, showing that by the end of the second quarter of 2007, the "market-based assets," were substantially larger than bank assets.

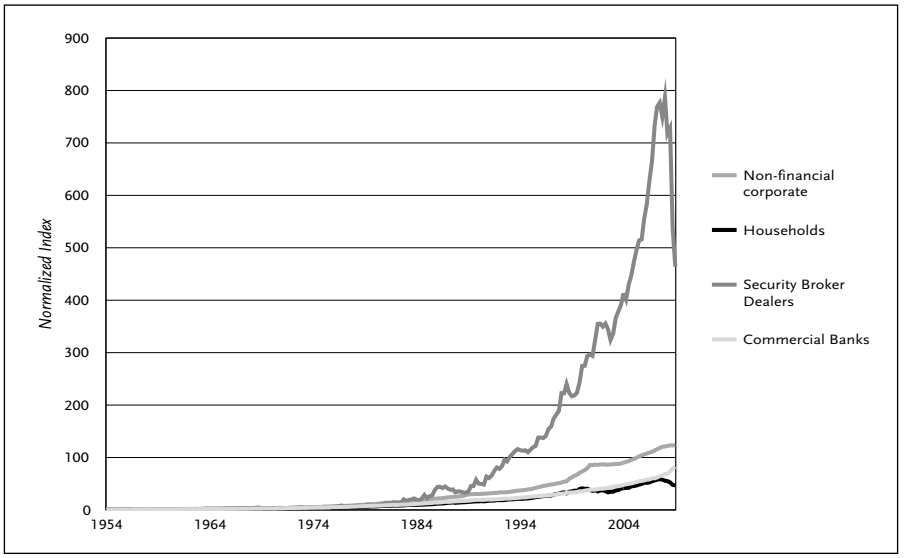
The growing importance of the market-based system is evident in Figure 6 from Adrian and Shin (2009), which charts the assets held by four sectors in the United States—the household sector, nonfinancial corporate sector, commercial banking sector, and the security broker-dealer sector.

Figure 5: Total Assets at 2007Q2



Source: Adrian and Shin (2009)

Figure 6: Growth of Assets of Four Sectors in the United States (Each Normalized to a Base of Unity in March 1954



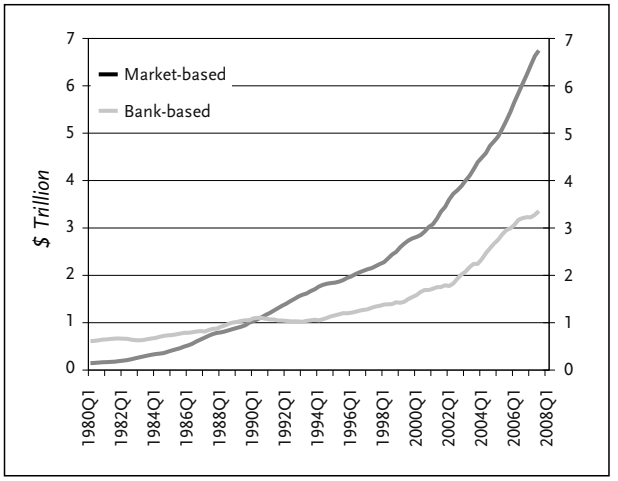
Source: Adrian and Shin (2009)

The rapid expansion in broker-dealers' assets can mostly be explained by the changing structure of the US financial system and, in particular, by the changing nature of the residential mortgage market and the growing importance of securitization. Until the early 1980s, banks were the dominant holders of home mortgages, but bank-based hold-

ings were overtaken by market-based holders. In Figure 7, taken from Adrian and Shin (2009), "bank-based holdings" comprise the holdings of commercial banks, savings institutions, and credit unions. Market-based holdings are the remainder—the government-sponsored enterprises (GSE) mortgage pools, private label mortgage pools, and the GSE holdings themselves. By 2008, market-based holdings constituted two-thirds of the $11 trillion total of home mortgages.

This shift from the bank-based to market-based parts of the financial system may have a significant effect on the scope, strength, and efficiency of existing policies, since a significant part of the financial activity may now take place in the less regulated parts of the financial system.

Figure 7: Market Based and Bank-Based Holding of Home Mortgages

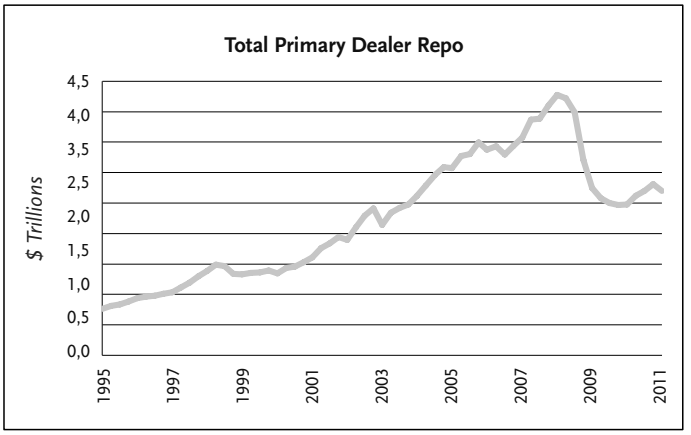


Source: Adrian and Shin (2009)

2.1.4 Reliance on Repo

Another important change in the financial sector is the growing importance and size of the repo market. Figure 8 shows the total primary dealer repo activity. Gorton and Metrick (2010) estimate the size of the overall repo market to be around (or larger than) $10 trillion. During the financial crisis, repo markets experienced disruptions that contributed to the near-failure or failure of some major financial institutions.

Figure 8: Total Primary Dealer Repo

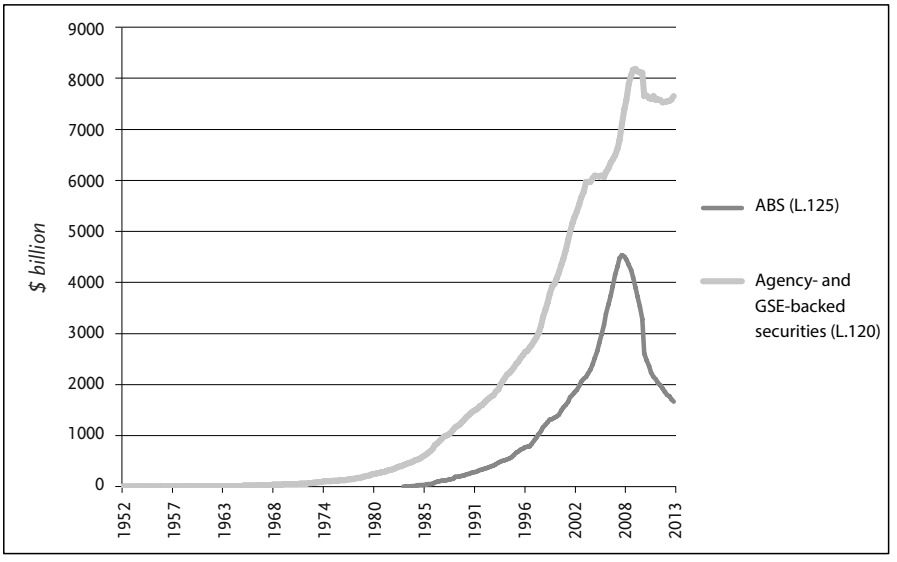


Source: Federal Reserve

2.1.5 Securitization

Related to the earlier discussion, another important change in financial intermediation is securitization (Figure 9). Academic studies identify the effects of securitization in weakening incentives to monitor loans because they are no longer on the balance sheets of the financial institutions that originate them (Parlour and Plantin, 2008). Therefore, securitization is one issue that one should think about carefully when designing new rules to strengthen overall financial stability.

Figure 9: Importance of Securitization



Source: Federal Reserve Flow of Funds

Banking and financial intermediation has gone through significant changes in recent decades. Banks are much more reliant on wholesale funding, and much more international (making resolution of insolvency much more difficult). These changes pose important challenges for policymakers to improve and design a framework for supervision and regulation that would address important issues that have been raised by the current crisis.

2.2 Disruptions During the Crisis[16]

During the crisis many markets and institutions experienced disruptions, where borrowing rates and haircuts reached record high levels and some markets completely froze. Next, we discuss several markets and institutions that experienced significant distress during the crisis. For each case, we provide a discussion of the size and the evolution of the market, the sources of the disruptions, and the policy responses aimed at mitigating distress and making markets more liquid.[17] In particular, we consider commercial paper, asset-backed commercial paper, money market mutual funds, the bilateral and tri-party repo markets, credit commitments by banks, dollar funding of non-US banks, and the fragility associated with wholesale funding, using a discussion of the Northern Rock episode.

2.2.1 Commercial Paper

Commercial paper (CP) is a key source of short-term financing for corporations and financial institutions. Disruptions to the CP market may result in higher funding costs, forced asset sales to raise cash, and pressure on credit lines extended by commercial banks. CP outstanding peaked at $2.2 trillion in July 2007.[18] At that time, asset-backed commercial paper (ABCP) accounted for 55% of the market, financial CP for 36% and corporate (nonfinancial) CP for 9%.

Unsecured financial CP is typically issued by US subsidiaries of foreign banking organizations, bank-related finance companies (such as funding subsidiaries of large bank holding companies), and captive finance companies (like subsidiaries of auto or other manufacturing companies). Corporate CP is typically issued by large, highly rated, publicly traded nonfinancial corporates. Issuers use CP to finance current business transactions, such as the funding of operating expenses or current assets. CP is attractive to investors given its short duration; the maturity of CP is limited to 270 days, but averages close to thirty days.

The vulnerability of CP markets is attributable to the type of investors who purchase CP, the short-term nature of the market, and the rollover risk faced by institutions reliant on it, which became evident during the recent crisis. The ABCP market was hit particularly hard after the summer of 2007, yet financial and corporate unsecured issuance remained stable. The unsecured CP market came under pressure following Lehman Brothers' bankruptcy in September 2008 and the Reserve Primary Fund's announcement

16 The discussion in this section builds on Yorulmazer (2014b).

17 See Fleming (2012) for a discussion of the measures taken by the Federal Reserve for liquidity provision during the crisis of 2007-09.

18 Source: Federal Reserve Board.

that it had "broken the buck" due to its exposure to Lehman. These events triggered massive redemptions from prime money market funds, which subsequently reduced their holdings of CP as investors became increasingly skeptical, especially of ABCP (given its complexity and opaque nature) and of unsecured CP with longer-dated maturities (Kacperczyk and Schnabl, 2010). Total outstanding CP fell 15% between August and October 2008, and financial CP outstanding fell 32%. Securities firms, banks, and insurance firms found their ability to issue mostly limited to the overnight market, and the weakest institutions found themselves excluded altogether.

In response to the dislocation in the CP market following the Lehman bankruptcy, and to shield the real economy from liquidity distortions created by the run on money market instruments, the Federal Reserve created on October 7, 2008, the Commercial Paper Funding Facility (CPFF).[19] CPFF was designed to provide temporary support to all CP-issuer types through the provision of a liquidity backstop.

Through the CPFF, the Fed would purchase three-month commercial paper directly from eligible issuers to provide assurance to both issuers and investors that firms would be able to roll over their maturing CP. At its peak, the Fed owned 22.4% of the CP market. By the expiration of CPFF on February 1, 2010, the Fed had purchased up to $370 billion in CP, making it the single largest buyer (Kacperczyk and Schnabl, 2010).

