CHAPTER 12

Liquidity and Leverage

One of the most important aspects of the subprime crisis was the sudden reluctance of financial institutions to lend money, and the increased reluctance to borrow on the part of financial as well as nonfinancial businesses and households, a development called "The Great Deleveraging." It contributed to the rapid decline in the market prices of risky assets and was self-perpetuating. In this chapter, we try to disentangle the concepts of liquidity and leverage. We give definitions of each, showing how they are related, and, in Chapter 14, explain their role in financial crises.

The term "liquidity" has been defined in myriad ways that ultimately boil down to two properties, *transactions liquidity*, a property of assets or markets, and *funding liquidity*, which is more closely related to creditworthiness. Transaction liquidity is the property of an asset being easy to exchange for other assets. Most financial institutions are heavily leveraged; that is, they borrow heavily to finance their assets, compared to the typical nonfinancial firm. Funding liquidity is the ability to finance assets continuously at an acceptable borrowing rate. For financial firms, many of those assets include short positions and derivatives.

As with "liquidity," the term "liquidity risk" is used to describe several distinct but related phenomena:

Transaction liquidity risk is the risk of moving the price of an asset adversely in the act of buying or selling it. Transaction liquidity risk is low if assets can be liquidated or a position can be covered quickly, cheaply, and without moving the price "too much." An asset is said to be liquid if it is "near" or a good substitute for cash. An asset is said to have a *liquidity premium* if its price is lower and expected return higher because it isn't perfectly liquid. A market is said to be liquid if market participants can put on or unwind positions quickly, without excessive transactions costs and without excessive price deterioration.

Balance sheet risk or funding liquidity risk. Funding liquidity risk is the risk that creditors either withdraw credit or change the terms on which it is granted in such a way that the positions have to be unwound and/or are no longer profitable. Funding liquidity can be put at risk because the borrower's credit quality is, or at least perceived to be, deteriorating, but also because financial conditions as a whole are deteriorating.

Systemic risk refers to the risk of a general impairment of the financial system. In situations of severe financial stress, the ability of the financial system to allocate credit, support markets in financial assets, and even administer payments and settle financial transactions may be impaired.

These types of liquidity risk interact. For example, if a counterparty increases collateral requirements or otherwise raises the cost of financing a long position in a security, the trader may have to unwind it before the expected return is fully realized. By shrinking the horizon of the trade, the deterioration of funding liquidity also increases the transaction liquidity risk. The interaction also works the other way. If a leveraged market participant is perceived to have illiquid assets on its books, its funding will be in greater jeopardy.

We begin our discussion of liquidity risk by discussing its credit aspect, funding liquidity risk, and the ways in which this risk can manifest itself, in more detail. Later sections discuss transactions liquidity. The discussion of liquidity risk will provide important background for understanding financial panics, the subject of Chapter 14.

12.1 FUNDING LIQUIDITY RISK

12.1.1 Maturity Transformation

Funding liquidity risk arises for market participants who borrow at short term to finance investments that require a longer time to become profitable. Many traders and investors, such as banks, securities firms, and hedge funds, are largely short-term borrowers, so their capacity to maintain long-term positions and their flexibility when circumstances or expectations change is limited. The balance-sheet situation of a market participant funding a longer-term asset with a shorter-term liability is called a *maturity mismatch*.

Managing maturity mismatches is a core function of banks and other financial intermediaries. All financial and economic investment projects take time, in some cases a very long time, to come to fruition. To provide the needed capital, financial intermediaries effect a *maturity transformation* and

possibly also a *liquidity transformation*; they obtain shorter-term funding and provide longer-term funding to finance projects. Funding longer-term assets with longer-term debt is called *matched funding*.

Intermediaries engage in maturity mismatch because it is generally profitable. Every market participant has a *cost of capital*, the rate of return on all its liabilities, including equity. The most "expensive" capital is equity, because it takes the most risk; it has no contractually stipulated remuneration and is the first liability to bear losses. To convince providers of capital to place equity with a firm, they must be promised a high expected return. At the other end of the spectrum, short-term debt instruments generally have lower required returns and contribute less to the cost of capital, as long as the borrower's credit risk is perceived to be low.

The spread between the interest intermediaries pay—their funding cost—and the interest they earn is called the *net interest margin*. Yield curves are typically upward sloping. Intermediaries therefore have a powerful incentive to introduce maturity mismatches into their balance sheets. In the aftermath of economic downturns and financial crises, the yield curve typically has a sharper upward slope, increasing net interest margin, which becomes an important part of banks' rebuilding following the downturn.

Because short-term rates are generally lower than long-term rates, there is a powerful incentive to borrow short-term if possible. Funding long-term assets with short-term debt exposes an intermediary to *rollover risk*, the risk that the short-term debt cannot be refinanced, or can be refinanced only on highly disadvantageous terms. In a rollover risk event, cash flow can become negative. For example, an investor may be financing bonds with short-term borrowing at a positive spread. If the debt cannot be refinanced at an interest rate below the bond yield, negative cash flow and losses result.

Funding conditions can change rapidly. A firm or investor can, after a long period of short-term funding with positive cash flow, suddenly find himself in a negative cash flow situation from which there is no obvious escape if short-term funding is suddenly closed to him or its costs escalate. Because of this binary character, rollover risk is sometimes called "cliff risk." The liquidity condition of a market participant relying heavily on short-term funding can reach a state of distress very quickly.

12.1.2 Liquidity Transformation

Intermediaries earn net interest margin from maturity transformation because short-term debt generally carries lower interest than longer-term debt. Very short-term yields—money-market rates—are almost invariably lower. But the short-term funding of an intermediary is the short-term asset of the lender, and may provide liquidity and payment services to the investor as well as a flow of interest payments. Money-market instruments such

as short-term interbank loans to sound banks, commercial paper of creditworthy issuers, repos with adequate haircuts, and government bills, are not generally classified as money, but have certain characteristics of money. They can be readily exchanged for cash, and roll off into cash within a short time. Short-term yields are lower because short-term debt partially satisfies the need for liquidity as well as having far less interest-rate risk, as we saw in Chapter 4.

The major exception to this general observation are short-term interest rates on currencies in imminent danger of devaluation (see Chapter 14). Because a discrete depreciation causes an instantaneous capital loss to market participants long the currency, short-term yields of currencies under pressure can rise to extremely high levels, limited only by uncertainty about whether and when the depreciation will take place.

Some forms of very short-term debt serve the means-of-payment function of money, particularly those forms that are checkable, that is, can be very easily transferred to a third party: demand deposits and money market mutual fund (MMMF) liabilities. These types of debt have even lower yields than can be explained by their short maturities because of their usefulness as means of payment and settling debts. Providing liquidity and payment services contributes to intermediaries' net interest margin. The liquidity transformation bundled with maturity transformation has long made banks more efficient intermediaries.

The process by which financial intermediaries use their balance sheets to create assets that can be used as money goes back to the origins of banking. Prior to the mid-1970s, this activity was the almost exclusive province of commercial banks. Nowadays, the money supply is defined to include certain nonbank liabilities such as those of MMMFs, as well as banknotes and bank deposits. They have in common that, in contrast to other short-term debt instruments, their values don't depend on interest rates, and they can be used to buy both goods and assets. To the extent that an asset has the characteristics of *immediacy* and certainty, they resemble money and are said to be liquid.

Deposit liabilities of banks were at one time the main form of money not created by central banks. In the contemporary financial system, the core banking functions of maturity and liquidity transformation are increasingly carried out by other means and other institutions, such as the commercial paper markets and MMMFs. With the introduction and growth of money market funds, an important new type of short-term assets that could be used as money was created. In the United States, retail MMMF balances are included in the M2 measure of the money supply, accounting for roughly 10 percent of the total. Institutional MMMF balances are about twice as large as retail, but are not included in U.S. monetary aggregates.

Market participants hold money to conduct transactions and for speculative reasons. In Keynes' well-known explanation of the demand for money, balances held for the purpose of conducting transactions include a portion attributable to uncertainty about the timing and volume of cash flows. But market participants also hold money out of a *speculative motive* which is a function of current asset prices, especially interest rates, uncertainty about future asset prices, and risk preferences. Keynes denoted this motive as "speculative" because of his focus on one of the key phenomena in financial crises, namely, asset-price spirals in which market participants want to hold cash because they expect asset prices to be lower in the future, thus driving prices lower in fact (see Chapter 14).[1]

Uncertainty of value is a property even of assets that have minimal credit risk, but mature in the future, such as U.S. Treasury bills, because their values depend on interest rates. Interest rates fluctuate, and affect the price even of short-term T-bills; hence T-bills are not money. However, if, like T-bills, their interest-rate risk is very low, and they also have little or no credit risk, they are viewed as relatively liquid and thus close in character to money.

Keynes's term for the demand for money, *liquidity preference*, has become particularly pertinent during the subprime crisis. In normal times, the desire for liquidity is counterbalanced by the zero or low yields earned by cash and liquid assets. In crises, risk-aversion and uncertainty are high, so market participants wish to hold a much larger fraction of their assets in liquid form, and are relatively indifferent to the yield. In the terminology of economics, the *velocity of money* declines drastically. Market participants desire larger liquidity portfolios, they prefer cash to money-market instruments, and become abruptly more sensitive to even the relatively low credit and counterparty risk of instruments other than government bills.[2]

12.1.3 Bank Liquidity

The core function of a commercial bank is to take deposits and provide commercial and industrial loans to nonfinancial firms. In doing so, it carries out a liquidity and maturity, as well as a credit, transformation. It transforms long-term illiquid assets—loans to businesses—into short-term liquid ones, including deposits and other liabilities that can be used as money.

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[1] In his typically memorable phrasing, these motives were the answer to the question, "Why should anyone outside a lunatic asylum wish to use money as a store of wealth?" (Keynes [1937], p. 216).

[2] In the older economics literature, this urge is called *hoarding*.

Liquidity Transformation by Banks Banks carry out their functions through operations on both sides of the balance sheet. Prior to the advent of shadow banking and the incursion of commercial banks into investment banking, depository institutions generally earned most of their revenues from net interest margin. In contemporary finance, banks earn a higher proportion of revenues from origination, investment banking, and other fees. They also have important revenues from market making, that is, earning the bid-ask spread on transactions executed for customers, and proprietary trading, taking risky positions in assets with their own capital. But net interest margin remains a crucial source of revenues.

The balance sheet of a "classic bank," that is, one chiefly reliant on deposits for funding, might look like this:

Assets	Liabilities
Cash and government bonds $15	Common equity $10
5-year corporate loans $85	Deposits $90

Banks and similar intermediaries are *depository institutions*, that is, institutions that borrow from the public in the form of liabilities that must be repaid in full on demand, instantly, in cash, on a first-come first-served basis. This aspect of the deposit contract is called the *sequential service constraint*, and contrasts sharply with bankruptcy, in which claims are paid pro rata. Deposits pay zero or relatively low rates of interest, though one of the main areas of financial innovation over the past few decades has been in making it possible for lenders to earn interest while still enjoying such benefits of liquidity as check-writing, for example, in MMMFs.

Banks can also tap the broader capital markets and raise funds by issuing bonds, commercial paper, and other forms of debt. These sources of *wholesale funding* are, on the one hand, generally of longer term than deposits, which can be redeemed at short notice. However, deposits are considered "sticky." Depositors tend to remain with a bank unless impelled to switch by a life change such as moving house; bankers joke that depositors are more apt to divorce than remove deposits. Depositors are also a naturally diversified set of counterparties, so a large deposit base reduces reliance on a small number of lenders.

Shorter-term forms of wholesale funding such as commercial paper are less reliable and potentially more concentrated sources of longer-term liquidity than a solid deposit base. These funding decisions are nowadays

also heavily influenced by regulatory capital requirements (see Chapter 15), which can favor or disfavor particular types of assets and thus influence their funding costs as liabilities.

The borrowing firms invest the loan proceeds in physical and other capital. A span of time and many stages are needed, in addition to the capital resources, before these projects produce goods and services that can be sold to repay the loans that finance them. Until then, the invested capital can be sold only at a loss, so the firms cannot in general repay the loans in full prior to maturity.

The bank could borrow at a longer term to match the maturity of its assets, but this would reduce its net interest margin. The bank would still be rewarded for another important set of banking functions, namely selecting worthy projects thats are likely to repay loans fully and timely, and monitoring borrowers' financial condition and timely payment of principal and interest. And to the extent that the banks' *delegated monitoring* function does not produce added value, borrowers could turn directly to the bond markets themselves.

The investments on the asset side of the bank's balance sheet not only have longer terms to maturity than their liabilities, they are also less liquid; deposits in contrast are very close substitutes for cash. The liquidity transformation function of banks has been described as "turning illiquid assets into liquid ones." However, this transformation depends on confidence in the bank's solvency.

How, then, can the liquidity and maturity transformations be made to work? Only a small fraction of deposits and other short-term funding are expected to be redeemed at any one time. Banks engage in *asset-liability management* (ALM). This is a technique for aligning available cash and short-term assets with expected requirements. A well-managed bank leaves an ample buffer of cash and highly liquid assets for unexpected redemptions of deposits and other funding.

Fragility of Commercial Banking The classic depository institution we have been describing is a *fractional-reserve* bank, that is a bank that lends deposits. The alternative to a fractional-reserve bank is a 100 percent reserve bank, which lends only its own capital, or funds raised in capital markets, and keeps a reserve of cash and highly liquid securities equal to its entire deposit base. Throughout the history of banking, almost all banks have been fractional-reserve banks. Banking originated in the Low Countries, and a bit later in Italy, in the thirteenth century. In its earlier stages, customers of banks deposited money in the form of gold and silver coin for safekeeping. The warehouse receipts the bank issued as evidence of a deposit could be used as money, as long as the bank was trusted to return the coin on demand, and receipts were easier and safer to transport and exchange.

As long as warehouse receipts were issued only against the coin brought to the bank for safekeeping, commercial loans could only be made with the owners' equity or with capital-market borrowing. Eventually, banks discovered that they could issue warehouse receipts, and later private banknotes, in a greater volume than the amount of coin deposited with them; that is, loans were made by issuing banknotes. In a fractional-reserve banking system, if depositors wish to make withdrawals in excess of a bank's reserves, and the bank cannot liquidate enough loans or other assets to meet the demand immediately, it is forced into *suspension of convertibility*; that is, it will not be able to convert its deposits and notes into money immediately.

