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Special Issue:
The Stability of Funding Models

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under significant distress at this time. For each case, Yorulmazer discusses the size and evolution of the funding mechanism, the sources of the disruptions, and the policy responses aimed at mitigating distress and making markets more liquid. The review serves as a reference on the vulnerabilities of funding structures and is useful for those considering the scope and design of reform efforts.

29 Stability of Funding Models: An Analytical Framework

Thomas Eisenbach, Todd Keister, James McAndrews, and Tanju Yorulmazer

With the recent financial crisis, many financial intermediaries experienced strains created by declining asset values and a loss of funding sources. In reviewing these stress events, one notices that some arrangements appear to have been more stable—that is, better able to withstand shocks to their asset values and/or funding sources—than others. Because the precise determinants of this stability are not well understood, gaining a better grasp of them is a critical task for market participants and policymakers as they try to design more resilient arrangements and improve financial regulation. This article uses a simple analytical framework to illustrate the determinants of a financial intermediary's ability to survive stress events. An intermediary in the framework faces two types of risk: the value of its assets may decline and/or its short-term creditors may decide not to roll over their debt. The authors measure stability by looking at the combinations of shocks the intermediary can experience while remaining solvent. They study how stability depends on the intermediary's balance-sheet characteristics, such as its leverage, the maturity structure of its debt, and the liquidity and riskiness of its asset portfolio. They also show how the framework can be applied to examine current policy issues, including liquidity requirements, discount window policy, and different approaches to reforming money market mutual funds.

Tanju Yorulmazer

Introduction

The financial crisis of 2007-09 highlighted the fragility of many financial intermediaries and markets. As asset values declined and funding sources dried up, a significant number of commercial banks, investment banks, and money market mutual funds experienced distress, as did some market-based intermediation arrangements such as asset-backed commercial paper. Borrowing rates and haircuts reached record-high levels and some funding markets completely froze. These difficulties were severe enough to cause several institutions to fail and others to require extraordinary public support.

This special issue of the *Economic Policy Review* examines the stability of different "funding models," or arrangements for financial intermediation. The first of the three featured papers is a review of the economics literature on the stability of financial intermediaries, with a focus on intermediaries' funding models. The paper discusses the standard framework used in the literature to analyze the fragility associated with financial institutions that perform maturity and liquidity transformation and the potential factors that amplify or mitigate such fragility. Furthermore, it reviews developments in the financial sector that may have affected the stability of funding models.

The second paper presents case studies of several major financial markets and intermediaries 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 that were implemented to mitigate distress and make markets and intermediaries more liquid. We analyze the markets for auction rate securities, commercial paper, asset-backed commercial paper, and bilateral and tri-party repo, as well as credit commitments by banks, dollar funding of non-U.S. banks, and money market mutual funds. We also consider the fragility associated with wholesale funding, using the run on Northern Rock as our case study.

In reviewing recent events, we find that some markets and intermediaries appear to have been more fragile—that is, less able to withstand shocks to their asset values and funding sources—than others. The third paper develops a simple analytical framework to analyze the factors that affect markets' and intermediaries' ability to survive stress events. A financial intermediary faces two types of risk: the value of its assets may decline, and/or its short-term creditors may decide not to roll over their debt. 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 absorb and still remain solvent. We also study how the intermediary's stability depends on balance sheet characteristics such as leverage, the maturity structure of its debt, and the liquidity and riskiness of its asset portfolio. Finally, we employ our framework to analyze current policy issues and recently proposed regulatory changes.

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Literature Review on the Stability of Funding Models

- Financial intermediaries perform maturity and liquidity transformation by issuing liquid, short-term liabilities while holding illiquid, longer-term assets.
- This study discusses the intermediaries' role as liquidity provider and the inherent fragility associated with it.
- Yorulmazer reviews the standard framework of the literature to consider factors that make financial intermediaries more or less stable, such as the combination of deposit-taking and loan-making activities and the role of interbank markets for coinsurance against liquidity shocks.
- The study also looks at developments in the financial sector affecting the stability of intermediaries. These include the shift of some activity to less regulated parts of the financial system and the growing importance and size of the repo market.

1. Introduction

This article provides a review of the economics literature on the stability of banks and other financial intermediaries, with a policy-oriented focus on their funding models. We first discuss the standard framework used in the literature to analyze the fragility of financial institutions that perform maturity and liquidity transformation. Then we consider potential factors that amplify or mitigate such financial fragility. Finally, we review developments in the financial sector that may have affected the stability of funding models.

2. The Standard Framework

2.1 What Is Maturity Transformation and Why Does It Cause 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

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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. In this section, we discuss the role of financial intermediaries as liquidity providers and the inherent fragility associated with this role.

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. This framework 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.

[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.

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.

Although the Diamond-Dybvig model focuses on the role of intermediaries as providers of liquidity, other functions performed by intermediaries could be added to the framework. For example, intermediaries play the important role of delegated monitors for creditors. Diamond (1984) develops a theory of financial intermediation based on minimum cost production of costly information about borrowers. An intermediary (for example, a bank) performs the task of costly monitoring of loan contracts written with the borrowing firms. It has a cost advantage in doing so because the alternative is either duplication of effort, if each lender monitors directly, or a free-rider problem, in which case no lender monitors and no valuable information is produced. If this intermediary also performs maturity transformation by issuing short-term liabilities, the type of fragility described above can easily arise.

[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).

2.2 What Causes Runs—Fundamental Asset Values or Fear?

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 U.S. data from the late nineteenth and early twentieth centuries to investigate the origins of banking panics and finds a close relationship 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 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]

In a recent article, Morris and Shin (2009) try to 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 "illiquidity 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.

[4] Although the business cycle view of bank runs has strong empirical support, there are also instances in which 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.

3. Factors That Affect Runs and the Damage They Cause

In this section, we discuss various factors that make financial intermediaries more or less stable. First, we talk about various features specific to banks that may help stability, such as banks combining deposit-taking and loan-making activities. We then consider the fragility associated with short-term wholesale funding. We review the role of interbank markets for coinsurance against liquidity shocks as well as various frictions that may undermine this important role. We also talk about the damaging effects of fire sales and briefly mention various regulatory and supervisory policies used for sustaining stability.

3.1 Why Are Banks Organized as Deposit-Taking and Loan-Making Institutions?

The fact that banks combine the activities of deposit-taking and lending (through the lines of credit they provide to firms) may give them an advantage over financial arrangements in which these activities are performed separately. Kashyap, Rajan, and Stein (2002) provide theoretical and empirical evidence that banks benefit from the synergies of these two activities. A simple example can be used to illustrate their point. Suppose there are two intermediaries: a finance company that relies on long-term debt, and a bank that issues demand deposits. Since depositors have the option of liquidation on demand, everything else equal, the bank can raise funds by offering a lower return than that of the finance company. The downside of demand deposits is that withdrawals can be unpredictable such that the bank must carry some cash in its portfolio and incur the opportunity cost for doing so. Let us assume that these two intermediaries also compete

to attract corporate loans. To keep the story simple, let us also assume that line-of-credit usage and deposit withdrawals are perfectly and negatively correlated. In this situation, the bank does not need to hold any additional cash in its portfolio for the credit line. By combining the two activities, a bank is able to economize on cash holdings, carrying a smaller buffer than what would have been needed by a financial institution that performs these services separately. Therefore, banks can provide liquidity to both depositors and firms in a more efficient way than if these activities were provided separately.

Of course, firms (particularly large ones) can use alternative sources to satisfy their liquidity needs, such as the commercial paper market. As documented by Saidenberg and Strahan (1999), large firms' use of these alternative sources has significantly increased over time in the United States. However, in times of financial distress, even large firms may have difficulty raising funds through these alternative sources or may find these sources too costly. To insure against this situation, firms also maintain credit lines with banks. Saidenberg and Strahan (1999) show that during the 1998 Long-Term Capital Management turmoil, firms shifted from the commercial paper market to banks for liquidity. They also show that during this period, banks experienced deposit inflows, verifying that line-of-credit usage and deposit withdrawals were negatively correlated. As a result, banks still play an important role as "liquidity providers of last resort," even to large businesses. Gatev and Strahan (2006) provide further evidence on the same issue for the United States. However, Ivashina and Scharfstein (2010) show that after the failure of Lehman Brothers, banks simultaneously experienced runs by short-term creditors when borrowers drew down their credit lines.

These results depend on the assumption that banks do not actually fail in the distressed states studied. In a recent study, Santos (2011) documents that while deposits may flow back to banks in the aggregate during periods of crisis, depositors tend to exit banks that are doing poorly. At the same time, corporate borrowers increase their drawdown rates on credit lines, and this effect is more pronounced among banks experiencing larger losses. As a result, banks that experience larger losses during a crisis experience both a decline in deposits and an increase in demand for liquidity through existing credit lines, indicating a limit to the synergies between deposit-taking and loan-making.

3.2 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.

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. In a recent article, 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.

3.3 Interbank Markets as a Source of Liquidity

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; 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

[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.

[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.

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. 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 that 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]

[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.

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

[9] Malherbe (forthcoming) 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. 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 U.S. 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.

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]

3.4 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. 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).

3.5 How Have Governments Attempted to Protect against These Vulnerabilities?

To mitigate the fragility of financial intermediaries and 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, in this article we focus on the question of how the financial system has evolved and whether these policies are sufficient and effective in the new world.

4. How Has the World Changed Leading Up to the Crisis?

In this section, we look at some of the changes that have taken place in the financial sector in recent decades, and how those changes have affected the stability of financial intermediation.

[10] Also, see Nier et al. (2007) for an analysis of contagion through interlinkages.

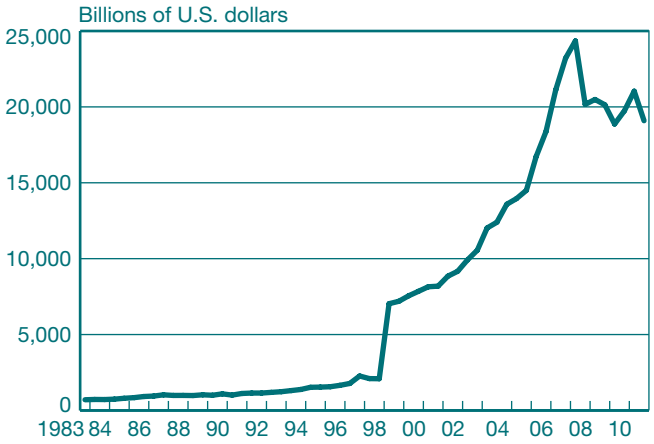
[11] A series of empirical papers—Sheldon and Maurer (1998) for Switzerland, Furfine (1999) for the United States, Upper and Worms (2002) for Germany, and Wells (2002) for the United Kingdom, to cite only a few—analyze the potential for failures resulting from these interlinkages.

[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, Bharath, and Srinivasan (2007) for the entire universe of defaulted firms in the United States over the period 1981–99 (see also Berger, Ofek, and Swary [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.

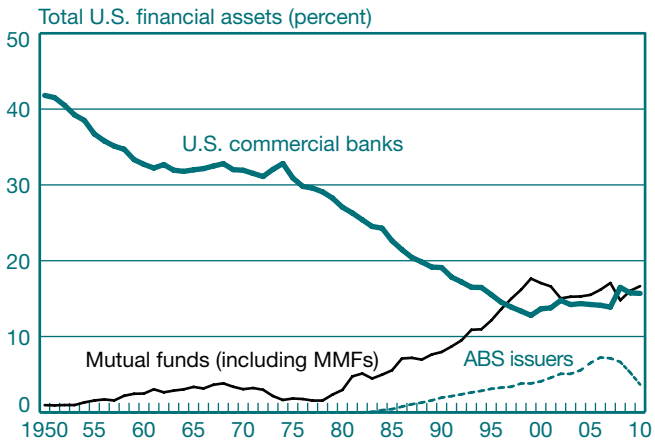
[14] See James (1991) for evidence.