2.2.2 *Asset-Backed Commercial Paper*

ABCP is a form of secured, short-term borrowing. ABCP programs first appeared in the mid-1980s. While they were primarily sponsored by commercial banks to provide trade receivable financing to their corporate customers, they grew to serve a wide variety of needs, in particular warehousing of assets prior to term securities issuance, investment in rated securities for arbitrage profit, provision of leverage to mutual funds, and off-balance sheet funding of selected assets.[20]

ABCP was only about 6% of the total commercial paper market in 1990, but it accounted for about 55% of the total market in mid-2007, or approximately $1.2 trillion. From its peak in July 2007, and after the first collapse in the second half of 2007 the outstanding total dropped to about $800 billion.[21]

ABCP was issued by off-balance-sheet conduits of large financial institutions. As their role evolved over time, they increasingly held long-term assets, thus becoming significant vehicles of maturity transformation. In order to enhance their attractiveness to prospective investors, their rating status was boosted with guarantees, typically provided by the sponsoring institutions. Since most sponsors were large banks with the highest credit ratings, the provision of such guarantees effectively transferred the rating status of the sponsor to the conduit. In 2003, the Financial Accounting Standards Board issued a guideline that would have required sponsoring banks to consolidate ABCP conduits on their balance sheets. However, the following year, the US bank regulatory agencies issued a ruling that allowed banks to exclude sponsored conduits from consolidation

19 See Adrian, Kimbrough and Marchioni (2011) for details on the CPFF.
20 "The Fundamentals of Asset-Backed Commercial Paper." Moody's Special Report, February 2003.
21 Source: Federal Reserve Board.

requirements. Moreover, the sponsoring banks were granted a favorable capitalization rule for the provision of their guarantees. Namely, while credit enhancements required full capitalization, liquidity enhancements required banks to hold capital only at a 10% conversion rate. Because of the high rating status and the short-term characteristics of their liability notes, ABCP conduits were considered especially attractive to money market funds, which are restricted in their investment opportunities.

As mentioned above, the ABCP market collapse began in August 2007 as a result of increasing uncertainty about the quality of the assets backing commercial paper issuance. This enhanced uncertainty, coupled with the pronounced maturity mismatch of conduits' balance sheets, triggered what has been characterized as a run on their liabilities (Covitz, Liang and Suarez, 2013). The market was further hit in the aftermath of Lehman's bankruptcy, as a result of the run on one of the largest money market funds, the Reserve Primary Fund.

Following August 2007 and prior to Lehman's default, policy action mainly focused on providing liquidity to banks by reducing the discount window rates and extending the loan terms, followed by the institution of the Term Auction Facility (TAF) in late December 2007.[22] However, it was only after Lehman's failure that policy actions were specifically aimed at the commercial paper market. On September 19, 2008, the Federal Reserve announced the institution of the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF). The AMLF provided nonrecourse loans to commercial banks to purchase eligible ABCP from money market mutual funds (MMFs).[23] Moreover, on October 7 of that year, the Federal Reserve announced the purchase of commercial paper through the CPFF, aimed directly at issuers of commercial paper. These facilities closed on February 1, 2010. In 2010, new accounting rules were introduced (Financial Accounting Standards 166 and 167), requiring consolidation for accounting purposes of most ABCP conduits on the balance sheet of the sponsoring institution, thus reducing the scope for ABCP market growth based on regulatory arbitrage motives.

2.2.3 Money Market Mutual Funds

MMFs are key intermediators of short-term debt, particularly for financial issuers. All MMFs that are regulated under Rule 2a-7 of the Investment Company Act of 1940 maintain a stable share price of $1. In part because of their record in maintaining a stable share price, MMFs serve as an important cash-management tool for individuals, firms, institutions, and governments.[24]

The historical success of the funds in maintaining principal stability attracted a large,

22 The maximum term on discount window loans was extended to thirty days in August 2007 and then to ninety days in March 2008. The spread between the primary credit rate and the target fed funds rate was reduced from 100 basis points to 50 basis points in August 2007 and to 25 basis points in March 2008. More information can be found at http://www.newyorkfed.org/aboutthefed/fedpoint/fed18.html.

23 The US Treasury also provided a temporary guarantee on the share price of MMFs through the Temporary Guarantee Program for Money Market Funds and the Federal Reserve announced another lending program, the Money Market Investor Funding Facility (MMIFF), as a complement to the AMLF intended to provide nonrecourse loans to money market funds. However, no loans were made under the MMIFF. The facility was closed on October 30, 2009.

24 MMFs keep their net asset value (NAV) between 99.5 cents and 100.5 cents per share and rely on penny rounding to keep the share price at $1 per share.

highly risk-averse shareholder base that included institutional investors that were not reluctant to pull away at any sign of trouble.[25]

Investors have a strong incentive to run from a distressed MMF because redemptions can shift risks and costs to remaining shareholders. Most importantly, because MMFs round their share price to the nearest cent, an investor who redeems shares from a fund that has incurred a loss of less than 0.5% may still be able to obtain $1 per share. In effect, the fund transfers a redeeming shareholder's pro-rata share of the loss to the fund's nonredeeming shareholders. In addition, MMFs meet redemptions by disposing of their highly liquid assets, rather than selling a cross-section of all of their holdings, which typically include some less liquid securities. This, in turn, can help the funds avoid losses from sale of less liquid securities. However, during periods of market strain, the investors that redeem pose a negative externality on nonredeeming investors by leaving them with a less liquid pool of assets.

Given the size of the money fund industry and its importance in allocating short-term funding to financial institutions, this vulnerability posed a considerable risk to the US financial system. The potential consequences of a run on MMFs became evident in September 2008, when the Lehman bankruptcy caused the Reserve Primary Fund to "break the buck," (stating a share price lower than $1, which, in turn, triggered significant redemptions from MMFs[26]). These outflows contributed to a freezing of short-term funding markets and a broader curtailment of credit supply.

Policymakers responded with both emergency and longer-term reform measures. Emergency measures included the Treasury's Temporary Guarantee Program, which temporarily provided a guarantee against loss for shareholders in participating MMFs. Also, the Federal Reserve's AMLF supported MMF liquidity by providing nonrecourse financing for bank purchases of ABCP from MMFs. In the wake of the crisis, the Securities and Exchange Commission (SEC) modified rule 2a-7 to further limit the liquidity, credit, and market risks in MMFs. The revisions also enhanced fund transparency, and made it easier for boards of directors to close troubled MMFs.[27]

2.2.4 Repo Markets

A repurchase agreement, known as "repo," is the sale of a security, coupled with the promise to repurchase the security at a specific price at a prespecified future date. The difference between the repurchase price and the original sale price represents interest, which may be expressed as a "repo rate." The market value of the securities purchased typically exceeds the value of the cash the borrower receives. This difference, which is normally expressed as a percentage, is called the "margin" and measures the extent to which the implicit cash loan is overcollateralized.

It is useful to distinguish different market segments by the way repos settle. In the

25 Cipriani, Martin and Parigi (2013) build a model where MMFs are subject to runs and show that a banking system intermediated through MMFs can be more unstable than one in which investors interact directly with banks.

26 Prior to 2008, only one money fund "broke the buck" since 1983, when the SEC adopted rule 2a-7 to govern MMFs.

27 See McCabe et al. (2012) for a proposal for money market reform, which requires that a small fraction of each MMF investor's recent balances, called the "minimum balance at risk," be demarcated to absorb losses if the fund is liquidated.

bilateral market, the settlement of the repo is handled by the two counterparties, while in the tri-party repo market a third party clearing bank provides settlement and collateral management services.

Lack of data makes it difficult to estimate the size of the US repo market. Data have been available for the tri-party repo market since 2008. At its peak in April 2008, this market reached a volume of around $2.8 trillion. The volume shrank to about $1.6 trillion in late 2009 (Copeland, Martin and Walker, 2010). The largest borrowers in the tri-party repo market are securities dealers. Money market mutual funds and securities lenders are the two largest groups of cash investors, representing together over half of the cash invested in that market. JPMorgan Chase (JPMC) and Bank of New York Mellon (BNY Mellon) are the two tri-party clearing banks. We have very little information on the size of the bilateral repo market.[28]

Risk associated with repo arises from many factors such as the term of the security, the quality of the collateral, and the strength of the counterparties involved. Short maturities and the risk of fire sales are two factors that exacerbate fragility for repo financing. Short maturities can create rollover risk when the buyers get concerned and pull out, similar to a run. Repos are exempt from the automatic stay of bankruptcy, meaning that if a borrower defaults and fails to repurchase its securities, the buyer can liquidate them.[29] If the market for the securities is not very liquid, or if the amount of securities being sold is very large, the lender may be forced to sell its assets at fire-sale prices and could suffer losses.[30]

Disruptions in repo markets contributed to the failure or near-failure of major financial institutions during the crisis. Gorton and Metrick (2010; 2012) analyze haircuts in an interdealer market for less liquid collateral and show that during 2007-08, the repo haircuts on a variety of assets rose on average from zero in early 2007 to nearly 50% in late 2008. They also report that some collateralized debt obligations could not be financed at all (100% haircut) during the crisis. In contrast, the level of haircuts and the amount of funding were stable in the tri-party repo market from July 2008 to early 2010 (Copeland, Martin and Walker, 2010). However, Bear Stearns and Lehman Brothers experienced problems borrowing in the tri-party repo market in the period leading up to their collapse.[31] The evidence suggests that runs in the tri-party repo market may occur precipitously, more like traditional bank runs, rather than manifest themselves in the form of large increases in margins.[32]

28 Copeland et al. (2012) provide estimates for the bilateral and the aggregate repo market. Gorton and Metrick (2012) estimate the size of the aggregate repo market to be around $10 trillion.

29 A defaulting dealer is likely to be liquidated by the Securities Investor Protection Corporation (SIPC), which obtains from the bankruptcy court an order that imposes a stay preventing its repo investors from taking certain actions, including disposing of repo collateral, without SIPC consent. While SIPC has issued letters in the past suggesting that it will act promptly on requests to liquidate collateral, consent might take several days.

30 See Acharya, Gale, and Yorulmazer (2011) for a model of fire sales and rollover risk, and Begalle et al. (2013) for a discussion of the risk of fire sales in the tri-party repo market.

31 The Tri-Party Repo Infrastructure Task Force's 2010 report notes that, "At several points during the financial crisis of 2007-2009, the tri-party repo market took on particular importance in relation to the failures and near-failures of Countrywide Securities, Bear Stearns, and Lehman Brothers. The potential for the tri-party repo market to cease functioning, with impacts to securities firms, money market mutual funds, major banks involved in payment and settlements globally, and even to the liquidity of the US Treasury and Agency securities, has been cited by policymakers as a key concern behind aggressive interventions to contain the financial crisis."

32 Krishnamurthy, Nagel and Orlov (2012) measure the repo funding extended by MMFs and securities lenders to the shadow banking system. They show that the contraction in repo with private sector collateral is relatively insignificant

The Federal Reserve established several funding programs to backstop the tri-party repo market, provide emergency liquidity to dealers, and strengthen investor confidence in dealers' ability to repay funds borrowed under repo agreements. The Term Securities Lending Facility (TSLF) was announced on March 11, 2008. The TSLF periodically auctioned loans of Treasury securities to primary dealers against eligible collateral for twenty-eight days. The Primary Dealer Credit Facility (PDCF) was created on March 16, 2008, as an overnight loan facility that provided funding to primary dealers in exchange for a specific range of eligible collateral.[33] Six months later, the Federal Reserve expanded the facility to accept a broader range of collateral. Prior to the creation of these facilities, dealers had no lender-of-last-resort access. These facilities were effective in stabilizing repo markets; however, both were temporary and were closed on February 1, 2010.

