

## Credit Derivatives

Unless purchasing what are considered default-free instruments, such as U.S. Treasuries, German bunds, or U.K. gilts, bond investors are exposed to *credit risk*. This is the risk that the debt issuer will default either on servicing the loan—delaying or failing to make the coupon payments, known as a *technical* default—on paying back the principal, an *actual* default. To hedge this risk, investors may use credit derivatives. These instruments, which were introduced in significant volume only in the mid-1990s, were originally designed to protect banks and other institutions against losses arising from credit events. Today they are used to trade credit and to speculate, as well as for hedging.

Gup and Brooks (1993) noted that swaps' credit risk, unlike their interest rate risk, could not be hedged. That was true in 1993. The situation changed quickly, however, in years following. By 1996 a liquid market existed in instruments designed for just such hedging. Credit derivatives are, in essence, insurance policies against a deterioration in the credit quality of borrowers. The simplest ones even require regular premiums, paid by the protection buyer to the protection seller, and make payouts should a specified credit event occur.

As noted, credit derivatives may be used by investors to manage the extra risk they take on by opting for the higher returns of non-default-free debt. The instruments can also be used, however, to synthesize the exposure itself, if, for instance, compelling reasons exist for not putting on the cash-market position. Since credit derivatives are OTC products, they can be tailored to meet specific requirements.

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**FIGURE 10.1** *Corporate Bond Credit Ratings*

FITCH	MOODY'S	S&P	SUMMARY DESCRIPTION
<i>Investment Grade</i>			
AAA	Aaa	AAA	Gilt edged, prime, maximum safety, lowest risk, and when sovereign borrower considered "default-free"
AA+	Aa1	AA+	
AA	Aa2	AA	High-grade, high credit quality
AA-	Aa3	AA-	
A+	A1	A+	
A	A2	A	Upper-medium grade
A-	A3	A-	
BBB+	Baa1	BBB+	
BBB	Baa2	BBB	Lower-medium grade
BBB-	Baa3	BBB-	
<i>Speculative Grade</i>			
BB+	Ba1	BB+	
BB	Ba2	BB	Low grade, speculative
BB-	Ba3	BB-	
B+	B1		
B	B	B	Highly speculative
B-	B3		
<i>Predominantly Speculative, Substantial Risk, or in Default</i>			
CCC+		CCC+	
CCC	Caa	CCC	Substantial risk, in poor standing
CC	Ca	CC	May be in default, very speculative
C	C	C	Extremely speculative
		Cl	Income bonds—no interest being paid
DDD			
DD			Default
D		D	

## Credit Risk

When a technical or actual default occurs, bondholders suffer losses as the value of their assets declines or, in the worst case, disappears entirely. The extent of credit risk varies with the fiscal condition of the borrowers and the health of the greater economy. The magnitude of the risk is usually encapsulated in a formal credit rating, assigned by agencies such as Standard & Poor's, Moody's, and Fitch. The agencies arrive at these ratings, shown in **FIGURE 10.1**, after analyzing a company's business and circumstances. Among the issues they consider are the following:

- 1 The financial position of the company, as determined by its balance sheet and anticipated cash flows and revenues
  - Other issues, such as the quality of the management and succession planning
  - The company's ability to meet scheduled interest and principal payments both in its domestic and in foreign currencies
- 2 The outlook for the company's industry as whole and the competition within it
- 3 The health of the domestic economy