Chart 1
Aggregate International Claims



Source: Bank for International Settlements, International Banking Statistics.

Chart 2
Commercial Banks versus Mutual Funds (including MMFs) and ABS Issuers



Source: Federal Reserve Flow of Funds.

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. Next, we discuss the changes in the financial system that had significant effects on the stability of the financial system and the effectiveness of the policies in place.[15]

4.1 Banks Are More Vulnerable

Equity capital can act as a buffer against losses and can induce prudent risk management by increasing banks' "skin in the game" (Gale 2004; Gale and Özgür 2005). 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 percent of banks' assets, whereas the ratio fell steadily for about a century and settled in the 6 to 8 percent range from the mid-1940s to the 1990s.

[15] The second article in this special issue (Yorulmazer 2014) provides case studies that focus on disruptions in some major markets and the difficulties experienced by financial institutions, with a discussion of the policy responses.

4.2 Globalization of Financial Intermediation

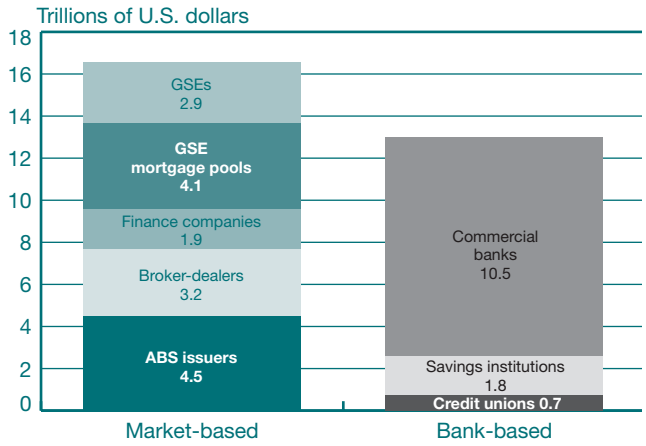
Another factor is the globalization of banking. Chart 1, taken from Cetorelli and Goldberg (2012), shows the aggregate international claims of Bank for International Settlements (BIS) reporting country banks, where international claims comprise both cross-border claims and local foreign claims. The increase in the aggregate international claims shows clearly the globalization trend in the banking industry.

4.3 Financial Intermediation Is Less Bank-Centric Now

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).

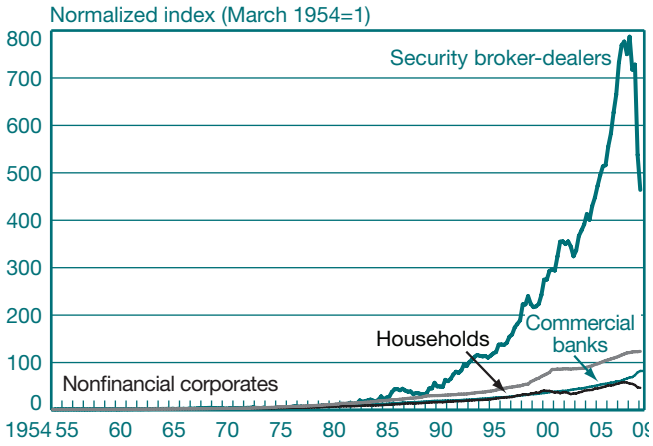
Chart 2 shows the trend for banks' share of financial sector assets since the 1950s. The chart also illustrates the growth of nonbank intermediaries that compete with banks on both sides of the balance sheet. For instance, on the liability side, mutual funds and, more recently, money market mutual funds (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.

Chart 3
Total Market-Based and Bank-Based Assets at 2007:Q2



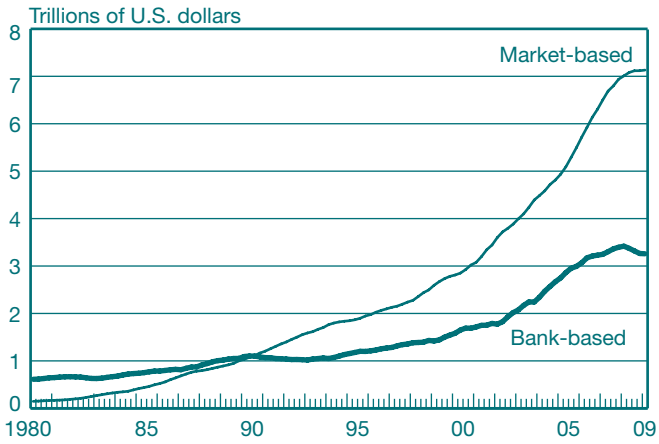
Source: Federal Reserve Flow of Funds.

Chart 4
Growth of Assets of Four Sectors in the United States



Source: Federal Reserve Flow of Funds.

Chart 5
Market-Based and Bank-Based Holdings of Home Mortgages



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.

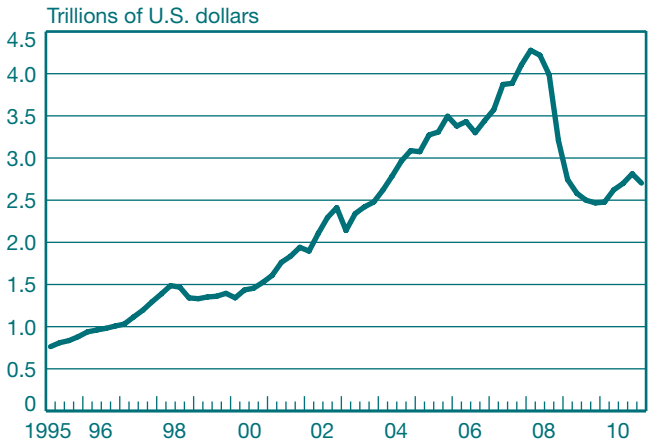
Chart 3, taken from Adrian and Shin (2009), compares total assets held by banks with the assets of securitization pools or at institutions that fund themselves mainly by issuing securities, showing that by the end of the second quarter of 2007, the "market-based assets," were substantially larger than bank assets.

The growing importance of the market-based system is evident in Chart 4, from Adrian and Shin (2009), which tracks 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.

The rapid expansion in broker-dealers' assets can mostly be explained by the changing structure of the U.S. 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 holdings were overtaken by market-based holders. In Chart 5, 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-enterprise (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.

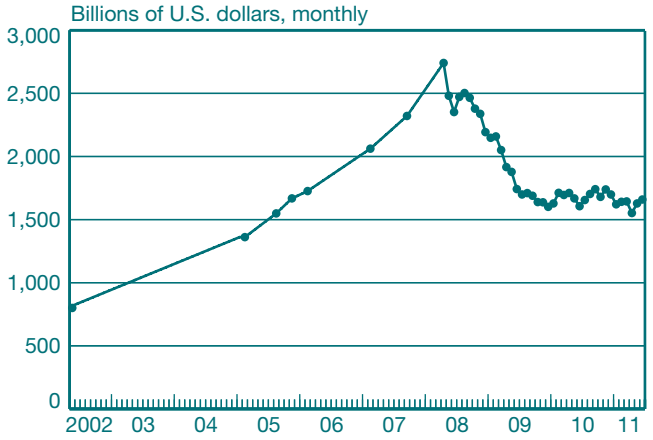
This shift from the bank-based to market-based parts of the financial system may have a significant effect on the scope, strength, and efficiency of existing policies, since a significant part of the financial activity may now take place in the less regulated parts of the financial system.

Chart 6
Total Primary Dealer Repo Activity



Source: Federal Reserve Flow of Funds.

Chart 7
Aggregate Value of the Tri-Party Repo Market

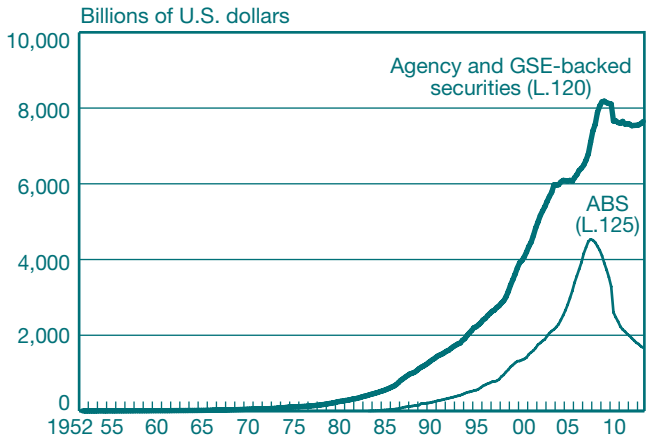


Source: Federal Reserve Bank of New York.

4.4 The Rise of Repo

Another important change in the financial sector is the growing importance and size of the repo market. Chart 6 shows the total primary dealer repo activity, while Chart 7, taken from Copeland, Martin, and Walker (2010), depicts the total size of the tri-party repo market. 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

Chart 8
Importance of Securitization



Source: Federal Reserve Flow of Funds.

experienced disruptions that contributed to the near-failure or failure of some major financial institutions.[16]

4.5 Securitization

Related to the earlier discussion, another notable issue is the importance of securitization (Chart 8). 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.

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.

[16] The second article in this special issue (Yorulmazer 2014) provides a case study on the disruptions in repo markets and the policy responses in the crisis of 2007-09.

5. Conclusion

This article provides a review of the literature on the stability of banks and other financial intermediaries. In particular, it presents a discussion of the fragility associated with financial intermediaries that perform liquidity and maturity transformation and the factors that affect such fragility. It also discusses developments in the financial sector that affect the stability of financial intermediaries. In sum, this article offers a framework that the other two articles in this special issue (Yorulmazer 2014; Eisenbach et al. 2014) build upon.

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Tanju Yorulmazer

Case Studies on Disruptions during the Crisis

- The 2007-09 financial crisis saw many funding mechanisms experiencing disruptions, with borrowing rates and haircuts reaching record highs and some funding markets freezing entirely.
- Yorulmazer presents case studies of several major financial markets and intermediaries that experienced significant distress during the crisis.
- The author discusses the size and evolution of each market, the sources of disruption, and the policy responses aimed at mitigating distress and restoring market liquidity.
- The review's broad focus includes auction-rate securities, commercial paper, money market mutual funds, and repo markets.
- The article serves as a reference on key episodes of financial market stress, and is useful for policymakers contemplating the scope and design of future market stabilization efforts.

1. Introduction

During the crisis of 2007-09, many funding mechanisms experienced disruptions, when borrowing rates and haircuts reached record-high levels and some funding markets completely froze. This paper discusses several funding mechanisms that experienced significant distress during the crisis. For each case, we provide a discussion of the size and the evolution of the mechanism, the sources of the disruptions, and the policy responses aimed at mitigating distress and making markets more liquid.[1] In particular, we consider auction rate securities, 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-U.S. banks, and the fragility associated with wholesale funding, using a discussion of the Northern Rock episode.

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

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2. Auction-Rate Securities

2.1 Background

An auction-rate security (ARS) is a long-term debt security-whose interest rate is reset regularly via an auction process. On each auction date, current investors decide how many shares they wish to redeem, bidders place bids for these shares, and a stop-out rate is determined. This interest rate is then paid by the issuer on all shares until the next auction date. An auction fails if there are fewer bids than investors seeking to redeem shares. In this case, the interest rate on the securities is reset to a maximum "penalty" rate to compensate investors for the inability to redeem their shares and to provide the issuer with an incentive to restructure the obligation.