2.2.5 Credit Commitments

Historically, banks have been the main source of credit to corporations, but they have also provided corporations liquidity insurance by extending them lines of credit and loan commitments. Firms value credit lines because they protect them against changes in interest rates, help them signal their true quality, or reduce instances of credit rationing. Also, it is believed that banks' access to deposit funding gives them an advantage in providing credit commitments to firms—as long as the drivers of deposit withdrawals and firms' drawdowns are not correlated, banks can save on the amount of liquidity they need to meet the demands from both firms and depositors. With the advent of the originate-to-distribute model, where lenders originate loans with the intention of selling them to other investors as opposed to holding until maturity, banks increasingly moved pools of loans into structured investment vehicles financed with short-term commercial paper.

To make these vehicles more attractive to investors, banks offered credit enhancements to reduce the risk to investors in the event of unexpected losses and provided liquidity backstops to insure against refinancing risk. Virtually all banks offer credit lines to firms. As for the credit commitments to ABCP programs, these were predominantly extended by the banks (mostly larger banks) that embraced the originate-to-distribute model.

There are two major sources of fragility. First, deposit withdrawals and firms' drawdowns will likely come together in instances when there is uncertainty about the financial condition of the bank. On those occasions, depositors will have an incentive to withdraw their deposits and firms will have an incentive to draw down their credit lines, putting liquidity pressure on banks. Second, when banks provide credit commitments to ABCP programs or to back up CP programs, they create a liquidity exposure to a new factor—the CP market. Anything that disrupts this market will translate into a liquidity shock to the banks.

There is evidence that banks which had larger losses, as measured by their charge-offs,

compared with the contraction in ABCP during the crisis. However, the contraction in repo particularly affected key dealer banks with large exposures to private sector securities and the dealers to take defensive actions, given their own capital and liquidity problems, raising credit terms to their borrowers. The authors argue that their findings look less like a traditional bank run and more like a credit crunch among dealer banks.

33 See Fleming, Hrung and Keane (2009) for details on the TSLF and Adrian, Burke and McAndrews (2009) for details on the PDCF.

experienced both an increase in the drawdown rates on their credit lines and a runoff in uninsured deposits (Santos 2011). This combination is bound to have put liquidity pressure on these banks. Also, as structured investment vehicles accumulated losses and investors lost confidence in them, these vehicles increasingly became unable to fund themselves in the CP market, and calls on banks' liquidity started to mount. Lastly, the run on the money market fund industry that followed the events at the Reserve Primary Fund raised concerns about the ability of commercial paper issuers to renew their debt and the demand for liquidity from banks via drawdowns on backup credit lines.

The increase in the deposit limit covered by deposit insurance from $100,000 to $250,000 and the guarantee in full of non-interest-bearing transaction accounts appears to have helped stabilize the exodus of deposits from the banking industry.[34] The Temporary Guarantee Program for Money Market Funds by the US Treasury Department also helped the stability of this business and, by extension, the commercial paper market, reducing the pressure on banks' liquidity demands. Lastly, all of the liquidity made available to banks, via the discount window, or the other facilities that were put in place, also likely helped banks defray the liquidity pressure they were under during these "freezes" of the commercial paper market.

2.2.6 Dollar Funding of Non-US Banks

Non-US banks accumulated sizable US dollar assets in the past decade. For example, European banks had assets equal to $3.2 trillion at the end of 2010 Q4, according to European Central Bank (ECB) estimates,[35] amounting to slightly more than one-quarter of the total assets of FDIC-insured commercial banks. Various explanations are provided for the rapid expansion. One basic argument is that the growth in dollar assets was associated with increased investment opportunities during this period. For example, non-US banks made loans to US companies and invested in AAA-rated tranches of US structured financial products. Other arguments focus on European banking regulations that were primarily concerned with the amount of capital relative to a bank's risk weighted assets. Finally, the international role of the dollar as a medium of exchange in global trade also contributed to the dollar exposures of non-US banks.

These same banks had substantial dollar liabilities on the other side of their balance sheets. Available data suggest that, even when the net dollar imbalance was small, the system-wide bank funding risk associated with gross positions could be large (Fender and McGuire, 2010b). Due to the costs and restrictions associated with establishing a US commercial bank and qualifying for federal deposit insurance, as well as limitations on internal capital market transfers between related organizations under the Federal Reserve

34 The temporary increase from $100,000 to $250,000 was effective from October 3, 2008, through December 31, 2010. On May 20, 2009, the temporary increase was extended through December 31, 2013. On July 21, 2010, the insurance coverage was permanently raised to $250,000. See the Federal Deposit Insurance Corporation (FDIC) press release at http://www.fdic.gov/news/news/press/2010/pr10161.html. On October 14, 2008, the FDIC implemented the Temporary Liquidity Guarantee Program (TLGP). One of the two components of the TLGP was the Transaction Account Guarantee Program (TAGP), which introduced a guarantee in full of noninterest-bearing transaction accounts through December 31, 2009. The deadline was extended twice and the program expired on December 31, 2010. See the FDIC press release at http://www.fdic.gov/regulations/resources/TLGP/.

35 ECB Financial Stability Review, June 2011.

Act,[36] most non-US banks meet their dollar funding needs by issuing dollar-denominated wholesale debt, such as certificates of deposits (CDs) and commercial paper, out of US bank branches and other corporate entities. US investors such as MMFs buy these debt instruments and constitute the main source of dollar funding of European banks.

The fragility of the dollar funding model of non-US banks during times of crisis arises from its dependence on the wholesale funding markets. US wholesale investors, in particular the MMFs that are sensitive to risk, tend to pull back and reduce lending when investment risks intensify. Such a pullback occurred during the subprime crisis and has recurred during the European debt crisis. For example, estimates from Fitch Ratings indicate that, since the end of May 2011, the ten largest US MMFs have reduced their exposure to European banks by 45%.

Non-US banks can fill the dollar funding gap by "deleveraging" or shrinking dollar assets so as to reduce their need for dollars. They can also transfer dollars intrafirm (that is, US branches of non-US banks receive dollars from their foreign parents). The most widely used alternative is to convert domestic currency liabilities into dollars for a fixed period through foreign exchange swaps (Fender and McGuire, 2010a). Finally, non-US banks may borrow dollars from central bank dollar liquidity facilities.

The Federal Reserve provided dollar loans to US branches of foreign banks through the discount window (DW) and the Term Auction Facility, which operated from December 2007 to March 2010.[37] Of 411 banks that were awarded funds in the TAF during this period, seventy-three (or almost 18%) were non-U.S. banks. TAF loans reached almost $500 billion on March 4, 2009, of which almost 40% were outstanding to non-US banks. Non-US bank participation in the DW was smaller, and constituted about 3% of the total between 2008 and 2011.

In addition, the Federal Reserve, in coordination with other central banks, put in place temporary reciprocal currency arrangements, or central bank liquidity swaps, in December 2007.[38] Under these arrangements, the Federal Reserve provides US dollars in exchange for an equivalent amount of foreign currency based on prevailing market exchange rates for a predetermined period. The foreign central bank makes loans to banks in its jurisdiction, and bears the credit risk associated with those loans. The dollar loans were provided at a rate that made it attractive for banks to borrow in times of crisis, but not during more normal market conditions. Consequently, banks borrowed from their own central banks that used the dollar swap facilities. The amount outstanding in central bank liquidity swaps reached a peak of more than $550 billion during the last quarter of 2008.

Faced with market concerns about stigma associated with using the central bank liquidity swaps in November 2011 the ECB, the Bank of England, the Swiss National Bank, the Bank of Canada, and the Bank of Japan further facilitated access to dollars by lowering the cost of dollars borrowed. Moreover, in December 2011, the ECB eased

36 See the Federal Reserve Act, Section 23A at http://www.federalreserve.gov/aboutthefed/section23a.htm.

37 See Armantier, Krieger and McAndrews (2008) for a discussion of the TAF.

38 The swap arrangements expired in February 2010, but were renewed in May 2010, when the lack of dollar liquidity once more became pronounced. See Fleming and Klagge (2010) and Goldberg, Kennedy and Miu (2011) for details on the dollar swap lines.

access to dollar liquidity (as well as euro liquidity) by expanding the set of eligible collateral at its facilities.

2.2.7 Wholesale Funding and Northern Rock

In September 2007, Northern Rock—the fifth largest mortgage lender in the United Kingdom—experienced an old-fashioned bank run, the first in the United Kingdom since the collapse of City of Glasgow Bank in 1878. The run could only be contained by the government's announcement that it would guarantee all deposits in Northern Rock.

Since its conversion from a building society to a bank in 1997, Northern Rock grew rapidly to reach £113.5 billion in assets by June 2007. Northern Rock relied on securitization and funding from wholesale markets rather than "traditional" funding from retail deposits and holding loans until maturity. Northern Rock had only seventy-six branches in 2007 and retail deposits accounted for only 27% of its liabilities, whereas wholesale funding accounted for 68% of its liabilities and mortgage loans comprised 77% of its assets.

The drying-up of liquidity in wholesale markets in the summer of 2007 adversely affected Northern Rock. In August, Northern Rock informed authorities about its funding difficulties, and on September 13, the Bank of England agreed to provide emergency assistance, which was publicly announced on Friday, September 14. This news confirmed the extent of difficulties and resulted in a run on Northern Rock. On the evening of Monday, September 17, the government announced it would guarantee all existing deposits to contain the run.

Table 2: Balance Sheet Data (Percent)

	Mortgage	Deposits	Wholesale	Equity
Abbey National	53	34	21	1.7
Alliance & Leicester	55	45	52	3.0
Barclays	6	26	19	2.5
Bradford & Bingley	62	51	44	3.2
Halifax Bank of Scotland	37	38	36	3.6
HSBC	4	48	17	6.2
Lloyds TSB	28	42	27	3.4
Northern Rock	77	27	68	3.1
Royal Bank of Scotland	8	43	24	4.8
Standard Chartered	17	58	20	7.1
Average	34.7	41.2	32.8	3.86

Source: Goldsmith-Pinkham and Yorulmazer (2010). Notes: Mortgage represents mortgage loans. Deposits represent customer deposits. Wholesale is the sum of debt securities in issue and deposits from other banks, and represents funding from wholesale markets. Equity represents shareholders' equity, all as a percentage of total liabilities. Data for mortgage loans are for the 2006 year-end and are collected from the website of Council of Mortgage Lenders (http://www.cml.org.uk/cml/statistics), except for Standard Chartered, which are from the interim results for June 30, 2007. All other data are from interim results for June 30, 2007, except for Bradford & Bingley, which are from the annual report for December 31, 2006.

Goldsmith-Pinkham and Yorulmazer (2010) provide an analysis of the run on Northern Rock and analyze the spillover effects on other banks from the difficulties of Northern Rock.[39] Table 2 shows the balance sheet data for the ten largest U.K. banks analyzed in that study.[40] The authors show that the main driver of the spillover effect on the other U.K. banks was the funding difficulty in wholesale markets, where banks that relied on wholesale markets were affected severely.[41, 42] Furthermore, the institutions shown to have been affected experienced subsequent failures (or near failures). Examples include the takeover of Alliance & Leicester by Grupo Santander; the partial nationalization and the purchase of the savings business of Bradford & Bingley by Grupo Santander; Lloyds TSB's acquisition of HBOS; and HBOS' pre-tax loss of £10.8 billion in 2008 hitting Lloyds TSB, which had to be recapitalized by the U.K. government.