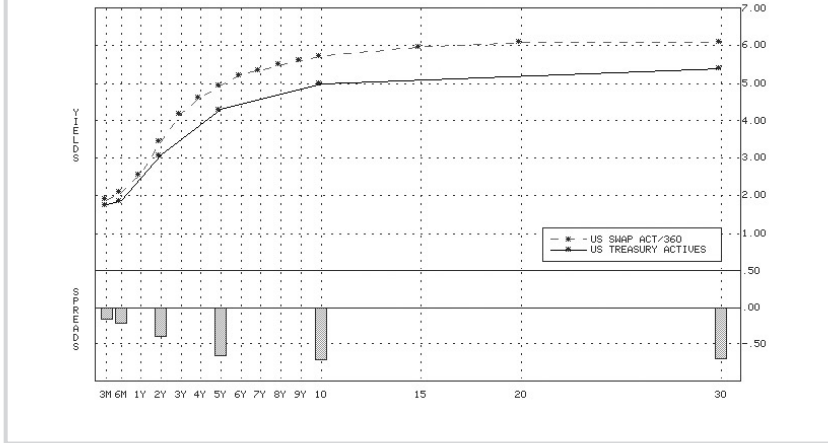
Another indicator of credit risk is the credit risk premium: the spread between the yields on corporate bonds and those of government bonds in the same currency. This spread is the compensation required by investors for holding bonds that are not default-free. The size of the credit premium changes with the market's perception of the financial health of individual companies and sectors and of the economy in general. The variability of the premium is illustrated in **FIGURES 10.2** and **10.3** on the following page, which show the spreads between the U.S.-dollar-swap and Treasury yield curves in, respectively, February 2001 and February 2004.

The credit spread reflects a number of macroeconomic and microeconomic factors, and at any one time is a good snapshot indicator of the perceived health and future prospect of the economy. For example, the reduction in spread from 2001 to 2004 reflects a general increase in favorable perception on the health of the U.S. economy, following the technology and dot-com boom and bust of the previous years and the market disruption following September 11, 2001.

## Credit Risk and Credit Derivatives

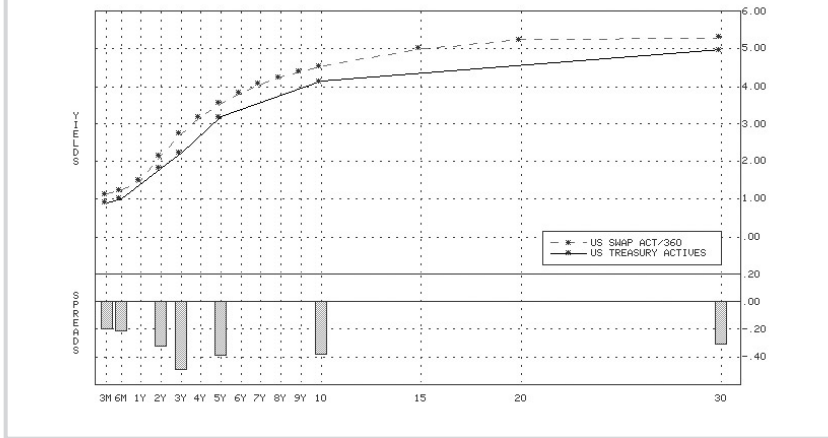
Credit derivatives are financial contracts designed to reduce or eliminate credit risk exposure by providing insurance against losses suffered because of credit events. The loan or bond carrying the credit risk in question is the ref-

**FIGURE 10.2** *Yield Curves for Active U.S. Treasury Securities and U.S. Dollar Swaps on February 2, 2001*



Source: Bloomberg

**FIGURE 10.3** *Yield Curves for Active U.S. Treasury Securities and U.S. Dollar Swaps on February 3, 2004*



Source: Bloomberg

erent, or underlying, asset. The referent asset issuer or borrower is the obligor. The terms of a credit derivative usually include specifications of the type of events that will trigger payouts. These typically include the following:

- ❑ Bankruptcy or insolvency of the reference asset obligor
- ❑ Financial restructuring required under bankruptcy protection
- ❑ Technical default
- ❑ The bond's credit spread over Treasuries widens beyond a specified level
- ❑ A downgrade in credit rating below a specified level

### ***Applications of Credit Derivatives***

Any institution—including investment and commercial banks, insurance companies, corporations, fund managers, and hedge funds—that is or desires to be exposed to credit risk may use credit derivatives to manage or create it. The credit risk managed may be the one inherent in corporate- or non-AAA-sovereign-bond portfolios or the risk associated with commercial loan books. Indeed, commercial loans were credit derivatives' first area of application. Intense competition to make loans, combined with rapid disintermediation—the lessening of the role of banks as intermediaries—forced commercial banks to reevaluate their lending policies with a view to improving profitability and return on capital. Credit derivatives helped them restructure their businesses by enabling them to repackage and parcel out credit risk while retaining assets on their balance sheets (when required) and thus maintaining client relationships. Credit derivatives are particularly well suited for these and similar purposes for the following reasons:

- ❑ The issuer of the original debt or borrower of the original loan, known as the *reference entity*, need not be a party to the credit risk transfer and in fact is usually not even aware of the transaction, thus allowing the client relationship between the lending bank and the borrower to be maintained.

