# Structured Credit Risk

# 8



## Learning Objectives

After completing this reading you should be able to:

- Describe common types of structured products.
- Describe tranching and the distribution of credit losses in a securitization.
- Describe a waterfall structure in a securitization.
- Identify the key participants in the securitization process, and describe conflicts of interest that can arise in the process.
- Compute and evaluate one or two iterations of interim cashflows in a three-tiered securitization structure.
- Describe a simulation approach to calculating credit losses for different tranches in a securitization.
- Explain how the default probabilities and default correlations affect the credit risk in a securitization.
- Explain how default sensitivities for tranches are measured.
- Describe risk factors that impact structured products.
- Define implied correlation and describe how it can be measured.
- Identify the motivations for using structured credit products.

*Excerpt is Chapter 9 of* Financial Risk Management: Models, History, and Institutions, *by Allan Malz.*

This chapter focuses on a class of credit-risky securities called *securitizations* and *structured credit products.* These securities play an important role in contemporary finance, and had a major role in the subprime crisis of 2007 and after. These securities have been in existence for some time, and their issuance and trading volumes were quite large up until the onset of the crisis. They have also had a crucial impact on the development of the financial system, particularly on the formation of the market-based or "shadow banking system" of financial intermediation.

In this chapter, we look at structured products in more detail, with the goal of understanding both the challenges they present to risk management by traders and investors, and their impact on the financial system before and during the crisis. These products are complex, so we'll employ an extended example to convey how they work. They are also issued in many variations, so the example will differ from any extant structured product, but capture the key features that recur across all variants. A grasp of structured credit products will also help readers understand the story of the growth of leverage in the financial system and its role in the subprime crisis.

## STRUCTURED CREDIT BASICS

We begin by sketching the major types of securitizations and structured credit products, sometimes collectively called *portfolio credit products.* These are vehicles that create bonds or credit derivatives backed by a pool of loans or other claims. This broad definition can't do justice to the bewildering variety of structured credit products, and the equally bewildering terminology associated with their construction.

First, let's put structured credit products into the context of other securities based on pooled loans. Not surprisingly, this hierarchy with respect to complexity of structure corresponds roughly to the historical development of structured products that we summarized:

*Covered bonds* are issued mainly by European banks, mainly in Germany and Denmark. In a covered bond structure, mortgage loans are aggregated into a *cover pool*, by which a bond issue is secured. The cover pool stays on the balance sheet of the bank, rather than being sold off-balance-sheet, but is segregated from other assets of the bank in the event the bank defaults. The pool assets would be used to make the covered bond owners whole before they could be applied to repay general creditors of the bank. Because the underlying assets remain on the issuer's balance sheet, covered bonds are not considered full-fledged securitizations. Also, the principal and interest on the secured bond issue are paid out of the general cash flows of the issuer, rather than out of the cash flows generated by the cover pool. Finally, apart from the security of the cover pool, the covered bonds are backed by the issuer's obligation to pay.

*Mortgage pass-through securities* are true securitizations or structured products, since the cash flows paid out by the bonds, and the credit risk to which they are exposed, are more completely dependent on the cash flows and credit risks generated by the pool of underlying loans. Mortgage pass-throughs are backed by a pool of mortgage loans, removed from the mortgage originators' balance sheets, and administered by a *servicer*, who collects principal and interest from the underlying loans and distributes them to the bondholders. Most pass-throughs are *agency MBS*, issued under an explicit or implicit U.S. federal guarantee of the performance of the underlying loans, so there is little default risk. But the principal and interest on the bonds are "passed through" from the loans, so the cash flows depend not only on amortization, but also voluntary prepayments by the mortgagor. The bonds are repaid slowly over time, but at an uncertain pace, in contrast to bullet bonds, which receive full repayment of principal on one date. Bondholders are therefore exposed to prepayment risk.

*Collateralized mortgage obligations* were developed partly as a means of coping with prepayment risk, but also as a way to create both longer- and shorter-term bonds out of a pool of mortgage loans. Such loans amortize over time, creating cash flow streams that diminish over time. CMOs are "sliced," or tranched into bonds or *tranches*, that are paid down on a specified schedule. The simplest structure is *sequential pay*, in which the tranches are ordered, with "Class A" receiving all principal repayments from the loan until it is retired, then "Class B," and so on. The higher tranches in the sequence have less prepayment risk than a pass-through, while the lower ones bear more.

*Structured credit products* introduce one more innovation, namely the sequential distribution of credit losses. Structured products are backed by credit-risky loans or bonds. The tranching focuses on creating bonds that have different degrees of credit risk. As losses occur, the tranches are gradually written down. Junior tranches are written down first, and more senior tranches only begin to bear credit losses once the junior tranches have been written down to zero.

This basic credit tranching feature can be combined with other features to create, in some cases, extremely complex security structures. The bottom-up treatment of credit losses can be combined with the sequential payment technology introduced with CMOs. Cash flows and credit risk arising from certain constituents of the underlying asset pool may be directed to specific bonds.



Securitization is one approach to financing pools of loans and other receivables developed over the past two decades. An important alternative and complement to securitization are entities set up to issue *asset-backed commercial paper* (ABCP) against the receivables, or against securitization bonds themselves.

A structured product can be thought of as a "robot" corporate entity with a balance sheet, but no other business. In fact, structured products are usually set up as *special purpose entities* (SPE) or *vehicles* (SPV), also known as a *trust.* This arrangement is intended to legally separate the assets and liabilities of the structured product from those of the original creditors and of the company that manages the payments. That is, it makes the SPE *bankruptcy remote.* This permits investors to focus on the credit quality of the loans themselves rather than that of the original lenders in assessing the credit quality of the securitization. The underlying debt instruments in the SPV are the robot entity's assets, and the structured credit products built on it are its liabilities.

Securitizations are, depending on the type of underlying assets, often generically called *asset-* (ABS) or *mortgage-backed securities* (MBS), or *collateralized loan obligations* (CLOs). Securitizations that repackage other securitizations are called *collateralized debt obligations* (CDOs, issuing bonds against a collateral pool consisting of ABS, MBS, or CLOs), *collateralized mortgage obligations* (CMOs), or *collateralized bond obligations* (CBOs). There even exist third-level securitizations, in which the collateral pool consists of CDO liabilities, which themselves consist of bonds backed by a collateral pool, called *CDO-squareds.*

There are several other dimensions along which we can classify the great variety of structured credit products:

*Underlying asset classes.* Every structured product is based on a set of underlying loans, receivables, or other claims. If you drill down far enough into a structured product, you will get to a set of relatively conventional debt instruments that constitute the *collateral* or *loan pool.* The collateral is typically composed of residential or commercial real estate loans, consumer debt such as credit cards balances and auto and student loans, and corporate bonds. But many other types of debt, and even nondebt assets such as recurring fee income, can also be packaged into securitizations. The credit quality and prepayment behavior of the underlying risks is, of course, critical in assessing the risks of the structured products built upon them.

*Type of structure.* Structured products are tools for redirecting the cash flows and credit losses generated by the underlying debt instruments. The latter each make contractually stipulated coupon or other payments. But rather than being made directly to debt holders, they are split up and channeled to the structured products in specified ways. A key dimension is tranching, the number and size of the bonds carved out of the liability side of the securitization. Another is how many levels of securitization are involved, that is, whether the collateral pool consists entirely of loans or liabilities of other securitizations.

*How much the pool changes over time.* We can distinguish here among three different approaches, tending to coincide with asset class. Each type of pool has its own risk management challenges:

*Static pools* are amortizing pools in which a fixed set of loans is placed in the trust. As the loans amortize, are repaid, or default, the deal, and the bonds it issues, gradually wind down. Static pools are common for such asset types as auto loans and residential mortgages, which generally themselves have a fixed and relatively long term at origination but pay down over time.

*Revolving pools* specify an overall level of assets that is to be maintained during a *revolving period.*

As underlying loans are repaid, the size of the pool is maintained by introducing additional loans from the balance sheet of the originator. Revolving pools are common for bonds backed by credit card debt, which is not issued in a fixed amount, but can within limits be drawn upon and repaid by the borrower at his own discretion and without notification. Once the revolving period ends, the loan pool becomes fixed, and the deal winds down gradually as debts are repaid or become delinquent and are charged off.

*Managed pools* are pools in which the manager of the structured product has discretion to remove individual loans from the pool, sell them, and replace them with others. Managed pools have typically been seen in CLOs. Managers of CLOs are hired in part for skill in identifying loans with higher spreads than warranted by their credit quality. They can, in theory, also see credit problems arising at an early stage, and trade out of loans they believe are more likely to default. There is a secondary market for syndicated loans that permits them to do so, at least in many cases. Also, syndicated loans are typically repaid in lump sum, well ahead of their legal final maturity, but with random timing, so a managed pool permits the manager to maintain the level of assets in the pool.



The number of debt instruments in pools depends on asset type and on the size of the securitization; some, for example CLO and commercial mortgage-backed securities (CMBS) pools, may contain around 100 different loans, each with an initial par value of several million dollars, while a large residential mortgage-backed security (RMBS) may have several tens of thousands of mortgage loans in its pool, with an average loan amount of $200,000.

The assets of some structured products are not cash debt instruments, but rather credit derivatives, most frequently CDS. These are called *synthetic* securitizations, in contrast to *cash* or *cash-flow* securitizations. The set of underlying cash debt instruments on which a synthetic securitization is based generally consists of securitization liabilities rather than loans, and is called the *reference portfolio.*

Each structured product is defined by the cash flows thrown off by assets and the way they are distributed to the liabilities. Next, we examine the mechanisms by which they are distributed: the capital structure or tranching, the waterfall, and overcollateralization.

## Capital Structure and Credit Losses in a Securitization

Tranching refers to how the liabilities of the securitization SPV are split into a capital structure. Each type of bond or note within the capital structure has its own coupon or spread, and depending on its place in the capital structure, its own priority or seniority with respect to losses. The general principle of tranching is that more senior tranches have priority, or the first right, to payments of principal and interest, while more junior tranches must be written down first when credit losses occur in the collateral pool. There may be many dozen, or only a small handful of tranches in a securitization, but they can be categorized into three groups:

*Equity.* The equity tranche is so called because it typically receives no fixed coupon payment, but is fully exposed to defaults in the collateral pool. It takes the form of a note with a specified notional value that is entitled to the residual cash flows after all the other obligations of the SPE have been satisfied. The notional value is typically small compared to the market value of the collateral; that is, it is a "thin" tranche.

*Junior debt* earns a relatively high fixed coupon or spread, but if the equity tranche is exhausted by defaults in the collateral pool, it is next in line to suffer default losses. Junior bonds are also called *mezzanine tranches* and are typically also thin.