Leading into the crisis, ARS were mostly issued by municipalities or their authorities in the form of tax-exempt or taxable bonds (municipal ARS, or MARS), by corporations or by closed-end mutual funds in the form of preferred stocks (ARPS), or by student loan authorities (student loan ARS, or SLARS).

Investors were typically corporate treasurers and high-net-worth individuals looking for liquid securities yielding more than money market funds or other cash accounts. In terms of size, the ARS market was substantial: ARS outstanding totaled about $330 billion at the end of 2007, roughly half of which was accounted for by MARS (Han and Li 2010).

2.2 Source of Fragility

The ARS was a form of maturity transfo0rmation. The underlying asset was a long-term debt security, but holders of the security—in normal times—could withdraw their funds by redeeming shares in the next auction. Importantly, there was little to no market for these securities outside of the regularly scheduled auctions. A holder of the security who expects future auctions to fail may want to sell in the current auction to avoid being locked into the security. Similarly, new investors may be unwilling to bid in the current auction if they expect that future auctions may fail. In this way, a fear of failed auctions may become self-fulfilling.

Two features served to limit fragility in this market in the pre-crisis period. One was the penalty rate imposed after a failed auction, which made the security attractive to some investors even in the event that future auctions failed. The other was the possibility that a market maker would step in and submit sufficient bids to prevent an auction from failing (Han and Li 2010). While this type of support was not guaranteed, it was provided by dealers on occasion prior to the crisis and many investors may have anticipated that it would be present in periods of market stress.[2]

2.3 Crisis

Some signs of stress appeared in the ARS market in August 2007 due to investor concern about the credit quality of the underlying instruments. Auction failures became much more widespread in February 2008, with a majority of auctions failing for all types of assets. Gradually, two distinct types of outcomes emerged. For those securities with a relatively low penalty rate, the auctions largely continued to fail and investors were, for the most part, unable to redeem shares. For those securities with a relatively high penalty rate, many auctions remained successful although the clearing rates increased substantially. In this latter case, investors were able to exit the market without experiencing losses, but issuers paid substantially higher rates.

2.4 Policy Response

There was no formal policy response to the disruptions in the ARS market during the crisis. In subsequent months and years, many investors in ARS sued their brokers, claiming they were misled about the liquidity risks involved.

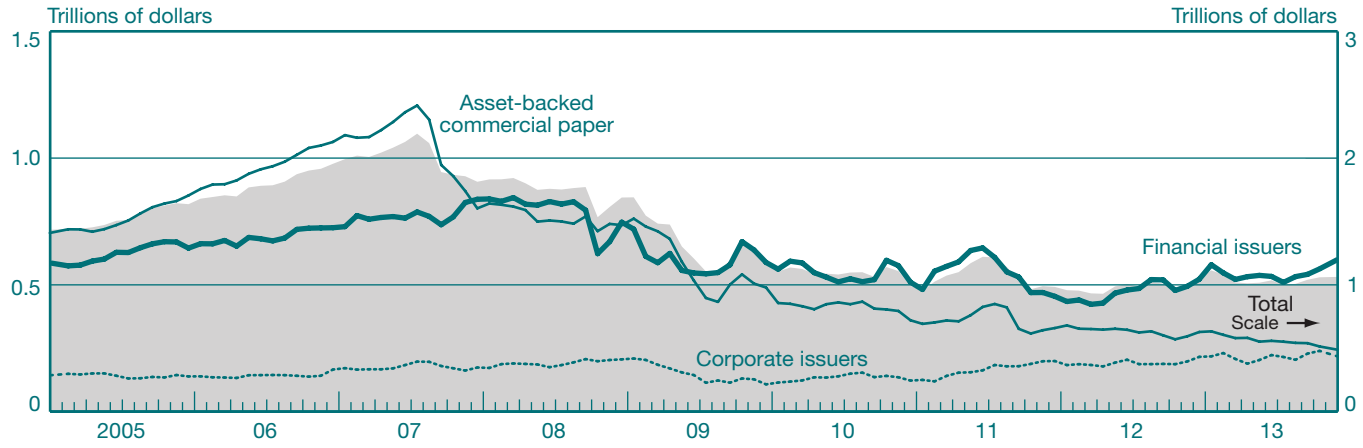
3. Commercial Paper

3.1 Background

Commercial paper (CP) is a key source of short-term financing for U.S. 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 (see chart). At that time, asset-backed commercial paper (ABCP) accounted for 55 percent of the market, financial CP for 36 percent and corporate (nonfinan-

[2] See Han and Li (2010) for a discussion.

Commercial Paper Outstanding



Sources: Federal Reserve Board; Haver Analytics.

Note: Trend lines for asset-backed, financial, and corporate commercial paper outstanding track to the scale on the left-side Y-axis; shaded gray area representing total commercial paper outstanding tracks to the scale on the right-side Y-axis.

cial) CP for 9 percent.[3] As of November 2013, commercial paper outstanding stood at $1.06 trillion, with ABCP accounting for 23 percent of the market, financial CP for 57 percent, and corporate CP for 20 percent.

Unsecured financial CP is typically issued by U.S. 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 typically 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.

3.2 Crisis

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.

[3] A separate case study on the ABCP market is provided in the next section.

The unsecured CP market came under pressure following Lehman Brothers' bankruptcy in September 2008 and the Reserve Primary Fund's announcement 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 percent between August and October 2008, and financial CP outstanding fell 32 percent. 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.

3.2 Policy Response

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).[4] The CPFF was designed to provide temporary support to all CP issuer types through the provision of a liquidity backstop. Through

[4] See Adrian, Kimbrough, and Marchioni (2011) for details on the CPFF.

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 the peak, the Fed owned 22.4 percent of the CP market. By the expiration of the 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).

4. Asset-Backed Commercial Paper

4.1 Background

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.[5]

ABCP was only about 6 percent of the total commercial paper market in 1990, but it accounted for about 55 percent 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, where the outstanding total dropped to about $800 billion, the market has regressed steadily and it is currently at about $290 billion.[6]

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 U.S. bank regulatory agencies issued a ruling that allowed banks to exclude sponsored conduits from consolidation 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 percent 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.

[5] "The Fundamentals of Asset-Backed Commercial Paper." Moody's Special Report, February 2003.

[6] Source: Federal Reserve Board.

4.2 Crisis

Recall that 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.

4.3 Policy Response

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.[7] 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).[8] Moreover, on October 7 of that year, the Federal

[7] 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.

[8] The U.S. 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.

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.

5. Money Market Mutual Funds

5.1 Background

MMFs are key intermediators of short-term debt, particularly for financial issuers, with total assets under management of $2.6 trillion as of April 2013. 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.[9]

The historical success of the funds in maintaining principal stability attracted a large, highly risk-averse shareholder base that included institutional investors that were not reluctant to pull away at any sign of trouble.[10]

5.2 Source of Fragility and the Crisis

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 percent 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 U.S. 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).[11] These outflows contributed to a freezing of short-term funding markets and a broader curtailment of credit supply.

5.3 Policy Response

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 of MMFs. The revisions also enhanced fund transparency, and made it easier for boards of directors to close troubled MMFs.[12]

6. 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.

[9] 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.

[10] 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.

[11] Prior to 2008, only one money fund had "broken the buck" since 1983, when the SEC adopted rule 2a-7 to govern MMFs.

[12] 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.

It is useful to distinguish different market segments by the way repos settle. In the 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 U.S. 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 and has been steady around that level since then (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 and Bank of New York Mellon are the two tri-party clearing banks. We have very little information on the size of the bilateral repo market.[13]

6.1 Source of Fragility and the Crisis

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.[14] 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.[15]

Disruptions in repo markets contributed to the failure or near-failure of major financial institutions during the crisis of 2007-09. 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 percent in late 2008. They also report that some collateralized debt obligations could not be financed at all (100 percent 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.[16] 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.[17]

6.2 Policy Response

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.[18] Six months later, the Federal Reserve expanded the facility to accept a broader range of collateral. Prior to the creation of these facilities,

[13] 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.

[14] 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.

[15] 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.

[16] 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 U.S. Treasury and Agency securities, has been cited by policymakers as a key concern behind aggressive interventions to contain the financial crisis."

[17] Krishnamurthy, Nagel, and Orlov (forthcoming) 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 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.

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

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.

7. Credit Commitments

7.1 Background

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.

7.2 Source of Fragility

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.

7.3 Crisis

There is evidence that banks that had larger losses, as measured by their charge-offs, 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 back-up credit lines.

7.4 Policy Response

The increase in the deposit limit covered by deposit insurance from $100,000 to $250,000 and the guarantee in full of noninterest-bearing transaction accounts appear to have helped stabilize the exodus of deposits from the banking industry.[19] The Temporary Guarantee Program for Money Market Funds by the U.S. 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.

[19] 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, 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/.

8. Dollar Funding of Non-U.S. Banks

8.1 Background

Non-U.S. banks accumulated sizable U.S. 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,[20] 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-U.S. banks made loans to U.S. companies and invested in AAA-rated tranches of U.S. structured financial products. Other arguments focus on European banking regulations that was 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-U.S. 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 U.S. commercial bank and qualifying for federal deposit insurance, as well as limitations on internal capital market transfers between related organizations under the Federal Reserve Act,[21] most non-U.S. banks meet their dollar funding needs by issuing dollar-denominated wholesale debt, such as certificates of deposits (CDs) and commercial paper, out of U.S. bank branches and other corporate entities. U.S. investors such as MMFs buy these debt instruments and constitute the main source of dollar funding of European banks.

8.2 Crisis

The fragility of the dollar funding model of non-U.S. banks during times of crisis arises from its dependence on the wholesale funding markets. U.S. 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 U.S. MMFs have reduced their exposure to European banks by 45 percent.

Non-U.S. 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, U.S. branches of non-U.S. 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-U.S. banks may borrow dollars from central bank dollar liquidity facilities.

8.3 Policy Response

The Federal Reserve provided dollar loans to U.S. branches of foreign banks through the discount window (DW) and the Term Auction Facility, which operated from December 2007 to March 2010.[22] Of 411 banks that were awarded funds in the TAF during this period, seventy-three (or almost 18 percent) were non-U.S. banks. TAF loans reached almost $500 billion on March 4, 2009, of which almost 40 percent were outstanding to non-U.S. banks. Non-U.S. bank participation in the DW was smaller, and constituted about 3 percent 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.[23] Under these arrangements, the Federal Reserve provides U.S. 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.

[20] ECB *Financial Stability Review*, June 2011.

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

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

[23] 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.

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

9. 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 percent of its liabilities, whereas wholesale funding accounted for 68 percent of its liabilities and mortgage loans comprised 77 percent 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.

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.[24] The table shows the balance-sheet data for the ten largest U.K. banks analyzed in that study.[25] 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.[26, 27] 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.

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 (as a percentage of total assets). 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.

[24] See also Shin (2009) for a discussion of the Northern Rock case.

[25] The ten largest U.K.-owned banks accounted for around 90 percent of U.K.-owned bank assets.

[26] 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 percent), Bradford & Bingley (-18.8 percent), and HBOS (-5.7 percent) during the event window of September 14-17.

[27] Furthermore, some banks that 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.

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 Kindgom were another contributing factor. U.K. deposit insurance at that time only covered 100 percent of the first £2,000 and 90 percent 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.

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Stability of Funding Models: An Analytical Framework

- During the recent financial crisis, many institutions and some market-based intermediation arrangements experienced strains owing to declining asset values and a drying-up of funding sources.
- Although these stress events led several institutions to fail and others to require extraordinary public support, a full understanding of their causes still proves elusive.
- This study clarifies that understanding by providing a rigorous, yet easily applicable, framework for analyzing the sources of the stress events and the effect of various funding structure characteristics on financial stability.
- The framework can potentially help policymakers form views on regulatory reform and evaluate the ways that policy options may affect financial stability.