- ❑ The credit derivative can be tailored to the requirements of the protection buyer, as opposed to the liquidity or term of the underlying loan.

- ❑ Credit derivatives can be used to synthesize the economic effect of selling a bank loan short—a transaction not possible in the cash market—and do so theoretically without the risk of a liquidity or delivery squeeze, since a specific credit risk is being traded.

- ❑ Because the derivatives isolate credit risk from other factors, such as client relationships and interest rate risk, they offer a formal mechanism for pricing credit issues only. A market in credit alone can thus evolve, allowing still more efficient pricing and the modeling of a term structure of credit rates.

- ❑ Unless embedded in fixed-income products, such as structured or credit-linked notes, the derivatives are off the balance sheet. This status endows them with tremendous flexibility and leverage, characteristics they

share with other financial derivatives. For instance, bank loans are often deemed unattractive as investments because of the administration that managing and servicing a loan portfolio requires. Investors can acquire exposure to bank loans' returns while avoiding the administrative costs through, say, a total return swap. The same transaction allows banks to distribute their loan credit risk.

Credit derivatives are important tools not only for commercial banks but also for bond portfolio managers, who can use them to increase the liquidity of their portfolios, profit from credit-pricing anomalies, and enhance returns. Credit derivatives separate the ownership and management of the credit risk associated with the assets in question from ownership of their other features. This means that banks can transfer the credit risk exposures of illiquid assets, such as bank loans and illiquid bonds, thus protecting themselves against credit loss, even if they cannot transfer the assets themselves. Among the reasons banks use credit derivatives are the following:

**To diversify their credit portfolios.** Banks may wish to take on additional credit exposure by selling credit protection on assets they own to other banks or investors, thus enhancing their portfolio returns. They may sell derivatives to non-bank clients who don't want to buy the associated assets directly but do want exposure to the credit risk of the assets. In such a transaction, the bank acts as a credit intermediary.

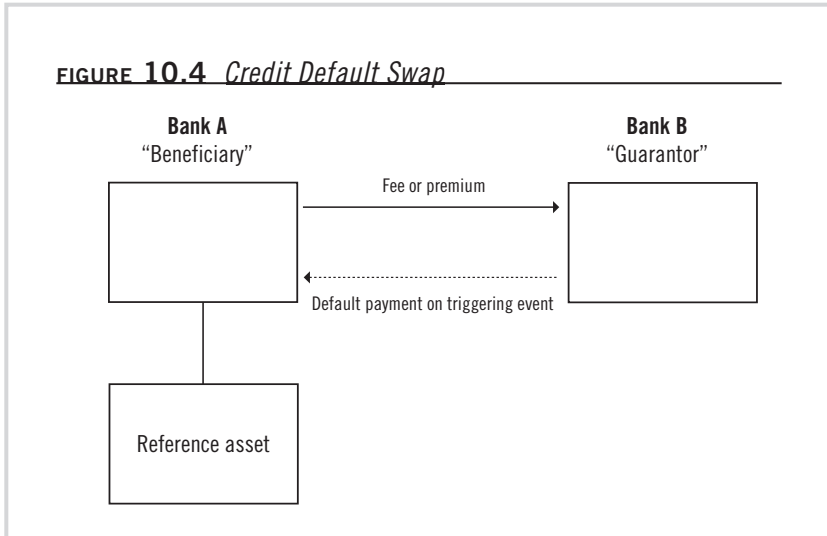
**To reduce their credit exposure.** By buying credit default swaps, banks can reduce their credit exposure on individual assets or sector concentrations. This tactic is especially useful when the positions in question cannot be sold because of relationship or tax issues.