*Senior debt* earns a relatively low fixed coupon or spread, but is protected by both the equity and mezzanine tranches from default losses. Senior bonds are typically the bulk of the liabilities in a securitization. This is a crucial feature of securitization economics, as we will see later. If the underlying collateral cannot be financed primarily by low-yielding senior debt, a securitization is generally not viable.

The capital structure is sometimes called the "capital stack," with senior bonds at the "top of the stack." Most securitizations also feature securities with different maturities but the same seniority, a technique similar to sequential-pay CMOs for coping with variation in the term to maturity and prepayment behavior of the underlying loans, while catering to the desire of different investors for bonds with different durations.

The example of the next few sections of this chapter features three tranches, a simple structure that can be summarized in this balance sheet:

| Assets | Liabilities |
|---|---|
| | Equity |
| Underlying debt instruments | Mezzanine debt |
| | Senior debt |

The boundary between two tranches, expressed as a percentage of the total of the liabilities, is called the *attachment point* of the more senior tranche and *detachment point* of the more junior tranche. The equity tranche only has a detachment point, and the most senior only has an attachment point.

The part of the capital structure below a bond tranche is called its *subordination* or *credit enhancement.* It is the fraction of the collateral pool that must be lost before the bond takes any loss. It is greater for more senior bonds in the structure. The credit enhancement may decline over time as the collateral experiences default losses, or increase as *excess spread*, the interest from the collateral that is not paid out to the liabilities or as fees and expenses, accumulates in the trust.

A securitization can be thought of as a mechanism for securing long-term financing for the collateral pool. To create this mechanism, the senior tranche must be a large portion of the capital structure, and it must have a low coupon compared to the collateral pool. In order to create such a liability, its credit risk must be low enough that it can be marketed. To this end, additional features can be introduced into the cash flow structure. The most important is *overcollateralization*; that is, selling a par amount of bonds that is smaller than the par amount of underlying collateral. Overcollateralization provides credit enhancement for all of the bond tranches of a securitization.

There are typically reserves within the capital structure that must be filled and kept at certain levels before junior and equity notes can receive money. These reserves can be filled from two sources: gradually, from the excess spread, or quickly via overcollateralization. These approaches are often used in combination. The latter is sometimes called *hard credit enhancement*, in contrast to the *soft credit enhancement* of excess spread, which accrues gradually over time and is not present at initiation of the securitization. Deals with revolving pools generally have an *early amortization trigger* that terminates the replenishment of the pool with fresh debt if a default trigger is breached.

Typically, the collateral pool contains assets with different maturities, or that amortize over time. Loan maturities are uncertain because the loans can be prepaid prior to maturity, possibly after an initial *lockout period* has elapsed. The senior liabilities in particular are therefore generally amortized over time as the underlying loans amortize or mature; while they may have legal final maturity dates that are quite far in the future, their durations are uncertain and much shorter. Risk analysis therefore generally focuses on the *weighted average life* (WAL) of a securitization, the weighted average of the number of years each dollar of par value of the bond will remain outstanding before it is repaid or amortized. A WAL is associated with a particular prepayment assumption, and standard assumptions are set for some asset classes by convention.

As noted above, the sequential-pay technology can be combined with credit tranching in securitizations. This creates multiple senior bonds with different WALs, to better adapt the maturity structure of the liabilities to that of the collateral pool. This feature is called *time tranching* to distinguish it from the seniority tranching related to credit priority in the capital structure. The example presented in the rest of this chapter abstracts from this important feature. Thus, in addition to the credit risk that is the focus of this chapter, securitizations also pose prepayment and *extension risk* arising from loans either prepaying faster or slower than anticipated, or being extended past their maturity in response to financial distress.

In any securitization, there is a possibility that at the maturity date, even if the coupons have been paid timely all along, there may not be enough principal left in the collateral pool to redeem the junior and/or senior debt at par unless loans can be refinanced. The bonds are therefore exposed to the *refinancing risk* of the loans in the collateral pool. If some principal cash flows are paid out to the equity note along the way, refinancing risk is greater. Time tranching of the senior bonds, and their gradual retirement through amortization, is one way securitizations cope with this risk.

The tranche structure of a securitization leads to a somewhat different definition of a default event from that pertaining to individual, corporate, and sovereign debt. Losses to the bonds in securitizations are determined by losses in the collateral pool together with the waterfall. Losses may be severe enough to cause some credit loss to a bond, but only a small one. For example, if a senior ABS bond has 20 percent credit enhancement, and the collateral pool has credit losses of 21 percent, the credit loss or writedown to the bond will be approximately $1/100-20$ or 1.25 percent, since the bond is 80 percent of the balance sheet of the trust. The LGD of a securitization can therefore take on a very wide range, and is driven by the realization of defaults and recoveries in the collateral pool.

For a corporate or sovereign bond, default is a binary event; if interest and/or principal cannot be paid, bankruptcy or restructuring ensues. Corporate debt typically has a "hard" maturity date, while securitizations have a distant maturity date that is rarely the occasion for a default. For these reasons, default events in securitizations are often referred to as *material impairment* to distinguish them from defaults. A common definition of material impairment is either missed interest payments that go uncured for more than a few months, or a deterioration of collateral pool performance so severe that interest or principal payments are likely to stop in the future.

## Waterfall

The *waterfall* refers to the rules about how the cash flows from the collateral are distributed to the various securities in the capital structure. The term "waterfall" arose because generally the capital structure is paid in sequence, "top down," with the senior debt receiving all of its promised payments before any lower tranche receives any monies. In addition to the coupons and other payments promised to the bonds, there are fees and other costs to be paid, which typically take priority over coupons.

A typical structured credit product begins life with a certain amount of hard overcollateralization, since part of the capital structure is an equity note, and the debt tranches are less than 100 percent of the deal. Soft overcollateralization mechanisms may begin to pay down the senior debt over time with part of the collateral pool interest, or divert part of it into a reserve that provides additional credit enhancement for the senior tranches. That way, additional credit enhancement is built up at the beginning of the life of the product, when collateral cash flows are strongest. Typically, there is a detailed set of *overcollateralization triggers* that state the conditions under which excess spread is to be diverted into various reserves.

To clarify these concepts and introduce a few more, let's develop our simple example. Imagine a CLO, the underlying assets of which are 100 identical leveraged loans, with a par value of $1,000,000 each, and priced at par. The loans are floating rate obligations that pay a fixed spread of 3.5 percent over one-month Libor. We'll assume there are no upfront, management, or trustee fees. The capital structure consists of equity, and a junior and a senior bond, as displayed in this schematic balance sheet:

| **Assets** | **Liabilities** |
|---|---|
| Underlying<br>debt instruments: | Equity note $5 million<br>Mezzanine debt $10 million<br>coupon: Libor+500 bps |
| $100 million<br>coupon: L+350 bps | Senior debt $85 million<br>coupon: Libor+50 bps |

For the mezzanine debt in our example, the initial credit enhancement is equal to the initial size of the equity tranche. For the senior bond, it is equal to the sum of the equity and mezzanine tranches. There is initially no overcollateralization.

The junior bond has a much wider spread than that of the senior, and much less credit enhancement; the mezzanine attachment point is 5 percent, and the senior attachment point is 15 percent. We assume that, at these prices, the bonds will price at par when they are issued. In the further development of this example, we will explore the risk analysis that a potential investor might consider undertaking. The weighted average spread on the debt tranches is 97.4 basis points.

The loans in the collateral pool and the liabilities are assumed to have a maturity of five years. All coupons and loan interest payments are annual, and occur at year-end.

We assume the swap curve ("Libor") is flat at 5 percent. If there are *no* defaults in the collateral pool, the annual cash flows are

| | Libor+ spread | × Principal amount | = Annual interest |
|---|---|---|---|
| Collateral | (0.050 + 0.0350) | × 100,000,000 | = $8,500,000 |
| Mezzanine | (0.050 + 0.0500) | × 10,000,000 | = $1,000,000 |
| Senior | (0.050 + 0.0050) | × 85,000,000 | = $4,675,000 |

The excess spread if there are no defaults, the difference between the collateral cash flows coming into the trust and the tranche coupon payments flowing out, is $2,825,000.

The assumption that all the loans and bonds have precisely the same maturity date is a great simplification in several respects. Although one of the major motivations of securitization is to obtain term financing of a pool of underlying loans, such perfect *maturity matching* is unusual in constructing a securitization. The problem of maturity transformation in financial markets is pervasive and important.

The example so far has assumed no defaults. Of course, there may well be at least some defaults in a pool of 100 loans, even in a benign economic environment. If defaults occur at a constant rate, and defaulted collateral is not replaced, the annual number of defaults will fall over time as the pool shrinks due to defaults that have already occurred. The cumulative number of defaults will grow at a progressively slower rate. Suppose, for example, the default rate is expected to be 5 percent annually. The number of defaults in a pool of 100 loans is then likely to be an integer close to 5. After four years, if only 80 loans are still performing and we still expect 5 percent to default, the expected number of defaults is 4.

Regardless of whether the default rate is constant, default losses accumulate, so for any default rate, cash flows from any collateral pool will be larger early in the life of a structured credit product, from interest and amortization of surviving loans and recovery from defaulted loans, than later.

The example also illustrates a crucial characteristic of securitizations: the *timing* of defaults has an enormous influence on the returns to different tranches. If the timing of defaults is uneven, the risk of inadequate principal at the end may be enhanced or dampened. If defaults are accelerating, the risk to the bond tranches will increase, and vice versa. Other things being equal, the equity tranche benefits relative to more senior debt tranches if defaults occur later in the life of the structured product deal.

## Issuance Process

The process of creating a securitized credit product is best explained by describing some of the players in the cast of characters that bring it to market. As we do so, we note some of the conflicts of interest that pose risk management problems to investors.

### *Loan Originator*

The loan originator is the original lender who creates the debt obligations in the collateral pool. This is often a bank, for example, when the underlying collateral consists of bank loans or credit card receivables. But it can also be a specialty finance company or mortgage lender. If most of the loans have been originated by a single intermediary, the originator may be called the *sponsor* or *seller.*

### *Underwriter*

The *underwriter* or *arranger* is often, but not always, a large financial intermediary. Typically, the underwriter aggregates the underlying loans, designs the securitization structure and markets the liabilities. In this capacity, the underwriter is also the *issuer* of the securities. A somewhat technical legal term, *depositor*, is also used to describe the issuer.

During this aggregation phase, the underwriter bears *warehousing risk*, the risk that the deal will not be completed and the value of the accumulated collateral still on its balance sheet falls. Warehousing risk became important in the early days of the subprime crisis, as the market grew aware of the volumes of "hung loans" on intermediaries' balance sheets. Underwriting in the narrow sense is a "classical" broker-dealer function, namely, to hold the finished securitization liabilities until investors purchase them, and to take the risk that not all the securities can be sold at par.