At the extreme, all or a large number of depositors may ask for the return of their money simultaneously, an event called a *bank run*. Depositors and other short-term creditors are aware the banks cannot meet large-scale redemption requests. If they are concerned about banks' liquidity, they will endeavor to redeem before other depositors and lenders.

No asset-liability management system can protect a fractional-reserve bank against a general loss of confidence in its ability to pay out depositors. As long as the bank carries out a liquidity and maturity transformation, and has liabilities it is obligated to repay at par and on demand, no degree of liquidity that a bank can achieve can protect it completely against a run. Fragility can be mitigated through higher capital, which reduces depositors' concern about solvency, the typical trigger of a run, and higher reserves, which reduces concern about liquidity. Historically, banks have also protected themselves against runs through individual mechanisms such as temporary suspension of convertibility, and collective mechanisms such as clearing-houses.

Because banking is fragile, there have from time to time been calls to abolish traditional, deposit-dependent commercial banking, and replace it with a more robust type of financial institution. An alternative view is that depository institutions must be restricted in their activities and closely supervised to prevent them from taking risks that could jeopardize their ability to meet withdrawals. Under the rubric "Volcker Rule," it has been incorporated in the regulatory restructuring mandated by the 2010 Dodd-Frank Act. We discuss these issues particularly in the context of deposit insurance and the lender of last resort function of central banks in Chapter 15.

Apart from deposits, banks are generally dependent on short-term financing, exposing them to rollover risk events that, while less extreme than runs, can be costly or increase fragility. Commercial banks' main source of funding is deposits; in the United States, deposits account for about 60 percent of banks' liabilities. Banks rely on capital markets for much of the rest of their funding. Commercial paper is an important component and accounts for roughly 1.5 percent of U.S. banks' liabilities.

The commercial paper market in the immediate aftermath of the Lehman bankruptcy provides an example of how quickly funding conditions can change, and of the fragility of bank funding. The upper panel of Figure 12.1 displays the volume outstanding of commercial paper by AA-rated financial firms, a category comprised mostly of banks, but also including nonbank intermediaries such as GE Capital. Financial firms' issuance of commercial paper had grown rapidly between 2004 and the end of 2007, as their leverage and balance-sheet expansion increased. The amount borrowed via commercial paper became more volatile, but continued to grow, as banks sought to finance previously off-balance-sheet assets and credit lines they granted earlier were drawn upon. Commercial paper borrowing declined precipitously following the Lehman bankruptcy, as it could no longer be placed.

The lower panel displays the shares in total issuance of shorter- and longer-term commercial paper. With the onset of the subprime crisis, financial firms attempted to reduce the volume of both, and to "term out" the issuance, that is, increase the average term of the smaller total. The share of very short-term paper in total issuance declined from about 80 to about 60 percent during the 18 months preceding the Lehman bankruptcy. After the Lehman event, banks faced difficulty in rolling over longer-term commercial paper, and more generally in obtaining funding with maturities of more than a few weeks. The share of very short-term issuance rose dramatically, to near 90 percent, as financial firms had few other alternatives. The European debt crisis had a similar, but more muted, impact in the spring of 2010. The funding difficulty was reflected also in the Libor-OIS spread, as can be seen in Figure 14.10.

The Federal Reserve intervened following the Lehman bankruptcy and amid subsequent fears of a run on MMMFs to support liquidity via the Commercial Paper Funding Facility (CPFF), which purchased commercial paper from issuers unable to roll paper over, and the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF), which lent to financial institutions purchasing ABCP from MMMFs.

12.1.4 Structured Credit and Off-Balance-Sheet Funding

Structured credit products *per se* do not face funding liquidity problems, as they are maturity matched. Asset-backed securities (ABS), mortgage-based securities (MBS), and commercial mortgage-based securities (CMBS) themselves primarily carry out a credit and liquidity, rather than a maturity transformation. They can be viewed as providing matched funding for the assets in the collateral pool. The securities issued typically include at least some longer-term bonds.

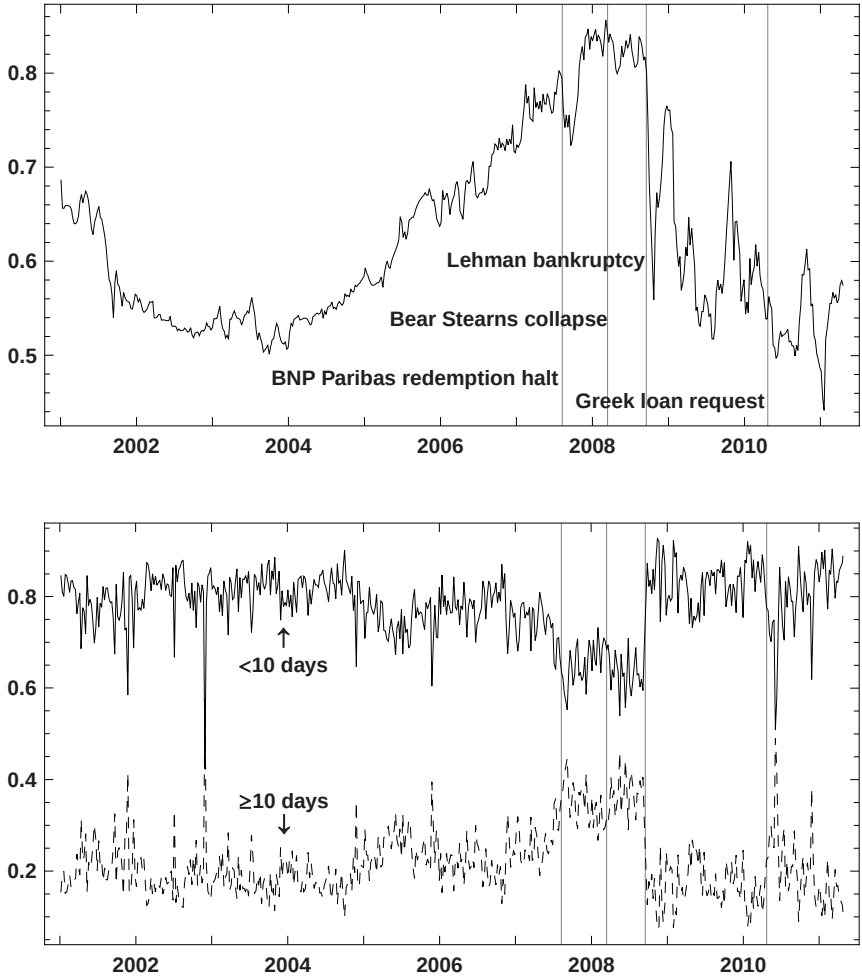

FIGURE 12.1 Short-Term Commercial Paper of Financial Institutions
Upper panel: Amount outstanding of AA financial commercial paper, weekly, beginning of 2001 to end-April, 2011, trillions of US$.
Lower panel: Shares (summing to 1) of total dollar amount issued of AA financial commercial paper with original maturities between 1 and 9 days (solid line, marked "<10 days") and maturities of 10 days or more (dashed line, marked "≥10 days"), weekly.
Source: Federal Reserve Board, available at www.federalreserve.gov/releases/cp/.

The way the securitization liabilities themselves are financed by investors can, however, introduce liquidity risk. The difficulties experienced by securitization have been related not only to the questionable credit quality of underlying assets such as real estate loans. Prior to mid-2008, the liabilities were held substantially by investors relying on short-term financing, increasing the fragility of the financial system.

The short-term financing of securitizations played a crucial role in the subprime crisis and in the opaque increase in financial system leverage prior to the subprime crisis. There were two major forms of such financing, *securities lending*, the use of structured credit products as collateral for short-term loans, which we discuss in detail later in this chapter, and off–balance-sheet vehicles.

Like securitizations themselves, off-balance-sheet vehicles are "robot companies" or special-purpose vehicles (SPVs) that are defined by their assets and liabilities. They issue asset-backed commercial paper (ABCP), which, in contrast to most commercial paper, is secured rather than unsecured debt. The two major types are:

1. *Asset-backed commercial paper conduits* purchase various types of assets, including securities as well as whole loans and leases, and finance the assets by issuing ABCP. They typically enjoy explicit credit and liquidity support from the sponsors in the form of credit guarantees and liquidity support should the conduit be unable to roll over the debt. Because of the guarantees, ABCP conduits generally have little equity.
2. *Structured investment vehicles* (SIVs) are similar to ABCP conduits in some respects, but differ in the crucial matter of credit and liquidity support. SIVs typically did not enjoy full explicit support by sponsors. They invested primarily in highly rated securitized credit products, and to a lesser extent in whole loans. Their funding mix was also generally somewhat different from that of ABCP conduits. In addition to ABCP, many SIVs issued medium-term notes (MTNs), which are at least somewhat less vulnerable to rollover risk. They also typically had larger equity cushions.

In spite of their differences, the two types were economically similar in many ways. Both types of vehicles profited from the spread between the asset yields and the funding cost. Another similarity is their economic function of maturity and liquidity transformation. The assets in the vehicles have longer, and possibly much longer, maturities than the commercial paper with which they are funded. This is typical for a bank; indeed, this maturity intermediation is the essence of what a bank does. However, instead of

carrying out this function on its own balance sheet, the sponsoring bank has been able to reduce its balance sheet and its regulatory capital, while still deriving the economic benefits.

The vehicles also carried out liquidity transformation, creating ABCP, which is not only a much shorter-term, but, until the subprime crisis, was a more liquid asset than the underlying assets in the conduit or SIV. The final step in the liquidity transformation was the purchase of ABCP and money-substitute creation by MMMFs.

These financial innovations were accompanied and enabled by changes in regulatory capital and accounting rules that permitted firms to hold less capital against given levels of economic risk. The use of these vehicles did not lead to bona fide risk transfer. Even in the absence of explicit guarantees, sponsors that were large intermediaries felt obliged to provide support or assume the assets onto their balance sheets when the ABCP could no longer be rolled over. In spite of the fact that the vehicles were off-balance-sheet from an accounting and regulatory perspective, they contributed greatly to the leverage and fragility of the sponsors, largely banks.

12.1.5 Funding Liquidity of Other Intermediaries

Depository institutions and MMMFs are at an extreme position, because they must repay depositors instantly on demand. But other types of financial intermediaries face similar problems. These examples focus on the liquidity risk events they experienced during the subprime crisis.

Securities Firms Securities firms hold inventories of securities for sale, and finance them by borrowing at short term. The collapse of Bear Stearns in March 2008 was an extreme case of a securities firm's lenders abruptly withdrawing credit. Bear Stearns, like other large broker-dealers, had relied to a large extent on short-term borrowing. Bear was particularly dependent on free cash deposits of the firm's large base of brokerage and clearing customers, including many hedge funds. These cash deposits were often collateralized, but generally not by better-quality collateral. Hedge funds withdrew deposits—and their business—rapidly towards the end of Bear's existence, in what was essentially a run. Bear also issued MTNs and commercial paper to fund its activities. We discuss these forms of borrowing in more detail later in this chapter, and discuss the Bear Stearns episode in more detail in Chapter 14.

Money Market Mutual Funds MMMFs provide instant liquidity for their investors by giving them the ability to draw on their accounts via checks and

electronic bank transfers. MMMFs are designed to invest in money market securities of high credit quality with just a few weeks or months to maturity. In this design, the market and credit risks of the assets are low, but still material. The assets can fluctuate in value, so the ability to offer unlimited instantaneous withdrawals is potentially limited if asset values fall. They are thus similar to banks in that their investments are less liquid than their liabilities. The liabilities of a MMMF are, however, quite different from those of banks. The account holders' claims are not first-priority unsecured debt, like those of bank depositors, but rather equity. A further structural feature is therefore required for these liabilities to become money substitutes.

MMMFs are similar in many ways to other mutual funds, which are organized in the United States under the Investment Company Act of 1940. This permits the instantaneous withdrawal of equity. But in contrast to other mutual funds, equity is not added or withdrawn at a fluctuating market-determined net asset value (NAV). Under the U.S. Securities and Exchange Commission's (SEC) Rule 2a-7, they are permitted to use a form of accounting, the "amortized cost method," that further reduces the tension—in normal times—between instant withdrawal and fluctuating asset value. The rule permits MMMFs to use the historical or acquisition cost of the money-market paper they purchase, plus any accrual gains. The reasoning is that, as long as the short-term debt is expected to be redeemed at par within a short time, it is not necessary to revalue it in response to fluctuations in interest rates and credit spreads. Because the paper is short-term, these fluctuations are likely in any case to be relatively small.

Other mutual funds must mark assets to market each day. This daily NAV is the price at which investors can contribute and withdraw equity. MMMFs, in contrast, are able to set a notional value of each share equal to exactly $1.00, rather than an amount that fluctuates daily. The residual claim represented by the shares is paid the net yield of the money market assets, less fees and other costs. MMMF shares thereby become claims on a fixed nominal value of units, rather than proportional shares of an asset pool. Their equity nature is absorbed within limits by fluctuations in the net yield.

This structure only works if market, credit, and liquidity risks are managed well. Some losses cannot be disregarded under the amortized cost method, particularly credit writedowns. These losses can cause the net asset value to fall below $1.00, a phenomenon called "breaking the buck."

Liquidity risk can also jeopardize the ability of a MMMF to maintain a $1.00 net asset value. In this respect, it is much like a classic commercial bank, and similarly vulnerable to runs. If a high proportion of shareholders attempt to redeem their shares simultaneously under adverse market conditions, the fund may have to liquidate money market paper at a loss,

forceing writedowns and potentially breaking the buck. An episode of this kind involving credit writedowns by a MMMF, the Reserve Fund, was an important event in the subprime crisis, as we see in Chapter 14.