While Northern Rock's heavy reliance on wholesale funding markets played an important role in the run, some particular features of the deposit insurance scheme in the United Kingdom were another contributing factor. U.K. deposit insurance at that time only covered 100% of the first £2,000 and 90% of the next £33,000. Furthermore, the deposit insurance fund was not ex-ante funded and it could take about six months for depositors to access their funds.

2.3 Conclusions

Leading up to the financial crisis, fragility had been building up in the financial sector. Financial institutions and the financial system at large had become particularly vulnerable on the funding side. Short-term wholesale financing and opaqueness in the (asset-backed) commercial paper market, in money market mutual funds, and the repo and securitization markets made the system quite vulnerable. The complexities in these markets also manifested themselves in a mushrooming interconnectedness further augmenting opaqueness, and ultimately leading to systemic, market wide freezes and break downs. The policy responses typically involved providing public back-stops in order to lubricate the various funding markets. Governments literally became the market makers and financiers of last resort.

39 See also Shin (2009) for a discussion of the Northern Rock case.

40 The ten largest U.K.-owned banks accounted for around 90% of U.K.-owned banks' assets.

41 To analyze the effect of bank characteristics on stock price returns, a series of regressions are run, where the dependent variable is the abnormal return during the period of interest and the explanatory variables are the bank balance sheet characteristics. Significant negative abnormal returns are regarded as evidence of spillover. The results show significant negative abnormal returns for Alliance & Leicester (-34.8%), Bradford & Bingley (-18.8%) and HBOS (-5.7%) during the event window of September 14-17.

42 Furthermore, some banks which are dissimilar to Northern Rock such as Abbey National (with a lower level of wholesale funding) actually experienced positive returns during this period. In other words, the spillover was confined to the set of banks that had a similar business model to Northern Rock and relied on wholesale markets for funding.

3 The regulatory response

While it is tempting to consider banking a (increasingly) lightly regulated industry in the years leading up to the crisis, relatively heavy handed regulation has always been part of the financial sector. To strengthen the stability of financial institutions, policymakers have designed and implemented various strategies over time. While some of these guidelines aim directly at the liability side of banks' balance sheets such as capital requirements and deposit insurance, others target the asset side of the balance sheets, such as liquidity and reserve requirements, and asset restrictions as applied to money market funds.

Some of the important policies that aim at promoting stability are as follows:

- Deposit insurance
- Lender of last resort
- Supervision
- Capital requirements
- Reserve requirements
- Liquidity requirements
- Transparency and disclosure requirements

While there is an extensive literature on each of these policies, our focus lies on the changes after the crisis with a discussion of why the policies were not adequate and how this may have contributed to the crisis.

Prior to the crisis, international bank regulation was governed by rules set by the Basel Accords, namely Basel I and II. Basel I was introduced in 1988 and implemented in 1993. Basel I set minimum capital requirements for banks. In particular, it required banks to hold a minimum of 8% of their risk-weighted assets (RWA) as capital, that is,

$$\textit{Capital ratio} = \frac{\textit{Capital}}{\textit{Risk Weighted Assets}} \geq 8\%.$$

Total capital is the sum of Tier 1 (Core) and Tier 2 (Supplementary) capital, where Tier 2 capital cannot be more than 50% of total capital.[43]

Basel I had only five risk categories to calculate risk weighted assets, which did not properly reflect actual credit risk exposure. For example, the rules assumed that banking risk is the same across countries and that mortgages had a risk weight that is half the risk weight for business loans. This created incentives for exploitation and risk taking. Furthermore, Basel I treated each investment in isolation and did not reward any diver-

43 Tier 1 capital comprises common stock, retained earnings, capital surplus and disclosed capital reserves, whereas Tier 2 capital comprises loan loss allowances, preferred stock with maturity of at least 20 years, subordinated obligations (both stock and debt) with an original average maturity of at least 7 years, undisclosed capital reserves and hybrid capital instruments.

sification efforts in bank portfolios. Also, capital ratios were expressed in book value and failed to adjust for changing market conditions.

As a response to the shortcomings of Basel I, Basel II was introduced in 2004. Basel II features finer risk categories and it accounted for the risk mitigation efforts of banks and made greater use of banks' internal risk assessments. While Basel I mainly focused on credit risk, Basel II set requirements against operational risk and market risk in addition to credit risk. It had three main pillars:

- Pillar 1: Minimum capital requirements;
- Pillar 2: Regulatory monitoring, where supervisors are expected to evaluate how banks are assessing their capital needs and encourage banks to develop and use better risk management techniques;
- Pillar 3: Market discipline, which required increased disclosure and transparency to increase market monitoring.

While introducing finer risk categories could be interpreted as a move in the right direction to more accurately reflect the underlying risk exposures, it made the calculation of capital requirements rather complex and opened the door for potential errors that may arise from models and the underlying assumptions used in calculating risk weights. Hence, Basel II was criticized for having an amplifying effect on cycles, where during good times perceived risks were low resulting in low capital requirements and during crisis periods risks were perceived to be too high inducing a credit crunch. Moreover, Basel II did not provide a framework to address liquidity risk and the fragility in funding structures in particular.

3.1 Basel III

As a response to the shortcomings of Basel II, regulators designed new set of rules, so called Basel III, which was agreed by the members of the Basel Committee on Banking Supervision in 2010-11.[44] Full implementation of Basel III has been extended a few times and the rules are planned to be implemented fully until 31 March 2019. Below we discuss the changes and the new rules introduced in Basel III.

3.1.1 Credit Risk

One of the lessons from the crisis was the build-up of excessive on- and off-balance sheet leverage in the banking system even though banks were maintaining strong risk-based capital ratios due to the risk weights being very low during the build up to the crisis. When banks were forced to delever, it led to enormous downward pressure on asset prices, leading to further sales and a fire-sale spiral. To address the building up of leverage and the potential underestimation of risks during boom periods, Basel III introduced a non-risk-based leverage ratio, which would act as a

44 For details, see "Basel III: A global regulatory framework for more resilient banks and banking systems", BCBS (2011).

backstop for risk-based capital requirements.[45] In particular, the leverage ratio is calculated as[46]

$$\text{Leverage ratio} = \frac{\text{Tier 1 Capital}}{\text{Total Consolidated Assets}}$$

Implementation of the leverage ratio requirement has begun in 2013 and a minimum requirement of 3% has been set.[47]

Basel III introduces a general increase in required capital levels. In particular, starting in 2015, banks are required to hold 4.5% (up from 2% in Basel II) of risk weighted assets in the form of common equity Tier 1 capital. Furthermore, starting in 2015, the minimum Tier 1 capital requirement increases from 4% in Basel II to 6% of risk weighted assets, which is composed of 4.5% of common equity Tier 1, plus an extra 1.5% of additional Tier 1 capital.

Furthermore, Basel III introduced two additional capital buffers, namely a mandatory capital conservation buffer, equivalent to 2.5% of risk weighted assets and a discretionary counter-cyclical buffer, allowing national regulators to require up to an additional 2.5% of capital during periods of high credit growth. The counter-cyclical buffer must be met by common equity Tier 1 capital. As we discussed, one criticism of the capital requirements in Basel II was their amplification effect on cycles. The counter-cyclical capital buffer, previously used in Spain for example, aims at counter-weighting this effect. In particular, banks build capital buffers during good times, which is easier and less costly than in stress periods, to be used in bad times. Furthermore, the counter-cyclical capital buffers would help prevent excessive credit expansion.

3.1.2 Liquidity Risk

Basel I and Basel II mainly focused on bank loss reserves (capital). Historically, banks were subject to reserve requirements to address some of the issues that may arise due to liquidity risk, where banks are required to hold a fraction of their deposits as cash or deposits at the central bank, so called reserves.

However, reserve requirements lost their effectiveness over time. Reserve requirements were set against bank deposits and other forms of borrowing such as time deposits and, more importantly, wholesale funding that do not have reserve requirements became more common over time, which undermined the effectiveness of reserve requirements. Furthermore, there is no international consensus on the level of reserve requirements. Some countries (Canada, United Kingdom, New Zealand, Australia and Sweden) do not have reserve requirements at all whereas requirements vary among countries (Eurozone 1%, Switzerland 2.5%, Turkey 8.5% and China 20.5%).

Basel III recognizes liquidity risk and the risk of loss of funding and introduces two

45 For details of the leverage ratio requirement, see"Basel III leverage ratio framework and disclosure requirements", BCBS (2014b).

46 The denominator is the sum of exposures of all assets and nonbalance sheet items.

47 In July 2013, the US Federal Reserve announced that the minimum Basel III leverage ratio would be 6% for 8 systemically important US banks and 5% for their insured bank holding companies.

new measures: Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR).[48] The Liquidity Coverage Ratio aims at promoting the short-term resilience of banks against liquidity risk. In particular, LCR requires a bank to have an adequate stock of unencumbered high-quality liquid assets (HQLA) that consists of cash or assets that can be converted into cash at little or no loss of value in private markets, to meet its liquidity needs for a 30 day liquidity stress scenario. While it ensures that the bank can survive a stress scenario event for 30 days, it gives regulators time to take appropriate measures if needed. Formally, the LCR requirement can be stated as:

$$LCR = \frac{Stock\ of\ HQLA}{Cash\ Outflows\ in\ the\ Net\ 30\ Days} \geq 100\%.$$

One issue is the usability of the stock of liquid assets. In recognition of this, during a stress period banks may use their stock of HQLA, thereby falling below 100%. Supervisors will subsequently assess the situation and can adjust the response flexibly according to the circumstances. The LCR was introduced on 1 January 2015, but the minimum requirement is set at 60% and will rise 10 percentage points each year to reach 100% on 1 January 2019.

The second requirement is the Net Stable Funding Ratio, which complements the LCR with a longer time horizon. The NSFR is defined as the amount of available stable funding relative to the amount of required stable funding and the ratio is required to be at least 100%.

3.2 Resolution[49]

During the recent crisis, we witnessed the failure or near failure of some of the most prominent financial institutions (Table 1). In the United States, prior to the passage of the Dodd Frank Act, insolvent nondeposit-taking institutions were dealt with under the Bankruptcy Code, as opposed to the special resolution regime administered by the Federal Deposit Insurance Corporation (FDIC). Figure 10 shows the largest corporate bankruptcies in US history; Lehman Brothers was by far the greatest. In the absence of an orderly resolution regime, the failure of Lehman led to unprecedented disruptions in financial systems globally. While many counterparties to Lehman suffered direct losses, others experienced distress due to information contagion and fire-sale externalities from a sell-off in assets.

One of the most significant effects was on the money market mutual fund industry, where the Reserve Primary Fund, the oldest money market fund, "broke the buck" because of its exposure to Lehman Brothers debt securities and had to be liquidated. It marked only the second such episode in history. This event led to a run on the money market mutual fund industry, which adversely affected the shadow banking industry.