### *Rating Agencies*

Rating agencies are engaged to assess the credit quality of the liabilities and assign ratings to them. An important part of this process is determining attachment points and credit subordination. In contrast to corporate bonds, in which rating agencies opine on creditworthiness, but have little influence over it, ratings of securitizations involve the agencies in decisions about structure.

Rating agencies are typically compensated by issuers, creating a potential conflict of interest between their desire to gain rating assignments and expand their business, and their duty to provide an objective assessment.

The potential conflict is exacerbated by the rating agencies' inherent role in determining the structure. The rating agency may tell the issuer how much enhancement is required, given the composition of the pool and other features of the deal, to gain an investment-grade rating for the top of the capital stack. These seniormost bonds have lower spreads and a wider investor audience, and are therefore uniquely important in the economics of securitizations. Or the issuer may guess at what the rating agency will require before submitting the deal to the agency for review. Either way, the rating agency has an incentive to require less enhancement, permitting the issuer to create a larger set of investment-grade tranches. Investors can cope with the potential conflict by either demanding a wider spread or carrying out their own credit review of the deal.

Ratings may be based solely on the credit quality of the pool and the liability structure. In many cases, however, bonds have higher ratings because of the provision of a guarantee, or *wrap*, by a third party. These guarantees are typically provided by *monoline insurance companies.* Monolines have high corporate ratings of their own and ample capital, and can use these to earn guarantee fees. Such guarantees were quite common until the subprime crisis caused large losses and widespread downgrades among monoline insurers.

### *Servicers and Managers*

The servicer collects principal and interest from the loans in the collateral pool and disburses principal and interest to the liability holders, as well as fees to the underwriter and itself. The servicer may be called upon to make advances to the securitization liabilities if loans in the trust are in arrears. Servicers may also be tasked with managing underlying loans in distress, determining, for example, whether they should be resolved by extending or refinancing the loan, or by foreclosing. Servicers are thereby often involved in conflicts of interest between themselves and bondholders, or between different classes of bondholders.

One example arises in CMBS. If one distressed loan is resolved by foreclosure, the senior bonds are unlikely to suffer a credit writedown, but rather will receive an earlier-than-anticipated repayment of principal, even if the property is sold at a loss. The junior bond, however, may suffer an immediate credit writedown. If, in contrast, the loan is extended, the junior bond avoids the immediate loss, and has at least a small positive probability of a recovery of value. The senior bond, in contrast, faces the risk that the loss on the property will be even greater, eroding the credit enhancement and increasing the riskiness of the bond. The servicer is obliged to maximize the total present value of the loan, but no matter what he does, he will take an action that is better aligned with the interests of some bonds than of others.

Managers of actively managed loan pools may also be involved in conflicts of interest. As is the case with bankers, investors delegate the task of monitoring the credit quality of pools to the managers, and require mechanisms to align incentives. One such mechanism that has been applied to managed as well as static pools is to require the manager to own a first-loss portion of the deal. This mechanism has been enshrined in the Dodd-Frank Act changes to financial regulatory policy. Such conflicts can be more severe for asset types, especially mortgages, in which servicing is not necessarily carried out by the loan originator. Third-party servicing also adds an entity whose soundness must be verified by investors in the bonds.

Among the economically minor players are the *trustee* and *custodian*, who are tasked with keeping records, verifying documentation, and moving cash flows among deal accounts and paying noteholders.

## CREDIT SCENARIO ANALYSIS OF A SECURITIZATION

The next step in understanding how a securitization works is to put together the various elements we've just defined—collateral, the liability structure, and the waterfall—and see how the cash flows behave over time and in different default scenarios. We'll continue to use our three-tranche example to lay these issues out. We'll do this in two parts, first analyzing the cash flows prior to maturity, and then the cash flows in the final year of the illustrative securitization's life, which are very different.

Let's take as a base assumption an annual expected default rate of 2 percent. As we will see, the securitization is "designed" for that default rate, in the sense that if defaults prove to be much higher, the bond tranches may experience credit losses. If the default rate proves much lower, the equity tranche will be extremely valuable, and probably more valuable than the market requires to coax investors to hold the position at par.

## Tracking the Interim Cash Flows

Let's introduce a simple overcollateralization mechanism into our example. Instead of letting all the excess spread flow to the equity note, we divert up to \$1,750,000 per year to a reserve account, which we will call the "overcollateralization account," where it will earn the financing/money market rate of 5 percent. This is a bit of a misnomer, since the funds in the account represent soft rather than hard credit enhancement. If excess spread is less than \$1,750,000, that smaller amount is diverted to the overcollateralization account. If excess spread is greater than \$1,750,000, the amount that exceeds \$1,750,000 is paid out to the equity.

The funds in the overcollateralization account will be used to pay interest on the bonds if there is not enough interest flowing from the loans in the collateral pool during that period. Any remaining funds in the account will be released to the equity tranche only at maturity. It is not a robust mechanism for protecting the senior bonds, but at least has the virtue that, unless defaults are very high early in the deal's life, the overcollateralization account is likely to accumulate funds while cumulative defaults are low.

We assume that the loans in the collateral pay no interest if they have defaulted any time during the prior year. There is no partial interest; interest is paid at the end of the year by surviving loans only.

We also have to make an assumption about recovery value if a loan defaults. We will assume that in the event of default, the recovery rate is 40 percent, and that the recovery amount is paid into the overcollateralization account, where it is also invested at the financing/money market rate. We have to treat recovery this way in order to protect the senior bond; if the recovery amounts flowed through the waterfall, the equity would perversely benefit from defaults. In a typical real-world securitization, the recovery would flow to the senior bonds, and eventually the mezzanine bond tranche, until they are paid off. Time-tranching would endeavor to have recoveries that occur early in the life of the deal flow to short-duration bonds and later recoveries to long-duration bonds. To keep our example simple, we "escrow" the recovery and defer writedowns until the maturity of the securitization.

We need some notation to help us track cash flows in more detail for different default scenarios. We'll assign these symbols to the cash flows and account values:

- $N$ — Number of loans in initial collateral pool; here $N = 100$
- $d_t$ — Number of defaults in the course of year $t$
- $L_t$ — Aggregate loan interest received by the trust at the end of year $t$
- $B$ — Bond coupon interest due to both the junior and senior bonds (a constant for all $t$; here \$5,675,000).
- $K$ — Maximum amount diverted annually from excess spread into the overcollateralization account; here \$1,750,000
- $OC_t$ — Amount actually diverted from excess spread into the overcollateralization account at the end of year $t$
- $R_t$ — Recovery amount deposited into the overcollateralization account at the end of year $t$
- $r$ — Money market or swap rate, assumed to be constant over time and for all maturities; here $r = 0.05$

Once we take defaults into account, the loan interest flowing from the surviving collateral at the end of year $t$ is

$$L_t = (0.050 + 0.035) \times \left( N - \sum_{\tau=1}^{t} d_\tau \right) \times 1000000 \qquad t = 1, \ldots, T-1$$

Let's tabulate the interim cash flows for three scenarios, with default rates of 1.5, 5.25, and 9.0 percent annually. As noted, the cash flows during the first four years of our five-year securitization are different from the terminal cash flows, so we tabulate them separately a bit further on.

Interest equal to \$5,675,000 is due to the bondholders. The excess spread is $L_t - B$. The excess spread will turn negative if defaults have been high. In that case, bond interest can't be paid out of the collateral cash flow, but must come in whole or in part out of the overcollateralization account.

The amount diverted from the excess spread to the overcollateralization account is

$$\max[\min(L_t - B, K), 0] \qquad t = 1, \ldots, T-1$$

If the excess spread is negative, any bond interest shortfall will be paid out of the overcollateralization account. Also, additional funds equal to

$$R_t = 0.4 d_t \times 1{,}000{,}000 \qquad t = 1, \ldots, T-1$$

will flow into the overcollateralization account from default recovery. Thus the value of the overcollateralization account at the end of year $t$, including the cash flows from recovery and interest paid on the value of the account at the end of the prior year, is

$$R_t + OC_t + \sum_{\tau=1}^{t-1}(1+r)^{t-\tau}OC_\tau \qquad t = 1, \ldots, T-1$$

This value is not fully determined until we know $OC_t$. And as simple as this securitization structure is, there are a few tests that the custodian must go through to determine the overcollateralization cash flow. These rules can be thought of as a two-step decision tree, each step having two branches. The test is carried out at the end of each year. In the first step, the custodian tests whether the excess spread is positive; that is, is $L_t - B > 0$?

- If $L_t - B \geq 0$, the next test determines whether the excess spread is great enough to cover $K$; that is, is $L_t - B \geq K$?
  - If $L_t - B \geq K$, then $K$ flows into the overcollateralization account, and there may be some excess spread left over for the equity, unless $L_t - B = K$.
  - If $L_t - B < K$, then the entire amount $L_t - B$ flows into the overcollateralization account, and there is no excess spread left over for the equity. If $L_t - B = 0$, then there is exactly enough excess spread to cover bond payments and nothing flows into the overcollateralization account.
- If the excess spread is negative ($L_t - B < 0$), the custodian tests whether there are enough funds in the overcollateralization account, plus proceeds from recovery on defaults over the past year, to cover the shortfall. The funds in the overcollateralization account from prior years amount to $\Sigma_{\tau=1}^{t-1}(1+r)^{t-\tau}OC_\tau$ and current year recoveries are $R_t$, so the test is

$$\sum_{\tau=1}^{t-1}(1+r)^{t-\tau}OC_\tau + R_t \geq B - L_t$$

  - If the shortfall can be covered, then the entire amount $B - L_t$ flows out of the overcollateralization account.
  - If not, that is, if

$$\sum_{\tau=1}^{t-1}(1+r)^{t-\tau}OC_\tau + R_t < B - L_t$$

    then $\Sigma_{\tau=1}^{t-1}(1+r)^{t-\tau}OC_\tau + R_t$ flows out of the overcollateralization account, leaving it entirely depleted.

The amount to be diverted can be written

$$OC_t = \begin{Bmatrix} \min(L_t - B, K) \\ \max[L_t - B, -(\Sigma_{\tau=1}^{t-1}(1+r)^{t-\tau}OC_\tau + R_t)] \end{Bmatrix} \quad \text{for} \quad \begin{Bmatrix} L_t \geq B \\ L_t < B \end{Bmatrix}$$

Once we know how much excess spread, if any, flows into the overcollateralization account at the end of year $t$, we can determine how much cash flows to the equity noteholders at the end of year $t$. The equity cash flow is

$$\max(L_t - B - OC_t, 0) \qquad t = 1, \ldots, T-1$$

Obviously, there is no cash flow to the equity prior to maturity unless there is positive excess spread.

The results for our example can be presented in a cash flow table, presented as Table 8-1, that shows the cash flows in detail, as specified by the waterfall, in each period. There is a panel in the cash flow table for each default scenario.