Hedge Funds Hedge funds face liquidity risk all through their capital structures. In contrast to the equity capital of corporations, which may be traded but not withdrawn, but much like mutual fund investments, hedge fund capital can be redeemed. Hedge funds permit investors to withdraw their funds at agreed intervals. Quarterly withdrawals are the rule, though some funds have annual and a very small number of monthly withdrawals. These withdrawal terms, colloquially called the "liquidity" of the fund, are subject in general to additional restrictions called "gates," that permit a suspension or limitation of withdrawal rights if investors collectively request redemptions in excess of some limit.[3]

The potential extent of liquidity demands by investors is shown in the decline in assets under management by hedge funds during the subprime crisis, displayed in Figure 1.7; the decline in assets was a result of both investment losses and redemptions of capital. These redemptions hit not only those hedge funds experiencing or expected to experience large losses. Redemption requests were submitted also to hedge funds that were profitable or had low losses. Investors sought at the onset of the crisis to marshal cash balances from all possible sources, among which were intact hedge fund investments. Hedge funds were obliged to liquidate assets, or impose barriers to redemptions so far as offering documents permitted. Hedge funds were in essence being asked to become liquidity providers to investors, a function for which they are not well-designed and were never intended, rather than to the markets.

Like other intermediaries, hedge funds also face short-term funding risk on their assets. Hedge funds typically have no access to wholesale funding and rely entirely on collateral markets, short positions, derivatives, and other mechanisms we describe below to take on leverage.

12.1.6 Systematic Funding Liquidity Risk

Funding liquidity is a latent risk factor in major corporate financial transactions. A dramatic example are leveraged buyouts (LBOs), which we discussed in Chapter 1. LBOs are generally financed by large loans, called *leveraged*

[3]Similar mechanisms have been used by commercial banks; for example in eighteenth-century Scotland, to limit the impact of bank runs by depositors in the absence of public-sector deposit insurance.

loans. As LBOs and private equity funds grew, leveraged loans became the dominant type, by volume, of *syndicated loans*, originated by banks, but distributed to other investors and traded in secondary markets. Many leveraged loans became part of CLO pools, and tranches of CLOs were important in CDO pools. The shadow banking system and the "CDO machine" were important providers of funding to private equity and LBOs. Other corporate events, such as mergers and acquisitions, are also dependent on financing.

The funding liquidity risk in corporate transactions is both idiosyncratic and systematic. Funding for a particular LBO or merger might fall through, even if the deal would otherwise have been consummated. But funding conditions generally can change adversely. This occurred in mid-2007 as the subprime crisis took hold. Many LBO and merger deals fell apart as financing came to a halt. Banks also incurred losses on inventories of syndicated loans, called "hung loans," that had not yet been distributed to other investors or into completed securitizations, as noted in Chapter 9. As risk aversion and demand for liquidity increased, the appetite for these loans dried up, and their prices fell sharply.

Apart from providers of financing, other participants in these transactions, such as hedge funds involved in *merger arbitrage*, also experienced losses. Mergers typically result in an increase in the target acquisition price, though not usually all the way to the announced acquisition price, and in a decrease in the acquirer's price, since the acquirer often takes on additional debt to finance the acquisition. Merger arbitrage exploits the remaining gap between the current and announced prices. The risk arises from uncertainty as to whether the transactions will be closed. In the early stages of the subprime crisis, merger arbitrage strategies generated large losses as merger plans were abandoned for lack of financing.

Investors taking on exposure to such transactions are therefore exposed not only to the idiosyncratic risk of the deal, but to the systematic risk posed by credit and funding conditions generally. This risk factor is hard to relate to any particular time series of asset returns. Rather, it is a "soft factor," on which information must be gathered from disparate sources ranging from credit and liquidity spreads to quantitative and anecdotal data on credit availability. We look at such data more closely in Chapter 14.

Systematic funding liquidity risk is pervasive. Other asset types or strategies that are good examples of sensitivity to the "latent" factor of economy-wide financing conditions include real estate, convertible bonds, and statistical arbitrage. Real estate is one of the longest-lived assets. Mortgages—loans collateralized by real estate—are therefore traditionally and most frequently originated as long-term, amortizing, fixed-rate loans. The typical home mortgage, for example, is a 30-year amortizing, fixed-rate loan. When lending practice departs from this standard and shorter-term loans predominate,

lenders and borrowers both face funding liquidity risk, as borrowers are unlikely to be in a position to repay unless they can refinance. This risk is primarily systematic, as it is likely to affect all borrowers and lenders at the same time.

Convertible bond prices are generally only slightly lower than their theoretical prices based on the replicating portfolio of plain-vanilla equity options and bonds that should mimic convert bonds' values. Traders, many of them at hedge funds and dependent on credit extended by broker-dealers, take advantage of this gap to earn excess returns. The strategy is only attractive with leverage, as it has relatively low unlevered returns, but is generally also relatively low-risk given the arbitrage relationship between the convert bonds and the replicating portfolio.

Convert returns do, however, have a systematic extreme-loss risk. When the financing becomes unavailable because of credit conditions in the economy, converts cheapen dramatically. This effect is compounded by redemptions from convertible-bond funds, compounding the funding liquidity problem with a market liquidity problem.

These episodes of convert bond illiquidity also illustrate the effect of concentrated positions. Convertible bonds have a limited "clientele" among investors. When the existing clientele develops an aversion to the product during a period of market stress, it is difficult to move the product smoothly into new hands without large price declines.

Figure 12.2 displays a measure of arbitrage opportunities in the convertible bond market: the cheapness of bonds to their theoretical replicating portfolios. At the height of the pre-crisis boom, the gap had not only disappeared, but became negative. In a sense, investors were overpaying for the package in their search for yield. As the subprime crisis evolved, the positive discount to theoretical was first reestablished, and eventually widened to an unprecedented extent. Viewed from a different angle, under conditions of severe liquidity stress, even a large gap between convert prices and their replicating portfolio did not bring arbitrage capital into the market.

A similar problem occurred for securitized credit products in the fall of 2008. The clientele for the bonds had relied to a large extent on short-term finance via repo, SIVs, and other mechanisms. When financing for the SIVs disappeared, a new investor base for the bonds could not be established quickly, and spreads on securitized credit products widened dramatically. Figure 14.14 displays the impact on structured product credit spreads.

A final example is statistical arbitrage, which we discussed briefly in Chapter 1. Like convert arbitrage, statistical arbitrage requires some degree of leverage for profitability. In August 2007, as the subprime crisis got underway, one of its first effects was on statistical arbitrage strategies. Curtailing the liquidity of these strategies caused losses and return volatility

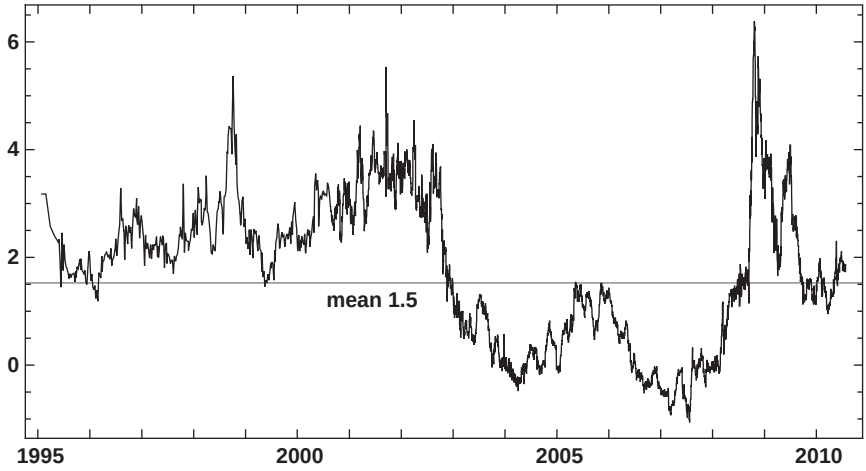

FIGURE 12.2 Convertible Bond Cheapness
Difference between theoretical and market prices of convertible bonds in the Merrill Lynch All U.S. Convertibles Index (VXA0), weekly through 1997 and daily through July 2010, in percent. The theoretical price is the value of the replicating portfolio, taking the credit, risk-free rates, and the embedded option into account. *Source*: Bank of America Corp.

that were extremely far outside the range of historical experience. In fact, this episode was one of the first overt signs of how severe the crisis could potentially become.

12.2 MARKETS FOR COLLATERAL

Markets for collateral are formed when securities are used as collateral to obtain secured loans of cash or other securities. The loans are used to finance securities holdings or otherwise invest, often as part of a larger trade. Securities used as collateral "circulate," since the borrower of securities can typically lend them to another, a practice called *rehypothecation* or *repledging* of collateral we described in Chapter 6. In this way, the supply of securities that can be used as collateral is an important element in facilitating leverage in the financial system.

Collateral has always played an important role in credit transactions by providing security for lenders and thus ensuring the availability of credit to borrowers. The role of collateral has changed and expanded in contemporary finance, hand in hand with the development of securitization, but also with the growing volume and transactions liquidity of securities trading.

The obvious and direct effect of securitization is to remove credit intermediation from the balance sheets of financial intermediaries. However, it also creates securities that can be pledged as collateral in further credit transactions. Securities have additional economic value to the extent that they not only throw off cash flows and may appreciate in value, but can be used as collateral to obtain credit.

Collateral markets are an important institutional element supporting the growth of nonbank intermediation. Participants in these markets include:

- Firms such as life insurance companies may own portfolios of high-quality securities that can be used as collateral to borrow cash at the low interest rates applicable to well-collateralized loans. The motivation is to borrow cash at a low rate, which it can then reinvest, earning a spread.
- Firms such as hedge funds have inventories of securities that they finance by pledging the securities as collateral. The motivation is to obtain financing of the portfolio at a lower rate than unsecured borrowing, if the latter is available at all.
- Firms may have excess cash that they are willing to lend out at a low interest rate, as long as they are appropriately secured by collateral.

The securitization process relied heavily on rating agencies to create bonds "with the highest credit rating," which could then be lent, repoed out, or pledged as collateral by their owners.

12.2.1 Structure of Markets for Collateral

Firms can borrow or lend collateral against cash or other securities. A *haircut* ensures that the full value of the collateral is not lent. A haircut of 10 percent, for example, means that if the borrower of cash wants to buy $100 of a security, he can borrow only $90 from the broker and must put $10 of his own funds in the margin account by the time the trade is settled. Similarly, the lender of cash will be prepared to lend $90 against $100 of collateral.

Borrowing may be at short term, such as overnight, or for longer terms. Overnight borrowing may be extended automatically until terminated. As the market value of the collateral fluctuates, variation margin may be paid. Most collateralized borrowing arrangements provide for such *remargining*. The total margin at any point in time, if adequate, provides a liquidation cushion to the lender. If, for example, the loan has a maturity of (or cannot be remargined for the duration of) one week, a 10 percent haircut ensures that the value of the securities held as collateral can fall 10 percent and still

leave the loan fully collateralized. The variation margin protects the lender of cash against fluctuations in the value of the collateral.

Markets for collateral have existed for a long time in three basic forms that are economically very similar, although they differ in legal form and market practice.

Margin Loans *Margin lending* is lending for the purpose of financing a security transaction in which the loan is collateralized by the security. It is generally provided by the broker intermediating the trade, who is also acting as a lender. Margin lending is generally short term, but rolled over automatically unless terminated by one of the counterparties.

Collateralization for the loan is achieved by having the broker retain custody of the securities in a separate customer account, but in "street name," that is, registered in the name of the broker rather than in the name of the owner. This simplifies the process of seizing the securities and selling them to cover the margin loan if it is not repaid timely. But registration in street name also lets the broker use the securities for other purposes, for example, lending the securities to other customers who want to execute a short sale.

In practice, the most important purpose for which the broker is likely to use the customer's collateral is to borrow money in the secured money market to obtain the funds it lends to margin customers. The repledged securities become the collateral for a margin loan to the broker, and the collateral is moved to the broker's customer account with its creditor. Collateral may, however, also be repledged in order to borrow another security rather than cash collateral. This will typically be done in order to short the borrowed security or to facilitate a client's short position. In extreme market conditions, such as the subprime crisis, the practice of rehypothecation of securities can become quite important, as it introduces additional risk for the broker's customers. We saw a dramatic example as part of our discussion of counterparty risk in Chapter 6.

In the United States, initial haircuts on equity purchases are set at 50 percent by the Federal Reserve Board's Regulation T ("Reg T"), but, as we will see, derivatives can be used to increase the amount implicitly borrowed. Many transactions occur outside U.S. jurisdiction in order to obtain lower haircuts.

Reg T governs initial margin for common stock and other listed securities. After a position is established, the margin will be adjusted as the value of the security fluctuates. As the market value of a long position declines, the broker loses the protection the collateral provides against the customer defaulting on the margin loan, so he will issue a *margin call* to the customer. Most customers have portfolios of long and short positions in cash

securities, so *cross-margining agreements* are put in place to govern the net margin assessed.

Repurchase Agreements *Repurchase agreements* or *repos* are matched pairs of the spot sale and forward repurchase of a security. Both the spot and forward price are agreed now, and the difference between them implies an interest rate. The collateralization of the loan is achieved by selling the security temporarily to the lender. The collateralization is adjusted for the riskiness of the security through the haircut.

Repos are also a fairly old form of finance, but have grown significantly in recent decades. More significantly, the range of collateral underlying repos has widened. At one time, repo lending could be secured only by securities with no or de minimis credit risk. A few decades ago, repo began to encompass high-yield bonds and whole loans, and more recently, structured credit products. It has been a linchpin of the ability of large banks and brokerages to finance inventories of structured credit products, facilitated also by extending high investment-grade ratings to the senior tranches of structured credit products such as ABS and CDOs.

The mechanics of repo lending are similar to margin loans. Like margin lending, repo creates a straightforward liability on the economic balance sheet. However, under certain circumstances, such as back-to-back security lending and borrowing for customers, transactions can be combined so as to permit the gross economic exposure to remain off-balance-sheet.

Securities Lending In a *securities lending* transaction, one party lends a security to another in exchange for a fee, generally called a *rebate*. The security lender, rather than the borrower, continues to receive dividend and interest cash flows from the security. A common type of securities lending is stock lending, in which shares of stock are borrowed.

As in repo transactions, the "perfection" of the lien on the collateral is enhanced by structuring the transaction as a sale, so that the lender holding the collateral can rehypothecate it or, in the event that the loan is not repaid, sell it with minimal delay and transactions costs.