1. Introduction

The recent financial crisis highlighted the fragility of many financial intermediaries. A large number of commercial banks, investment banks, and money market mutual funds (MMFs) experienced strains created by declining asset values and a loss of funding sources, as did some market-based intermediation arrangements such as asset-backed commercial paper (ABCP). These strains were severe enough to cause several institutions to fail and others to require extraordinary public support. In reviewing these events, one notices that some arrangements appear to have been more stable—that is, better able to withstand shocks to their asset values and/or funding sources—than others.[1] The precise determinants of this stability are not well understood. Gaining a better understanding of these determinants is a critical task for both market participants and policymakers as they try to design more resilient arrangements and improve financial regulation.

In this article, we use a simple analytical framework to illustrate how the characteristics of an arrangement for financial intermediation (a funding model) affect its ability to survive stress events. There is a large and growing literature on this issue; see Yorulmazer (2014b) for a detailed review. Our

[1] See Yorulmazer (2014a) for a detailed discussion of the experiences of several distinct types of intermediation arrangements during the crisis.

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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 hope is that this analysis will provide policymakers with a useful starting point for more detailed evaluations of alternative arrangements and for the analysis of regulatory proposals.

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 and/or its short-term creditors may decide not to roll over their debt. 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.

An important issue in any such analysis lies in determining the conditions under which short-term creditors will and 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 model 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. The insights from our analysis are likely to carry over to more complex models where creditor behavior is endogenous; developing such models is a promising area for future research.[2]

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 with 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. 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.

We then show how our framework can be applied to study various policy issues. While capital requirements have traditionally been a tool for regulators, recently there have been attempts at introducing liquidity requirements. First, we analyze how liquidity holdings and equity capital interact in achieving bank stability. Again, the results can be quite subtle. As one would expect, liquidity and capital can be substitutes but they can also be complements. If the risky asset pays more than cash in expectation, higher liquidity holdings can decrease the return on the bank's portfolio and therefore would result in the bank requiring more equity capital to achieve the same level of stability.

In the wake of the crisis, a number of policies related to financial intermediation are being reconsidered and new regulations are being designed. We show how our framework can help illustrate the effects of the Basel III Liquidity Coverage Ratio. We show that liquidity requirements can have competing effects on stability, making a bank more resilient to funding shocks but less resilient to shocks to the value of its risky assets.

We also show how the framework can be used to study discount window (DW) policy, where the bank can borrow from the window rather than liquidating the risky asset at a cost. We show that a lenient DW policy that has a lower haircut and a lower interest rate can allow the bank to withstand higher shocks ex post. However, we should mention that any

[2] 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.

such ex post benefit should be weighed against the effect on bank behavior ex ante.

Since the crisis, the difference between collateralized and uncollateralized funding and asset encumbrance has received attention. We use our framework to study the effect of asset encumbrance on bank stability. We show that asset encumbrance can increase insolvency risk when the fraction of encumbered assets is sufficiently high.

Money market mutual funds were at the heart of many important debates since the Reserve Primary Fund "broke the buck" after the failure of Lehman Brothers. We use our framework to analyze different approaches to reforming money market mutual funds. In particular, we analyze the effect of the minimum-balance-at-risk proposal, where creditors can only redeem up to a fraction of their claims early while the remaining fraction becomes a long-term junior debt claim. This increases the resilience of the fund to funding shocks and mitigates the fragility created by the requirement to sustain a net asset value of 1.

In the next two sections, we present our baseline model and examine the determinants of stability within this framework. In section 4, we adapt the model in order to apply it to a collection of current policy issues, including the effects of liquidity regulation, discount window policies, and approaches to reforming money market mutual funds. We offer some concluding remarks in section 5.

2. 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.

2.1 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. 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.[3] 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.[4] The bank's balance sheet thus has the following form:

Assets	Liabilities
m	s
y	ℓ
	e

.

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 debtholder, Assumption 1 states that short-term debt is cheaper than long-term debt ex post if and only if it is rolled over or 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 liquidating the risky asset.

[3] The framework can be easily generalized by allowing these returns to differ.

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

2.2 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,

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

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

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

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.[5] 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,

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

Note that solvency of the bank at $t = 2$ implies that it is also solvent at $t = 1$. We can rewrite condition 3 as

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

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

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

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

6) $$\theta(\alpha) = \frac{s r_s + \ell r_\ell + [1/\tau - r_s]\alpha s - (1/\tau) m}{y} \equiv \theta^*(\alpha)$$

$$\text{for all } \alpha > \frac{m}{s}.$$

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

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

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

[5] 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.

2.3 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? Exhibit 1 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 $\overline{\theta}$, 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 blue line in the exhibit, we say the bank is *conditionally insolvent*. Finally, when θ is larger than $\overline{\theta}$, the bank will be solvent regardless of the actions of short-term debtholders. In this case, we say the bank is *fundamentally solvent*.

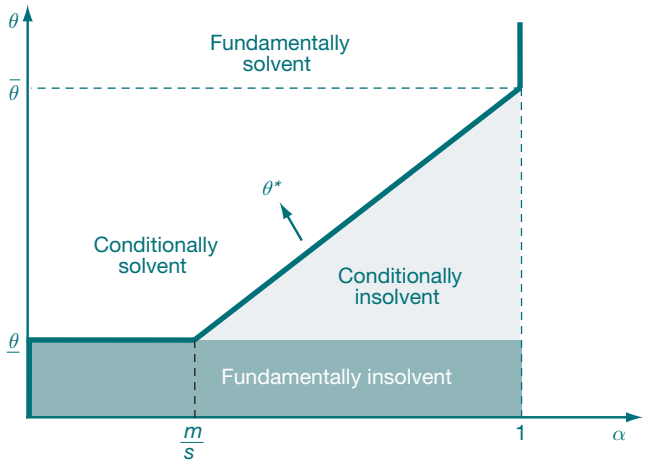
In the sections that follow, we ask how the characteristics of the bank's balance sheet determine the size of the four regions in the diagram in Exhibit 1. We then use this diagram to study how various changes and policy reforms would affect the bank's ability to survive these stress events.

2.4 Discussion

Our goal is to present an analysis of bank stability that can be largely understood graphically, using diagrams like that in Exhibit 1. This approach requires keeping the model simple, so that the relevant information can be conveyed clearly. One of our key simplifying assumptions is that the behavior of short-term debtholders is exogenous to the model. In particular, we assume that the joint probability distribution over the random variables (α, θ) is independent of the bank's balance sheet. It is worth noting, however, that short-term debtholders' incentives are perfectly aligned with the regions in this diagram. Specifically, we show in the appendix that individual short-term debtholders would prefer to roll over their claims at $t = 1$ if and only if the realization of (α, θ) places the bank in one of the two solvency regions in Exhibit 1. In this sense, our analysis is at least broadly consistent with optimizing behavior by debtholders.

There is a large literature that uses equilibrium analysis to study the determinants of creditor behavior in settings similar to the one we study here. The seminal paper by Diamond and Dybvig (1983), for example, shows how multiple equilibria

Exhibit 1
Solvency Regions



can arise in the game played by a bank's depositors—one in which they leave their funds deposited and the bank survives, and another in which they withdraw their funds and the bank fails. The subsequent literature has debated the extent to which historical banking panics were driven by this type of self-fulfilling belief or by real shocks that made banks fundamentally insolvent.[6] Other papers have aimed to uniquely determine creditor behavior within the model in order to pin down the set of states in which insolvency occurs.[7] We do not attempt to contribute to either of these debates here. Instead, we take an intentionally agnostic view of creditor behavior: The fraction of short-term creditors that withdraw funding is random and is determined by factors outside of our simple model. Doing so allows us to focus on our question of interest—the determinants of a bank's ability to survive stress events—with minimal technical complication.

3. Determinants of Bank Stability

In this section, we investigate how the stability of the bank depends on the parameters of the model. We begin by examining how the solvency regions in Exhibit 1 depend on two characteristics of the bank's liabilities: its leverage and the maturity structure of its debt. We then evaluate

[6] See, for example, Gorton (1988), Saunders and Wilson (1996), Allen and Gale (1998), and Ennis (2003).

[7] Contributions on this front include Postlewaite and Vives (1987), Chari and Jagannathan (1988), and Goldstein and Pauzner (2005).

the effects of changing two asset-side characteristics: the liquidation value of the risky asset and the composition of the bank's asset portfolio.

3.1 Leverage

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

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

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

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

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.

Using this modified notation, the cutoff value $\underline{\theta}$ below which the bank is fundamentally insolvent, as defined in equation 5, can be written as.

9) $$\underline{\theta} = \frac{[\sigma r_s + (1-\sigma) r_\ell](1-e) - r_s m}{y}.$$

This cutoff is strictly decreasing in e: More equity (that is, lower leverage) reduces the size of the fundamental insolvency region because there is less total debt that must be repaid. In the region where $\alpha s > m$ and the bank must liquidate assets at $t = 1$, the critical value separating conditional solvency and insolvency defined in equation 6 can be written as

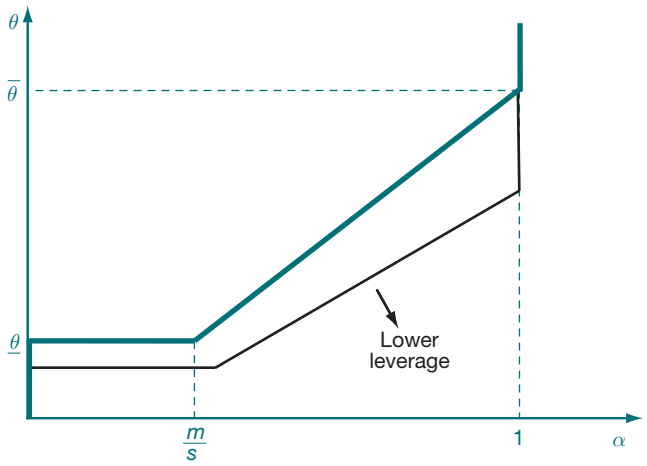
10) $$\theta^*(\alpha) = \frac{[\sigma(\alpha \frac{1}{\tau} + (1-\alpha) r_s) + (1-\sigma) r_\ell](1-e) - \frac{1}{\tau} m}{y}.$$

This cutoff is also strictly decreasing in e, for exactly the same reason. The changes in these two solvency boundaries are depicted in Exhibit 2, where an increase in equity (that is, a decrease in leverage) corresponds to a move from the blue curve to the black one. The exhibit 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.

The sensitivity of the solvency threshold $\theta^*(\alpha)$ to additional withdrawals is given by the derivative

11) $$\frac{d\theta^*(\alpha)}{d\alpha} = \frac{\sigma(\frac{1}{\tau} - r_s)(1-e)}{y}.$$

Exhibit 2
Effect of Leverage



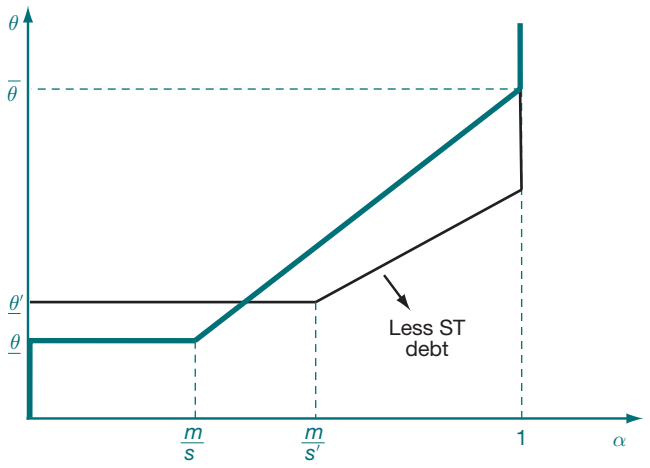
This derivative corresponds to the slope of the line separating the conditionally solvent and conditionally insolvent regions in the exhibit. The slope is positive because additional withdrawals reduce the value of the bank's remaining assets by more than they reduce the value of its remaining liabilities, effectively increasing the debt burden at $t = 2$. Notice, however, that the slope is decreasing in e. 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 depicted in Exhibit 2.