We can now summarize the results. The excess spread declines over time in all scenarios as defaults pile up, as one would expect. For the high-default scenarios, the loan interest in later years is not sufficient to cover the bond interest and the excess spread turns negative.

The overcollateralization amount is capped at $1,750,000, and when the default rate is 2.0 percent that amount can be paid into the overcollateralization account in full every year. For higher default rates, the cap kicks in early on. For the highest default rate, in which the excess spread in the later years turns negative, not only is no additional overcollateralization diverted away from the equity, but rather funds must be paid out of the overcollateralization account to cover the bond interest.

The most dramatic differences between the default scenarios are in the equity cash flows, the last cash flows to be determined. For the lowest default rate, the equity continues to receive at least some cash almost throughout the life of the securitization. In the higher default scenarios, interim cash flows to the equity terminate much earlier.

Because the recovery amounts are held back rather than used to partially redeem the bonds prior to maturity, and because, in addition, even in a very high default scenario, there are enough funds available to pay the coupons on the bond tranches, the bonds cannot "break" before maturity. In real-world securitizations, trust agreements are written so that in an extreme scenario, the

**TABLE 8-1** Interim Cash Flow Table for the CLO

| (1) *t* | (2) Def | (3) Cum | (4) Srv | (5) Loan int | (6) Exc spr | (7) OC | (8) Recov | (9) OC+Recov | (10) Eq flow | (11) Results | (12) OC a/c |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Default rate 2.0 percent* | | | | | | | | | | | |
| 1 | 2 | 2 | 98 | 8,330,000 | 2,655,000 | 1,750,000 | 800,000 | 2,550,000 | 905,000 | Y | 2,550,000 |
| 2 | 2 | 4 | 96 | 8,160,000 | 2,485,000 | 1,750,000 | 800,000 | 2,550,000 | 735,000 | Y | 5,227,500 |
| 3 | 2 | 6 | 94 | 7,990,000 | 2,315,000 | 1,750,000 | 800,000 | 2,550,000 | 565,000 | Y | 8,038,875 |
| 4 | 2 | 8 | 92 | 7,820,000 | 2,145,000 | 1,750,000 | 800,000 | 2,550,000 | 395,000 | Y | 10,990,819 |
| *Default rate 7.5 percent* | | | | | | | | | | | |
| 1 | 8 | 8 | 92 | 7,820,000 | 2,145,000 | 1,750,000 | 3,200,000 | 4,950,000 | 395,000 | Y | 4,950,000 |
| 2 | 7 | 15 | 85 | 7,225,000 | 1,550,000 | 1,550,000 | 2,800,000 | 4,350,000 | 0 | Y | 9,547,500 |
| 3 | 6 | 21 | 79 | 6,715,000 | 1,040,000 | 1,040,000 | 2,400,000 | 3,440,000 | 0 | Y | 13,464,875 |
| 4 | 6 | 27 | 73 | 6,205,000 | 530,000 | 530,000 | 2,400,000 | 2,930,000 | 0 | Y | 17,068,119 |
| *Default rate 10.0 percent* | | | | | | | | | | | |
| 1 | 10 | 10 | 90 | 7,650,000 | 1,975,000 | 1,750,000 | 4,000,000 | 5,750,000 | 225,000 | Y | 5,750,000 |
| 2 | 9 | 19 | 81 | 6,885,000 | 1,210,000 | 1,210,000 | 3,600,000 | 4,810,000 | 0 | Y | 10,847,500 |
| 3 | 8 | 27 | 73 | 6,205,000 | 530,000 | 530,000 | 3,200,000 | 3,730,000 | 0 | Y | 15,119,875 |
| 4 | 7 | 34 | 66 | 5,610,000 | −65,000 | -65,000 | 2,800,000 | 2,735,000 | 0 | Y | 18,610,869 |

Key to columns:
(1) Year index
(2) Number of defaults during year *t*
(3) Cumulative number of defaults $\Sigma_{\tau=1}^{t} d_\tau$ at the end of year *t*
(4) Number of surviving loans $N - \Sigma_{\tau=1}^{t} d_\tau$ at the end of year *t*
(5) Loan interest
(6) Excess spread
(7) Overcollateralization increment
(8) Recovery amount $R_t$
(9) Aggregate flow into overcollateralization account $OC_t + R_t$
(10) Interim cash flow to the equity at the end of year *t*.
(11) Results of a test to see if interest on the bonds can be paid in full at the end of year *t*.
(12) The value of the overcollateralization account at time *t*.

securitization can be unwound early, thus protecting the bond tranches from further loss.

## Tracking the Final-Year Cash Flows

To complete the cash flow analysis, we need to examine the final-year payment streams. Our securitization has an anticipated maturity of five years, and we have tabulated cash flows for the first four. Next, we examine the terminal, year 5, cash flows. There are four sources of funds at the end of year 5:

1. Loan interest from the surviving loans paid at the end of year 5, equal to
$$\left(N - \sum_{t=1}^{T} d_t\right) \times (0.05 + 0.035) \times 1{,}000{,}000$$
2. Proceeds from redemptions at par of the surviving loans:
$$\left(N - \sum_{t=1}^{T} d_t\right) \times 1{,}000{,}000$$
3. The recovery from loans defaulting in year 5:
$$R_T = 0.4 \times d_T \times 1{,}000{,}000$$
4. The value of the overcollateralization account at the end of year 5, equal to $1 + r$ times the value displayed, for each default rate, in the last row of the last column of Table 8-1:
$$\sum_{\tau=1}^{T} (1+r)^{t-\tau} OC_\tau$$

There is no longer any need to divert funds to overcollateralization, so all funds are to be used to pay the final coupon and redemption proceeds to the bondholders, in order of priority and to the extent possible. There is also no longer any need to carry out an overcollateralization test.

Next, we add all the terminal cash flows and compare their sum with the amount due to the bondholders. If too many loans have defaulted, then one or both bonds may not receive its stipulated final payments in full. The terminal available funds are:

$$F = \sum_{t=1}^{T-1} (1+r)^{t-\tau} OC_\tau + \left[\left(N - \sum_{t=1}^{T} d_t\right) 1.085 + 0.4 d_T\right] \times 1{,}000{,}000$$

If this amount is greater than the \$100,675,000 due to the bondholders, the equity note receives a final payment. If it is less, at least one of the bonds will default.

The custodian therefore must perform a sequence of two shortfall tests. The first tests if the senior note can be paid in full:

$$F \begin{Bmatrix} \geq \\ < \end{Bmatrix} 89{,}675{,}000$$

If this test is passed, the senior bond is money good. If not, we subtract the shortfall from its par value. The senior bond value then experiences a credit loss or writedown of \$89,675,000 − $F$. We can express the loss as max(89,675,000 − $F$, 0).

Since the senior bond must be paid first, the default test for the junior bond is

$$F - 89{,}675{,}000 \begin{Bmatrix} \geq \\ < \end{Bmatrix} 11{,}000{,}000$$

which is the amount due the mezzanine note holders. If there is a shortfall, the credit loss of the mezzanine is max[11,000,000 − ($F$ − 89,675,000), 0].

The credit risk to the bonds is of a shortfall of interest and, potentially, even principal. What about the equity? The equity is not "owed" anything, so is there a meaningful measure of its credit risk? One approach is to compute the equity tranche's *internal rate of return* (IRR) in different scenarios. Credit losses in excess of expectations will bring the rate of return down, possibly below zero, if not even the par value the equity investor advanced is recovered over time. The equity investor will typically have a target rate of return, or *hurdle rate*, representing an appropriate compensation for risk, given the possible alternative uses of capital. Even if the rate of return is nonnegative, it may fall below this hurdle rate and represent a loss. We could use a posited hurdle rate to discount cash flows and arrive at an equity dollar price. While the results would be somewhat dependent on the choice of hurdle rate, we can speak of the equity's value more or less interchangeably in terms of price or IRR.

To compute the equity IRR, we first need to assemble all the cash flows to the equity tranche. The initial outlay for the equity tranche is \$5,000,000. If the equity tranche owner is both the originator of the underlying loans and the sponsor of the securitization, this amount represents the difference between the amount lent and the amount funded at term via the bond tranches. If the equity tranche owner is a different party, we assume that party bought the equity "at par." Recall that we've assumed that the bond and underlying loan interest rates are market-clearing, equilibrium rates. We similarly assume the equity has a market-clearing expected return at par.

We saw earlier that the interim cash flows to the equity, that is, those in the first 4 years, are $\max(L_t - B - OC_t, 0)$, $t = 1, \ldots, 4$. The terminal cash flow to the equity is $\max(F - 100{,}675{,}000, 0)$, since the bond tranches have a prior claim to any available funds in the final period. Thus the IRR is the value of $x$ that satisfies

$$0 = -5{,}000{,}000 + \Sigma_{t=1}^{T-1} (1 + x)^{-t} \max(L_t - B - OC_t, 0)$$
$$+(1 + x)^{-T} \max(F - 100{,}675{,}000, 0)$$

To complete the scenario analysis, we display these values for the three default scenarios in Table 8-2. The first three rows of data display the final-year default count, and the cumulative number of defaulted and surviving loans. The next five rows of data show the terminal available funds and how they are generated—loan interest, redemption proceeds, and recovery. The main driver is, not surprisingly, redemption proceeds from surviving loans. The next row of data is the amount owed to the bondholders at time $T$, the same, of course, in all default scenarios.

We can see that in the low default scenario, the bonds will be paid in full and the equity tranche will get a large final payment. At higher default rates, the equity receives no residual payment, and one or both of the bonds cannot be paid in full.

For the expected default rate of 2 percent, the equity IRR is 23 percent. At high default rates, the IRR approaches minus 100 percent. At a default rate of 10 percent, for example, the equity receives an early payment out of excess spread, but nothing subsequently, so the equity

**TABLE 8-2** Terminal Cash Flows of the CDO

| | | | |
|---|---|---|---|
| Default rate | 2.0 | 7.5 | 10.0 |
| *Time T default counts*: | | | |
| Final period current default count | 2 | 5 | 7 |
| Final period cumulative default count | 10 | 32 | 41 |
| Final period surviving loan count | 90 | 68 | 59 |
| *Available funds at time T*: | | | |
| Final period loan interest | 7,650,000 | 5,780,000 | 5,015,000 |
| Loan redemption proceeds | 90,000,000 | 68,000,000 | 59,000,000 |
| Final period recovery amount | 800,000 | 2,000,000 | 2,800,000 |
| Ending balance of overcollateralization account | 11,540,360 | 17,921,525 | 19,541,412 |
| Total terminal available funds | 109,990,360 | 93,701,525 | 86,356,412 |
| Owed to bond tranches | 100,675,000 | 100,675,000 | 100,675,000 |
| *Equity returns*: | | | |
| Equity terminal cash flow | 9,315,360 | 0 | 0 |
| Equity internal rate of return (%) | 23.0 | −92.1 | −95.5 |
| *Bond writedowns*: | | | |
| Total terminal bond shortfall | 0 | 6,973,475 | 14,318,588 |
| Terminal mezzanine shortfall | 0 | 6,973,475 | 11,000,000 |
| Terminal senior shortfall | 0 | 0 | 3,318,588 |

tranche owner is “out” nearly the entire $5,000,000 initial investment.