There are a few typical patterns of securities lending:

- In a stock lending transaction, the source of the securities is a large institutional investor in equities or a hedge fund. The investor makes the equities available for lending by holding them at the custodian or prime broker in "street name," so that they can be rehypothecated to a trader who wishes to sell the securities short. The owner receives a rebate in exchange. A securities lending transaction is generally "born"

on the broker's balance sheet; that is, the securities are already in a margin account when a customer indicates a desire to go short.

- A typical fixed-income securities lending transaction aims to earn a spread between less- and more-risky bonds. The transaction would again typically start with an institutional investor in, say, U.S. Treasury or agency bonds that can be used as collateral for a short-term loan at a rate lower than other money-market rates, and a low haircut. The investor receives *cash collateral* in exchange for the loan of the Treasury bonds. The cash can then be used to invest in other, higher-yielding securities.

Much securities lending is carried out via *agency securities lending* programs, whereby a third party, usually a large broker-dealer, or a custodial bank with many institutional clients (e.g. State Street), intermediates between the lender and borrower of securities.

Total Return Swaps The ability to short equities depends on the ability to borrow and lend stock. An important instrument of many short stock trades are *total return swaps* (TRS), in which one party pays a fixed fee and receives the total return on a specified equity position on the other. TRS are OTC derivatives in which one counterparty, usually a bank, broker-dealer or prime broker, takes on an economic position similar to that of a stock lender, enabling the other counterparty, often a hedge fund, to establish a synthetic short stock position, economically similar to that of a borrower of stock. The broker then needs either to lay off the risk via a congruent opposite TRS, or to hedge by establishing a short position in the cash market.

12.2.2 Economic Function of Markets for Collateral

There are two main purposes served by collateral markets. First, they create the ability to establish leveraged long and short positions in securities. Without these markets, there would be no way to short a cash security; short positions could only be created synthetically.

Second, collateral markets enhance the ability of firms to borrow money. In collateral markets, cash is just another—and not necessarily the primary—asset to be borrowed and lent, alongside securities of all types, hence the term "cash collateral."

It helps in understanding the risks of securities lending and its role in the financial system to flesh out how it is embedded in and has supported a number of important activities in finance. Repo and securities lending

are mechanically distinct, but economically similar. They both enable market participants to finance assets with borrowed funds using the assets as collateral. They are both structured in such a way that the party investing in the assets appears to have "borrowed" the assets, though economically having bought them. However, in a repo transaction, the assets are financed directly, while in a securities lending transaction, the investor starts off owning liquid assets that are "good currency" and can be used to obtain cash collateral with a relatively low haircut. The investor can then step forward as a lender of cash against the securities in which he wants to invest, or as an outright buyer, rather than, as would be the case in a repo, as a borrower of cash to purchase the securities.

Fixed-income securities lending, like repo programs, has historically functioned primarily as a source of short-term financing for financial firms, and as an additional source of revenue for institutional investors and insurance companies. In more recent years, it has been an important element facilitating credit creation in the bank and nonbank intermediation systems. It supported the "manufacturing system" for securitized credit products. The ability to finance positions in securitized credit products via securities lending made the bonds more marketable and increased their value, that is, decreased their required credit spreads. These programs also provided a channel through which firms using cash collateral to invest in higher-risk bonds could increase leverage and returns.

Different forms of collateral markets serve different trading motivations, but these forms are economically so similar that no hard-and-fast distinctions can be drawn:

- Margin lending, the simplest form of a market for collateral, is primarily used by investors wishing to take leveraged *long* positions in securities, most often equities.
- Reverse repo transactions are similar, in that they are often used to finance long positions in securities, typically bonds. Repo transactions, in contrast, are usually intended to borrow cash by owners of bonds.

  However, in some instances, a repo or reverse repo transaction is focused on the need of one counterparty to establish a long position in a particular security. An important example is the U.S. Treasury *specials* market, in which a scarcity arises of a particular bond. The mechanism by which the market is cleared is a drop in the implied interest rate for loans against a bond "on special," which can become zero or even negative. Recently issued U.S. Treasury notes typically go on special when dealers sell them to customers prior to the issue date on a when-issued basis, and have underestimated the demand. Following the next

U.S. government bond auction, when the bond is issued, the dealer must borrow it to deliver to the customer at a penalty rate, expressed in the cheap rate at which the dealer must lend cash collateral to borrow the security.

- Securities lending has typically been focused on the securities rather than the cash collateral, typically to establish short positions. In recent years, the focus of their use has shifted to borrowing cash collateral.

High-quality bonds that can be readily used as collateral command higher prices than bonds that cannot be used in this way. This creates additional demand for high-quality collateral; their utility as collateral adds to the value of securitized credit products, and provided an additional incentive to create them.

Collateral markets bring owners of securities, such as institutional investors and insurance companies, into the financing markets. They lend their securities to earn extra return. Whether through repo or securities lending, they earn an extra return by making their securities available for other market participants to use as collateral.

A crucial element in permitting bonds to serve as collateral is their credit quality. Credit-rating agencies are important participants in collateral markets because of the need for highly rated bonds. Conversely, awarding high ratings to lower-quality bonds added a large volume of collateral to these markets that evaporated almost overnight during the subprime crisis.

These markets grew tremendously in volume in the years preceding the subprime crisis, as the range and amount of collateral that could be lent expanded. Figure 12.3 shows net repo market borrowing by U.S. broker-dealers. The volumes displayed in the graph are likely much smaller than the gross amounts. Reported balance sheet volumes understate the volume of repo lending and the amount of leverage introduced into the financial system by excluding transactions in which a dealer hypothecates one security in order to borrow a different security. Broker-dealers carry out a large volume of such transaction on behalf of customers. Net repo use more than tripled between mid-2004 and its peak in mid-2007. During the subprime crisis, net repo liabilities contracted by about two-thirds. The three-year spike is likely due in large part to the expansion in use of non-Treasury securities as collateral and the growth in hedge fund funding business, which we now briefly discuss.

12.2.3 Prime Brokerage and Hedge Funds

Much of the growth in volume in collateral markets is intermediated through *prime brokers*, subsidiaries of large banks and broker dealers that have

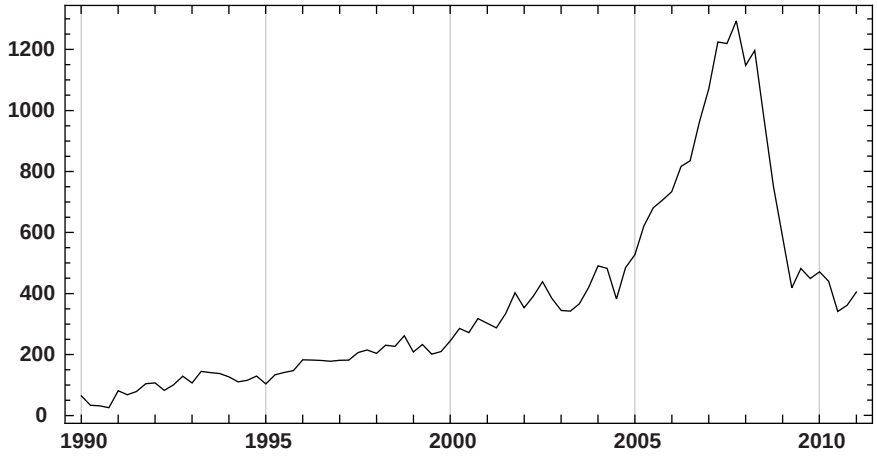

FIGURE 12.3 U.S. Broker-Dealer Repo 1980–2011
Net liabilities under security repurchase agreements of U.S. broker-dealers, billions of dollars.
Source: Federal Reserve Board, Flow of Funds Accounts of the United States (Z.1), Table L.129.

emerged as important service providers to the hedge fund industry. They serve as a single point of service that provides trading, clearing, custody, financing, and other services. In some cases, prime brokers have been involved in the hedge fund business itself through "capital introduction," that is, arranging contact between funds and potential investors.

Hedge funds often maintain portfolios of long and short positions. For both the hedge fund and the prime broker providing the financing, the net value may be quite small compare to the gross volume of lending. Within a firm's account with a broker, margin lending may be extended on a portfolio basis. This may be as simple as reducing the margin for offsetting long and short trades in the same security. Margin may also be reduced for less direct portfolio effects. Some brokers use risk models such as VaR to help determine the appropriate margin for an account.

Prime brokerage businesses have been valuable to large intermediaries not only because of the fees and spreads they earn on the services and lending they provide. As noted above in discussing the run on Bear Stearns, the intermediaries also benefit from the cash balances the hedge funds hold. Typically, even highly leveraged hedge funds maintain cash balances with prime brokers, so the prime brokerage business becomes an important funding source, akin to retail deposits, but far less "sticky." The cash balances

at prime brokers are part of the intermediaries' general liquidity pool. They are available to finance any of the intermediaries' other activities. Short positions also generate cash, not all of which can be freely devoted to making additional investments.

The interest rates paid on these cash balances are generally somewhat higher than the funds could obtain from alternative money market investments, such as Treasury bills, commercial paper, and money market mutual funds. They are also, from the standpoint of the funds, riskier than the alternatives, as they are unsecured claims against the intermediary, or are secured by possibly inadequate collateral. Conversely, prime brokers are important intake points for banks and broker-dealers to gather collateral and cash that can be used to finance their activities. Earlier in this chapter, we observed that hedge funds were drawn on as sources of liquidity by their investors during the subprime crisis. Their prime brokerage relationships are an equally counterintuitive instance of the "peacetime" role of hedge funds as liquidity providers.

12.2.4 Risks in Markets for Collateral

The risks in markets for collateral are similar to those of other leveraged positions. They comprise market, credit, and counterparty risks. There are some risks in common for the borrower and lender of securities, and some that are unique to only one side of the transaction. The risks vary widely, depending on the motivation of the trade, what type of collateral is involved, and how the cash generated is deployed. For example, the market risk of reversing in a bond is a rise in long-term interest rates. A trader selling borrowed equities short will gain if the stock price falls.

Prior to the subprime crisis, many institutional investors and mutual funds maintained large securities lending programs, in which they lent high-quality securities and received cash collateral, which they invested in higher-yielding bonds. These "sec-lending" programs invested heavily in structured credit products, as they had AAA ratings, thus satisfying investment mandates, but had somewhat higher yields than the bonds lent. These programs were intended to earn a narrow but steady interest margin, but had severe losses during the crisis, as securitized product prices collapsed.

Another major market risk in markets for collateral is changes in lending rates or other terms of margin, repo, or securities loans. The loans themselves are generally short-term, so losses to a borrower of securities in a decline in rates are generally small. However, the transactions liquidity risk can be high. We have already discussed one important example, the Treasury specials market.

Another example is the phenomenon of *hard-to-borrow* securities in equity markets. In order to establish a short position, even one expressed via TRS, stock must be located and borrowed. Smaller stocks and stocks under price pressure can be difficult to borrow, as many owners will not be willing to lend.

Collateral markets permit owners of high-quality collateral—or collateral perceived by the market as high-quality—to borrow or to finance positions in high-quality collateral at low interest rates. The upper panel of Figure 12.4 displays the overnight repo rate at which market participants can borrow against collateral consisting of U.S. Treasury obligations, the highest-quality collateral available even after the S&P downgrade of the U.S. long-term credit rating. In normal times, the repo rate is very close to the yield of T-bills or other short-term lending rates, and the spread between them is close to zero. However, when times are not normal, for example during the subprime crisis, rates on loans collateralized by the highest-quality securities drop even faster than interest rates generally. Having the very best collateral in a stressed market is almost as good as having cash, because you can then borrow cash at a low or even zero rate using such collateral. Lenders will provide cash at a low rate to gain custody of such collateral. This is evident in the upper panel, where one can see downward spikes in the Treasury repo rate following the inception of each phase of the subprime crisis.

The center and lower panels of Figure 12.4 display the spread between overnight Treasury repo and interbank rates (center panel), and the spread between Treasury repo and repo rates for loans collateralized by a different type of collateral, agency MBS (lower panel). Agency MBS are also highly creditworthy, but not quite as unquestionably so as Treasuries, and are also not as liquid. In times of stress, rates on loans with agency MBS collateral will not fall quite as low as for the very best collateral. Both spreads are close to zero in normal times, widening and becoming highly volatile during the crisis. Questions about the solvency of the issuers of agency bonds, the government-sponsored enterprices (GSEs), exacerbated the size and volatility of these spreads. The data illustrate a key point regarding funding liquidity risk: The higher the quality of the securities a market participant owns unencumbered, the more liquid he is.

The owner of high-quality collateral who uses it to finance a position in lower-quality bonds can maintain a highly leveraged position, since haircuts on the collateral lent are typically small. When the subprime crisis began, and values of low-quality collateral began to fall, investors engaged in this trade suffered large losses via forced sales. The lenders demanded variation margin in cash as specified in margin agreements. If the investor was unable or unwilling to meet that demand, positions had to be liquidated.