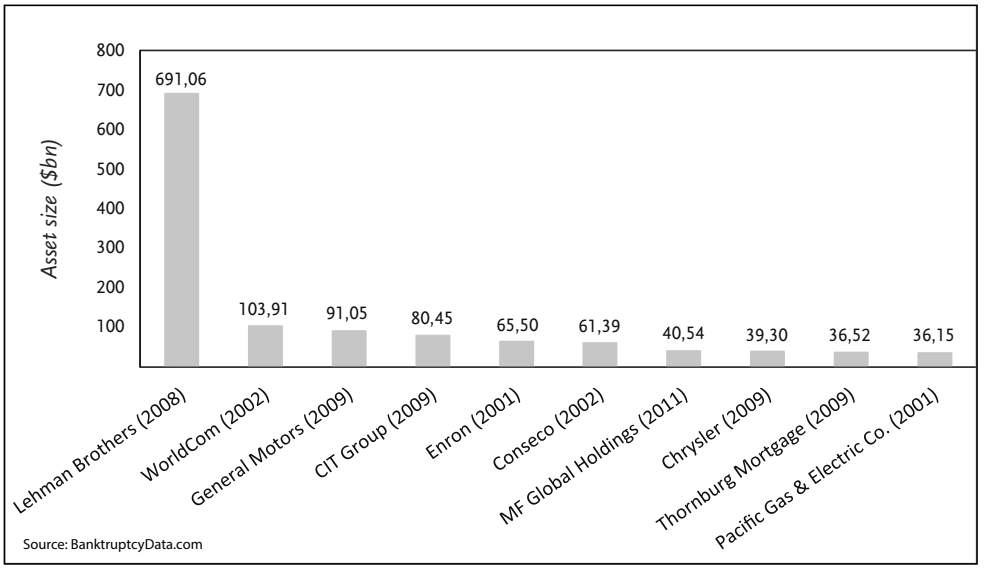
48 For details, see "Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools", BCBS (2013) and "Basel III: The Net Stable Funding Ratio", BCBS (2014a).

49 The discussion builds on parts of White and Yorulmazer (2014).

Regulators attempted to contain the disruptions in financial markets with extraordinary interventions including capital injections, debt guarantee programs and many lending facilities.

Financial intermediaries and banks perform important roles for the efficient functioning of the economy, such as channeling funds from savers to investors and providing payment services where their liquid liabilities can act as money. As a result, failure of these institutions can pose significant disruptions. The developments during the crisis highlighted some of the shortcomings of the regulatory framework to resolve financial institutions and the need for a special resolution regime for systemically important institutions in cases where bankruptcy may not be an effective option. This led to a revision of the current regulatory framework to deal with distressed institutions. Next, we review recent developments in the United States, the United Kingdom and the European Union on the resolution of financial institutions.

Figure 10: Largest Public Company Bankruptcy Filings



3.2.1 United States

In the United States, the FDIC possesses expansive powers to resolve failed federally insured depository institutions under the statutory objective to maximize the institution's return on assets and minimize costs to the insurance fund. In contrast to corporate bankruptcy proceedings, the FDIC, acting as receiver of a failed institution, is not subject to court supervision, and assumes the rights and powers of the institution's stockholders, directors, and parties with contractual rights. This includes the power to merge the institution with another insured depository institution without the need for consent.

The failure of a number of firms such as Lehman Brothers proved that US regulatory

agencies did not have adequate tools for resolving systemically important nonbank institutions. Below we discuss two recent developments that resulted from the Dodd-Frank Act: 1) the resolution and recovery plans of its Title I; and 2) the Orderly Liquidation Authority of its Title II.

Title I of the Dodd-Frank Act requires all bank holding companies with total consolidated assets greater than $50 billion and all nonbank financial companies designated as systemically important by the Financial Stability Oversight Council to submit resolution plans, or "living wills," to the Federal Reserve and the FDIC. Each plan must provide a strategic analysis of the institution's rapid and orderly resolution in the event of material financial distress or failure, through a reorganization or liquidation under the US Bankruptcy Code. For their initial resolution plans, filers were provided with a set of baseline economic conditions to use in their analysis, although subsequent submissions need to create a plan for resolution under "adverse" and "severely adverse" economic conditions.

The Orderly Liquidation Authority (OLA), established in 2010 under Title II of the Dodd-Frank Act, expands FDIC's authority to resolve failing banks by including systemically important nonbank financial institutions (SIFIs), which previously would have been resolved through corporate bankruptcy. Further, for banks that are consolidated under a bank holding company, Title II acts under a "single point of entry" framework to facilitate continuity of critical services and reduces costs.

In resolving a failed institution, FDIC would assign losses to shareholders and unsecured creditors of the holding company and transfer sound subsidiaries to a new solvent entity. As receiver, the FDIC can raise funds (up to a limit) through a line of credit from the US Treasury, but Title II includes a provision that prohibits the use of taxpayer funds to cover the cost of resolution; therefore all funds must be recovered.

Before a firm can enter orderly liquidation proceedings, the Treasury secretary must receive a written recommendation based on a two-thirds vote from the Board of Governors of the Federal Reserve System and another regulator, and, in consultation with the US President, determine that the financial institution is in danger of default and that failure would have "serious adverse effects on the financial stability of the United States." It must also be determined that there is no viable private sector alternative available.

3.2.2 United Kingdom

The failure of Northern Rock in 2007 was a wake-up call for regulators and since then there have been wide reforms of financial regulation in the United Kingdom. Prior to 2008, the British legal system did not distinguish between banks and other failing companies, and therefore authorities did not have the ability to take Northern Rock into receivership. The Banking (Special Provisions) Act was passed in 2008 as a temporary measure, giving the U.K. Treasury powers to facilitate orderly resolution through directed transfers of property, rights and claims of a failed depository institution.

The Banking Act of 2009 replaced the temporary regime and created a Special Resolution Regime (SRR) for failing banks, influenced by the US approach. The

Financial Services Authority (FSA), the regulator of financial firms at the time, was given the right to trigger the SRR. Under the SRR, the U.K. authorities have powers similar to the FDIC in resolving a failed institution. The choice of method would also involve a cost test.

However, the regime set up under the Banking Act of 2009 did not cover nondeposit-taking financial firms. To address this and improve financial supervision generally, further reforms were implemented in April 2013. Under the new regulatory regime, the FSA ceased to exist, and the Prudential Regulation Authority (PRA) was formed as part of the Bank of England to regulate deposit-takers, insurers, and major investment firms. Firms will assist the PRA and the SRR in assessing resolvability and drawing up Recovery and Resolution Plans. The PRA, in consultation with the Bank of England and the Treasury, makes the decision to initiate the SRR for a failing institution.

In addition, the publication of the Report of the Independent Commission on Banking led by John Vickers (known as the "Vickers Report") made formal recommendations for further reform in 2011. The focus of the Vickers Report is the notion that banks should "ring-fence" retail and commercial banking operations by establishing a separate legal entity to carry out these activities. The purpose is to protect these operations from the riskier wholesale and investment banking services. The Vickers Report also recommends that large UK ring-fenced retail banks hold a greater amount of capital than what is proposed under Basel III in order to improve their "loss-absorbency." Many of the recommendations outlined in the Vickers Report have been incorporated in the Banking Reform Bill of 2013 (BRB). This legislation would give the new PRA power to enforce the full separation of banking activities.

3.2.3 European Union

More recently, in response to the financial crisis, EU authorities have worked to improve the framework of banking regulation within the European Economic and Monetary Union. Prior to the crisis, many EU countries relied on insolvency (bankruptcy) proceedings to deal with bank failures, which is not well suited for the resolution of financial institutions. The EU Commission has taken steps under the Bank Recovery and Resolution Directive to establish a common set of rules to follow when winding down failed banks.
In 2012, the ECB proposed the creation of a European Banking Union, which would involve the establishment of the Single Supervisory Mechanism (SSM), the Single Resolution Mechanism (SRM), and a common system of deposit protection. Under the SSM, the ECB supervises banks in the euro area and other member states, and, when a bank is in severe stress, it informs the Single Resolution Board, who would oversee the resolution. SRM implements the framework for the recovery and resolution of credit institutions and investment firms that are in danger of failing. The SSM became operational in 2014; the SRM will be operational in 2016.[50] An essential part of the SRM is the creation of the Single Resolution Fund to finance the restructuring of failing credit institutions.

50 See chapter 15 in Greenbaum, Thakor and Boot (2016) for an overview of the various regulatory initiatives.

3.2.4 Bail-in Debt

The resolution directive proposed by the EU is focused on the idea that the shareholders and creditors must face losses before a failing bank can receive any taxpayer bailouts. It proposes that shareholders, unsecured creditors and uninsured depositors (with deposits greater than €100,000), in that order, would be forced to cover at least 8% of the institution's total liabilities before the resolution fund provides any support. Power to carry out bail-in within resolution is listed as one of the key attributes of effective resolution regimes for financial institutions by the Financial Stability Board (2011), which the Federal Reserve and the FDIC helped to develop and which G20 leaders endorsed in 2011. In general, this method could include writing down and/or converting to equity any or all unsecured and uninsured creditor claims in a manner that respects the hierarchy of the claims. Importantly, it would provide a capital buffer for distressed firms that would otherwise have difficulty raising new equity.

In the United States and elsewhere, requirements for contingent convertible bonds (CoCos) and bail-in debt have been proposed. CoCos are loss-absorbing instruments which are converted to equity if a predetermined trigger, based on regulatory capital levels, is hit. The United Kingdom is working to include bail-in measures in their resolution regime. Meanwhile, Swiss authorities support bail-ins of a range of creditors, including shareholders, holders of CoCos and other bondholders, especially for the country's largest banks, UBS and Credit Suisse. In general, while a number of issues will need to be addressed, a bail-in resolution method may come with significant advantages; it can provide capital during times of distress and reduce moral hazard and disruptions to customers and markets in the case of a systemic failure.[51]

3.3 Global Systemically Important Banks (G-SIBS)

G-SIBs are big, highly interconnected and typically involved in complex transactions and financial instruments. Hence, difficulties in G-SIBs can have enormous disruptions on the entire financial system. As a result, regulators pay a closer attention to G-SIBs. First, the regulators decided to designate G-SIBs. In designating G-SIBs regulators focus on criteria such as cross-border activity, size, interconnectedness, complexity of the bank's activities and the substitutability of the bank's services.

The first G-SIB list was published in November 2011, and has been updated each year in November since then.[52] Furthermore, regulators set more stringent requirements for G-SIBs. In particular, G-SIBs are required to hold additional common equity Tier 1 capital ranging from 1%-3.5% depending on the systemic importance of the bank. In addition, G-SIBs with headquarters in United States and Europe, are required

51 There is considerable debate on the desirability of CoCos. Many are ill designed and a key question is why not require more equity rather than a complex – to be converted – debt instrument, see also Admati and Hellwig (2013).

52 The current list consists of Bank of America, Wells Fargo, Citibank, JP Morgan Chase, Goldman Sachs, Morgan Stanley, State Street and Bank of New York Mellon from the United States; Royal Bank of Scotland, Barclays, HSBC and Standard Chartered from the United Kingdom; Mizuho FG, Sumitomo Mitsui and Mitsubishi UFJ FG from Japan; Bank of China, ICBC and Agricultural Bank of China from China; BNP Paribas, Credit Agricole, Societe Generale and Banco Populare CE from France; BBVA and Santander from Spain; Credit Suisse and UBS from Switzerland; Deutsche Bank from Germany; Unicredit from Italy; ING from Netherlands and Nordea from Sweden.

to submit an updated emergency Resolution Plan to their Financial Supervision Authority each year.