**To act as market makers or traders in credit derivatives.** Credit derivative traders may or may not hold the reference assets directly, depending on their appetite for risk and the liquidity of the market they would need to use to hedge their derivative contracts.

## Credit Derivative Instruments

### **Credit Default Swap**

The most common credit derivative, and possibly the simplest, is the *credit default swap*—also known as the *credit* or *default* swap. As diagrammed in **FIGURE 10.4**, it is a bilateral contract in which a *protection seller*, or *guarantor*, in return for a periodic fixed fee or a onetime premium agrees to pay the *beneficiary* counterparty in case any of a list of specified credit events occurs. The fee is usually quoted as a percentage of the nominal value of the reference asset or basket of assets. The swap term does not have to



match the maturity of the reference asset and in most cases does not.

In a default, the swap is terminated, and the default payment is calculated and handed over. The amount of this payment may be linked to the change in price of the reference asset or another specified asset or fixed at a predetermined recovery rate. Alternatively, it may involve actual delivery of the reference asset at a specified price.

Banks may use default swaps to trade sovereign and corporate credit spreads without trading the actual assets. The party long the swap—the protection buyer—need not own or ever have owned the reference asset. Nevertheless, he or she profits should the obligor suffer a rating downgrade or perceived reduction in credit quality. This is because such an event increases the cost of protecting the asset, so the swap buyer can sell the position at a profit, assuming a purchaser can be found.

### **Credit Options**

*Credit options* are also bilateral OTC financial contracts. Like other options, they may be designed to meet specific hedging or speculative requirements. Also like other options, they may be plain vanilla or exotic. The buyer of a vanilla, or *standard*, credit call option has the right, but no obligation, to purchase the underlying credit-sensitive asset or credit spread at a specified price and at a specified time or during a specified period. The buyer of a vanilla credit put option has the right, but no obligation, to sell the underlying credit-sensitive asset or credit spread.

In exotic credit options, one or more parameters differ from the vanilla norm. A *barrier* credit option, for example, specifies a credit event

that would trigger the option or inactivate it. A *digital* credit option has a binary payout: if it is at or out of the money at expiration, it pays zero; otherwise, it pays a fixed amount, no matter how far in the money it is.

Bond investors can use credit options to hedge against rating downgrades and similar events that would depress the value of their holdings. To ensure that any loss resulting from such events will be offset by a profit on their options, they purchase contracts whose payoff profiles reflect their bonds' credit quality. The options also enable banks and other institutions to take positions on credit spread movements without taking ownership of the related loans or bonds. The writer of credit options earns fee income.

Credit options allow market participants to express their views on credit alone, without reference to other factors, such as interest rates, with no cost beyond the premium. For example, investors who believe that the credit spread associated with an individual entity or a sector (such as all AA-rated sterling corporates) will widen over the next six months can buy six-month call options on the relevant spread. If the spread widens beyond the strike during the six months, the options will be in the money, and the investors will gain. If not, the investors' loss will be limited to the premium paid.

### **Credit-Linked Notes**

*Credit-linked notes*, or CLNs, are known as *funded* credit derivatives, because the protection seller pays the entire notional value of the contract up front. In contrast, credit default swaps pay only in case of default and are therefore referred to as *unfunded*. CLNs are often used by borrowers to hedge against credit risk and by investors to enhance their holdings' yields.

Credit-linked notes are hybrid securities, generally issued by an investment-grade entity, that combine a credit derivative with a vanilla bond. Like a vanilla bond, a standard CLN has a fixed maturity structure and pays regular coupons. Unlike bonds, all CLNs, standard or not, link their returns to an underlying asset's credit-related performance, as well as to the performance of the issuing entity. The issuer, for instance, is usually permitted to decrease the principal amount if a credit event occurs. Say a credit card issuer wants to fund its credit card loan portfolio by issuing debt. To reduce its credit risk, it floats a 2-year credit-linked note. The note has a face value of 100 and pays a coupon of 7.50 percent, which is 200 basis points above the 2-year benchmark. If more than 10 percent of its cardholders are delinquent in making payments, however, the note's redemption payment will be reduced to \$85 for every \$100 of face value. The credit card issuer has in effect purchased a credit option that lowers its liability should it suffer a specified credit event—in this case, an above-expected incidence of bad debts.