The size and structure of collateral markets also contributes to systemic risk. Owners of lower-quality collateral may suddenly have their loans

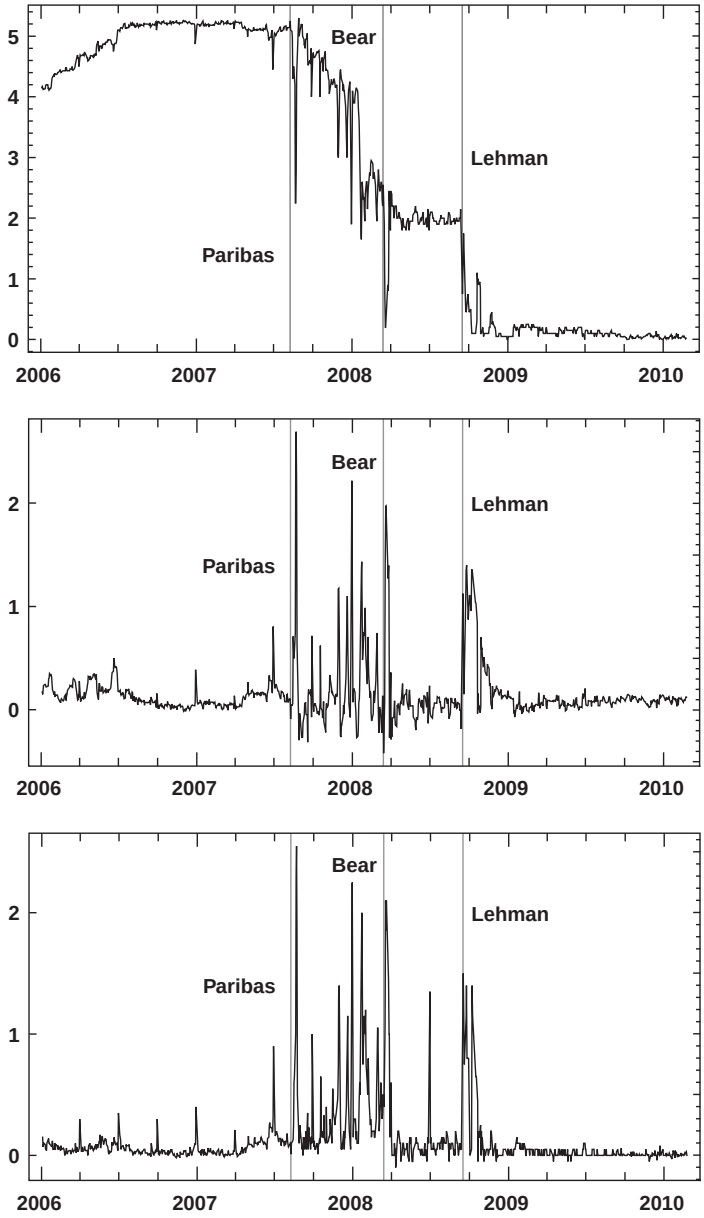

FIGURE 12.4 Repo Rates and Spreads 2006–2010
Upper panel: Overnight repo rates collateralized by U.S. Treasury securities, daily.
Center panel: Spread between one month OIS and overnight Treasury repo rates (OIS minus Treasury repo), daily.
Lower panel: Spread between overnight repo rates collateralized by U.S. Treasury securities and by agency MBS (agency repo minus Treasury repo), daily.
Source: Bloomberg Financial L.P.

terminated, or have the loans be subjected to sudden and large increases in the margin demanded by lenders of cash. Drastic remargining is tantamount to drastically decreasing the loan proceeds available to the borrower on the strength of the collateral. The owners of the collateral may then be forced to liquidate the assets. In a distressed market, this contributes to the rapid decline in asset prices.

Calling and remargining loans collateralized by securities gives rise to a phenomenon similar to classic bank runs, but involving nonbank intermediaries as well as banks, and focused on wholesale funding rather than deposits. One instance was the March 2008 collapse of Bear Stearns. Bear had large exposures to subprime residential mortgage debt in a number of forms, and its vulnerability in this respect had become clear in mid-2007 when several hedge funds that it sponsored collapsed. Once its solvency was called into question, providers of funding began to withdraw. As noted above, these included commercial paper lenders and hedge funds with free cash balances at Bear as part of its clearing and prime brokerage businesses. We study these and similar self-reinforcing mechanisms in crises in Chapter 14.

12.3 LEVERAGE AND FORMS OF CREDIT IN CONTEMPORARY FINANCE

12.3.1 Defining and Measuring Leverage

So far in this chapter, we have seen how pervasive leverage is in the financial system, and some of the new forms it takes. Next, we look at the mechanics of leverage, particularly via the economic, as opposed to the accounting, balance sheet of the firm. In Chapter 6, we presented the standard definition of leverage as the ratio of the firm's assets to its equity. The schematic balance sheet of the firm is

Assets	Liabilities
	Equity (E)
Value of the firm (A)	Debt (D)

The leverage ratio is defined as[4]

$$L = \frac{A}{E} = \frac{E + D}{E} = 1 + \frac{D}{E}$$

[4]The leverage ratio is sometimes defined as the debt-to-equity ratio $\frac{D}{E}$.

The lowest possible value of leverage is 1, if there is no debt. For a single collateralized loan, such as a mortgage or repo, leverage is the reciprocal of one minus the *loan-to-value ratio* (LTV). The borrower's equity in the position is one minus the LTV. The equity at the time a collateralized trade is initiated is the initial margin. For a firm, equity is also referred to as *net worth*.

Leverage is important because it provides an opportunity to increase returns to equity investors, the so-called *leverage effect*, which can be exploited whenever the return on the firm's assets is expected to exceed the cost of debt capital. The leverage effect is the increase in equity returns that results from increasing leverage and is equal to the difference between the returns on the assets and cost of funding.

The leverage effect can be seen by writing out the relationship between asset returns r^a, equity returns r^e, and the cost of debt r^d:

$$r^e = Lr^a - (L-1)r^d$$

The effect of increasing leverage is

$$\frac{\partial r^e}{\partial L} = r^a - r^d$$

Increasing leverage by one "turn," that is, increasing assets and taking on an equal amount of additional debt that increases leverage from an initial value L_0 to $L_0 + 1$ increases equity returns by $r^a - r^d$. By the same token, leverage will amplify losses should the asset return prove lower than the cost of debt.

In foreign exchange trading, leveraged trades, called *carry trades*, involve borrowing (going short) a low-interest rate currency, and using the proceeds to buy (go long) a higher-interest rate currency. The *net carry* is $r_a - r_d$, with r_a representing the higher and r_d the lower interest rate. Carry trades lose money when the low-yielding currency appreciates enough to more than offset the net carry.

The equity denominator of the leverage measure depends on what type of entity we are looking at and the purpose of the analysis. For an intermediary such as a bank or broker-dealer, the equity might be the book or market value of the firm. These firms also issue *hybrid capital*, securities such as subordinated preference shares that combine characteristics of debt and equity. Hybrid capital can be included or excluded from the denominator of a leverage ratio depending on the purpose of the analysis. As we see in Chapter 15, regulators have invested considerable effort in ascertaining the capacity to absorb losses and thus nearness to pure equity of these securities.

For a hedge fund, the appropriate equity denominator is the net asset value (NAV) of the fund, the current value of the investors' capital. For any investment firm or investment vehicle, the leverage of individual positions or of subportfolios can be calculated using the haircut, margin, or risk capital, which we study in the next chapter, as the equity denominator.

An alternative definition often used in fundamental credit analysis relates the debt, not to the assets of the firm, but to its cash flows. The cash flow measure typically used is earnings before interest, taxes, depreciation, and amortization (EBITDA). This measure of cash flow captures the net revenues of the firm, while excluding costs that are particularly heavily influenced by accounting techniques. It also excludes interest, which is determined less by the firm's business activities than by its choice of capital structure. Leverage is then defined as the ratio of debt to EBITDA.

Example 12.1 (Leverage and the Leverage Effect) Suppose the firm's return on assets is fixed at $r^a = 0.10$, while its cost of debt is $r^d = 0.05$, and initially has this balance sheet:

Assets	Liabilities
Value of the firm $A = 2$	Equity $E = 1$
	Debt $D = 1$

Its leverage is then 2 and its return on equity is

$$2 \cdot 0.10 - 0.05 = 0.15$$

Adding a turn of leverage, that is, borrowing an additional unit of funds and investing it in an additional unit of assets, changes the balance sheet to

Assets	Liabilities
Value of the firm $A = 3$	Equity $E = 1$
	Debt $D = 2$

and increases the equity return to 0.20.

In reality, of course, asset returns are not fixed, but risky. What if asset returns end up a disappointing 0 percent? The equity return with leverage of 2 will be a loss of 5 percent, and with leverage of 3, a loss of 10 percent.

The effect of leverage depends as much on the cost of funding as on the asset return. Investors sometimes choose a degree of leverage based on the return they need to achieve. For a given cost of debt, and a given asset return, there is a unique leverage ratio that will permit the equity owners to "break even," in the sense of reaching a given hurdle rate, or required rate of return on equity. This orientation has surfaced in the debates on bank regulatory capital (see Chapter 15), in which some bankers and observers have stated that increased capital requirements will oblige banks to reduce their return-on-equity (ROE) targets.

Example 12.2 (Leverage and Required Returns) Continuing the previous example, suppose the firm's return on assets is $r^a = 0.10$, while its cost of debt is $r^d = 0.05$. If the hurdle rate or return on equity is 15 percent, the firm will choose leverage of 2. If the hurdle rate, however, is 25 percent, then the firm will choose a leverage ratio of 4:

$$4 \cdot 0.10 - 3 \cdot 0.05 = 0.25$$

Many leveraged fixed-income trades involve spreads. If a fixed-income security has a coupon rate higher than the borrowing rate on a loan collateralized by the security, for example via a repo transaction, the rate of return to a leveraged purchase is limited only by the haircut. To see this, denote the coupon rate by c, the haircut by h, and the repo rate by r, and assume $c > r$ (all in percent). The coupon and repo rates have a time dimension; the haircut does not. For every \$100 of par value, the investor puts up capital of h, earns a coupon of c, and pays $(1 - h)r$ in repo interest. The leverage is equal to $\frac{1}{h}$. The leveraged return, measured as a decimal fraction of the investor's equity capital, is

$$\frac{c - (1 - h)r}{h} = c + \frac{1 - h}{h}(c - r)$$

As h decreases, the levered return rises. The increase in returns as the debt-to-equity ratio $\frac{1-h}{h}$ rises is proportional to the spread $c - r$. Conversely, the increase in returns as the spread $c - r$ rises is proportional to the debt-to-equity ratio $\frac{1-h}{h}$.

The tension between required returns and leverage played an important role in creating the conditions of the subprime crisis, in an environment in which prospective asset returns were falling more rapidly than funding costs; the decline in credit spreads in the years just prior to the subprime crisis, displayed in Figure 14.14 is one example. Higher leverage is needed to achieve a given required rate of return on capital as the spread $c - r$ contracts, and mechanisms were found to achieve it. For example, the net spreads earned

by the off-balance-sheet vehicles described earlier in this chapter, ABCP conduits and SIVs, were extremely tight, often under 10 bps. But with sufficient leverage, it could be turned into a substantial return stream.

The use of leverage applies not only to financial intermediaries, but also to households able to borrow to finance asset purchases. Most households that own homes, for example, have borrowed at least part of the purchase price by means of a mortgage loan. The down payment is the household's equity and is a form of haircut. The leverage is the ratio of the value of the house to the down payment (and inversely related to the LTV). During the decade preceding the subprime crisis, the terms on which mortgage credit was granted were loosened to permit higher leverage and low initial interest rates, which amplified the impact of the prevailing low-interest rate environment. As discussed in Chapter 11, analysis of credit risk in residential mortgage loans assumed rising house prices. For households, equally confident that house prices would rise, or at least not fall, easy credit terms created strong incentives to make leveraged investments in housing, as shown in Example 12.3.

Example 12.3 (Leveraged Returns to Housing) Suppose house values are expected to rise 10 percent a year, including, for simplicity, rental income and net of property maintenance costs. The following table shows the resulting annual rate of return to the homeowner for different down payments and loan rates (all data in percent):

Down payment	Loan rate	
	5.5	8.0
10	50.5	28.0
20	28.0	18.0

The returns are calculated as

$$100\frac{\text{House price appreciation} - (1 - \text{Down payment})\text{Loan rate}}{\text{Down payment}}$$

Lowering the lending rate and the down payment or haircut increases the leveraged return from 18 to over 50 percent per annum. We return to the phenomenon of leveraged investment in housing in discussing asset price targeting in Chapter 15.

Leverage ratios can amplify sensitivity to changes in cash flow. If the net cash flow on a leveraged trade or of a leveraged firm is positive, but small, a small change in interest rates can make the cash flow negative.

These relationships show why firms or investors employ leverage. It also illustrates why leverage is often used as a measure of risk, and why leverage

is sometimes considered to be an independent source of risk. These last two ideas can be misleading. Leverage is not a well-defined risk measure. Part of the difficulty is that financial accounting standards have been developed with a view to solving a completely different set of problems, for example, accurately recognizing profits, or accurately capturing the explicit liabilities of the firm.

Although it is difficult to state an unambiguous definition of leverage, it is an important concept. Most severe losses suffered by financial intermediaries involve leverage in some way, and it is important to understand the extent to which borrowing is being used, implicitly or explicitly, to boost returns. To do so, we can construct an economic balance sheet for a firm or an investor that captures the implicit or *embedded leverage* in short positions, swaps, and options. This can at least provide a reasonable answer to the question of how much he has borrowed to finance positions.

We've reviewed some of the financial instruments by which credit is extended outside the traditional bank lending and bond markets in our discussion of collateral markets earlier in this chapter, in our discussion of financial innovation in Chapter 1, and in our introduction to credit risk concepts in Chapter 6. Here, we show, using T-accounts, the great extent to which a financial firm can use them to take on leverage. Some of these forms of credit are by no means new, but their volume has grown enormously in recent decades with the rise in the volume of trading in securities and OTC derivatives. Among the reasons for their growth are:

- They have lower transactions costs than traditional bank or capital markets debt. Originating a bank loan or security is a cumbersome, slow, and expensive process. It requires underwriting, syndication, and distribution by banks or securities firms. Most of the forms of credit discussed here require only a counterparty. But along with that cost saving, counterparty risk has become more prevalent.
- The granting of credit is an inherent part of trading in the assets being financed, and the amount of credit granted adjusts naturally to the size of the position being financed.
- Collateralization of the loan and adjustments to the amount lent occur naturally as part of trading and brokering trades.

These forms of borrowing are generally collateralized in some way, which also affects the economic leverage. When borrowing is explicit, as for example through taking loans or deposits, or issuing bonds, the impact on leverage is straightforward. In other forms of borrowing, some analysis is required to measure leverage. For each of these forms, we see how to determine the amount of borrowing or leverage implicit in the position.

12.3.2 Margin Loans and Leverage

Margin lending has a straightforward impact on leverage. The haircut determines the amount of the loan that is made: at a haircut of h percent, $1 - h$ is lent against a given market value of margin collateral, and h percent of the position's market value is the borrower's equity in the position. The leverage on a position with a haircut of h percent is $\frac{1}{h}$.