3.4 Stress Testing

Stress tests are used to analyze the resiliency of banks to adverse economic developments such as shocks to GDP growth, interest rates, an equity market crash, loss of significant funding etc.. While stress tests have been widely used by banks and also by regulators in the past, they became a regulatory requirement after the crisis. The first European stress test was conducted in 2011 and the second was completed in 2014. Going forward stress tests will be conducted yearly. In the US, after October 2012, largest US banks are required to go through stress tests twice a year (once internally and once by the regulators). Starting 2014, mid-sized firms (assets between $10-50 billion) are also required to go through stress tests.

While stress tests are useful in identifying the resiliency of banks to shocks, they also have implications for banks to raise new capital and for their dividend policies. Regulators ask banks that fall short during the stress test to raise capital.[53]

3.5 Lender of Last Resort and Asset Purchase Programmes

Historically, central banks performed their role as the lender of last resort during crisis periods.[54] After the devastating effects of the 1907 panic, one of the reasons for the establishment of the U.S. Federal Reserve in 1914 was its lender-of-last-resort role.

In performing this role central banks typically lent mostly to commercial banks with very short maturities and against high-quality collateral like treasuries. However, during the crisis this was not sufficient to mitigate distress in markets. Hence, many new lending facilities—some targeted at specific segments of the financial system—have been introduced. Maturities got significantly longer and central banks lent against a larger set of collateral. While we have already included many lender-of-last-resort activities in Chapter 2, we will add more detail here, in part also with the question in mind whether the crisis has led to a different way of looking at lender-of-last-resort activities.

In recent years when interest rates effectively hit the zero lower bound, central banks looked for alternative ways to stimulate economies. In particular, in many countries such as the US, United Kingdom, Japan and the euro area, central banks engaged in quantitative easing. Federal Reserve launched its asset purchase program in November 2008, where it purchased longer-term securities issued by the US government and longer-term securities issued or guaranteed by government-sponsored agencies such as Fannie Mae or Freddie Mac. The aim was to stimulate the economy by increasing the price of the assets purchased such as houses, which then would create a positive spillover effect on the prices of other assets.

53 For example, in the last European stress test 123 EU banks were tested. Twenty four banks came out to be undercapitalized, Monte dei Paschi from Italy having the largest capital shortfall of €2.1 billion. Banks were given 9 months to increase capital.

54 See, for example, Bagehot (1873) for a description of how the Bank of England performed this important role.

In late November 2008, the Federal Reserve started buying $600 billion in mortgage-backed securities. By March 2009, it held $1.75 trillion of bank debt, mortgage-backed securities, and Treasury notes, reaching a peak of $2.1 trillion in June 2010. In August 2010, the purchases have been resumed. In November 2010, the Fed announced a second round of quantitative easing, so called QE2, to buy $600 billion of Treasury securities by the end of the second quarter of 2011. A third round of quantitative easing, so called QE3, to purchase a new $40 billion per month was announced in September 2012. In December 2012, the amount of purchases has been increased from $40 billion to $85 billion per month. The Federal Reserve announced an end to the asset purchase program in October 2014 after accumulating $4.5 trillion in assets.

The European Central Bank (ECB) also provided liquidity to banks and markets in various ways. Through the late summer of 2011 ECB purchased bonds issued by states such as Spain and Italy. The Emergency Lending Assistance (ELA) program was designed for financial institutions in a liquidity crisis, such as the Greek banks in the course of the 2015 Greek financial turmoil, when banks experienced massive deposit outflows.

On 21 December 2011, the ECB instituted a program, so called Long-Term Refinancing Operations, of making low-interest loans with a term of three years and 1% interest to European banks accepting loans from the portfolio of the banks as collateral. Government securities issued by European states would be acceptable as collateral as would mortgage-backed securities and other commercial paper that can be demonstrated to be secure. Under the LTRO program, the ECB loaned €489 billion to 523 banks for an exceptionally long period of three years and a significant amount (€325 billion) was tapped by banks in Greece, Ireland, Italy and Spain. On 29 February 2012, a second program, so called LTRO2, was launched to provide euro-zone banks with further €529.5 billion in low-interest 3-year maturity loans.

In addition, the ECB announced an asset purchasing program in September 2014, where it will start buying covered bonds, bonds that are backed by public sector loans or mortgages, and other assets worth €60 billion per month.

In March 2009, the Bank of England started to purchase UK government securities (gilts) and, to a smaller extent, relatively high-quality debt issued by private companies from financial institution. Asset purchases amounted £175 billion by the end of October 2009. The asset purchase program has been extended several times reaching a total of £375 billion in July 2012.

Bank of Japan (BoJ) used quantitative easing policy in the early 2000s to fight deflation, where it provided banks with excess liquidity by purchasing government bonds, asset-backed securities and equities to promote private lending. Recently, starting in October 2010, the BoJ announced it would purchase assets to stimulate the economy. The size of the asset purchase program has been increased several times and in October 2014 the BoJ announced it would expand the program to buy ¥80 trillion (€580 billion) of bonds a year.[55]

55 In March 2009, the Swiss National Bank announced that it would be purchasing bonds issued by private borrowers. In February 2015, the Riksbank (Central Bank) in Sweden launched an asset purchase program to buy government bonds worth 10 billion kronor ($1.2bn).

3.6 Deposit Insurance

After the devastating effects of bank runs during the Great Depression, US established the Federal Deposit Insurance Corporation (FDIC) in 1933 that set up a national deposit insurance scheme. The United States was the second country, after Czechoslovakia, to have a national insurance scheme. Many countries followed the U.S. example and established deposit insurance schemes before the crisis.[56] However, there was no international convergence on deposit insurance before the crisis and countries differed significantly in terms of coverage limits, insurance being full or partial or the timeliness of payments. For example, even in the Euro area different countries had different limits. In the United Kingdom, the Northern Rock episode and the old-fashioned bank run with depositors queuing in front of Northern Rock branches marked the first bank run in the United Kingdom since the collapse of City of Glasgow Bank in 1878. Before the crisis, the United Kingdom had partial deposit insurance where the first £2000 were fully insured and the next £33,000 were insured only up to 90%. Furthermore, it would take 6 months for depositors to have access to their funds. It has been argued that these factors have contributed to the depositor panic and the bank run.

After the crisis deposit insurance coverage has been increased significantly. For example, in the United States coverage increased from $100,000 to $250,000, in the United Kingdom from £35,000 partial insurance to £85,000 full coverage. In the euro area, the coverage increased to €100,000 and became uniform across member countries.

3.7 Conclusions

In many ways policy makers have sought to address the vulnerabilities in the financial system. Requirements surrounding capital, liquidity and resolution have all been strengthened, and more focus is given to systemically important financial institutions (with additional requirements). Stress tests and an expansion of deposit insurance aim at further adding confidence to the stability of the financial sector. Time will tell how to evaluate the effectiveness of all these measures. If it comes to the vulnerability in funding structures, authorities have become well aware of the importance of liquidity in banks, and the system at large.

56 Australia and New Zealand were two notable exceptions for countries without an explicit government deposit insurance scheme. However, Australia announced on October 12, 2008 that 100% of all deposits would be protected over the subsequent three-year period. This was subsequently reduced to a maximum of $1 million per customer per institution. On 11 September 2011, it was announced that the guarantee would fall to $250,000, effective as of 1 February 2012. New Zealand announced the Crown Retail Deposit Guarantee Scheme, an opt-in scheme for retail deposits on October 12, 2008. An extension to the scheme was announced on 25 August 2009 and the scheme ran until 31 December 2011. From 1 January 2012 bank deposits in New Zealand are not protected by the Government.

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Appendix: Theoretical Framework on banks and balance sheet characteristics[57]

We present a simple analytical framework to illustrate how the characteristics of a financial intermediary affect its ability to survive stress events. The aim here is to present an approach that is sufficiently general to encompass a wide range of intermediation arrangements, but sufficiently simple to illustrate the economic forces at work in a transparent and intuitive way.

Our framework begins with the simplified balance sheet of a representative financial intermediary. The intermediary holds two types of assets: safe and risky. Safe assets are always liquid, but risky assets may be illiquid in the short run. On the liability side of its balance sheet, the intermediary has short-term debt, long-term debt, and equity. This intermediary faces two types of risk: The value of its assets may decline (credit risk) and/or its short-term creditors may decide not to roll over their debt (liquidity risk). We measure the stability of the intermediary by looking at what stress events it can survive, that is, what combinations of shocks to the value of its assets and to its funding it can experience while remaining solvent.[58]

We study how the stability of this intermediary depends on various balance sheet characteristics, such as its leverage, the maturity structure of its debt, and the liquidity and riskiness of its asset portfolio. Some of the results we derive are straightforward, such as the effect of higher leverage and a higher liquidation value of the risky asset. Higher leverage increases the debt burden of the financial intermediary, makes it more susceptible to creditor runs, and decreases the buffer provided by equity capital. As a result, higher leverage always makes the intermediary more vulnerable to shocks. As the liquidation value of the risky asset increases, the intermediary needs to liquidate a smaller portion of the risky asset in its portfolio to make the payments to the short-term creditors that choose not to roll over. As a result, a higher liquidation value of the risky asset always makes the intermediary more resilient to creditor runs.

Other results, however, demonstrate that the determinants of stability can be subtle. For example, lengthening the maturity structure of the intermediary's debt tends to make it more resilient to funding shocks by decreasing reliance on short-term debt that can be withdrawn. However, since long-term debt can be a more costly way of finance compared to short-term debt, lengthening the maturity structure can increase the debt burden and make the intermediary more vulnerable to shocks to the value of its assets.

57 The discussion builds on Eisenbach et al. (2014).

58 An important issue in any such analysis lies in determining the conditions under which short-term creditors will or will not choose to roll over their debt. We do not try to explain creditor behavior in our framework; instead, we treat this behavior as exogenous. This approach greatly simplifies the analysis and allows us to present an intuitive analysis of the determinants of stability. Again, a way to think of our analysis is that it subjects banks to different types of stress events. In most of our applications, we hold fixed the balance sheet of the bank, and ask whether the bank is stable for different sizes of short-term creditor runs and declines in the value of its assets. The creditor behavior in our framework is used as a parameter that generates a certain size of run on the bank. Within the growing literature on this topic, our paper is most closely related to that of Morris and Shin (2009), who also study the stability of an intermediary. They define the illiquidity component of credit risk to be the probability that the intermediary will fail because it is unable to roll over its short-term debt, even though it would have been solvent had the debt been rolled over. Morris and Shin (2009) use techniques from the theory of global games to determine creditors' behavior as part of the equilibrium of their model.

Similarly, holding a safer asset portfolio can make the intermediary either more or less vulnerable to shocks, depending on the other characteristics of its balance sheet. Some of these effects are dependent on the characteristics of both the asset and liability side of the bank's balance sheet and one advantage of our framework is that it allows us to consider the influence of both sides of the balance sheet simultaneously.[59]

A SIMPLE MODEL

There are three dates, labeled $t = 0, 1, 2$, and a single, representative financial institution. We refer to this institution as a bank for simplicity but, as we discuss below, it can be thought of as representing a variety of different arrangements for financial intermediation. We begin by specifying the elements of this bank's balance sheet.

The balance sheet

At $t = 0$, the bank holds m units of a safe, liquid asset, which we call cash, and y units of a risky, long-term asset. Cash earns a gross return r_1 between periods 0 and 1 and a gross return r_s between periods 1 and 2.[60] The risky asset yields a random gross return θ if held until $t = 2$, but a smaller return $\tau\theta$ if liquidated at $t = 1$. The realized value of θ is observed by all agents at the beginning of $t = 1$.