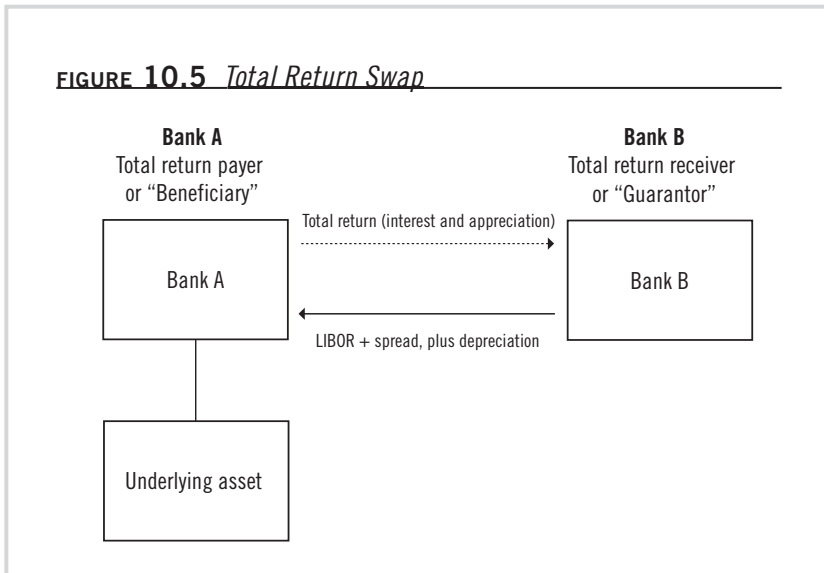
Why would investors purchase such a note? Because its coupon is higher than the one the credit card bank would pay on a vanilla bond and, presumably, higher than the rates for many other investments in the market. In addition, such notes are usually issued below par, so if they are redeemed at par, investors realize a substantial capital gain.

### Total Return Swaps

A *total return swap*, or TRS—also known as a *total rate of return swap*—is one of the principal instruments used by banks and other financial instruments to manage their credit risk exposure. As defined in Francis et al (1999), page 29, it is an agreement between two parties to exchange the total return from the reference asset or basket of assets—bank loans or credit-sensitive securities such as corporate loans or sovereign or corporate bonds—for some other fixed or floating cash flow, usually tied to LIBOR or other loans or credit-sensitive securities, in the process transferring the credit risk from one party to the other. The TRS differs from other credit derivatives in that the payments between its counterparties are connected to changes in the market value of the underlying asset as well as to changes resulting from a credit event.

In some versions of a TRS, the underlying asset is sold to the counterparty, with a corresponding swap transacted on the side; in other versions the underlying asset remains unsold. The term of the TRS need not match the maturity of the underlying security and, in fact, rarely does.

**FIGURE 10.5** diagrams a generic TRS. The two counterparties are la-



beled as banks, but the total return payer, or beneficiary, may be any financial institution, including an insurance company or hedge fund. In figure 10.5, Bank A, the beneficiary, has contracted to pay the total return—interest payments plus any appreciation in market value—on the reference asset. The appreciation may be cash settled, or Bank A may take physical delivery of the reference asset at swap maturity, paying Bank B, the total return receiver, the initial asset value. Bank B pays Bank A a margin over LIBOR and makes up any depreciation that occurs in the price of the asset—hence the label “guarantor.”

The economic effect for Bank B is that of owning the underlying asset. TR swaps are thus synthetic loans or securities. Significantly, the beneficiary usually (though not always) holds the underlying asset on its balance sheet. The TR swap can thus be a mechanism for removing an asset from the guarantor’s balance sheet for the term of the agreement.