3.2 Maturity Structure of Debt

Next, we study the effects of changing the maturity structure of the bank's debt. Recall from equation 8 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 was given in equation 9. Assumption 1 states that $r_\ell > r_s$ and hence this cutoff is strictly decreasing in σ. In other words, lengthening the average maturity of the bank's debt (by shifting some from short term to long term) makes the bank more likely to become fundamentally insolvent. 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,

Exhibit 3
Effect of Maturity Structure of Debt



in turn, implies that a higher return θ on the risky asset is required to avoid insolvency. This change is illustrated in Exhibit 3, 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.

Exhibit 3 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. This slope was given in equation 11 and—because $1/\tau > r_s$—is easily seen to be increasing in σ. 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.

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.

3.3 Liquidation Value

We now turn to the characteristics of the bank's asset holdings and ask how the solvency and insolvency regions in Exhibit 1 depend on the liquidation value τ. Equation 5 demonstrates that the bound for fundamental insolvency, $\underline{\theta}$, is independent of τ. 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.

Looking next at the threshold for conditional solvency in equation 6, we have

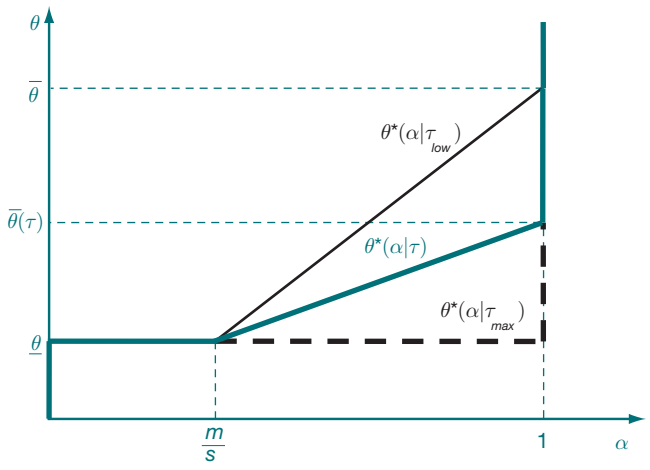
$$\frac{d\theta^{\star}(\alpha)}{d\tau} = -\frac{\alpha s - m}{\tau^2 y} < 0.$$

We know this expression is negative because $\theta^{\star}(\alpha)$ applies only in the region where $\alpha s > m$. This result demonstrates that for all such values of α, the threshold value $\theta^{\star}$ is strictly decreasing in τ.

Exhibit 4 illustrates this result. The blue curve corresponds to the baseline value of τ used in the previous exhibits. If the liquidation value is lower, such as at τ_{low}, the curve shifts to that depicted in black. For values of α smaller than m/s, there is no change in the threshold value $\theta^{\star}$ 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 $\theta^{\star}$ becomes larger (shifts up in the exhibit) because payments made to short-term creditors are now more expensive in terms of period-2 resources. As the exhibit 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 in the exhibit) and the solvency region becomes larger. The extreme case is where $\tau = 1/r_s$, which means that liquidating the long-term asset is not more costly than using cash to pay investors at $t = 1$. In this case, the

Exhibit 4
Effect of Asset Liquidation Value τ



threshold value $\theta^\star$ 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 Exhibit 4—the bank is solvent for values of θ above $\underline{\theta}$ and insolvent for values below $\underline{\theta}$, regardless of the value of α.

3.4 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 $\theta^\star(\alpha)$ for conditional insolvency depend on the composition of the bank's assets. Substituting $y = 1 - m$ into equations 5 and 6, these two critical values become

12) $$\underline{\theta} = \frac{sr_s + \ell r_\ell - r_s m}{1 - m}$$

and

13) $$\theta^*(\alpha) = \frac{s(\alpha\frac{1}{\tau} + (1-\alpha)r_s) + \ell r_\ell - \frac{1}{\tau}m}{1-m}.$$

Looking first at the critical value for fundamental insolvency, the effect of increasing cash and decreasing risky asset holdings by the same amount is given by

$$\frac{d\underline{\theta}}{dm} = \frac{\underline{\theta} - r_s}{1 - m}.$$

This expression is negative, and hence the risk of fundamental insolvency is reduced by a more liquid asset portfolio, if and only if $\underline{\theta} < r_s$. Intuitively, if $\underline{\theta}$ is less than r_s, then at the insolvency boundary, the return on the risky asset is lower than the return on cash, which means that having more cash raises the bank's total return on assets. In this case, insolvency risk is decreasing in liquidity holdings. However, if $\underline{\theta} > r_s$, then the risky asset pays off *more* than cash at the insolvency boundary and holding more cash lowers the bank's total return on assets. In this case, insolvency risk is *increasing* in liquidity holdings.

To see when this latter case of "harmful liquidity" applies, we can use the expression for $\underline{\theta}$ in equation 12 to show that $\underline{\theta} > r_s$ if and only if

$$sr_s + \ell r_\ell > r_s.$$

This condition is more likely to be satisfied, first, when total debt $s + \ell$ is large and second, when ℓ is large relative to s for given total debt. Since we have fixed the size of the balance sheet to $s + \ell + e = 1$, this means situations with high leverage and/or long debt maturity, respectively. The intuition for this result is as follows: Cash has return r_s, which is less than the interest rate on long-term debt r_ℓ. The only way to repay long-term debt is with assets that pay a higher return than cash. A bank with little equity and a large amount of long-term debt therefore increases its risk of fundamental insolvency if it shifts to a more liquid asset portfolio. These two possibilities are illustrated in Exhibit 5 for a bank with more long-term debt and higher leverage (thin black line) and a bank with less long-term debt and lower leverage (thick black line). Both banks share the same initial insolvency boundary (blue) but respond differently to an increase in their cash holdings from m to m'.

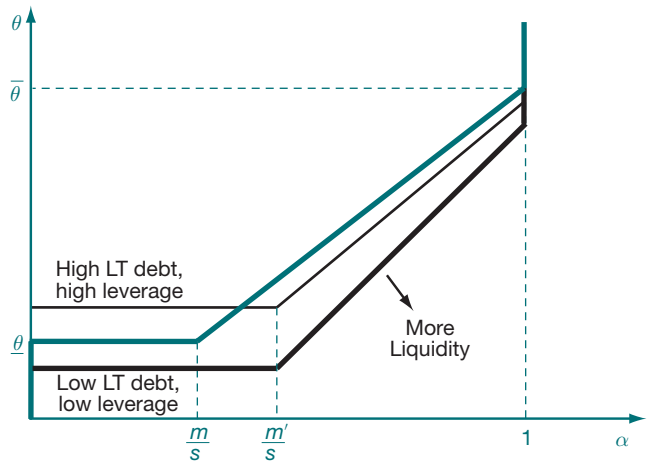
We now turn to the effect of asset composition on the risk of conditional insolvency. Using equation 13, we have

14) $$\frac{d\theta^\star(\alpha)}{dm} = \frac{\theta^\star(\alpha) - \frac{1}{\tau}}{1 - m}.$$

Similar to above, the effect of liquidity on conditional insolvency risk depends on the relative returns of risky assets and cash at the insolvency boundary. However, now the effective return to holding an extra unit of cash is $\frac{1}{\tau} > r_s$ because it saves on the liquidation of long-term assets at $t = 1$. Using the expression for $\theta^\star(\alpha)$ in equation 13, we can show that the derivative in equation 14 is always negative. First, equation 13 implies that $\theta^\star(\alpha) < \frac{1}{\tau}$ holds if and only if

15) $$s\left(\alpha\tfrac{1}{\tau} + (1-\alpha)r_s\right) + \ell r_\ell < \tfrac{1}{\tau}.$$

Exhibit 5
Effect of Liquidity Holdings



Note that the left-hand side of condition 15 is increasing in α, meaning that the condition is harder to satisfy with higher values of α. Setting $\alpha = 1$ and using the fact that $s + \ell + e = 1$, the condition simplifies to

$$\left(\tfrac{1}{\tau} - r_\ell\right)\ell + \tfrac{1}{\tau}e > 0,$$

which holds because Assumption 1 states that $r_\ell < 1/\tau$. Since condition 15 is satisfied for $\alpha = 1$, it is also satisfied for any $\alpha < 1$. We can therefore conclude that $d\theta^\star(\alpha)/\, dm < 0$, that is, extra liquidity unambiguously reduces the risk of conditional insolvency.

Looking at how liquidity holdings affect the slope of the conditional solvency threshold, we have

$$\frac{d\theta^\star(\alpha)}{d\alpha} = \frac{\sigma(\frac{1}{\tau} - r_s)(1 - e)}{1 - m}.$$

Recall that the slope $d\theta^\star(\alpha)/d\alpha$ represents the sensitivity of the solvency threshold $\theta^\star(\alpha)$ to additional withdrawals. Because we are in the region where some long-term assets must be liquidated at $t = 1$, additional withdrawals reduce the value of the bank's remaining assets by more than they reduce the value of its remaining liabilities, increasing its debt burden at $t = 2$. Meeting this higher debt burden requires a higher total return on assets ($\theta(1 - m) + \frac{1}{\tau}m$). Holding a more liquid asset portfolio reduces the sensitivity of this total payoff to the asset payoff θ, meaning that for a given increase in α, a larger increase in θ is required to maintain conditional solvency: The slope gets steeper.

These different effects of liquidity on bank stability are all present in Exhibit 5. Where insolvency is conditional—that is, the boundary has a positive slope—the curve shifts down and becomes steeper for both banks (thin black and thick black lines): 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 (thick black line), but it can also increase it if leverage is high and/or debt maturity is long (thin black line).

3.5 Discussion

The results in this section have shown how the determinants of a bank's ability to survive stress events are often intuitive, but can sometimes be rather 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.

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.

In the next section, we build on the results presented so far to study a range of current policy issues. In each case, we study how a particular change or policy proposal would affect the balance-sheet characteristics of the relevant financial intermediaries. We then derive the corresponding changes in the solvency regions of our diagram and interpret the results.

4. Applications

In this section, we utilize our framework to analyze a series of current policy issues. First, we analyze the effect of liquidity and capital on stability and the trade-off between the two. We then study the effects of policy tools such as the Liquidity Coverage Ratio and discount window lending. Another issue we analyze is the effect of encumbered assets on bank stability. As a specific intermediation structure, we study asset-backed commercial paper structures, which illustrate an interesting case with their asset structure and heavy reliance on short-term debt. Finally, we analyze money market mutual funds and various policy proposals to make them more stable.

4.1 Liquidity versus Capital

Traditionally, capital requirements have been the main tool of bank regulators. Since the financial crisis, liquidity requirements have received increased attention. Further below we analyze a specific liquidity requirement, the Liquidity Coverage Ratio. But first, we study more generally how liquidity holdings (on the asset side) and equity capital (on the liability side) interact in our framework and whether they are substitutes or complements.