The bank has issued s units of short-term debt that matures at $t = 1$ and ℓ units of long-term debt that matures at $t = 2$. To simplify the analysis, we assume that the promised return on the bank's short-term debt is the same as the return it earns on the liquid asset, that is, r_1 between periods 0 and 1 and r_s between periods 1 and 2. The long-term debt ℓ promises a gross interest rate $r_\ell > r_s$ between periods 0 and 2. In addition, the bank has an amount e of equity. We normalize $r_1 = 1$ throughout the analysis.[61]

Short-term debtholders decide whether to roll over their claims at $t = 1$ after observing the realized value of θ. If the bank is able to meet its obligations to all debtholders, any remaining funds at $t = 2$ are paid to equityholders. If the bank is unable to meet its obligations, it enters bankruptcy and a fraction Φ of its assets is lost to bankruptcy costs. The remaining assets are then distributed to debtholders on a pro-rata basis. We make the following assumptions on parameter values:

Assumption 1: $r_s < r_\ell < \frac{1}{\tau}$.

This assumption ensures that neither form of financing—long-term or short-term debt—strictly dominates the other. As will become clear below, $1/\tau$ is the cost of repaying short-term debtholders that withdraw early and force asset liquidation, while r_s is the cost of repaying short-term debtholders that roll over. Since r_ℓ is the cost of repaying a long-term

59 This framework can easily be applied to study various policy issues such as how liquidity holdings and equity capital interact in achieving bank stability, the effects of the Basel III Liquidity Coverage Ratio, the discount window policy and various reform proposals for the money market mutual funds, to cite a few. For details see Eisenbach et al. (2014).

60 The framework can be easily generalized by allowing these returns to differ.

61 Alternatively, we can interpret s, ℓ and m and as the $t = 1$ values of each variable, including all interest accrued between $t = 0$ and $t = 1$.

debtholder, Assumption 1 states that short-term debt is cheaper than long-term debt ex post if and only if it does not force early liquidation.

Assumption 2: $\theta\tau \leq 1$.

This second assumption implies that paying an early withdrawal with cash is always cheaper than by liquidating the risky asset.

Solvency

The bank is solvent if it is able to meet all of its contractual obligations in both periods. The solvency of the bank will depend on the realized return on its assets as well as the rollover decisions of the short-term debtholders. Let α denote the fraction of short-term debtholders who decide not to roll over – that is, to withdraw funding from the bank – at $t = 1$. If $\alpha s \leq m$, the bank can pay all of these claims from its cash holdings. If $\alpha s > m$, however, the bank does not have enough cash to make the required payments and must liquidate some of the long-term asset.

The matured value of the bank's remaining assets at $t = 2$ when $\alpha s \leq m$ holds is given by

$$\theta y + r_s(m - \alpha s).$$

In this case, paying out an additional dollar at $t = 1$ would reduce the bank's cash holdings by one unit, lowering the $t = 2$ value of assets by r_s. When $\alpha s \geq m$, however, paying out an additional dollar at $t = 1$ requires liquidating $1/(\tau\theta)$ units of the long-term asset, which lowers the $t = 2$ value of the bank's assets by $1/\tau$. In this case, the matured value of the bank's remaining assets at $t = 2$ can be written as

$$\theta\left(y - \frac{\alpha s - m}{\tau\theta}\right).$$

We can combine these two expressions by defining $\chi(\alpha)$ to be the marginal cost at $t = 2$ of funds used to make $t = 1$ payments, that is,

$$\chi(\alpha) \equiv \begin{cases} r_s & \text{for } \alpha \leq \frac{m}{s} \\ 1/\tau & \text{for } \alpha > \frac{m}{s} \end{cases}. \tag{1}$$

The matured value of the bank's remaining assets at $t = 2$ can then be written for any value of α as

$$\theta y + \chi(\alpha)(m - \alpha s). \tag{2}$$

Note that if expression (2) is negative, the bank is actually insolvent at $t = 1$, as it is unable to meet its immediate obligations even after liquidating all of its assets. In this

case, short-term debtholders that withdraw funding at $t = 1$ in expectation receive a pro-rata share of the liquidation value of the bank's assets while all other debtholders receive zero.[62] When expression (2) is positive, short-term debtholders that withdraw funding at $t = 1$ receive full payment and the bank is solvent at $t = 2$ if and only if the matured value of its remaining assets is larger than its remaining debts, that is,

$$\theta y + \chi(\alpha)(m - \alpha s) \geq (1 - \alpha) s r_s + \ell r_\ell. \tag{3}$$

Note that solvency of the bank at $t = 2$ implies that it is also solvent at $t = 1$. We can rewrite this condition as

$$\theta \geq \frac{s r_s + \ell r_\ell + [\chi(\alpha) - r_s]\alpha s - \chi(\alpha) m}{y} \equiv \theta(\alpha). \tag{4}$$

The variable $\theta(\alpha)$ identifies the minimum return on the risky asset that is needed for the bank to be solvent, conditional on a fraction α of short-term debtholders withdrawing funding and the remaining $(1 - \alpha)$ rolling over their claims. For $\alpha s \leq m$, this cutoff value simplifies to

$$\theta(\alpha) = \frac{s r_s + \ell r_\ell - m r_s}{y} \equiv \underline{\theta} \qquad \text{for all } \alpha \leq \frac{m}{s}. \tag{5}$$

When none of the long-term asset is liquidated at $t = 1$, solvency of the bank depends only on the $t = 2$ values of its assets and debts. Within this range, the value of α does not matter because additional withdrawals at $t = 1$ reduce the value of the bank's assets and liabilities by exactly the same amount.

For $\alpha s > m$, the cutoff becomes

$$\theta(\alpha) = \frac{s r_s + \ell r_\ell + [1/\tau - r_s]\alpha s - (1/\tau) m}{y} \equiv \theta^*(\alpha) \qquad \text{for all } \alpha > \frac{m}{s}. \tag{6}$$

In this case, Assumption 1 implies that $\theta^*(\alpha)$ is increasing in α. Additional withdrawals at $t = 1$ now force liquidation of the long-term asset and thus reduce the value of the bank's assets more than they reduce the value of its liabilities. As a result, a higher return on the long-term asset is required to maintain solvency. If all short-term creditors withdraw funding, we have

$$\theta(1) = \frac{s + \tau \ell r_\ell - m}{\tau y} \equiv \bar{\theta}. \tag{7}$$

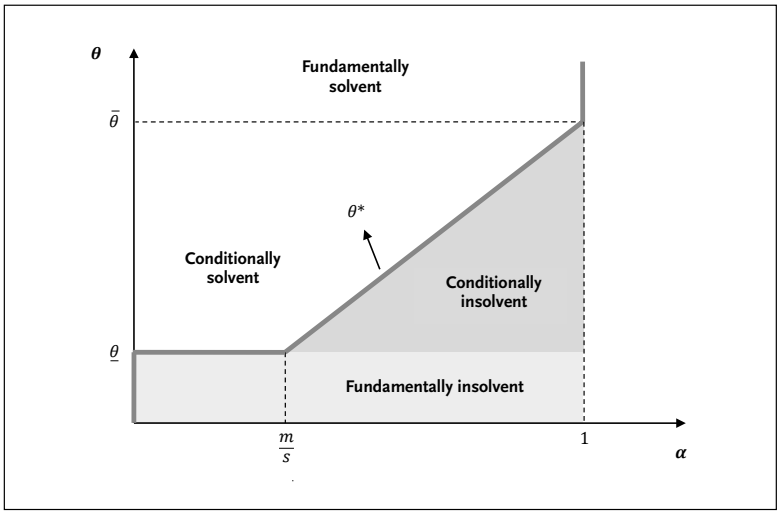
62 We assume that the bank cannot suspend convertibility, so that the bank pays in full the promised amount to short-term debtholders that withdraw at $t = 1$ until it runs out of funds. We assume that the position of the short-term debtholders that decide to withdraw at $t = 1$ in the line is randomly assigned from a uniform distribution. Thus, short-term debtholders that withdraw at $t = 1$ in expectation receive a pro-rata share of the liquidation value of the bank's assets while all other debtholders receive zero.

If the realized return θ is greater than $\bar{\theta}$, the bank will be solvent at $t = 2$ regardless of the actions short-term debtholders take at $t = 1$.

Stability

We measure the stability of the bank by asking for what combinations of α and θ it remains solvent. In other words, what stress events, in terms of both asset values and funding conditions, will the bank survive? Figure A illustrates the answer by dividing the space of pairs (α, θ) into four regions. When θ is below $\underline{\theta}$, the return on the risky asset is so low that the bank will be insolvent regardless of how many short-term debtholders roll over their claims. In this case, we say the bank is *fundamentally insolvent*. When θ is between $\underline{\theta}$ and $\bar{\theta}$, the bank will survive if sufficiently many short-term debtholders roll over their claims, but will fail if too few do. In the former case, we say the bank is *conditionally solvent*, meaning that the fact that it remains solvent depends on the realized rollover decisions of the short-term debtholders. In the latter case, when (α, θ) fall in the triangular region below the gray line, we say the bank is *conditionally insolvent*. Finally, when θ is larger than $\bar{\theta}$, the bank will be solvent regardless of the actions of short-term debtholders. In this case, we say the bank is *fundamentally solvent*.

Figure A: Solvency Regions



Determinants of bank stability

Next, we investigate how the stability of the bank depends on the bank's balance sheet characteristics and parameters of the model. We begin by examining how the solvency regions in Figure A depend on two characteristics of the bank's liabilities: its leverage and the maturity structure of its debt. We then evaluate the effects of changing two asset-side characteristics: the liquidation value of the risky asset and the composition of the bank's asset portfolio.

Leverage

Let $d \equiv s + \ell$ denote the bank's total amount of debt and let

$$\sigma \equiv \frac{s}{s+\ell} \tag{8}$$

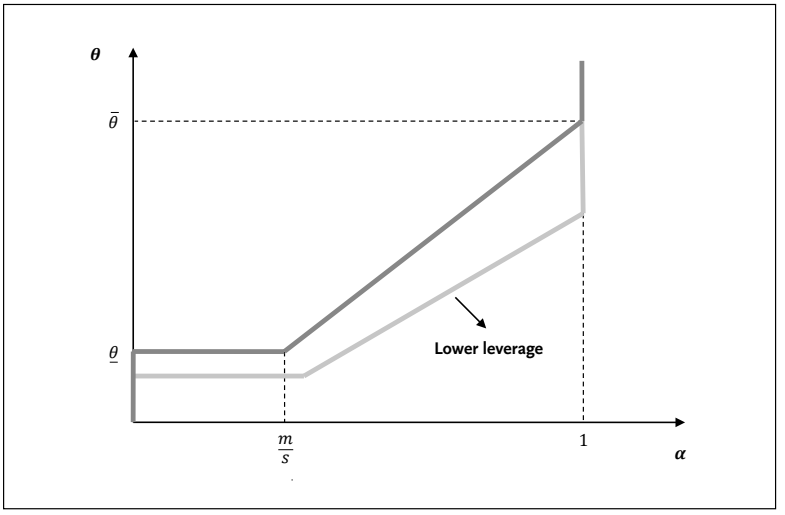
denote the fraction of this debt that is short term. We normalize the total size of the bank's balance sheet to 1, so that the amount of equity is given by $e = 1 - d$. We can then write the quantities of short-term and long-term debt, respectively, as

$$s = \sigma(1-e) \quad \text{and} \quad \ell = (1-\sigma)(1-e).$$

To examine the effect of leverage, we hold the maturity structure σ of the bank's debt fixed and vary the amount of equity e.