The swap payments are usually quarterly or semiannual. On the interest-reset dates, the underlying asset is marked to market, either using an independent source, such as Bloomberg or Reuters, or as the average of a range of market quotes. If the reference asset obligor defaults, the swap may be terminated immediately, with a net present value payment changing hands and each counterparty liable to the other for accrued interest plus any appreciation or depreciation in the asset value. Alternatively, the swap may continue, with each party making appreciation or depreciation payments as appropriate. The second option is available only if a market exists for the asset, an unlikely condition in the case of a bank loan. The terms of the agreement typically give the guarantor the option of purchasing the underlying asset from the beneficiary and then dealing directly with the loan defaulter.

Banks and other financial institutions may have a number of reasons for entering into TR swap arrangements. One is to gain off-balance-sheet exposure to the reference asset without having to pay out the cash that would be required to purchase it. Because the swap maturity rarely matches that of the asset, moreover, the swap receiver may benefit, if the yield curve is positive, from positive *carry*—that is, the ability to roll over the short-term funding for a longer-term asset. Higher-rated banks that can borrow at Libid can benefit by funding on-balance-sheet credit-protected assets through a TR swap, assuming the net spread of asset income over credit-protection premium is positive.

The swap payer can reduce or remove credit risk without selling the relevant asset. In a vanilla TR swap, the total return payer retains rights to the reference asset, although, in some cases, servicing and voting rights may be transferred. At swap maturity, the swap payer can reinvest the asset, if it still owns it, or sell it in the open market. The swap can thus be

considered a synthetic repo—that is, an arrangement in which the holder of a bond (usually a government issue) sells it to a lender, promising to buy it back a short time later at an agreed-upon price that gives the lender a low-risk rate of return, termed the *repo rate*.

Total return swaps are increasingly used as synthetic repo instruments, most commonly by investors who wish to purchase the credit exposure of an asset without purchasing the asset itself. This is similar to what happened when interest rate swaps were introduced, enabling banks and other financial institutions to trade interest rate risk without borrowing or lending cash funds. Banks usually enter into synthetic repos to remove assets from their balance sheets temporarily. The reason may be that they are due to be analyzed by credit-rating agencies, or their annual external audit is imminent, or they are in danger of breaching capital limits between quarterly return periods. In the last case, as the return period approaches, lower-quality assets may be removed from the balance sheet by means of a TR swap with, say, a two-week term that straddles the reporting date. Bonds sold as part of a TR swap transaction are removed from the seller's balance sheet because the bank selling the assets is not legally required to repurchase them from the swap counterparty, nor is the total return payer obliged to sell them back—or indeed to sell them at all—at swap maturity.

TR swaps may also be used for speculation. Bond traders who believe that a particular bond not currently on their books is about to decline in price have a couple of ways to profit from this view. One method is to sell the bond short and cover their position through a repo. The cash flow to the traders from this transaction consists of the coupon on the bond that they owe as a result of the short sale and, if the shorted bond falls in price as expected, the capital gain from the short sale plus the repo rate—say, LIBOR plus a spread. The danger in this transaction is that if the shorted bond must be covered through a repo at the *special* rate instead of the higher *general collateral* rate—the one applicable to Treasury securities—the traders will be funding it at a loss. The yield on the bond must also be lower than the repo rate.

Alternatively, the traders can enter into a TR swap in which they pay the total return on the bond and receive LIBOR plus a spread. If the bond yield exceeds the LIBOR payment, the funding will be negative, but the trade will still gain if the bond falls in price by a sufficient amount. The traders will choose this alternative if the swap's break-even point—the price to which the bond must decline for a gain from the short sale to offset the trade's funding cost—is higher than in the repo approach. This is more likely if the bond is special.

## Investment Applications

This section explores the ways bond investment managers typically use credit derivatives.

### **Capital Structure Arbitrage**

In capital structure arbitrage, investors exploit yield mismatches between two loans from the same reference entity. Say an issuer has two debt instruments outstanding: a commercial bank loan paying 330 basis points over LIBOR and a subordinated bond issue paying LIBOR plus 230 basis points. This yield anomaly can be exploited with a total return swap in which the arbitrageur effectively purchases the bank loan and sells the bond short.