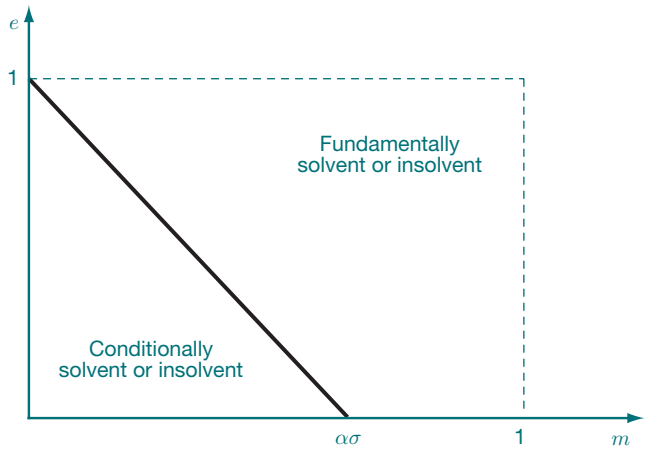
As in sections 3.1 and 3.4, we normalize the size of the bank's balance sheet to 1 so that $y + m = 1$ on the asset side and $s + \ell + e = 1$ on the liability side, and then denote the fraction of short-term debt by $\sigma \equiv s/(s + \ell)$. We now take α and θ as given and study bank solvency for different combinations of m and e. Note the difference from the analysis before, where we took m and e as given and studied bank solvency for different combinations of α and θ.

As before, one of two solvency conditions will be relevant, depending on whether the bank is facing fundamental insolvency or conditional insolvency. The distinction is whether the bank has to liquidate assets to satisfy withdrawals or not, that is, $\alpha\sigma(1 - e) \gtrless m$. This condition divides the m-e space into two regions with the dividing line given by:

$$e = 1 - \tfrac{1}{\alpha\sigma} m.$$

Exhibit 6 illustrates the two regions. For combinations (m, e) above and to the right of the line, the bank has enough cash to pay all withdrawing creditors so it is either fundamentally solvent or fundamentally insolvent. For combinations (m, e) below and to the left of the line, the bank is forced to liquidate assets so it is either conditionally solvent or conditionally insolvent.

Exhibit 6
Different Regions in *m*-*e* Space



We start with the region of conditional solvency/insolvency where the solvency constraint is given by:

$$\theta(1 - m) + \tfrac{1}{\tau} m \geq \left[\sigma\left(\alpha\tfrac{1}{\tau} + (1 - \alpha)r_s\right) + (1 - \sigma)r_\ell\right](1 - e).$$

To depict this solvency threshold in the m-e space, we solve for e:

$$e = 1 - \frac{\theta(1 - m) + \frac{1}{\tau} m}{\sigma(\alpha\frac{1}{\tau} + (1 - \alpha)r_s) + (1 - \sigma)r_\ell}.$$

For a given level of withdrawals α and a given asset payoff θ, this line is the solvency threshold in terms of liquidity m and capital e. Therefore, it represents the trade-off between different combinations of liquidity and capital that keep the bank on the solvency threshold. To illustrate this trade-off, we note that the slope of the line is:

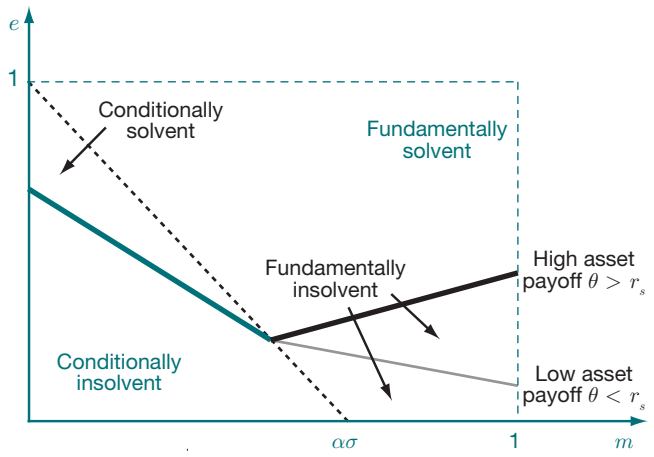
$$\frac{de}{dm} = \frac{\theta - \frac{1}{\tau}}{\sigma(\alpha\frac{1}{\tau} + (1 - \alpha)r_s) + (1 - \sigma)r_\ell} < 0.$$

The slope is negative since $\theta\tau < 1$ by Assumption 2. This implies that liquidity and capital are substitutes: An increase in liquidity holdings can compensate for a decrease in capital while maintaining the same level of bank stability. The blue line in Exhibit 7 represents this threshold between conditional solvency and conditional insolvency.

We now turn to the region of fundamental solvency or insolvency. Here the solvency constraint is given by:

$$\theta(1 - m) + r_s m \geq [\sigma r_s + (1 - \sigma)r_\ell](1 - e).$$

Exhibit 7
Trade-Off Liquidity versus Capital



Again, we solve for e to depict the solvency threshold in the m-e space:

$$e = 1 - \frac{\theta(1-m) + r_s m}{\sigma r_s + (1-\sigma) r_\ell}.$$

To illustrate the trade-off between liquidity and capital, we derive the slope of the solvency threshold:

$$\frac{de}{dm} = \frac{\theta - r_s}{\sigma r_s + (1-\sigma) r_\ell}.$$

The sign of this slope depends on the relative size of θ and r_s. For low asset payoffs $\theta < r_s$, the slope is negative so that liquidity and capital are substitutes as in the region of conditional solvency/insolvency. The thin black line in Exhibit 7 illustrates this trade-off.

For any asset payoff $\theta > r_s$, however, the slope is positive as illustrated by the thick black line in Exhibit 7. This implies that liquidity and capital are complements, so an increase in liquidity holdings requires an increase in capital for the bank to maintain the same level of stability. The intuition for this case is similar to the situation of "harmful liquidity" in section 3.4. If the assets pay off more than cash, higher liquidity holdings reduce the bank's total payoff and therefore weaken its solvency position. To compensate, the bank has to hold more capital.

4.2 Liquidity Coverage Ratio

The new regulatory framework proposed by Basel III introduces new liquidity requirements for banks. In particular, the Liquidity Coverage Ratio requires banks to hold sufficient high-quality liquid assets to cover their total net cash outflows over thirty days under a stress scenario.

In this section, we analyze the potential effects of the Liquidity Coverage Ratio on bank stability. In particular, we focus on a liquidity requirement where banks are required to hold high-quality liquid assets equal to at least a fraction γ of their short-term liabilities s, that is, $m \geq \gamma s$. Since holding liquid assets entails opportunity costs in terms of forgone investment opportunities in the risky asset, we assume that this requirement will be binding, that is, banks will hold $m = \gamma s$ on their balance sheet. We analyze the effect of making the liquidity requirement more strict, that is, increasing γ. This would qualitatively have a similar effect as increasing liquidity holdings m, as analyzed in section 3.4. In particular, we obtain for the fundamental insolvency threshold:

$$\underline{\theta} = \frac{s r_s (1-\gamma) + \ell r_\ell}{1 - \gamma s},$$

which implies

$$\frac{d\underline{\theta}}{d\gamma} = \frac{s(\underline{\theta} - r_s)}{1 - \gamma s}.$$

Analogous to section 3.4, if the critical value $\underline{\theta}$ is less than the return on cash r_s, then the risk of fundamental insolvency is decreasing in the liquidity requirement; at the insolvency boundary, the assets pay off less than cash, so having more cash is better than having more assets. However, if instead $\underline{\theta} \geq r_s$, then fundamental insolvency risk is *increasing* in the liquidity requirement; the assets pay off *more* than cash at the insolvency boundary, so having more cash is *worse* than having more assets. As discussed in section 3.4, this possibility of liquidity regulation being harmful is more likely for institutions with high leverage and/or long debt maturity.

In the case of insufficient cash to pay for withdrawals and therefore liquidation ($\alpha s \geq m$), the critical value for conditional solvency is

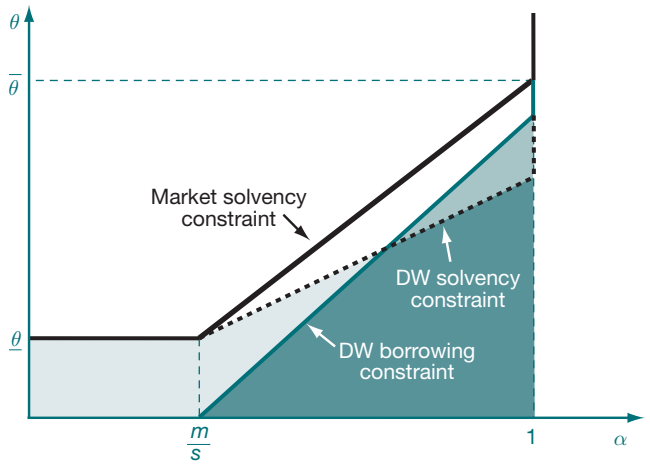
$$\theta^*(\alpha) = \frac{s(\alpha \frac{1}{\tau} + (1-\alpha) r_s) + \ell r_\ell - \frac{1}{\tau}\gamma s}{1 - \gamma s}.$$

The overall effect of γ on $\theta^*(\alpha)$ is again most clearly illustrated by the following:

$$\frac{d\theta^*(\alpha)}{d\gamma} = \frac{s(\theta^*(\alpha) - \frac{1}{\tau})}{1 - \gamma s}.$$

As in section 3.4, we can show that $\theta^*(\alpha) < \frac{1}{\tau}$, and therefore the risk of conditional insolvency is unambiguously reduced by stricter liquidity requirements. Finally, looking at the slope of $\theta^*(\alpha)$,

Exhibit 8
Discount Window Constraints



$$\frac{d\theta^*(\alpha)}{d\alpha} = \frac{s(\frac{1}{\tau} - r_s)}{1 - \gamma s},$$

we see that making the liquidity requirement more strict (increasing γ) strictly *increases* the sensitivity of the critical value to withdrawals. The effects are analogous to the effects of increasing m, which are illustrated in Exhibit 5.

4.3 Discount Window

Traditionally, central banks have attempted to address banks' liquidity problems with discount window lending, where the principle of lending to banks that are solvent but illiquid is set out by Bagehot (1873). In our model, this corresponds to banks in the conditional insolvency region that would be solvent if fewer of their creditors demanded liquidity. An interesting question is whether discount window lending can eliminate the entire conditional insolvency region.

We assume that in period 1 a bank can borrow from the central bank's discount window at an interest rate $r_d \geq r_s$, but has to pledge assets as collateral subject to a haircut h_d. Since the DW does not address issues of fundamental insolvency, the threshold $\underline{\theta}$ remains unchanged from the benchmark setting:

$$\underline{\theta} = \frac{sr_s + \ell r_\ell - mr_s}{y}.$$

When facing conditional insolvency, that is, once the bank runs out of cash ($\alpha s > m$), it can access the DW to borrow the shortfall $d = \alpha s - m$. However, due to the haircut h_d, DW borrowing is constrained:

$$d \leq (1 - h_d)\theta y.$$

Substituting in for d, this is a constraint on α and θ:

16) $$\alpha s - m \leq (1 - h_d)\theta y.$$

As long as the shortfall is not too large, the bank can use the DW loan to pay all withdrawals in period 1.