The final rows of the table show credit losses, if any, on the bond tranches. At a default rate of 2 percent, both bonds are repaid in full. At a default rate of 7.5 percent, the junior bond loses its final coupon payment and a portion of principal. At a default rate of 10 percent, even the senior bond cannot be paid off in full, but loses part of its final coupon payment.

The table shows extreme loss levels that will “break” the bonds and essentially wipe out the equity tranche. We have focused here on explaining how to take account of the structure and waterfall of the securitization in determining losses, while making broad-brush assumptions about the performance of the collateral pool. Another equally important task in scenario analysis is to determine what are reasonable scenarios about pool losses. How we interpret the results for a 10 percent collateral pool default rate depends on how likely we consider that outcome to be. It is difficult to estimate the probabilities of such extreme events precisely. But we can make sound judgements about whether they are highly unlikely but possible, or close to impossible.

For structured credit products, such judgements are based on two assessments. The first is a credit risk assessment of the underlying loans, to determine how the distribution of defaults will vary under different economic conditions, requiring expertise and models pertinent to the type of credit in the pool, say, consumer credit or commercial real estate loans. The second is a judgement about how adverse an economic environment to take into account. The latter is based on both economic analysis and the risk appetite of the investor.

## MEASURING STRUCTURED CREDIT RISK VIA SIMULATION

Up until now, we have analyzed losses in the securitization for specific default scenarios. But this approach ignores default correlation, that is, the propensity of defaults to coincide. Once we take default correlation into account, we can estimate the entire probability distribution of losses for each tranche into account. The loss distributions provide us with insights into valuation as well as risk.

Chapter 7 introduced two approaches to taking account of default correlation in a credit portfolio, one based on the single-factor model and the other on simulation via a copula model. We'll apply the simulation/copula approach to the loan portfolio that constitutes the securitization trust's collateral pool. While in Chapter 7, we applied the simulation approach to a portfolio of two credit-risky securities, here we apply it to a case in which the underlying collateral contains many loans. This simulation-based analysis of the risk of a securitization, by taking into account the default correlation, unlocks the entire distribution of outcomes, not just particular outcomes.

### The Simulation Procedure and the Role of Correlation

The simulation process can be summarized in these steps:

*Estimate parameters.* First we need to determine the parameters for the valuation, in particular, the default probabilities or default distribution of each individual security in the collateral pool, and the correlation used to tie the individual default distributions together.

*Generate default time simulations.* Using the estimated parameters and the copula approach, we simulate the default times of each security (here, the underlying loans) in the collateral pool. With the default times in hand, we can next identify, for each simulation thread and each security, whether it defaults within the life of the securitization, and if so, in what period.

*Compute the credit losses.* The default times can be used to generate a sequence of cash flows from the collateral pool in each period, for each simulation thread. This part of the procedure is the same as the cash flow analysis of the previous section. The difference is only that in the simulation approach, the number of defaults each period is dictated by the results of the simulation rather than assumed. The securitization capital structure and waterfall allocate the cash flows over time, for each simulation thread, to the securitization tranches. For each simulation thread, the credit loss, if any, to each liability and the residual cash flow, if any, to the equity tranche can then be computed. This gives us the entire distribution of losses for the bonds and of IRRs for the equity. The distributions can be used to compute credit statistics such as Credit VaR for each tranche.

The default probability parameters can, as usual, be estimated in two ways, either as a physical or, if comparable spread data is available, as a risk-neutral probability. We have $N$ (in our example, 100) pieces of collateral in the pool, so we need up to $N$ distinct default probabilities $\pi_n$, $n = 1, \ldots, N$. If we want to use time-varying hazard rates, we also need a term structure of default probabilities. For our securitization example, we assume, as in Chapter 7, that we have obtained a one-year physical default probability $\pi_n$ from an internal or external rating. We convert this to a hazard rate using the formula

$$\pi_n = 1 - e^{-\lambda_n} \quad \Leftrightarrow \quad \lambda_n = -\log(1 - \pi_n) \quad n = 1, \ldots, N$$

We'll assume each loan has the same probability of default, so $\pi_n = \pi$, $n = 1, \ldots, 100$.

The correlations $\rho_{m,n}$, $m, n = 1, \ldots, N$ between the elements of the collateral pool are more difficult to obtain, since the copula correlation, as we have seen, is not a natural or intuitive quantity, and there is not much market or financial data with which to estimate it. We'll put only one restriction on the correlation assumption: that $\rho_{m,n} \geq 0$, $m, n = 1, \ldots, N$.

In our example we assume the correlations are pairwise constant, so $\rho_{mn} = \rho$, $m, n = 1, \ldots, 100$. We will want to see the effects of different assumptions about default probability and correlation, so, for both the default probability and correlation parameter, we'll compare results for different pairs of $\pi$ and $\rho$. Our posited loan default probabilities range from $\pi = 0.075$ to $\pi = 0.975$, in increments of 0.075, and we apply correlation parameters between $\rho = 0$ and $\rho = 0.9$, in increments of 0.3. This gives us a total of 52 pairs of default probability and correlation parameter settings to study.

Once we have the parameters, we can begin to simulate. Since we are dealing with an $N$-security portfolio, each simulation thread must have $N$ elements. Let $I$ be the number of simulations we propose to do. In our example, we set the number of simulations at $I = 1{,}000$. The first step is to generate a set of $I$ draws from an $N$-dimensional joint standard normal distribution. This is an $N$-dimensional random variable in which each element is normally distributed with a mean of zero and a standard deviation equal to unity, and in which each pair of elements $m$ and $n$ has a correlation coefficient of $\rho_{m,n}$.

The result of this step is a matrix

$$\tilde{z} = \begin{pmatrix} \tilde{z}_{11} & \tilde{z}_{12} & \cdots & \tilde{z}_{1N} \\ \tilde{z}_{21} & \tilde{z}_{22} & \cdots & \tilde{z}_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{z}_{I1} & \tilde{z}_{I2} & \cdots & \tilde{z}_{IN} \end{pmatrix}$$

Each row of $\tilde{z}$ is one simulation thread of an $N$-dimensional standard normal variate with a covariance matrix equal to

$$\Sigma = \begin{pmatrix} 1 & \rho_{12} & \cdots & \rho_{1N} \\ \rho_{12} & 1 & \cdots & \rho_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{1N} & \rho_{2N} & \cdots & 1 \end{pmatrix}$$

For example, suppose we take the correlations coefficient to be a constant $\rho = 0.30$. We can generate 1,000 correlated normals. The result of this step is a matrix

$$\tilde{z} = \begin{pmatrix} \tilde{z}_{1,1} & \cdots & \tilde{z}_{1,100} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{1000,1} & \cdots & \tilde{z}_{1000,100} \end{pmatrix}$$

with each row representing one simulation thread of a 100-dimensional standard normal variate with a mean of zero and a covariance matrix equal to

$$\begin{pmatrix} 1 & \cdots & \rho \\ \vdots & \ddots & \vdots \\ \rho & \cdots & 1 \end{pmatrix} = \begin{pmatrix} 1 & \cdots & 0.3 \\ \vdots & \ddots & \vdots \\ 0.3 & \cdots & 1 \end{pmatrix}$$

In the implementation used in the example, the upper left $4 \times 4$ submatrix of the matrix $\tilde{z}$ is

$$\begin{pmatrix} -1.2625 & -0.3968 & -0.4285 & -1.0258 & \cdots \\ -0.3778 & -0.1544 & -1.5535 & -0.4684 & \cdots \\ 0.2319 & -0.1779 & -0.4377 & -0.5282 & \cdots \\ -0.6915 & -0.5754 & -0.3939 & -0.1683 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix}$$

The actual numerical values would depend on the random number generation technique being used and random variation in the simulation results. For our example, we generate four such matrices $\tilde{z}$, one for each of our correlation assumptions.

The next step is to map each element of $\tilde{z}$ to a default time $\tilde{t}_{ni}$, $n = 1, \ldots, N, I = 1, \ldots, I$. If we have one hazard rate $\lambda_n$ for each security, we carry out the mapping via the formula

$$t_{ni} = -\frac{\log[1-\Phi(z_{ni})]}{\lambda_n} \qquad n = 1, \ldots, N; i = 1, \ldots I$$

giving us a matrix $\tilde{t}$ of default times. We can now count off the number of defaults, and the cumulative number, occurring in each period within the term of the securitization liabilities. Note that we need a distinct matrix of simulated standard normals for each correlation assumption, but not for each default probability assumption.

In our example, we use a constant hazard rate across loans:

$$t_{ni} = -\frac{\log[1-\Phi(z_{ni})]}{\lambda} \qquad n = 1, \ldots, 100; i = 1, \ldots, 1000$$

For $\pi = 0.0225$, for example, we have $\lambda = -\log(1-\pi) = -\log(0.9775) = 0.022757$. Together with the assumption $\rho = 0.30$, this results in another $1{,}000 \times 100$ matrix. In our simulation example, it has upper left $4 \times 4$ submatrix

$$\begin{pmatrix} 4.7951 & 18.6433 & 17.8702 & 7.2705 & \cdots \\ 19.1194 & 25.3727 & 2.7262 & 16.9309 & \cdots \\ 39.3599 & 24.6542 & 17.6515 & 15.5915 & \cdots \\ 12.3274 & 14.5882 & 18.7161 & 24.9461 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix}$$

We generate as many such matrices of simulated default times as we have pairs of default time-correlation parameter assumptions, namely 52. For example, focusing on element (1,1) of the submatrix of correlated normal simulations of the previous page, we compute the corresponding element (1,1) of the matrix of default times as

$$-\frac{\log[1-\Phi(-1.2625)]}{-\log(1-0.0225)} = 4.7951$$

Note that there are two defaults (default times less than 5.0) within the five-year term of the securitization for these first four loans in the first four threads of the simulation for the parameter pair $\pi = 0.0225$, $\rho = 0.30$. Again, we have 52 such matrices, one for each parameter pair, each of dimension $1{,}000 \times 100$.

This completes the process of generating simulations of default times. The next step is to turn the simulated default times $\tilde{t}$ into vectors of year-by-year defaults and cumulative defaults, similar to columns (2) and (3) of the cash flow Table 8-1, and the row of final year defaults in Table 8-2. To do this, we count, for each of the 1,000 rows, how many of the 100 simulated default times fall into each of the intervals $(t-1, t]$, $t = 1, \ldots, T$. The result in our example is a set of 1,000 vectors of length $T = 5$, each containing the number of defaults occurring in each $\rho$ of the five years of the CLO. The cumulative sum of each of these vectors is the cumulative default count, also a five-element vector.