Haircut (%)	Amount borrowed (%)	Leverage
10	90	10
50	50	2
90	10	$\frac{1}{0.9}$

Example 12.4 (Leverage and Margin Loans) We take as the starting point of this and the remaining examples in this section a firm with $100 in cash, corresponding to an initial placement of $100 in equity by its owners. For concretness, we imagine a hedge fund account, Lever Brothers Multistrategy Master Fund LP, with this economic balance sheet on opening day:

Assets	**Liabilities**
Cash $100	Equity $100
	Debt $0

Assume Lever Brothers finances a long position in $100 worth of an equity at the Reg T margin requirement of 50 percent. It invests $50 of its own funds and borrows $50 from the broker. Immediately following the trade, its margin account has $50 in equity and a $50 loan from the broker:

Assets	**Liabilities**
Stock value $100	Equity $50
	Margin loan $50

The broker retains custody of the stock as collateral for the loan. Lever Brothers' full economic balance sheet, including the entries in its margin account, is now

Assets	Liabilities
Cash $50	Equity $100
Stock value $100	Margin loan $50

The firm's leverage has risen from 1 to 1.5.

12.3.3 Short Positions

Short positions lengthen the balance sheet, since both the value of the borrowed short securities and the cash generated by their sale appear on the balance sheet. They therefore increase leverage, which looks at the gross amount of assets, that is, longs plus the absolute value of short positions.

Example 12.5 (Leverage and Short Positions) Our starting point, as in Example 12.4, is a hedge fund with $100 in cash, corresponding to an initial placement of $100 in equity by its owners.

To create a short position in a stock, Lever Brothers borrows $100 of the security and sells it. It has thus created a liability equal to the value of the borrowed stock, and an asset, equal in value, consisting of the cash proceeds from the short sale. The cash cannot be used to fund other investments, as it is collateral; the broker uses it to ensure that the short stock can be repurchased and returned to the stock lender. It remains in a segregated short account, offset by the value of the borrowed stock. The stock might rise in price, in which case the $100 of proceeds would not suffice to cover its return to the borrower. Lever Brothers must therefore in addition put up margin of $50.

Immediately following this trade, Lever Brothers' margin and short accounts have $50 in equity and a $50 loan from the broker:

Assets	Liabilities
$150 Due from broker:	Equity $50
$50 Margin $100 Short sale proceeds	Borrowed stock $100

Lever Brothers' full economic balance sheet is

Assets	Liabilities
$50 Cash	Equity $100
$150 Due from broker	Borrowed stock $100

The firm has gone from leverage of 1 to 2. Notice that the leverage in this example is higher than in the example of a long position via margin lending. The reason is that in establishing a short position, the securities must be borrowed; leverage is inherent in short positions, but is a choice for long positions. In the example of the long position, only half the value of the purchased stock was borrowed, so the leverage was 1.5. Here, the entire stock position must be borrowed to execute the short. The fund could reduce its overall leverage by reducing its borrowing to finance long positions, but cannot reduce leverage in the short position itself.

Gross and Net Leverage Although, like any other risk asset, short positions generate leverage, they reduce risk if there are long positions with which they are positively correlated, or other short positions with which they are negatively correlated. If short positions play a hedging role in the portfolio, leverage will overstate the risk, since adding the short positions increases leverage, but reduces market risk.

This leads to a distinction between *gross* and *net leverage*. Gross leverage is defined as the sum of all the asset values, including cash generated by shorts or assets acquired with that cash, divided by capital. It can be thought of as the total "length" of the balance sheet divided by the capital. Net leverage is computed as the ratio of the difference between the market values of the long and short positions to the capital.

The balance sheet alone will not tell the risk manager whether the short positions are risk-augmenting or -reducing. Other information in addition to the long and short leverage, such as VaR and stress test reports, or a qualitative examination, are needed. For this reason, in reporting leverage, long positions and short positions should be reported separately. Leverage reporting is important, but far from a complete view of the risks of a portfolio.

12.3.4 Derivatives

Derivative securities are a means to gain an economic exposure to some asset or risk factor without buying or selling it outright. One motivation for market participants to use derivatives is as a means of increasing leverage. Leveraged ETFs are an example of an investment product that uses derivatives in order to create the economics of leveraged investment in, say, an equity index.

Although derivatives are generally off-balance-sheet items in standard accounting practice, they belong on the economic balance sheet, since they may have a large impact on returns. Each side of a derivatives contract is synthetically long or short an asset or risk factor. But the market values

of derivative securities are not equal to the value of the underlying asset, or the riskiness of the positions. Therefore, their market values or NPVs are generally not the best values to represent them. Rather, for purposes of measuring economic leverage, we wish to find, for each type of derivative, a *cash-equivalent market value*. As with most issues around the measurement and interpretation of leverage, as much judgment as science is involved.

As we discussed in Chapter 4, there are two basic types of derivatives, futures, forwards, and swaps on the one hand, and options on the other. Their use has a very different impact on leverage:

Futures, forwards, and swaps are linear and symmetric in the underlying asset price and can be hedged statically. Therefore, the amount of the underlying that the derivatives contract represents is set once and for all at the initiation of the contract, even though the net present value (NPV) may vary over time. The cash-equivalent market value of futures, forwards, and swaps can be represented on an economic balance sheet by the market value of the underlying security, rather than the NPV.

Options have a nonlinear relationship to the underlying asset price and must be hedged dynamically. Therefore, the amount of the underlying that the derivatives contract represents varies over time. It can be fixed approximately at any point in time by the option delta, or by a delta-gamma approximation. In general, volatility is important in the value of an option, so option contracts cannot generally have a zero NPV at initiation. Rather, it has a market value that can be decomposed into an *intrinsic value*, which may be zero, and a *time value*, which is rarely zero.

The cash-equivalent market value of options can be represented on an economic balance sheet by their delta equivalents rather than their market values. As the underlying price varies, the amount of the economic balance sheet exposure, and the leverage, will vary. Measured this way, the cash-equivalent market value doesn't take the time value and volatility of the option into account, except insofar as it influences the option delta.

Like margin arrangements, derivatives also generate counterparty credit risk. If the derivative creates a synthetic long (short) position, the economic balance sheet entries mimic those of a cash long (short) position. The implicit assets and liabilities created on the economic balance sheet are vis-à-vis the derivatives counterparties.

In the rest of this section, we illustrate these principles of how best to represent derivatives positions for purposes of computing leverage.

Example 12.6 (Leverage and Derivatives) We again take as the starting point a hedge fund account with $100 in cash, corresponding to an initial placement of $100 in equity by investors. Suppose Lever Brothers now adds:

- A one month currency forward, in which Lever Brothers is short $100 against the euro
- An at-the-money (currently 50-delta) three month long call option on S&P 500 equity index futures, with an underlying index value of $100
- A short equity position expressed via a three-month equity total return swap (TRS), in which Lever Brothers pays the total return on $100 market value of Intel and the short rebate, or cost of borrowing Intel stock
- Short protection on Ford Motor Co. via a five year credit default swap, with a notional amount of $100

We assume that the nonoption positions are initiated at market-adjusted prices and spreads, and therefore have zero NPV. We'll also assume that the counterparty is the same for all the positions, namely the prime broker or broker-dealer with which they are executed.

Let's look at the economic balance sheet for each position, assuming there is no initial margin. Then we'll consolidate the positions and add a margin requirement to find Lever Brothers' overall leverage, as if margin were being assessed by a single broker or counterparty on a portfolio basis.

We start with the currency forward, which is implicitly a pair of money market positions, a long one-month euro-denominated bank deposit with a value of $100, financed by borrowing $100 for one month. Assuming the one month forward exchange rate is $1.20 per euro, we have:

Assets	Liabilities
$100 equivalent of €80 bank deposit	$100 broker loan

The equity option, with a delta of 50 percent, is equivalent to having bought $50 worth of the S&P 500 index with a broker loan of $50:

Assets	Liabilities
$50 long S&P 500 position	$50 broker loan

The Intel TRS is equivalent to a short position in Intel stock (ticker INTC), established with no initial margin. If the price of INTC is $20, we have:

Assets	Liabilities
$100 due from broker (short sale proceeds)	Borrowed stock (5 sh INTC)

The short CDS protection position, finally, is equivalent to a long position in a par-value five year Ford floating-rate note (FRN), financed by borrowing at a floating rate at five years' term. We assume that the financing can be terminated early without penalty if there is a credit event. Its economic balance sheet is

Assets	Liabilities
$100 Ford FRN	$100 term loan

Note that the leverage in each of these transactions, if there is no initial margin requirement, is infinite.

Now let's put these positions together to get Lever Brothers' complete balance sheet. Recall that the account starts with $100 placed by investors. We make the additional assumption that the initial margin on the portfolio of these derivatives positions is $50.

Assets	Liabilities
Cash $50	Equity $100
$150 due from broker	
$50 margin	$150 short-term
$100 short sale proceeds	broker loan
$100 equivalent of	$100 term loan
€ 80 bank deposit	Borrowed stock
$50 long S&P 500 position	(5 sh INTC)
$100 Ford FRN	

The fund has attained leverage in its long positions of 3.5, plus a short position with a magnitude equal to its NAV. It has thus gained economic exposure to securities valued at $450, using only $50 in cash.

These examples illustrate a serious issue in computing and interpreting leverage ratios, which we alluded to in the context of gross and net leverage: how to treat routine hedges such as currency hedges for foreign currency-denominated positions, and risk-free rate hedges for credit-risky fixed-income positions. In general, these currency and rate exposures can

be neutralized quite accurately and reliably. The currency and rate hedges, however, are of the same order of magnitude as the underlying exposures themselves, and if carried on the economic balance sheet will bloat it, distort the resulting leverage reports, and obscure the more material risks in the portfolio.

12.3.5 Structured Credit

Structured credit also provides embedded leverage. As we saw in the securitization example of Chapter 9, the bond tranches take losses only in more extreme default and correlation scenarios. The mezzanine tranche is relatively thin, so while it takes an extreme default scenario to cause any loss at all to the mezzanine tranche, if a loss occurs, it is likely to be large. This property of thin subordinated securitization tranches is called "cuspiness," since it materializes when the attachment point of the bond is at the cusp of default losses in the pool.

The equity note bears most of the risk of loss in the securitization example of Chapter 9. It has, however, a notional amount of only $5,000,000, while the underlying collateral pool is $100,000,000, financed long-term through the bond tranches. Implicitly, the balance-sheet leverage used is a bit less than 20 turns, once we take account of the residual risk borne by the bonds. If the equity note itself is financed in the repo markets, with, say, an 80 percent haircut, the economic leverage could easily reach 100.

12.3.6 Asset Volatility and Leverage

Investing in assets with a higher return volatility is economically quite similar to leverage. Ignoring the potential reputational risk, losses beyond the investor's equity in a trade don't matter to him. An asset with more volatile returns provides a higher probability of higher leveraged returns to the investor, but also a higher probability of losses to the provider of credit. The upside adds to the investor's expected return, but the downside doesn't diminish it. In other words, leverage adds optionality or convexity to the return profile. Examples of the impact of the convexity inherent in leveraged returns include:

1. An investor in assets financed with margin loans can systematically favor more-volatile over less-volatile assets within a class with the same haircut. This behavior is also an example of adverse selection.
2. Equity holders may favor greater risk-taking by a firm than do its creditors because of the risk-shifting incentives discussed in Chapter 6. Public risk policy that leads creditors of financial intermediaries to believe that they will be made whole in the event of a systematic risk event ("too-big-to-fail") reduces credit risk premiums and makes leverage

more economically appealing to equity holders, compounding the effect. We discuss this phenomenon further in the context of financial stability policies in Chapter 15.

Leverage ratios do not capture the effect of volatility on convexity, which amplifies leverage economics and can make it more attractive. At the same time, volatility estimates do not capture the funding risk of a portfolio. Both are needed for genuine insight into the risk of a portfolio.

12.4 TRANSACTIONS LIQUIDITY RISK

Next, we turn to market or transactions liquidity risk. We begin by describing what is meant when we say an asset, as opposed to a market or a market participant, is "liquid." An asset is liquid if it resembles money, in that it can be exchanged without delay for other goods and assets, and in that its value is certain.[5] Most assets other than money do not completely share these characteristics of immediacy and certainty. They cannot be exchanged directly for other goods and assets, because we don't live in a barter economy; only money can do that. Nonmoney assets must be sold or liquidated before they can be exchanged for other goods or assets. This takes at least some time, and the proceeds from the sale are uncertain to at least some extent.

Transactions liquidity includes the ability to buy or sell an asset without moving its price. An order to buy an asset increases demand and causes its price to increase. The effect is usually small, but can be large when the order causes a large transitory imbalance between the demand and supply of the asset at the initial price. A market participant can thereby be locked into a losing position by lack of market liquidity.

12.4.1 Causes of Transactions Liquidity Risk

Transaction liquidity risk is ultimately due to the cost of searching for a counterparty, to the market institutions that assist in search, and to the cost of inducing someone else to hold a position. We can classify these *market microstructure* fundamentals as follows:

Cost of trade processing. Facilitating transactions, like any economic activity, has fixed and variable costs of processing, clearing,

[5]This is true even if there is inflation. At any moment, the holder of money knows exactly how many *nominal* units he has, even if he can't be quite sure what the *real* value of his money balances is.

and settling trades, apart from the cost of finding a counterparty and providing immediacy. These costs are tied partly to the state of technology and partly to the organization of markets. While processing may be a significant part of transaction costs, it is unlikely to contribute materially to liquidity risk. An exception is natural or man-made disasters that affect the trading infrastructure.

Inventory management by dealers. The role of dealers is to provide trade immediacy to other market participants, including other dealers. In order to provide this service, dealers must be prepared to estimate the equilibrium or market-clearing price, and to hold long or short inventories of the asset. Holding inventories exposes dealers to price risk, for which they must be compensated by price concessions. The dealers' inventory risk is fundamentally a volatility exposure and is analogous to short-term option risk.