In period 2, the bank receives back the assets it pledged but has to pay off the DW loan in addition to the long-term creditors and the remaining short-term creditors. The solvency condition in period 2 is therefore:

$$\theta y \geq (1 - \alpha)\, sr_s + \ell r_\ell + dr_d.$$

Substituting in for d, this condition becomes:

17) $$\theta y \geq sr_s + \ell r_\ell - mr_d + (r_d - r_s)\alpha s.$$

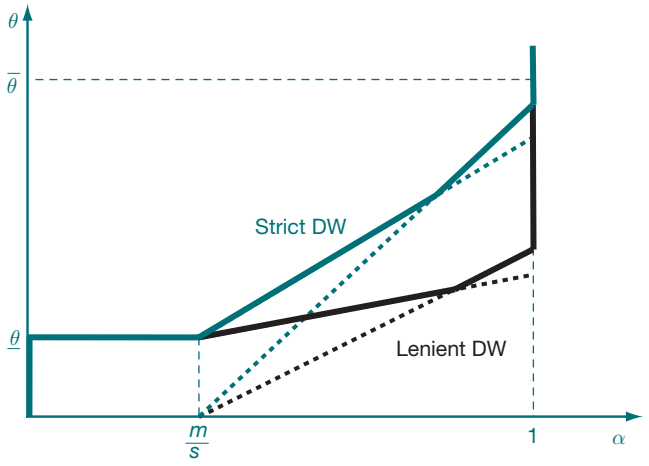
Hence, the DW entails two constraints on the rate of withdrawals α and the asset return θ. Constraint 16 is a period-1 constraint since it limits the DW borrowing capacity in period 1 when the bank has to meet withdrawals. If α is too high or θ is too low so that constraint 16 is violated, the bank cannot survive period 1 even if it pledges all its assets to the DW. This borrowing constraint is represented by the blue line in Exhibit 8. Only for combinations (α, θ) above and to the left of the blue line can the bank meet all withdrawals in period 1 with cash and DW borrowing.

Constraint 17 is a period-2 constraint since it gives the solvency condition in period 2 which is similar to the standard case. The key difference is that with DW access the bank regains the assets it pledged as collateral but has to pay off an additional loan. This solvency constraint is represented by the dashed line in Exhibit 8. The DW solvency constraint is very similar to the market solvency constraint in the benchmark case. The difference is that using the DW, the bank does not have to sell assets but incurs an additional liability. The solvency constraint imposed by the DW is flatter than the one imposed by the market—implying a larger solvency region—as long as $r_d < \frac{1}{\tau}$, that is, as long as the DW interest rate is small relative to the liquidation discount.

The combination of both DW constraints separates the solvency from the insolvency region with the stricter constraint forming the boundary at every point. To the left of the intersection of the two constraints the solvency constraint is binding while to the right of the intersection the borrowing constraint is binding.

Exhibit 9 compares two different DW policies $(h_d,\ r_d)$ and $(h_d',\ r_d')$; the first policy is stricter while the second policy is

Exhibit 9
Comparison of Discount Window Policies



more lenient: $h_d > h_d'$ and $r_d > r_d'$. The lower haircut and lower interest rate of the more lenient policy imply flatter slopes for both the borrowing constraint and the solvency constraint. The solvency region is therefore strictly larger for the more lenient policy.

4.4 Asset Encumbrance

Since the financial crisis, the difference between collateralized and uncollateralized funding has received increased attention.[8] We can use our framework to study the effect of asset encumbrance on bank stability. For simplicity, we assume that the bank has only short-term debt, some of which is collateralized debt c, the remainder is uncollateralized debt u. Both have the same interest rate $r_1 = 1$ between $t = 0$ and $t = 1$ and potentially different interest rates r_c and r_u, respectively, between $t = 1$ and $t = 2$. On the asset side, we assume that the bank only holds long-term assets, $y = 1$, a fraction $x \in [0, 1]$ of which is encumbered as collateral for the debt c. The bank's balance sheet therefore has the following form:

Assets	Liabilities
x	c
$1 - x$	u
	e

[8] See Perotti (2010) for a discussion of the risks originating in collateralized funding. For theories on the use of collateral see, for example, Bester (1985), Geanakoplos (2003), or Hart and Moore (1994).

For a given haircut h, the fraction x of assets that is encumbered is determined by the following condition:

$$E[\theta](1 - h)x = cr_c, \tag{18}$$

so that the expected value of the collateral in period 0 net of the haircut has to be sufficient to cover the secured creditors' claim. As the key feature of encumbered assets, we assume that they are held by the collateralized creditors and can therefore not be used by the bank to satisfy payouts to uncollateralized creditors.

Denoting the fraction of uncollateralized lenders that withdraw at $t = 1$ by α, the bank's solvency constraint in $t = 2$ becomes:

$$\theta(1 - x) - \alpha u\tfrac{1}{\tau} \geq (1 - \alpha)ur_u.$$

This condition states that the payoff of the unencumbered assets net of $t = 1$ liquidations has to be sufficient to repay the remaining uncollateralized creditors at $t = 2$.

Substituting in for x using equation 18, we can solve for the critical value:

$$\theta^\star(\alpha) = \frac{\alpha u\frac{1}{\tau} + (1 - \alpha)ur_u}{1 - \frac{cr_c}{E[\theta](1 - h)}}.$$

We see that the critical value $\theta^\star(\alpha)$ is increasing in the haircut h: With a higher haircut, more of the bank's assets are encumbered. Effectively, there is less "implicit collateral" for the unsecured creditors, which increases the risk of bank failure.

Keeping in mind that $u = 1 - e - c$, we can differentiate the critical value $\theta^\star(\alpha)$ with respect to the amount of collateralized debt to get:

$$\frac{d\theta^\star(\alpha)}{dc} = \frac{-(\alpha\tfrac{1}{\tau} + (1 - \alpha)r_u)\left(1 - \frac{(c + u)r_c}{E[\theta](1 - h)}\right)}{\left(1 - \frac{cr_c}{E[\theta](1 - h)}\right)^2}.$$

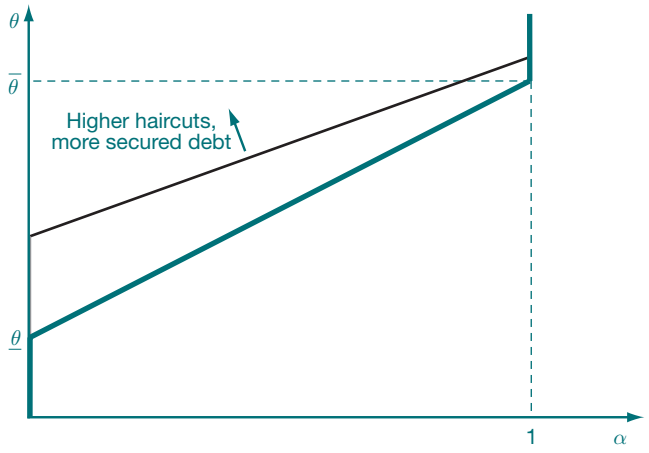
Substituting in $E[\theta](1 - h) = cr_c/x$ from equation 18, we can simplify the expression and arrive at:

$$\frac{d\theta^\star(\alpha)}{dc} = \frac{(\alpha\tfrac{1}{\tau} + (1 - \alpha)r_u)}{(1 - x)^2}\left(x\frac{u}{c} - (1 - x)\right)$$

$$> 0 \Leftrightarrow \frac{x}{1 - x} > \frac{c}{u}.$$

This implies that replacing uncollateralized funding with collateralized funding increases the critical value and therefore insolvency risk if and only if the ratio of encumbered to unencumbered assets is greater than the ratio of collateralized to uncollateralized funding. The reason is that

Exhibit 10
Effect of Asset Encumbrance



the explicit overcollateralization of secured funding due to haircuts reduces the implicit collateral for unsecured funding. Exhibit 10 illustrates the effects of secured funding for bank stability; for higher haircuts and/or greater reliance on secured funding, the solvency region shrinks (the curve shifts up).

4.5 Asset-Backed Commercial Paper Structures

Asset-backed commercial paper is a form of secured, short-term borrowing. Prior to the crisis, ABCP was widely issued by off-balance-sheet conduits of large financial institutions. These conduits increasingly held long-term assets, thus becoming significant vehicles of maturity transformation. In order to enhance their attractiveness, they relied on both credit and liquidity guarantees, typically provided by the sponsoring institutions. The ABCP market experienced significant distress starting in August 2007 as a result of increasing uncertainty about the quality of assets backing commercial paper issuance. This enhanced uncertainty, coupled with the pronounced maturity mismatch of conduits' balance sheets, triggered a run on their liabilities (Covitz, Liang, and Suarez 2013).

Here we use our framework to illustrate the insolvency risk associated with ABCP structures. The structures typically have long-term (risky) assets backing their short-term funding. Hence, the balance sheet of an ABCP conduit would look like:

Assets	Liabilities
$y = 1$	$s = 1$
	$\ell = 0$
	$e = 0$

Furthermore, the ABCP conduit would have a credit and/or liquidity enhancement from a sponsoring institution. First, we focus on the ABCP conduit solely, leaving aside the effect of the credit and liquidity enhancements.

Note that the ABCP conduit does not hold any cash, so that all early claims should be paid by liquidating the risky asset. Using our framework, we can show that the ABCP conduit is solvent at $t = 2$ if and only if $\theta(1 - \frac{\alpha}{\theta\tau}) \geq (1 - \alpha)r_s$, which gives us

$$\theta \geq (1 - \alpha)r_s + \frac{\alpha}{\tau} \equiv \theta^*(\alpha).$$

If all creditors roll over their debt at $t = 1$, that is, when $\alpha = 0$, the ABCP conduit is solvent when $\theta \geq r_s \equiv \underline{\theta}$. If no creditor rolls over its debt at $t = 1$, that is, when $\alpha = 1$, we obtain $\theta^*(1) = \frac{1}{\tau} \equiv \overline{\theta}$. Note that the ABCP structure does not hold any cash ($m = 0$). Hence, we do not observe a flat region, as in the case of an intermediary that holds some cash, where $\theta = \underline{\theta}$ for $\alpha \in [0, m]$. This is all illustrated in Exhibit 11.

As argued, ABCP conduits would typically have credit and/or liquidity enhancements from sponsoring institutions, which would make the liquidation of the assets less costly. For example, in a case where the sponsor guarantee is strong, the costs associated with liquidations can be completely eliminated, that is, $\tau = \frac{1}{r_s}$, so that there is only the risk of fundamental insolvency. Hence, the strength of the guarantee affects τ, which has already been analyzed in section 3.3.

4.6 Money Market Mutual Funds

Money market mutual funds typically attract highly risk-averse investors. Their liabilities are mostly short term that can be claimed at short notice, so that $s = 1$. On the asset side, they have mostly safe assets, that is, the asset side of the balance sheet would have a high value for m and a relatively small value for y. An important feature of an MMF is that when it states a share price lower than $1.00, the fund "breaks the buck." Hence, our analysis focuses on when an MMF breaks the buck, which would be analogous to a bank being insolvent in the benchmark case.[9]

Using our benchmark framework, we can find the threshold values for θ as follows. Suppose that a fraction α of creditors redeem at $t = 1$, whereas the remaining $1 - \alpha$ wait until $t = 2$. The fund can pay all creditors one unit and it does not break the buck when $\theta y + \chi(\alpha)(m - \alpha) \geq 1 - \alpha$.

[9] In a recent paper, Parlatore Siritto (2012) develops a general equilibrium model of MMFs and analyzes the effect of recently proposed regulations on liquidity provided by these funds and their fragility.