The full first row of $\tilde{t}$ for the parameter pair $\pi = 0.0225$, $\rho = 0.30$, for example, is

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4.80 | 18.64 | 17.87 | 7.27 | 3.86 | 18.39 | 3.89 | 5.85 | 11.37 | 25.80 |
| 22.39 | 5.35 | 17.60 | 20.62 | 0.84 | 4.27 | 39.38 | 11.22 | 30.37 | 3.44 |
| 6.70 | 10.21 | 29.41 | 26.93 | 8.79 | 36.20 | 24.55 | 48.12 | 2.48 | 0.55 |
| 11.89 | 4.55 | 12.81 | 69.02 | 24.22 | 7.99 | 16.70 | 4.94 | 12.36 | 7.48 |
| 2.55 | 8.12 | 4.75 | 91.37 | 32.10 | 35.34 | 25.53 | 0.39 | 3.55 | 10.55 |
| 1.83 | 2.80 | 0.79 | 1.26 | 5.72 | 2.69 | 1.12 | 0.91 | 3.94 | 32.04 |
| 2.69 | 2.94 | 12.66 | 9.80 | 2.40 | 40.70 | 7.47 | 0.46 | 15.31 | 16.72 |
| 5.31 | 5.85 | 0.14 | 5.89 | 25.30 | 9.80 | 13.96 | 8.73 | 5.73 | 48.27 |
| 26.22 | 7.39 | 5.25 | 3.13 | 0.68 | 4.51 | 1.88 | 3.31 | 39.46 | 8.38 |
| 42.29 | 0.73 | 4.53 | 11.38 | 15.70 | 0.99 | 0.91 | 22.43 | 1.94 | 12.41 |

It gives us the simulated default times in the first simulation thread of each of the 100 pieces of collateral. The associated current default count vector is

$$(11, 5, 7, 7, 7)$$

since there are 11 elements in the first row of $\tilde{\mathbf{t}}$ that are less than or equal to 1, 4 elements in the range (1, 2), and so on. The corresponding cumulative default count vector is

$$(11, 16, 23, 30, 37)$$

Thus, in that first simulation thread, there is a cumulative total of 37 defaults by the end of year 5. (This is, incidentally, one of the grimmer simulation threads for this parameter pair.) We generate 1,000 such cumulative default count vectors, one for each simulation thread, for this parameter pair.

We want to see the effects of different assumptions, so we repeat this procedure for all 52 pairs of default probabilities $\pi = 0.0075, 0.0150, \ldots, 0.0975$ and correlations $\rho = 0.00, 0.30, 0.60, 0.90$. One of the advantages of this approach is that, if we want to see the effects of changing distributional parameters, or characteristics of the collateral or liability structure, such as the recovery rate or the interest paid by the collateral, we don't have to do a fresh set of simulations. We only change the way the simulations are processed. We would need to do new simulations only if we want to increase the number of threads $I$ for greater simulation accuracy, or we change the number of loans in the collateral pool, or we introduce new correlation settings not included in the set {0.00, 0.30, 0.60, 0.90}.

The final step is to pass these loan-loss results, scenario by scenario, through the waterfall. To accomplish this, we repeat, for each simulation, the process we laid out for scenario analysis. For each simulation, we use the current and cumulative default count vectors to generate the cash flows, distribute them through the waterfall, and tabulate the cash flows for each security.

## Means of the Distributions

We can now describe the distributions of the results. We'll begin with the means.

The results for the equity tranche are displayed in the next table. Each value is the *mean* IRR over all the simulations for the parameter pair displayed in the row and column headers. For low default rates, the mean equity IRRs are over 30 percent per annum, while for high default rates and low correlations, the equity tranche is effectively wiped out in many simulation threads.

***Equity IRR (percent)***

| $\pi$ | $\rho = 0.00$ | $\rho = 0.30$ | $\rho = 0.60$ | $\rho = 0.90$ |
|---|---|---|---|---|
| 0.0075 | 33.9 | 32.4 | 30.8 | 32.2 |
| 0.0225 | 20.6 | 13.3 | 14.2 | 19.8 |
| 0.0375 | −2.8 | −8.1 | −0.9 | 10.5 |
| 0.0525 | −46.9 | −26.3 | −13.8 | 1.5 |
| 0.0675 | −79.3 | −41.2 | −24.0 | −6.5 |
| 0.0825 | −89.7 | −53.5 | −33.3 | −13.8 |
| 0.0975 | −93.8 | −63.1 | −41.1 | −20.3 |

In order to compute risk statistics such as VaR, we use dollar values rather than IRRs. To do so, we make a somewhat arbitrary parameter assignment, namely, that the equity hurdle rate is 25 percent. Some assumption on hurdle rates is required in order to identify the IRR at which a loss occurs, and is similar to our setting the market-clearing bond coupons as part of the example. This hurdle rate more or less prices the equity tranche at its par value of \$5,000,000 for $\pi = 2.25$ percent and $\rho = 0.30$. We use this hurdle rate to discount to the present the future cash flows to the equity tranche in each simulation scenario. The sum of these present values is the equity value in that scenario. A present value is computed for each simulation as:

$$\sum_{t=1}^{T-1}(1.25)^{-t}\max(L_t - B - OC_t, 0) + (1.25)^{-T}\max(F - 100675000, 0)$$

Averaging these present values over all 1,000 simulations gives us the estimated equity value for each $(\pi, \rho)$ pair. Table 8-3 tabulates the means of the simulated equity values and the bond credit writedowns. We display them graphically in Figure 8-1. Each result is the mean over the 1,000 simulations of the IRR or credit loss. The bond writedowns are expressed as a percent of the par value of the bond, rather than in millions of dollars to make comparison of the results for the mezzanine and senior bonds more meaningful.

The means of the mezzanine and senior bond writedowns don't "add up," even though the results add up simulation

**TABLE 8-3** Mean Equity Values and Bond Credit Losses

| Equity Value ($ million) | | | | |
|---|---|---|---|---|
| π | ρ = 0.00 | ρ = 0.30 | ρ = 0.60 | ρ = 0.90 |
| 0.0075 | 6.59 | 6.72 | 6.85 | 7.14 |
| 0.0225 | 4.44 | 4.98 | 5.61 | 6.33 |
| 0.0375 | 2.47 | 3.69 | 4.64 | 5.69 |
| 0.0525 | 1.06 | 2.75 | 3.90 | 5.08 |
| 0.0675 | 0.51 | 2.07 | 3.32 | 4.56 |
| 0.0825 | 0.33 | 1.57 | 2.84 | 4.13 |
| 0.0975 | 0.22 | 1.23 | 2.44 | 3.74 |
| **Mezzanine Bond Writedown (percent of tranche par value)** | | | | |
| π | ρ = 0.00 | ρ = 0.30 | ρ = 0.60 | ρ = 0.90 |
| 0.0075 | 0.00 | 1.11 | 3.36 | 4.84 |
| 0.0225 | 0.00 | 7.35 | 12.82 | 15.49 |
| 0.0375 | 1.03 | 19.30 | 23.97 | 23.14 |
| 0.0525 | 14.81 | 33.90 | 33.75 | 31.32 |
| 0.0675 | 49.86 | 46.45 | 43.82 | 39.64 |
| 0.0825 | 85.74 | 58.60 | 51.54 | 46.40 |
| 0.0975 | 103.92 | 69.58 | 58.68 | 52.87 |
| **Senior Bond Writedown (percent of tranche par value)** | | | | |
| π | ρ = 0.00 | ρ = 0.30 | ρ = 0.60 | ρ = 0.90 |
| 0.0075 | 0.00 | 0.05 | 0.41 | 1.31 |
| 0.0225 | 0.00 | 0.52 | 2.14 | 5.05 |
| 0.0375 | 0.00 | 1.44 | 4.36 | 8.81 |
| 0.0525 | 0.00 | 2.96 | 6.96 | 12.08 |
| 0.0675 | 0.12 | 5.17 | 9.71 | 15.49 |
| 0.0825 | 1.07 | 7.78 | 12.75 | 18.96 |
| 0.0975 | 4.02 | 10.64 | 15.92 | 22.29 |

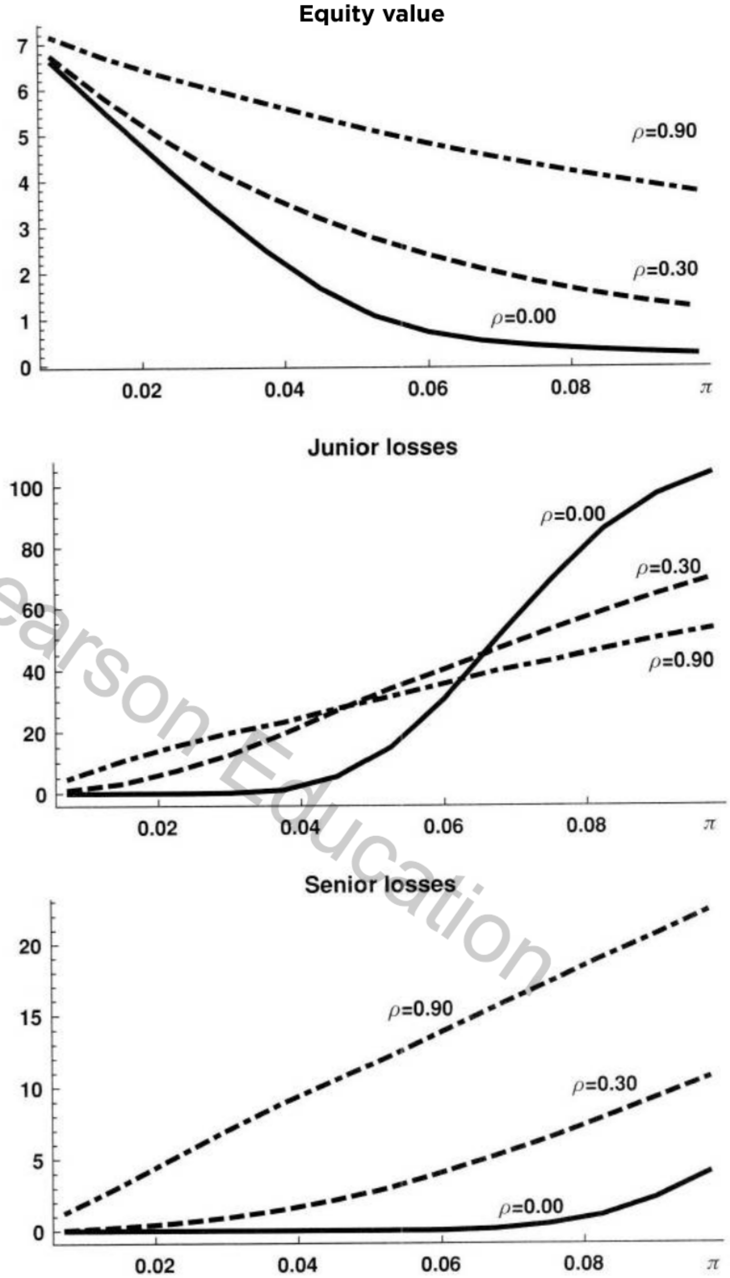


**FIGURE 8-1** Values of CLO tranches.

Equity value and bond losses in millions of $ as a function of default probabilities for different constant pairwise correlations. The equity is valued using a discount factor of 25 percent per annum. Bond losses are in percent of par value.

by simulation. Consider, for example, the parameter pair $\pi = 0.0225$ and $\rho = 0.30$. There are small losses for both the senior and junior bonds. How can there be losses to the senior at all, if the junior losses are small? The reason is that the senior loss of 0.05 percent of par stems from six simulation threads out of the 1,000 in which, of course, the junior tranche is entirely wiped out. However, there are only 19 threads in which the junior tranche experiences a loss at all, so the average loss for the parameter pair is low.