The swap is diagrammed in **FIGURE 10.6**. The arbitrageur receives the total return on the bank loan and pays the counterparty bank the bond return plus an additional 30 basis points, the price of the swap. These rates are applied to notional amounts of the loan and bond set at a ratio of 2 to 1, since the bond's price is more sensitive to changes in credit status than that of the loan.

The swap generates a net spread of 200 basis points as shown below:  $+ [(100 \text{ bps} \times \frac{1}{2}) + (250 \text{ bps} \times \frac{1}{2})]$ . That is,

$$\text{Receive Loan } CF = (+\text{Libor} + 330) \times 1 (\text{Loan Notional Principal})$$

$$\text{Bond } CF = (-\text{Libor} + 230 + 30) \times 0.5 (\text{Bond Notional Principal})$$

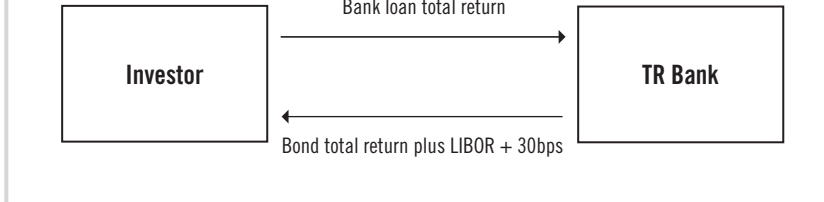
### **Exposure to Market Sectors**

To gain exposure to sectors where, for various reasons, they do not wish to make actual purchases, investors can use a variation on a TR swap called an *index* swap, in which one of the counterparties pays a total return tied to an external reference index and the other pays a LIBOR-linked coupon or the total return of another index. Indexes used include those for government bonds, high-yield bonds, and technology stocks. Investors who believe that the bank loan market will outperform the mortgage-backed bond sector, for instance, might enter into an index swap in which they pay the total return of the mortgage index and receive the total return of the bank-loan index.

### **Credit Spreads**

Credit default swaps can be used to trade credit spreads. Say investors believe the credit spread between certain emerging-market government bonds and U.S. Treasuries is going to widen. The simplest way to exploit

**FIGURE 10.6** *Total Return Swap Used in Capital Structure Arbitrage*



this view would be to go long a credit default swap on the emerging-market bonds paying 600 basis points. If the investors' view is correct and the bonds' credit spread widens, depressing their price, the premium payable on the credit swap will increase. The investors will then be able to sell their swap in the market at the higher premium.

### ***Funding Positions***

Investment banks and hedge funds often use TRS contracts to pay for positions in securities that they cannot—for operational, credit, or other reasons—fund using the interbank market or a classic repo. The TRS counterparty that is long the security swaps it with a counterparty that provides the money to pay for the asset in the market. This money is in effect a loan to the asset seller, at a cost of LIBOR plus a spread. During the swap term, the funds provider pays the asset seller the coupon/interest on the asset. On the swap-reset or maturity date, the asset is marked to market. If it has increased in value, the funds provider will pay the asset seller the difference; if it has fallen, the asset seller will pay the difference. The asset seller also pays the LIBOR-plus interest on the initial swap proceeds. In addition to funding the asset, this transaction removes it from the original holder's balance sheet, transferring it to the counterparty's for the term of the swap. As an illustration of how this works, consider the hypothetical transaction in **FIGURE 10.7** on the following page.

Note that the "haircut" is the amount of the bond value that is not handed over in the loan proceeds—it acts as a credit protection to the provider of funds in the event that the bond, which is in effect the collateral for the loan, drops in value during the term of the swap. For ease of illustration the haircut in this example is 0 percent so the loan is the full value of the bond collateral.