Exhibit 11
Stability of Asset-Backed Commercial Paper Structures

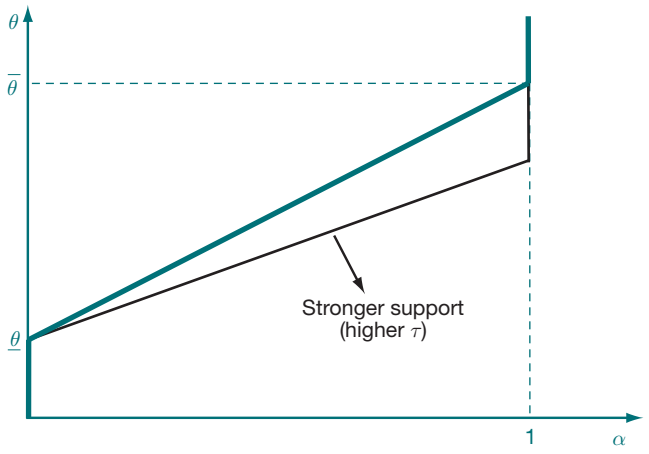
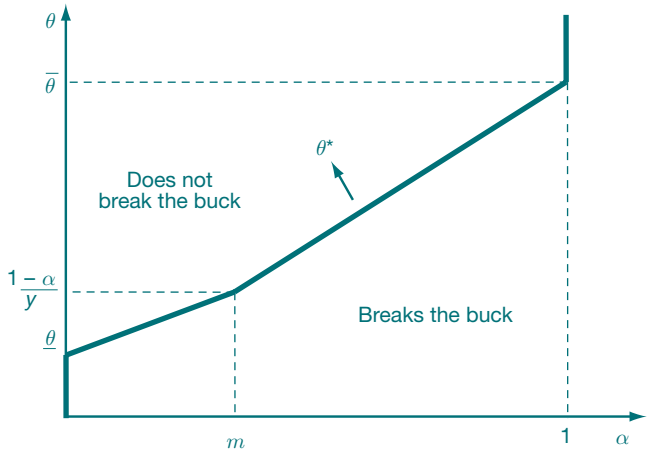


Exhibit 12
Money Market Mutual Fund Regions for "Breaking the Buck"



Note the difference between this case and an intermediary's solvency constraint, where the MMF does not break the buck when it can pay all creditors a minimum gross return of 1, whereas the intermediary has to pay the promised interest to the creditors to be solvent. This gives us

$$\theta \geq \frac{1-\alpha-\chi(\alpha)(m-\alpha)}{y} \equiv \theta^*(\alpha).$$

If $\alpha \leq m$, the fund can pay all early claims from its cash holdings so that $\chi(\alpha) = r_s$. For $\alpha > m$, the fund does not have enough cash for all early claims and needs to liquidate some of the risky asset so that $\chi(\alpha) = 1/\tau$. Hence, we obtain

$$19) \qquad \theta^*(\alpha) \equiv \begin{cases} \dfrac{1-\alpha-r_s(m-\alpha)}{y} \text{ for } \alpha \in [0,m] \\ \\ \dfrac{1-\alpha-(1/\tau)(m-\alpha)}{y} \text{ for } \alpha \in (m,1] \end{cases},$$

which is illustrated in Exhibit 12.[10]

Note that if all creditors redeem at $t = 1$, that is, for $\alpha = 1$we have $\theta^*(1) = \frac{1}{\tau} \equiv \overline{\theta}$. If the realized return from the risky asset is high enough, that is, for $\theta \geq \overline{\theta}$, the fund never breaks the buck at $t = 2$ regardless of the actions creditors take at $t = 1$.

Reform Proposals. While MMFs have performed well historically and are appreciated by investors for their stability, during the recent crisis the Reserve Primary Fund broke the buck after the failure of Lehman Brothers. This, in turn, affected financial markets significantly. Since then, there has been some debate about and reform proposals to increase the stability of MMFs. McCabe et al. (2012) develop a reform proposal for MMFs called "minimum balance at risk." The proposal implies that a creditor can only redeem up to a fraction $1-\mu$ of the claims early and the remaining fraction μ becomes a junior debt claim at $t = 2$ (or an equity claim, as we analyze in this section). In that case, the balance sheet of the fund effectively looks as follows:

Assets	Liabilities
m	$s = 1-\mu$
y	$\ell = \mu$
	$e = 0$

.

At $t = 1$, the realization of withdrawals is $\alpha(1-\mu)$. At $t = 2$, the creditors that redeemed at $t = 1$ are owed $\ell_J = \alpha\mu$, where ℓ_J represents junior debt. The creditors that did not redeem at $t = 1$ are owed $\ell_S = 1-\alpha$, where ℓ_S represents senior debt. The balance sheet of the fund looks as follows after the withdrawal decisions at $t = 1$:

Assets	Liabilities
m	$s = \alpha(1-\mu)$
y	$\ell_S = 1-\alpha$
	$\ell_J = \alpha\mu$
	$e = 0$

[10] Exhibit 12 illustrates the case where $mr_s > 1$.

The fund does not break the buck at $t = 2$ if and only if it can pay a return of 1 to all creditors, that is, when $\theta y + \chi(\alpha)(m - \alpha(1-\mu)) \geq \alpha\mu + 1 - \alpha$, which gives us

$$\theta^*_R(\alpha) = \frac{\alpha\mu + 1 - \alpha - \chi(\alpha)(m - \alpha(1-\mu))}{y}.$$

If $\alpha(1-\mu) \leq m$, the fund can pay all of the early claims from its cash holdings so that $\chi(\alpha) = r_s$. When $\alpha(1-\mu) > m$, the fund needs to liquidate some of its risky assets so that $\chi(\alpha) = 1/\tau$. Hence, we obtain

$$20) \qquad \theta^*_R(\alpha) \equiv \begin{cases} \dfrac{\alpha\mu + 1 - \alpha - r_s(m - \alpha(1-\mu))}{y} \\ \qquad \text{for } \alpha \in [0, \frac{m}{1-\mu}] \\ \dfrac{\alpha\mu + 1 - \alpha - (1/\tau)(m - \alpha(1-\mu))}{y} \\ \qquad \text{for } \alpha \in (\frac{m}{1-\mu}, 1] \end{cases},$$

which is illustrated by the black boundary in Exhibit 13, along with the blue original boundary for the MMFs characterized in equation 19.

Next, we analyze the effect of the reform proposal on the stability of MMFs. Note that the region over which the fund can use its cash holdings for the early withdrawals is larger in this case since $m < \frac{m}{1-\mu}$. We can also show that

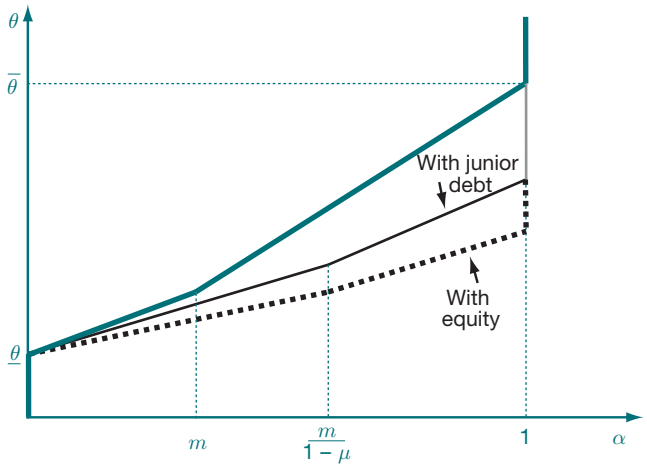
$$\theta^*_R(\alpha) = \theta^*(\alpha) - \frac{\alpha\mu(\chi(\alpha) - 1)}{y} < \theta^*(\alpha).$$

In the region where $\alpha \in (m, \frac{m}{1-\mu}]$, the slope of θ^*, which is $1/\tau$, is larger than the slope of θ^*_R, which is r_s. Hence, with the reform proposal the region in which the MMF breaks the buck shrinks, as illustrated in Exhibit 13. The reason for this is that the reform proposal limits the amount that can be redeemed early and hence mitigates the adverse effect of early withdrawals by lowering the amount of the risky asset the fund has to liquidate. This, in turn, makes it less likely that the fund breaks the buck.

Equity versus Junior Debt. A variant of the proposal is that the creditors that redeem at $t = 1$ become equityholders, rather than junior debtholders, at $t = 2$. In that case, the balance sheet looks as follows after the withdrawal decisions:

Assets	Liabilities
m	$s = \alpha(1-\mu)$
y	$\ell = 1 - \alpha$
	$e = \alpha\mu$

Exhibit 13
Money Market Mutual Fund Reform Proposals with Junior Debt and Equity



Hence, the withdrawals at $t = 1$ help create an equity buffer, which makes it harder for the fund to break the buck. The fund does not break the buck at $t = 2$ if and only if

$$\theta \geq \frac{1 - \alpha - \chi(\alpha)(m - \alpha(1-\mu))}{y} \equiv \theta^*_E(\alpha).$$

Note that if $\alpha(1-\mu) \leq m$, the fund can pay all of its early claims from its cash holdings so that $\chi(\alpha) = r_s$. When $\alpha(1-\mu) > m$, the fund needs to liquidate some of its risky assets so that $\chi(\alpha) = 1/\tau$. Hence, we obtain

$$21) \qquad \theta^*_E(\alpha) \equiv \begin{cases} \dfrac{1 - \alpha - r_s(m - \alpha(1-\mu))}{y} \\ \qquad \text{for } \alpha \in [0, \frac{m}{1-\mu}] \\ \dfrac{1 - \alpha - (1/\tau)(m - \alpha(1-\mu))}{y} \\ \qquad \text{for } \alpha \in (\frac{m}{1-\mu}, 1] \end{cases},$$

which is illustrated by the dashed boundary in Exhibit 13. The important difference between this proposal and the first proposal, where the creditors that redeem at $t = 1$ become junior debtholders at $t = 2$, is that in this case early withdrawals generate an equity cushion so that the region over which the fund does not break the buck widens. In particular, we have

$$\theta^*_E(\alpha) = \theta^*_R(\alpha) - \frac{\alpha\mu}{y}.$$

Hence, the region over which the fund breaks the buck shrinks further under the second proposal.

5. Conclusion

During the recent financial crisis, we observed disruptions and the near disappearance of important markets, record-high borrowing rates, haircuts almost reaching 100 percent, significant shortening of maturities, and institutions almost unable to borrow even against high-quality collateral. We are yet to fully understand the exact determinants of these disruptions. In this article, we present a simple analytical framework to tackle this important question. The framework provides an analytical and rigorous, yet easily applicable, tool to analyze the sources of fragility and the effect of various characteristics of funding structures on financial stability. Hence, it can be used to illustrate the trade-offs that may assist policymakers in forming their views about appropriate ways to approach regulatory reform and to evaluate various policy options in terms of their consequences for financial stability.

Appendix

We examine the rollover decision of an individual short-term debtholder. At $t = 1$, each agent observes the realized value of θ and anticipates some behavior of other short-term creditors, as summarized by the value of α.[11] The agent then decides whether or not to roll over its debt; the payoffs associated with each decision are:

	Roll Over	Not Roll Over
Solvent	r_s	1
Insolvent at $t = 2$	$(1-\phi)\left[\frac{\theta y + \chi(\alpha)(m-\alpha s)}{(1-\alpha)s r_s + \ell r_\ell}\right] r_s$	1
Insolvent at $t = 1$	0	$\frac{m+\tau\theta y}{\alpha s}$

If the bank is solvent, the agent would clearly prefer to roll over its claim and earn the return $r_s > 1$. If the bank is insolvent at $t = 1$, the agent would receive nothing if it rolled over its debt, so the agent would clearly prefer to redeem its claim at $t = 1$ and receive in expectation a pro-rata share of the bank's liquidated assets. Things are slightly more subtle in the intermediate case, where the bank survives at $t = 1$ but is insolvent at $t = 2$. In this case, the agent would receive the face value of its claim at $t = 1$ if the agent does not roll over. If the agent does roll over, it receives a pro-rata share of the bank's matured assets at $t = 2$, after the bankruptcy costs have been paid. If we assume that $\phi > 1 - \frac{1}{r_s}$, then this return is always smaller than 1, which gives us the following result:

Proposition 1: For $\phi > 1 - \frac{1}{r_s}$, *a short-term debtholder will choose to roll over its claim if and only if* (α, θ) *is such that the bank is solvent in all periods.*

[11] To keep things simple, we assume that an agent anticipates a particular value of α rather than having a belief represented by a probability distribution over different values of α.

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