There are several important patterns in the results we see in the example, particularly with respect to the interaction between correlation and default probability:

*Increases in the default rate* increase bond losses and decrease the equity IRR for all correlation assumptions. In other words, for any given correlation, an increase in the default rate will hurt all of the tranches. This is an unsurprising result, in contrast to the next two.

*Increases in correlation* can have a very different effect, depending on the level of defaults. At low default rates, the impact of an increase in correlation is relatively low. But when default rates are relatively high, an increase in correlation can materially *increase* the IRR of the equity tranche, but also *increase* the losses to the senior bond tranche. In other words, the equity benefits from high correlation, while the senior bond is hurt by it. We will discuss this important result in more detail in a moment.

The effect on the mezzanine bond is more complicated. At low default rates, an increase in correlation increases losses on the mezzanine bond, but decreases losses for high default rates. In other words, the mezzanine bond behaves more like a senior bond at low default rates, when it is unlikely that losses will approach its attachment point and the bond will be broken, and behaves more like the equity tranche when default rates are high and a breach of the attachment point appears likelier.

*Convexity.* At low correlations, the equity value is substantially *positively convex* in default rates. That is, the equity tranche loses value rapidly as default rates increase from a low level. But as default rates increase, the responsiveness of the equity value to further increases in the default rate drops off. In other words, you can't beat a dead horse: If you are long the equity tranche, once you've lost most of your investment due to increases in default rates, you will lose a bit less from the next increase in default rates.

For low correlations, the senior bond tranche has *negative convexity* in default rates; its losses accelerate as defaults rise. The mezzanine tranche, again, is ambiguous. It has negative convexity for low default rates, but is positively convex for high default rates. At high correlations, all the tranches are less convex; that is, they respond more nearly linearly to changes in default rates.

## Distribution of Losses and Credit VaR

Table 8-3 and Figure 8-1 display the means over all the simulations for each parameter pair. We can gain additional insights into the risk characteristics of each tranche by examining the entire distribution of outcomes for different parameter pairs; the patterns we see differ across tranches.

### *Characteristics of the Distributions*

Figures 8-2 through 8-4 present histograms of all 1,000 simulated values of each of the three CLO tranches for a subset of our 52 $(\pi, \rho)$ assumption pairs. Each histogram is labeled by its $(\pi, \rho)$ assumption. The expected value of the tranche for the $(\pi, \rho)$ assumption is marked by a solid grid line. The 0.01-(0.05)-quantile of the value distribution is marked by a dashed (dotted) grid line.

The distribution plots help us more fully understand the behavior of the mean values or writedowns of the different tranches. Before we look at each tranche in detail, let's recall how correlation affects the pattern of defaults. When correlation is high, defaults tend to arrive in clusters. Averaged over all of the simulations, the number of defaults will be approximately equal to the default probability. But the defaults will not be evenly spread over the simulation. Some simulations will experience unusually many and some unusually few defaults for any default probability. The higher the correlation, the more such extreme simulation results there will be.

*Equity tranche.* The results for the equity tranche (Figure 8-2) are plotted as dollar values, with the cash flows discounted at our stipulated IRR of 25 percent. The most obvious feature of the histograms is that for low correlations, the simulated values form a bell

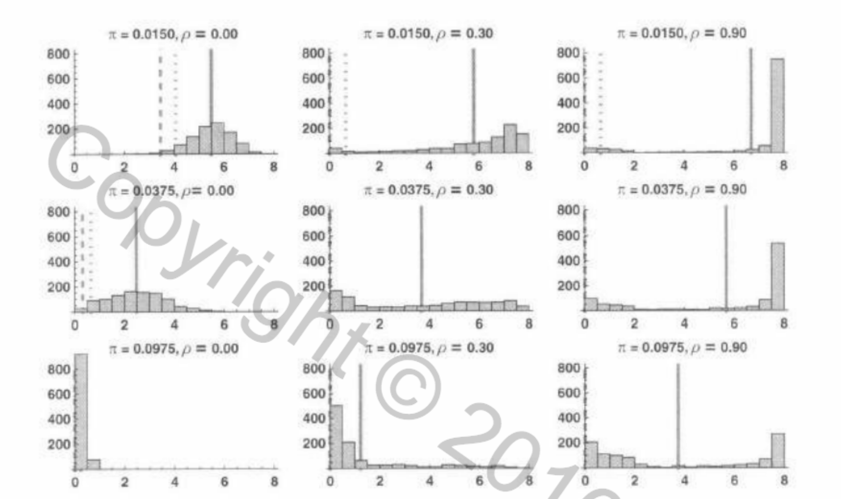


**FIGURE 8-2** Distribution of simulated equity tranche values.

Histograms of simulated values of equity tranche, in millions of $. Each histogram is labeled by its default probability and correlation assumption. Values are computed using a discounting rate of 25 percent. The solid grid line marks the mean value over the 1,000 simulations. The dashed and dotted grid lines mark the 0.01 and 0.05 quantile values.

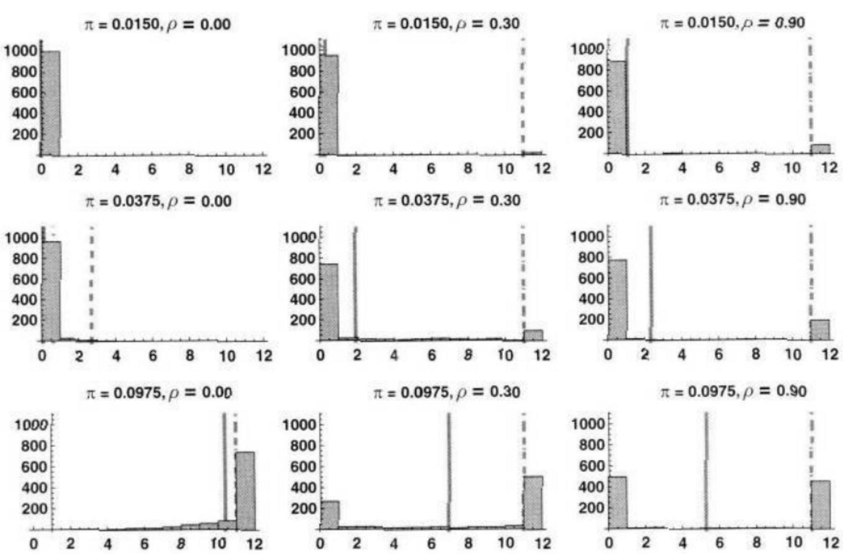


**FIGURE 8-3** Distribution of simulated mezzanine bond tranche losses.

Histograms of simulated losses of mezzanine bond, in millions of $. Each histogram is labeled by its default probability and correlation assumption. The solid grid line marks the mean loss over the 1,000 simulations. The dashed and dotted grid lines mark the 0.99 and 0.95 quantiles of the loss.

curve. The center of the bell curve is higher for lower default probabilities. For high enough default rates, the bell curve is squeezed up against the lower bound of zero value, as it is wiped out in most scenarios before it can receive much cash flow. In a low correlation environment, the equity note value is close to what you would expect based on the default probability. It is high for a low default rate and vice versa.

The surprising results are for high correlations. The distribution is U-shaped; extreme outcomes, good or bad, for the equity value are more likely than for low correlations. In a scenario with unusually many defaults, given the default probability, the equity is more likely to be wiped out, while in low-default scenarios, the equity will keep receiving cash flows for a surprisingly long time.

The equity note thus behaves like a lottery ticket in a high-correlation environment. If defaults are low, the high correlation induces a higher probability of a high-default state, reducing the equity note's value. If defaults are high, the high correlation induces a higher probability of a low-default state, raising the equity note's value.

If, in contrast, the correlation is low, some defaults will occur in almost every simulation thread. Since the equity tranche takes the first loss, this means that at least some equity losses are highly likely even in a relatively low-default environment. Therefore low correlation is bad for the equity. Correlation is more decisive for equity risk and value than default probability.

This behavior is related to the convexity of the mean equity values we see in Figure 8-1. At a low correlation, equity values have fewer extremes and are bunched closer to what you would expect based on the default probability,

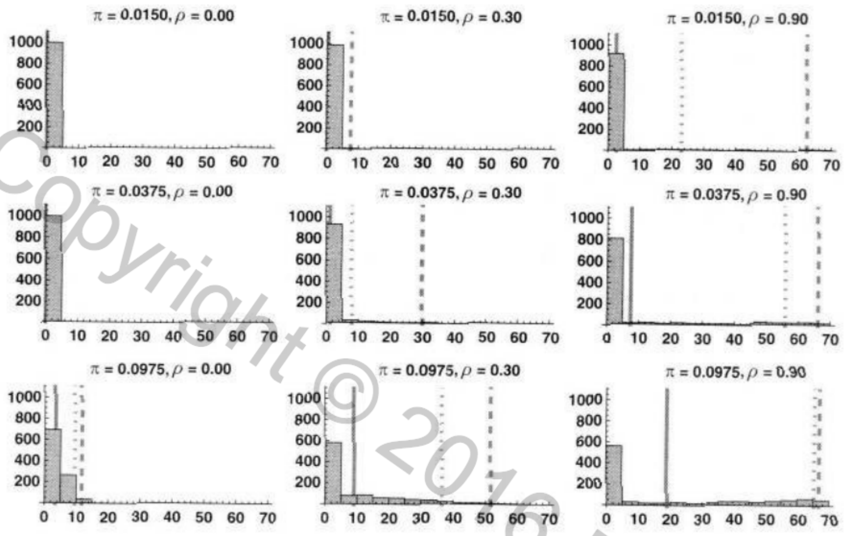


**FIGURE 8-4** Distribution of simulated senior bond tranche losses.

Histograms of simulated losses of senior bonds, in millions of \$. Each histogram is labeled by its default probability and correlation assumption. The solid grid line marks the mean loss over the 1,000 simulations. The dashed and dotted grid lines mark the 0.99 and 0.95 quantiles of the loss.

much like the results we obtained using default scenario analysis above. But there is only so much damage you can do to the equity tranche; as it gets closer to being wiped out, a higher default rate has less incremental impact.