Adverse selection. Some traders may be better informed than others, that is, better situated to forecast the equilibrium price. Dealers and market participants cannot distinguish perfectly between offers to trade arising from the counterparty's wish to reallocate into or out of cash, or responses to non-fundamental signals such as recent returns ("liquidity" or "noise" traders) from those who recognize that the prevailing price is wrong ("information" traders). A dealer cannot be sure for which of these reasons he is being shown a trade and therefore needs to be adequately compensated for this "lemons" risk through the bid-ask spread. A dealer does, however, have the advantage of superior information about the flow of trading activity, and learns early if there is a surge in buy or sell orders, or in requests for two-way prices.

Differences of opinion. Investors generally disagree about the "correct" price of an asset, or about how to interpret new information, or even about whether new information is important in assessing current prices. Investors who agree have less reason to trade with one another than investors who disagree. When agreement predominates, for example, when important and surprising information is first made public, or during times of financial stress, it is more difficult to find a counterparty.

These fundamentals take different forms in different types of market organization:

- In a *quote-driven system*, certain intermediaries, who may be dealers, market makers, or specialists, are obliged to publicly post two-way prices or quotes and to buy or sell the asset at those prices within known

transaction size limits. These intermediaries must be prepared to hold long or short inventories of the asset and typically trade heavily among themselves and with the "buy side" in order to redistribute inventories of securities and reduce them overall. Quote-driven systems are typically found in OTC markets.

- *Order-driven* systems come closest to the perfectly competitive auction model. In this type of market clearing, market participants transmit orders to an aggregation facility, for example, a broker, specialist, or electronic trading system. In some cases, a call auction is held in which the price is gradually adjusted until the volumes of bids and offers forthcoming at that price are equated. More typically, a continuous auction is conducted in which the best bids and offers are matched, where possible, throughout the trading session. Order-driven systems are typically found on organized exchanges.

12.4.2 Characteristics of Market Liquidity

A standard set of characteristics of market liquidity, focusing primarily on asset liquidity, helps to understand the causes of illiquidity:

Tightness refers to the cost of a round-trip transaction, and is typically measured by the bid-ask spread and brokers' commissions.

Depth describes how large an order it takes to move the market adversely.

Resiliency is the length of time for which a lumpy order moves the market away from the equilibrium price.

The latter two characteristics of markets are closely related to immediacy, the speed with which a market participant can execute a transaction.

Lack of liquidity manifests itself in these observable, if hard-to-measure ways:

Bid-ask spread. If the bid-ask spread were a constant, then going long at the offer and short at the bid would be a predictable cost of doing the trade. However, the bid-ask spread can fluctuate widely, introducing a risk.

Adverse price impact is the impact on the equilibrium price of the trader's own activity.

Slippage is the deterioration in the market price induced by the amount of time it takes to get a trade done. If prices are trending, the market can go against the trader, even if the order is not large enough to influence the market.

These characteristics, and particularly the latter two, are hard to measure, making empirical work on market liquidity difficult. Data useful for the study of market microstructure, especially at high-frequency, are generally sparse. Bid-ask spreads are available for at least some markets, while transactions volume data is more readily available for exchange-traded than for OTC securities.

12.5 LIQUIDITY RISK MEASUREMENT

12.5.1 Measuring Funding Liquidity Risk

Asset-Liability Management Remaining liquid in the sense of reducing funding liquidity risk is part of the traditional asset-liability management function in banks. This process includes measures such as

- Tracking and forecasting available cash and sources of funding on the one hand, and cash needs on the other
- Keeping certain ratios of ready cash and readily marketable securities to meet unusual demands by depositors and other short-term lenders for the return of their money

Example 12.7 (Goldman Sachs Global Core Excess) Goldman Sachs, for example, describes its liquidity risk management policy as maintaining a "Global Core Excess"

> to pre-fund what we estimate will be our likely cash needs during a liquidity crisis and hold such excess liquidity in the form of unencumbered, highly liquid securities that may be sold or pledged to provide same-day liquidity . . . to allow us to meet immediate obligations without needing to sell other assets or depend on additional funding from credit-sensitive markets.

The liquidity buffer accounts for about 20 percent of the balance sheet. It includes cash and a portfolio of securities that can be pledged as collateral rather than sold.[6]

Apart from cash, liquidity portfolios can contain cash equivalents, defined in the International Accounting Standards as "short-term, highly liquid

[6]See Goldman Sachs Group, Inc. (2010).

investments that are readily convertible to known amounts of cash and which are subject to an insignificant risk of changes in value."

Funding Liquidity Management for Hedge Funds Hedge funds, even if only moderately leveraged, are vulnerable to the withdrawal of liquidity, either by counterparties or through withdrawals of investor capital. Both have the same effect of potentially obliging the fund manager to unwind positions rapidly and generating exposure to transactions liquidity risk. When this happens to many funds at the same time, it can contribute to "fire sales," a financial crisis phenomenon we discuss in Chapter 14.

Hedge funds have a number of sources of liquidity that can be monitored as part of overall risk management:

Cash provides unfettered liquidity. It can be held in the form of money market accounts or Treasury bills. Excess cash balances with brokers and money market accounts are not entirely riskless and therefore are not perfectly liquid. Broker balances carry with them the counterparty risk of the broker; in the event the broker fails, the cash balances will be immobilized for a time and only a fraction may ultimately be paid out. Money market funds, as was demonstrated during the subprime crisis, may suspend redemptions or "break the buck" and pay out at less than 100 percent of par.

Unpledged assets (or assets "in the box") are unencumbered assets not currently used as collateral. They are generally also held with a broker, who in this case is acting only as a custodian and not as a credit provider.

This source of liquidity is limited by the price volatility of the assets and the ability to use the assets as collateral. In a financial crisis, only U.S. Treasuries, particularly short-term Treasuries, will be liquid enough to serve as near-cash assets. Other high-credit quality assets, such as U.S. agency bonds, that is, bonds issued by Fannie Mae and Freddie Mac, were less reliable stores of value during the subprime crisis. The usefulness of bonds other than Treasuries and agencies to serve as collateral and the ability to obtain funding by pledging them was also impaired during the crisis, as seen for agency debt in Figure 12.4 above. Haircuts on such debt were reportedly also rising.

Assets can be sold rather than pledged. This alternative route to liquidity is limited by the likely proceeds from a sale. In a distressed market, these may be far lower than recent market prices or a model-based fair value. Thus, as a source of funding liquidity, unpledged assets are subject not only to fluctuations in the amount of borrowing they can support, but also to transactions liquidity risk.

Unused borrowing capacity on pledged assets can be used to finance additional positions. Like unpledged assets, this form of liquidity is not unfettered. Rather, it is subject to revocation by counterparties, who may raise haircuts or decline to accept the securities as collateral when the time comes to roll over a collateralized securities loan. Since most of these collateralized loans are very short term, credit can disappear rapidly. This occurred for many lower-quality forms of collateral during the subprime crisis.

However, a systemic risk event, in which hedge fund investments are regarded as potential sources of liquidity by investors, will be a challenge even for most effective liquidity risk management. We referred to this phenomenon earlier in this chapter: Many hedge funds that had not experienced large losses received redemption requests for precisely that reason from investors who were themselves seeking liquidity.

12.5.2 Measuring Transactions Liquidity Risk

There are two major types of quantitative liquidity risk measures. They focus on the available data that are pertinent to liquidity risk:

- Bid-ask data
- Transaction or turnover volume data
- Data on the size outstanding of securities issues

Quantitative measures of transactions liquidity risk are not as widely used as funding liquidity risk measures, and quantitative liquidity risk measurement is generally less widely practiced than quantitative market and credit risk. Partly, this is because they have not been incorporated into the regulatory framework to the same extent as have standard models of market and credit risk measurement. As we see in Chapter 15, regulators have focused more intently on banks' liquidity risk since the onset of the subprime crisis. Partly, it is due to the measurement challenges alluded to above.

Transaction Cost Liquidity Risk These measures focus on the risk of variation in transactions costs. The starting point is a distributional hypothesis regarding the future bid-ask spread.

Daily changes in the relative bid-ask spread, that is, the spread as a fraction of the price, can be assumed as a starting point to be normally distributed with a mean of zero and a constant variance (estimated by the sample variance of the spread σ_s). The zero-mean assumption at least is unobjectionable, since bid-ask spreads cannot rise indefinitely or shrink to

zero. The expected transactions cost is the half-spread or mid-to-bid spread

$$E[P_{t+1}]\frac{\bar{s}}{2}$$

where

$$s = 2\frac{\text{ask price} - \text{bid price}}{\text{ask price} + \text{bid price}} = \frac{\text{ask price} - \text{bid price}}{\text{midprice}}$$

$\bar{s}$ is an estimate of the expected or typical bid-ask spread, and P is the asset midprice.

Under the zero-mean normality hypothesis, we set $\bar{s} = s$, the most recent observation on the relative spread. The 99 percent confidence interval on the transactions cost, in dollars per unit of the asset, is then

$$\pm\bar{P}\frac{1}{2}(\bar{s} + 2.33\sigma_s)$$

where $\bar{P}$ is an estimate of the next-day asset midprice. We typically set $\bar{P} = P$, the most recent observation on price. We refer to $\frac{1}{2}(\bar{s} + 2.33\sigma_s)$ as the 99 percent *spread risk factor*.

The transactions cost risk at a 99 percent confidence level is then measured by the current value of the spread risk factor, that is, by the 99th percentile of the actual proportional daily changes in the half-spread over a given historical period, say, the past two years. It represents the worst case, at a 99 percent confidence level, of the bid-ask spread cost of changing a position.

Measuring the Risk of Adverse Price Impact A tool for measuring the risk of adverse price impact is *liquidity-adjusted VaR*. The starting point is an estimate of the number of trading days, T, required for the orderly liquidation of a position. If the position is liquidated in equal parts at the end of each day, the trader faces a one-day holding period on the entire position, a two-day holding period on a fraction $\frac{T-1}{T}$ of the position, a three-day holding period on a fraction $\frac{T-2}{T}$ of the position, and so forth if he wishes to liquidate the position with no adverse price impact.

The next step is to arrive at an estimate of the one-day position VaR. Suppose the entire position X were being held for T days. The T-day VaR would be estimated by the familiar square-root-of-time rule:

$$\text{VaR}_t\left(\alpha, \frac{1}{252}\right)(X) \times \sqrt{1^2 + 1^2 + \cdots + 1^2} = \text{VaR}_t(\alpha, \tau)(X) \times \sqrt{T}$$

However, this would be an overstatement of the VaR; the VaR has to be greater than the one-day position VaR, but less than the one-day position VaR$\times\sqrt{T}$. We will be holding a sequence of position sizes $1, \frac{T-1}{T}, \frac{T-2}{T}, \ldots, \frac{T-2}{T}$, rather than $1, 1, \ldots, 1$, all with the same variance. The VaR is therefore

$$\begin{aligned}&\mathrm{VaR}_t\left(\alpha, \frac{1}{252}\right)(X) \times \sqrt{1 + \left(\tfrac{T-1}{T}\right)^2 + \left(\tfrac{T-2}{T}\right)^2 + \cdots + \left(\frac{1}{T}\right)^2} \\ &= \mathrm{VaR}_t\left(\alpha, \frac{1}{252}\right)(X) \times \sqrt{\sum_{t=1}^{T}\left(1 - \frac{t-1}{T}\right)^2}\end{aligned}$$

which simplifies to

$$\mathrm{VaR}_t\left(\alpha, \frac{1}{252}\right)(X) \times \sqrt{\frac{(1+T)(1+2T)}{6T}}$$

For example, suppose the trader estimates that a position can be liquidated in $T = 5$ trading days. The adjustment to the overnight VaR of the position is then 1.48324, that is, we increase the VaR by 48 percent. For $T \approx 10$, the liquidity risk adjustment doubles the overnight VaR of the position. These adjustments are large by comparison with the transaction cost liquidity risk measures of the previous section. Estimates of the time to liquidate or "time to escape" are usually based on a comparison of the position size with the daily transactions volume.

In extreme cases, or during financial crises, there may be several constraints on liquidation decisions. There may be trade-offs among adverse price impact, funding liquidity, and solvency. An example is that of a hedge fund facing redemptions. It must liquidate some positions to meet redemptions. Suppose it liquidates those with the smallest adverse price impact first, but redemptions continue. The fund may face collapse because it can not meet the ongoing withdrawals by quickly selling the remaining, relatively illiquid positions. If, on the other hand, it sells the least liquid positions first, it will incur losses due to adverse price impact, and likely post NAV losses earlier on, which may accelerate redemptions.

Liquidation decisions may also interact with the incentive structure of credit markets. An example of this is the "sellers' strike" observed early in the subprime crisis, in which banks were reluctant to reduce leverage by selling certain positions, often referred to as "toxic assets," primarily structured credit products and mortgage loans. However, prices for these products were falling rapidly, and the banks were reluctant to realize losses

at market valuations many considered to be well below fundamental value. The paradox of this phenomenon is that it was stronger banks that were the most active sellers, while the weaker banks were more inclined to hold back. By avoiding sales, weak banks increased the probability of illiquidity and possibly failure in the short run, but increased the potential profit from these assets in the long run once their prices recovered. In other words, they had an option-like position in the assets. The longer-term profit was conditional on the banks' survival through the crisis and on the fundamental values of the assets proving to be higher than their current market prices.

12.6 LIQUIDITY AND SYSTEMIC RISK

Systemic risk, the risk of severe, widespread financial stress and intermediary failure, possibly including disruption of payment systems, is a function among other things of economy-wide liquidity.

Systemic risk can be thought of as resulting from *external costs* in the production of financial services, analogous to pollution or traffic jams. Market participants, in this approach, incur risks that are partially shifted to the market as a whole. These collectively borne risks are generated by correlation between the impact of market events on different market participants. When general market conditions deteriorate, many borrowers are affected in the same way at the same time. One way this happens is when the value of collateral declines, or lenders become more concerned about the transactions liquidity risk of certain types of collateral. Another way many borrowers can be affected at once is when the market becomes more reluctant to finance certain types of trades or lend to certain types of institutions. Finally, asset price declines may contribute to the simultaneous deterioration of different market participants' financial positions.