**FIGURE 10.7** *Using a Total Return Swap to Fund a Security***Party A:** Asset seller, a hedge fund**Party B:** Funds provider, an investment bank**Asset:** \$50 million face value of an A-rated asset-backed security**Price:** 99.50**Asset value:** \$49,750,000**Date when swap is transacted:** February 3, 2004**Value date:** February 6, 2004**Swap term:** 14 days**Maturity date:** February 20, 2004**Haircut:** 0 percent**Initial swap proceeds:** \$49,750,000**Floating rate paid by the asset seller:** LIBOR plus 35 basis points**2-week LIBOR at start of swap:** 1.08125 percent**Swap floating rate:** 1.43125 percent

Assume that, at swap maturity, the stock has risen in price to 99.70, making its market value \$49,850,000. The investment bank would therefore owe the hedge fund a “performance payment” of \$100,000. The hedge fund, meanwhile, owes the investment bank \$27,690.71, which is 1.43125 percent interest on \$49,750,000 for fourteen days. The bank pays the fund a net payment of \$72,309. If there was a coupon payment during the term, it would be paid by the investment bank as part of the performance payment to the hedge fund.

## Credit-Derivative Pricing

Banks employ a number of methods to price credit derivatives. This section presents a quick overview. Readers wishing a more in-depth discussion should consult the references listed for this chapter in the References section.

Credit-derivative pricing is similar to the pricing of other off-balance-sheet products, such as equity, currency, and bond derivatives. The main difference is that the latter can be priced and hedged with reference to the underlying asset, and credit derivatives cannot. The pricing model for credit products incorporates statistical data concerning the likelihood of default, the probability of payout, and market level of risk tolerance.

### ***Pricing Total Return Swaps***

The guarantor in a TR swap usually pays the beneficiary a spread over LIBOR. Pricing in this case means determining the size of the LIBOR spread. This spread is a function of the following factors:

- The credit rating of the beneficiary
- The credit quality of the reference asset
- The face amount and value of the reference asset
- The funding costs of the beneficiary bank
- The required profit margin
- The capital charge—the amount of capital that must be held against the risk represented by the swap—associated with the TR swap

Related to these factors are several risks that the guarantor must take into account. One crucial consideration is the likelihood of the TR swap receiver defaulting at a time when the reference asset has declined in value. This risk is a function both of the financial health of the swap receiver and of the market volatility of the reference asset. A second important consideration is the probability of the reference asset obligor defaulting, triggering a default by the swap receiver before the swap payer receives the depreciation payment.

### ***Asset-Swap Pricing***

Asset-swap pricing is commonly applied to credit-default swaps, especially by risk management departments seeking to price the transactions held on credit traders' book. A par asset swap typically combines an interest rate swap with the sale of an asset, such as a fixed-rate corporate bond, at par and with no interest accrued. The coupon on the bond is paid in return for LIBOR plus, if necessary, a spread, known as the *asset-swap spread*. This spread is the price of the asset swap. It is a function of the credit risk of the underlying asset. That makes it suitable as the basis for the price payable on a credit default swap written on that asset.

The asset swap spread is equal to the underlying asset's redemption yield spread over the government benchmark, minus the spread on the associated interest rate swap. The latter, which reflects the cost of convert-

ing the fixed-rate coupons of benchmark bonds to a floating rate during the life of the asset, or the default swap, is based on the swap rate for the relevant term.

### ***Credit-Spread Pricing Models***

Practitioners increasingly model credit risk as they do interest rates and use spread models to price associated derivatives. One such model is the Heath-Jarrow-Morton (HJM) model described in chapter 4. This analyzes interest rate risk, default risk, and recovery risk—that is, the rate of recovery on a defaulted loan, which is always assumed to retain some residual value.

The models analyze spreads as wholes, rather than splitting them into default risk and recovery risk. Das (1999), for example, notes that equation (10.1) can be used to model credit spreads. Credit options can thus be analyzed in the same way as other types of options, modeling the credit spread rather than, say, the interest rate.

$$ds = k(\vartheta - s)dt + \sigma\sqrt{s}dZ \quad (10.1)$$

where

- $s$  = the credit spread over the government benchmark
- $ds$  = change in the spread over an infinitesimal change in time
- $k$  = the mean reversion rate of the credit spread
- $\vartheta$  = the mean of the spread over  $t$
- $\sigma$  = the volatility of the spread
- $dt$  = change in time
- $dZ$  = standard Brownian motion or Weiner process

For more detail on modeling credit spreads to price credit derivatives, see Choudhry (2004).