The changes in these two solvency boundaries are depicted in Figure B, where an increase in equity (that is, a decrease in leverage) corresponds to a move from the dark gray line to the light gray line. Figure B demonstrates that lower leverage strictly reduces the bank's insolvency risk by making it better able to withstand shocks to both its asset values and its funding. In other words, lower leverage is associated with unambiguously greater stability. Furthermore, holding more equity (and less debt) reduces the sensitivity of the debt burden to withdrawals and thus also reduces the sensitivity of the conditional solvency threshold to withdrawals. In other words, lower leverage makes the slope of the solvency boundary flatter, as illustrated in Figure B.

Figure B: Effect of Leverage



Maturity structure of debt

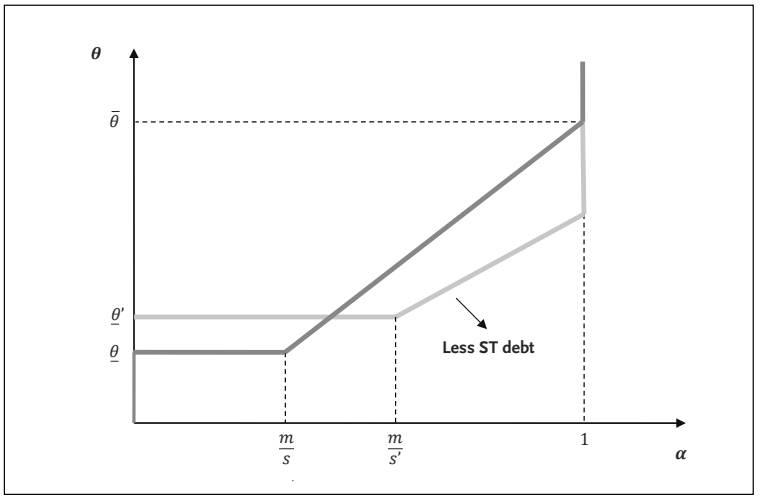
Next, we study the effects of changing the maturity structure of the bank's debt. Recall that σ measures the fraction of the bank's debt that is short term. Our interest is in how changing σ, while holding equity e and total debt d fixed, affects the bank's ability to survive stress events.

The cutoff value $\underline{\theta}$ below which the bank is fundamentally insolvent is strictly decreasing in σ. Intuitively, long-term debt is more costly than short-term debt and therefore lengthening the average maturity increases the bank's total debt burden at $t = 2$. The higher debt burden, in turn, implies that a higher return θ on the risky asset is required to avoid insolvency.

This change is illustrated in Figure C which shows the effect of lowering the quantity of short-term debt from s to s' while increasing the quantity of long-term debt by the same amount. For returns in the interval $(\underline{\theta},\underline{\theta}')$ the bank will now be fundamentally insolvent, whereas it would have potentially been solvent with the higher level of short-term debt s.

Figure C also highlights two countervailing effects of decreasing short-term debt. First, the cutoff point m/s increases, meaning that the bank can withstand a larger funding shock (α) without having to liquidate any of its long-term assets. In addition, the slope of the solvency boundary in the region where $\alpha > m/s$ becomes flatter. Taken together, these two changes imply that decreasing the bank's short- term debt shrinks the conditional insolvency region in the diagram. For any given funding shock α, a bank with less short-term debt will have less need to liquidate assets at $t = 1$ and is thus less likely to become insolvent due to the loss of funding.

Figure C: Effect of Maturity Structure



Our framework thus demonstrates how changing the maturity structure of a bank's debt has two competing effects on its ability to survive stress events. Having less short-term debt makes the bank less vulnerable to funding shocks by decreasing its dependence on the actions of short-term debtholders. At the same time, however, it also increases the bank's total debt burden at $t = 2$ and therefore increases the likelihood that the return on the bank's assets will be insufficient to cover these debts. Put differently, a bank financed largely by long-term debt and equity is protected from the conditional insolvency caused by a loss of funding from short-term debtholders. However, it is also clear that long-term debt is not equivalent to equity and increasing the long-term debt burden can raise the likelihood of fundamental insolvency.

A key takeaway from our analysis therefore is that having banks lengthen the maturity structure of their liabilities does not make them unambiguously more stable or less likely to become insolvent. Instead, the benefits of having lower rollover risk must be balanced against the costs associated with a higher debt burden.

Liquidation value

We now turn to the characteristics of the bank's asset holdings and ask how the solvency and insolvency regions in Figure A depend on the liquidation value τ. One policy for improving liquidation values can be for the central banks to act as a lender of last resort or purchase assets from banks rather than banks having to go to the market for asset sales at significant discounts.

Note that the bound for fundamental insolvency, $\underline{\theta}$, is independent of τ (see equation (5)). This lower bound represents a scenario in which the bank has enough cash to pay short-term debtholders that do not roll over at $t = 1$, so that no liquidation is needed and the value of τ has no effect on the bound.

Figure D: Effect of Liquidation Value τ

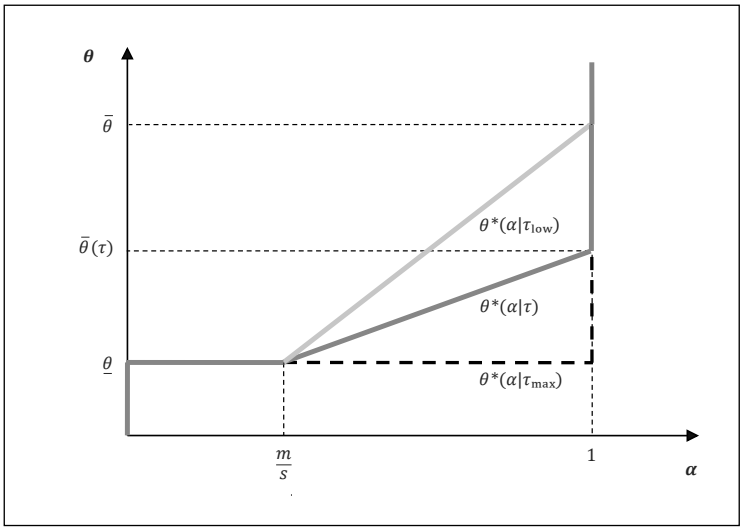


Figure D illustrates this result. The dark gray curve corresponds to the baseline value of τ. If the liquidation value is lower, such as at τ_{low}, the curve shifts to that depicted in light gray. For values of α smaller than m/s, there is no change in the threshold value θ^* because no liquidation takes place; insolvency in this case is determined solely by the period-2 value of assets and liabilities. For higher values of α, however, the threshold value θ^* becomes larger (shifts up because payments made to short-term creditors are now more expensive in terms of period-2 resources). As Figure D shows, shifting to τ_{low} shrinks the region of conditional solvency and expands the region of conditional insolvency.

If the liquidation value rises, however, the threshold value of θ^* falls (shifts down and the solvency region becomes larger). The extreme case is where $\tau = 1/r_s$, which means that liquidating the long-term asset is no more costly than using cash to pay investors at $t = 1$. In this case, the threshold value θ^* is equal to $\underline{\theta}$ for all values of α. The curve separating the solvency and insolvency regions in this case corresponds to the dashed black line in Figure D – the bank is solvent for values of θ above $\underline{\theta}$ and insolvent for values below $\underline{\theta}$, regardless of the value of α.

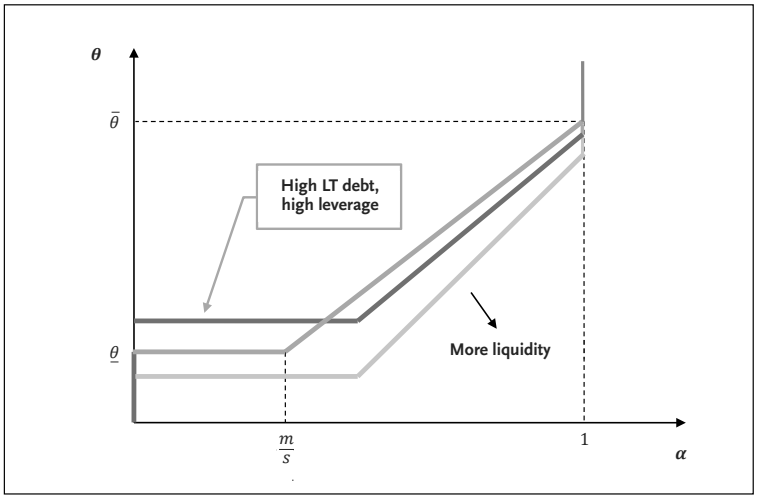
Liquidity holdings

We now study the effect of changing the composition of the bank's asset holdings. We again normalize the size of the bank's balance sheet to 1, so that we have $m + y = 1$. Both the critical value $\underline{\theta}$ for fundamental insolvency and the critical value $\theta^*(\alpha)$ for conditional insolvency depend on the composition of the bank's assets.

These different effects of liquidity on bank stability are all present in Figure E. Where insolvency is conditional—that is, the boundary has a positive slope—the curve shifts down and becomes steeper for both the dark gray and the light gray bank: More liquidity reduces insolvency risk but increases the sensitivity to withdrawals. Where insolvency is fundamental—and the boundary is horizontal—the line can shift up or down: more liquidity can reduce the risk of fundamental insolvency (light gray bank), but it can also increase it if leverage is high and/or debt maturity is long (dark gray bank).

The results have shown how the determinants of a bank's ability to survive stress events are often intuitive, but can sometimes be subtle. Decreasing leverage, for example, clearly improves stability, since it decreases both the probability of fundamental insolvency and the probability of conditional insolvency. Having a higher liquidation value for assets also unambiguously improves stability. While this change has no effect on the likelihood of a bank becoming fundamentally insolvent, it always reduces the likelihood of conditional insolvency.

Figure E: Effect of Liquidity Holdings



For other changes in balance sheet characteristics, however, a trade-off can arise in which improving stability in one dimension tends to undermine it in the other. Lengthening the average maturity of a bank's debt lowers the probability of conditional insolvency, for example, but raises the probability of fundamental insolvency. In other words, this change tends to make the bank better able to withstand shocks to its short-term funding sources, but less able to withstand shocks to the value of its assets. Shifting the composition of the bank's assets toward safe, liquid assets also tends to lower the probability of conditional insolvency, but can either raise or lower the probability of fundamental insolvency. In cases like this where the results are ambiguous, our framework helps illustrate the sources of this ambiguity and when a trade-off is most likely to arise. Increasing the bank's liquid asset holdings is most likely to raise the probability of fundamental insolvency when the bank is highly leveraged or has a large amount of long-term debt.

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Tanju Yorulmazer is Associate Professor in Finance at the University of Amsterdam. His research interests include the fields of Financial Economics, Systemic Risk, Liquidity, Financial Crises and Resolution, Financial Economics, Financial Institutions and Banking. Recent striking publications from his hand are his paper "Rollover Risk and Market Freezes", with Viral Acharya and Douglas Gale, *Journal of Finance* (2011) and his paper on "Crisis Resolution and Bank Liquidity", with Viral Acharya and Hyun Shin, *Review of Financial Studies* (2011). His articles have been published in journals such as the *Journal of Finance*, the *Review of Financial Studies*, the *American Economic Journal: Macroeconomics, Journal of Money, Credit and Banking* and the *Journal of Financial Intermediation.*

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