Liquidity is ephemeral for many securities. It tends to become impaired at precisely the moments when market participants most need it. Liquidity is a result of network effects and mutually reinforcing expectations that are hard to capture quantitatively. A well-functioning market can depend on whether the market will "all hold hands," or not, and on whether enough market makers will make two-way prices they would be willing to honor in actual transactions.

12.6.1 Funding Liquidity and Solvency

Liquidity is the ability to meet immediate demand for cash. Solvency is having a positive amount of equity capital, that is, assets exceeding liabilities. Liquidity and solvency are closely related, since both pertain to the ability

to repay debts. But a firm can be insolvent, yet able to continue for some time to roll over its debts, or may funded largely by long-term debt, and thus not face illiquidity. A firm may be solvent, that is, able to pay its long-term debt, because its assets will ultimately be worth more than its liabilities, but illiquid, since it cannot roll over short-term debt or raise enough cash to repay it timely. Liquidity and solvency are linked by asset values; large changes in the mark-to-market value of assets can expose a solvent financial intermediary to illiquidity.

Illiquidity can become insolvency if it is extreme enough, as a debtor can become unable to either borrow or realize the funds required to meet debt obligations by selling assets. Because intermediaries are not transparent—the asymmetric information problem of Chapter 6—liquidity and solvency are also linked by market perceptions about the state of intermediaries. The suspicion by market participants that a financial firm is insolvent can lead to that firm becoming illiquid. At the time of the bankruptcies of Bear Stearns and Lehman Brothers, and to this day, there was a great deal of debate of whether one or both firms were insolvent, or merely illiquid.

During the financial crisis, both illiquidity and insolvency played a role in causing the collapse of financial institutions. Schematically, the sequence of events in the collapse of an intermediary can be described this way:

- Reports of losses at the intermediary, or even losses to other institutions, raise questions about the firm's solvency. Actual losses at the intermediary are not necessary to set the process in motion.
- All firms, financial intermediaries as well as nonfinancial firms, become more reluctant to lend to the intermediary. The reluctance is reflected not only in higher credit spreads, but more importantly, in an inability of the affected firm to obtain the previous volume of loan proceeds.
- The intermediary is forced to raise cash by liquidating assets. In a distressed market, the firm is likely to realize losses by doing so.
- Lenders are aware that the intermediary's problems are now being compounded by realized mark-to-market losses, further reducing their willingness to extend credit.
- The process now accelerates, becoming a run. Lenders to the intermediary act out of the belief that it is insolvent and that they will be repaid in full only if they are repaid early. The intermediary cannot instantly liquidate its remaining assets for the full amount it owes. Within a very few days, the intermediary will be unable to meet the demand for cash.

It is the drain of cash, not defaults, that destroy the firm. But it is questionable whether a pure liquidity event, unaccompanied by even the shadow of a doubt about its solvency, can occur for one firm in isolation. We look at the mechanics of runs, and the role they play in financial crises, in Chapter 14.

We discuss the regulatory approach to the distinction between liquidity and solvency in Chapter 15 in our treatment of capital and reserve requirements and minimum liquidity ratios.

12.6.2 Funding and Market Liquidity

A key mechanism linking funding and market liquidity is leverage. A market participant with a long position for which it can no longer obtain funding is forced to sell. If funding has become tight in the market as a whole, the set of potential holders of the asset will be reduced. This mechanism depresses the asset price, regardless of its expected future cash flows. The effect may only be transitory, but "transitory" may be a relatively long time, and may affect the solvency of the initial holder of the asset during that period. This mechanism becomes most evident during financial crises. Rapid deleveraging causes a "debt-deflation crisis," which we discuss in more detail in Chapter 14.

Mark-to-market risk combines aspects of market and credit risk. It is often the case that the holding period of an asset, or the time horizon of a trade, is quite long. The investor or trader, however, may be required to report frequently the values of assets and liabilities.

Market liquidity can constrain funding liquidity. As we saw just above in describing the liquidation dilemma of a hedge fund facing redemptions, a market participant obliged to sell assets in order to raise cash faces a choice about what assets to sell first: those with the greatest or the least market liquidity. Such situations are most liable to arise during times of heightened financial fragility and distress, when there are many other traders in a similar situation, and possibly with a similar portfolio. The key trade-off is that by selling the most liquid assets first, the market participant incurs the smallest adverse impact, but left with a more illiquid portfolio with which to face any continuing funding liquidity pressure. If, instead, he sells illiquid assets first, the realized losses increase the real or perceived risk of insolvency, and may therefore worsen the funding liquidity pressure.

12.6.3 Systemic Risk and the "Plumbing"

An important channel through which liquidity risk events can become systemic risk events is through problems in the payments, clearing, and settlements systems. Disruptions in these systems, often called the "plumbing" of the financial system, can be systemic risk events in their own right, or amplify an initial market or credit risk event into a systemic problem. These systems, called *financial market infrastructures* or *utilities* in contemporary regulatory parlance, include securities exchanges, clearinghouses, securities

depositories and settlement systems, and payment systems. A disruption of any of these can impact many market participants simultaneously, and illiquidity or insolvency of one counterparty can have downstream effects on others through these systems.

The *tri-party repo system* is a relatively recently developed infrastructure that has rapidly gained in importance in the past decade. It differs from conventional repo in that securities are held in custody by a third party, almost always one of two major *clearing banks*, Bank of New York Mellon (BNY) and JPMorgan Chase. In the tri-party repo cycle, the counterparty borrowing cash collateralized by securities deposits the securities with the custodian, while the counterparty lending cash deposits the funds with the custodian. The custodian sees to it that the funds are made available to the borrower and maintains the securities in a segregated account so that they can be seized without delay by the lender should the borrower default.

Most tri-party repo transactions are short-term, often overnight. However, they are typically renewed regularly at maturity, so they become a part of the longer-term financing mix of the borrower. Tri-party repo is typically used by securities firms to finance securities portfolios. Funding, that is, cash collateral, is typically provided by money market mutual funds, insurance companies, and other institutional investors.

Tri-party repo has grown enormously over the past two decades, along with repo markets in general, as seen in Figure 12.3, reaching a volume of $2.8 trillion of securities financed by early 2008, encompassing a wide range of security types as collateral. Two reasons for this growth are economies of scale in clearing, which are generated in part by the greater scope for book-entry transactions rather than delivering securities, and the desirability of third-party custody of securities.

However, the mechanics of tri-party repo also involve liquidity risks. Like most repo contracts, much tri-party repo has a one-day term. Regardless of the term of the repo, each transaction is unwound daily. The clearing bank returns the securities to the account of the securities lender/borrower of cash, generally a large broker-dealer, and the cash to the account of the securities borrower/lender of cash. The clearing bank in effect finances the dealer, generally a broker-dealer financing its securities inventory, by permitting a *daylight overdraft*. Thus, apart from clearing and custody services, the custodial bank provides intraday credit to the borrower of cash, collateralized by the securities. The custodial bank thereby assumes an exposure to the cash borrower; that is, the counterparty credit risk that the value of the collateral, if liquidated, will not be enough to cover the debt.

A number of funding liquidity risks are inherent in this process. A clearing bank might decline credit to one of its customers, provoking or

amplifying a rollover risk event for the customer. The lenders of cash might decline to leave cash with a clearing bank, or might withdraw from the repo market generally. Tri-party repo is not only large, but concentrated; three dealers accounted for 38 percent of outstanding tri-party repo in early 2010. The default of a large dealer would likely trigger the immediate sale of the securities in its account that collateralize its intraday overdraft. The mere possibility that the dealer's account is undercollateralized would also call the clearing bank's liquidity and solvency into question. While these systemic risk events have not materialized, the risks were among the background factors in the Federal Reserve's introduction the Primary Dealer Credit Facility (PDCF) on March 17, 2008, during the run on Bear Stearns. The PDCF provided primary dealers with access to collateralized overnight funding.

12.6.4 "Interconnectedness"

Credit transactions, as we have now seen, take myriad forms. The set of market participants involved as either borrowers or lenders in at least some credit transactions includes most adults and every firm, including nonfinancial firms, even in less-developed economies. Credit relationships form a network in which each entity is a creditor and debtor of numerous other entities. Each entity's creditworthiness depends, therefore, in part on the creditworthiness of its obligors. If debts owed to a firm become uncollectible, it may become unable to pay its own creditors.

Financial intermediaries are the most enmeshed entities in this network, since they specialize in intermediating savings between lenders and borrowers and have leveraged balance sheets in which the bulk of the assets are debt of another entity. We have discussed the counterparty risks that arise from these networks, focusing on the standpoint of an individual firm managing these risks. Counterparty risk also has an important systemic risk aspect; a decline in the creditworthiness of its borrowers imperils the financial intermediaries' own creditworthiness.

Another aspect of interconnectedness is the prevalence in contemporary finance of long intermediation chains involving securitization, off-balance sheet vehicles, and MMMFs, in addition to traditional intermediaries. Some observers view these chains as proliferating potential points of failure in the financial system. The complexity of intermediation can make itself known in surprising ways, drawing attention to vulnerabilities that had not previously been widely identified, such as the hedge fund losses on securities in custody with Lehman during its bankruptcy. The web of credit thereby makes credit risk a matter of public policy and concern, as we see in Chapter 15, as well as a phenomenon for firms to cope with.

FURTHER READING

Greenbaum and Thakor (2007) provides a textbook introduction to financial intermediation by banks and other institutions. Much of the literature on intermediation tries to explain why commercial banks are so prominent in the financial landscape. Diamond and Dybvig (1983) and Diamond (1984) are classic papers on depository institutions. Diamond (1984) explains banks' prominence in intermediation from an information cost viewpoint. Diamond and Dybvig (1983) focuses on random fluctuations in households' need for cash to explain the susceptibility of banks to panics and runs. Diamond (1996, 2007) are accessible presentations of the theory in these papers. A counterpoint is provided by Calomiris and Kahn (1991) and Randall (1993), which argue that uninsured depositors also provide some restraint on excessive risk-taking by banks. Acharya, Gale, and Yorulmazer (2009) presents a model of rollover risk and an application to the subprime crisis. Goodhart (1990), 89ff., and Cowen and Kroszner (1990) discuss payment services provided by mutual funds with varying market values as an alternative to deposit banking based on par-value redemption.

Allen and Santomero (1997), and Dowd (1992) are critical surveys of this literature, testing its relevance against the evolution of finance from a banking-focused to a market-focused system.

The treatment of money as an asset among others in explaining the demand for money—or, in any event, the term "liquidity preference—goes back at least to Keynes (1936). Haberler (1958) is a history, by a participant, in the debates on the theory of money in their relationship to business cycles, up to and including Keynes. The classic "modern" exposition is Tobin (1958).

Developments in the commercial paper market leading up to and during the subprime crisis are discussed in Anderson and Gascon (2009), and in Adrian, Kimbrough, and Marchioni (2010). Pozsar, Adrian, Ashcraft, and Boesky (2010); Covitz, Liang, and Suarez (2009); Arteta, Carey, Correa, and Kotter (2010); and Acharya and Schnabl (forthcoming) provide details on leverage through ABCP conduits and SIVs and examples of specific vehicles. These papers also chronicle the unraveling of these vehicles during the subprime crisis and their contribution to its intensification.

Examples of the role of liquidity in the impact of the subprime crisis on specific investment strategies can be studied in Mitchell, Pedersen, and Pulvino (2007) (convertible bond arbitrage) and Khandani and Lo (2008) (statistical arbitrage). Case studies of the relationship of payments, clearing, and settlements system to systemic risk include Bernanke (1990) and Copeland, Martin, and Walker (2010).

The development of collateral markets and their role in financial developments leading up to the subprime crisis are reviewed in a series of papers including Gorton (2008, 2009), and Gorton and Metrick (2010). The role of rehypothecation in financial markets is emphasized in Singh and Aitken (2010). Shin (2009*b*) discusses the impact of the supply of securitizations on the volume of credit and of aggregate leverage.

Institutional aspects of collateral markets, particularly the mechanics of shorting and lending stock, are discussed in Weiss (2006) and D'Avolio (2002). Institutional and legal aspects of rehypothecation are discussed in Johnson (1997).

Breuer (2002) discusses the measurement of derivatives leverage. Carry trades in currency markets are discussed in Brunnermeier, Nagel, and Pedersen (2009), and in Clarida, Davis, and Pedersen (2009). Adrian and Shin (2009*a*, 2009*b*), and King (2008) discuss the increase in broker-dealer leverage during the years leading up to the subprime crisis. King (2008) in particular, explains how these transactions can be kept off-balance sheet, and provides a guide to extracting additional information on repo exposures from the footnotes to broker-dealer disclosures other than the balance sheet.

Introductions to market microstructure are provided by Stoll (2003) and O'Hara (1995). Demsetz (1968), Kyle (1985), and Amihud and Mendelson (1986) are important early papers on transactions liquidity. See Black (1986) and Shleifer and Summers (1990) on noise versus information trading. Madhavan (2000) and Madhavan (2002) are good starting points for the institutional background of transactions liquidity. Amihud, Mendelson, and Pedersen (2005) is an extensive survey focusing on transactions liquidity. Chordia, Roll, and Subrahmanyam (2001) focuses on volume data. Committee on the Global Financial System (1999*b*) is an introductory survey and review of policy issues, while Basel Committee on Banking Supervision (2000) presents recommendations on liquidity risk management.

Several papers, for example, Almgren and Chriss (2000, 2001), discuss trading and investment in the presence of market liquidity risk. Duffie and Ziegler (2003) treat the problem of whether to liquidate more- or less-liquid assets first in a liquidity risk event. Diamond and Rajan (2010) discuss the 2008 sellers strike. See also Acerbi and Finger (2010).

Hicks (1962) is an early treatment of the relationship between funding and market liquidity. Brunnermeier and Pedersen (2009) present a model of their interaction in stress scenarios. Brunnermeier, Nagel, and Pedersen (2009) discusses funding liquidity, together with fat-tailed returns, as an explanation of the option biases discussed in Chapter 10.

See Morgan Guaranty Trust Company (1996) and Marrison (2002) for a discussion of asset-liability management. Senior Supervisors Group (2009*b*) discusses liquidity risk management lessons from the subprime crisis.