*Bond tranches.* The bond tranche distributions (Figures 8-3 and 8-4) are plotted as dollar amounts of credit losses. They appear quite different from those of the equity; even for low correlations, they are not usually bell-curve-shaped. Rather, in contrast to the equity, the credit subordination concentrates the simulated losses close to zero, but with a long tail of loss scenarios. For the senior bond, this is particularly clear, as almost all simulation outcomes show a zero or small loss, unless both default probability and correlation are quite high.

But the distributions have one characteristic in common with the equity. The distribution of simulated loss tends towards a U shape for higher default probabilities and higher correlations. This tendency is much stronger for the mezzanine, which, as we have seen, behaves like the equity at high correlations and default probabilities.

For low correlations and high default probabilities, finally, we see an important contrast between the mezzanine and senior bonds. The mezzanine is a relatively thin tranche, so a small increase in default rates shifts the center of gravity of the distribution from par to a total loss. We can see this clearly by comparing the histograms for ($\pi = 0.0375$, $\rho = 0.00$) with that for ($\pi = 0.0975$, $\rho = 0.00$).

### *Credit VaR of the Tranches*

We can, finally, compute the Credit VaR. To do so, we need to sort the simulated values for each tranche by size. For the equity tranche, we measure the Credit VaR at a confidence level of 99 (or 95) percent as the difference between the 10th (or 50th) lowest sorted simulation value and the par value of \$5,000,000. The latter value, as noted, is close to the mean present value of the cash flows with $\pi = 2.25$ percent and $\rho = 0.30$. For the bonds, we measure the VaR as the difference between the expected loss and the 10th (or 50th) highest loss in the simulations.

The results at a 99 percent confidence level are displayed in Table 8-4. To make it easier to interpret the table, we have also marked with grid lines the 99th (dashed) and 95th (dotted) percentiles in Figures 8-2 through 8-4. The 99-percent Credit VaR can then be read graphically as the horizontal distance between the dashed and solid grid lines. To summarize the results:

*Equity tranche.* The equity VaR actually falls for higher default probabilities and correlations, because the expected loss is so high at those parameter levels. Although the mean values of the equity tranche increase with correlation, so also does its risk.

*Mezzanine bond.* The junior bond again shows risk characteristics similar to those of the equity at higher default rates and correlation and to those of the senior bond for lower ones.

The mezzanine, like the equity tranche, is thin. One consequence is that, particularly for higher ($\pi$, $\rho$) pairs, the Credit VaRs at the 95 and 99 percent

**TABLE 8-4** CLO Tranche Credit VaR at a 99 Percent Confidence Level

| Equity VaR ($ million) | | | | |
|---|---|---|---|---|
| $\pi$ | $\rho$ = 0.00 | $\rho$ = 0.30 | $\rho$ = 0.60 | $\rho$ = 0.90 |
| 0.0075 | 1.62 | 6.33 | 6.85 | 7.14 |
| 0.0225 | 2.53 | 4.98 | 5.61 | 6.33 |
| 0.0375 | 2.16 | 3.69 | 4.64 | 5.69 |
| 0.0525 | 0.95 | 2.75 | 3.90 | 5.08 |
| 0.0675 | 0.51 | 2.07 | 3.32 | 4.56 |
| 0.0825 | 0.33 | 1.57 | 2.84 | 4.13 |
| 0.0975 | 0.22 | 1.23 | 2.44 | 3.74 |
| **Mezzanine Bond VaR ($ million)** | | | | |
| $\pi$ | $\rho$ = 0.00 | $\rho$ = 0.30 | $\rho$ = 0.60 | $\rho$ = 0.90 |
| 0.0075 | 0.00 | 3.79 | 10.66 | 10.52 |
| 0.0225 | 0.00 | 10.26 | 9.72 | 9.45 |
| 0.0375 | 2.59 | 9.07 | 8.60 | 8.69 |
| 0.0525 | 7.09 | 7.61 | 7.63 | 7.87 |
| 0.0675 | 6.01 | 6.36 | 6.62 | 7.04 |
| 0.0825 | 2.43 | 5.14 | 5.85 | 6.36 |
| 0.0975 | 0.61 | 4.04 | 5.13 | 5.71 |
| **Senior Bond VaR ($ million)** | | | | |
| $\pi$ | $\rho$ = 0.00 | $\rho$ = 0.30 | $\rho$ = 0.60 | $\rho$ = 0.90 |
| 0.0075 | 0.00 | −0.04 | 11.23 | 48.30 |
| 0.0225 | 0.00 | 17.77 | 41.43 | 59.99 |
| 0.0375 | 0.00 | 28.82 | 49.76 | 58.61 |
| 0.0525 | 0.00 | 35.74 | 52.66 | 56.23 |
| 0.0675 | 2.85 | 39.89 | 52.75 | 53.57 |
| 0.0825 | 7.03 | 41.61 | 51.88 | 50.62 |
| 0.0975 | 8.33 | 42.60 | 50.25 | 47.79 |

confidence levels are very close together. This means that, conditional on the bond suffering a loss at all, the loss is likely to be very large relative to its par value.

*Senior bond.* We see once again that correlation is bad for the senior bond. At high correlations, the 99 percent Credit VaR of the senior bond is on the order of one-half the par value, while if defaults are uncorrelated, the bond is virtually risk-free even at high default probabilities.

For a correlation of 0.90, the risk of the senior bond at a 99 percent confidence level varies surprisingly little with default probability. The reason is that at a high correlation, clusters of defaults in a handful of simulations guarantee that at least 1 percent of the simulations will show extremely high losses.

Note that there is one entry, for the senior bond with $(\pi, \rho) = (0.0075, 0.30)$, for which the VaR is negative. This odd result is an artifact of the simulation procedure, and provides an illustration of the difficulties of simulation for a credit portfolio. For this assumption pair, almost all the simulation results value the senior bond at par, *including* the 10th ordered simulation result. There are, however, seven threads in which the senior bond has a loss. So the expected loss is in this odd case actually higher than the 0.01-quantile loss, and the VaR scenario is a gain.

The anomaly would disappear if we measured VaR at the 99.5 or 99.9 percent confidence level. However, the higher the confidence level, the more simulations we have to perform to be reasonably sure the results are not distorted by simulation error.

## Default Sensitivities of the Tranches

The analysis thus far has shown that the securitization tranches have very different sensitivities to default rates. Equity values always fall and bond losses always rise as default probabilities rise, but the response varies for different default correlations and as default rates change. This has important implications for risk management of tranche exposures. In this section, we examine these default sensitivities more closely.

To do so, we develop a measure of the responsiveness of equity value or bond loss to small changes in default probabilities. The "default01" measures the impact of an increase of 1 basis point in the default probability. It is analogous to the DV01 and the spread01 we studied in Chapter 6 and is calculated numerically in a similar way.

To compute the default01, we increase and decrease default probability 10bps and revalue each tranche at these new values of $\pi$. This requires repeating, twice, the entire valuation procedure from the point onward at which we generate simulated default times. We can reuse our correlated normal simulations $\tilde{\mathbf{z}}$. In fact, we should, in order to avoid a change of random seed and the attendant introduction of additional simulation noise. But we have to recompute $\tilde{\mathbf{t}}$, the list of vectors of default counts for each simulation, and all the subsequent cash flow analysis, valuation, and computation of losses. The default01 sensitivity of each tranche is then computed as

$$\frac{1}{20}[(\text{mean value/loss for } \pi + 0.0010) - (\text{mean value/loss for } \pi - 0.0010)]$$

We compute this default01 for each combination of $\pi$ and $\rho$. The results are displayed in Table 8-5 and Figure 8-5. Each default01 is expressed as a positive number and expresses the decline in value or increase in loss resulting from a 1-basis point rise in default probability.

For all tranches, in all cases, default01 is positive, as expected, regardless of the initial value of $\pi$ and $\rho$, since equity and bond values decrease monotonically as the default probability rises. The default01 sensitivity converges to zero for all the tranches for very high default rates (though we are not displaying high enough default probabilities to see this for the senior bond). Once losses are extremely high, the incremental impact of additional defaults is low.

The default01 varies most as a function of default probability when correlation is low. With $\rho = 0$, the default01 changes sharply in a certain range of default probabilities, and then tapers off as the tranche losses become very large. The differences in the patterns for the different tranches are related to the locations of their attachment points. For each tranche, the range of greatest sensitivity to an increase in defaults, that is, the largest-magnitude default01, begins at a default rate that brings losses in the collateral pool near that tranche's attachment point. Thus the peak default01 is at a default probability of zero for the equity tranche, and occurs at a lower default rate for the mezzanine than for the senior tranche because it has a lower attachment point. This introduces additional risk when structured credit exposures are put on in a low-correlation environment, or correlation is underestimated. Underestimation of default correlation in structured credit products was an important factor in the origins of the subprime crisis.

**TABLE 8-5** CLO Tranche Default Sensitivities

| Equity Loss ($ million per bp) | | | | |
|---|---|---|---|---|
| $\pi$ | $\rho = 0.00$ | $\rho = 0.30$ | $\rho = 0.60$ | $\rho = 0.90$ |
| 0.0075 | 0.0144 | 0.0129 | 0.0094 | 0.0069 |
| 0.0225 | 0.0140 | 0.0104 | 0.0076 | 0.0046 |
| 0.0375 | 0.0116 | 0.0076 | 0.0056 | 0.0039 |
| 0.0525 | 0.0065 | 0.0052 | 0.0038 | 0.0035 |
| 0.0675 | 0.0021 | 0.0039 | 0.0036 | 0.0030 |
| 0.0825 | 0.0009 | 0.0026 | 0.0032 | 0.0030 |
| 0.0975 | 0.0006 | 0.0021 | 0.0025 | 0.0024 |
| **Mezzanine Bond Loss (percent of par per bp)** | | | | |
| $\pi$ | $\rho = 0.00$ | $\rho = 0.30$ | $\rho = 0.60$ | $\rho = 0.90$ |
| 0.0075 | 0.0000 | 0.0231 | 0.0572 | 0.0843 |
| 0.0225 | 0.0000 | 0.0655 | 0.0658 | 0.0687 |
| 0.0375 | 0.0317 | 0.0924 | 0.0659 | 0.0436 |
| 0.0525 | 0.1660 | 0.0863 | 0.0658 | 0.0595 |
| 0.0675 | 0.2593 | 0.0753 | 0.0605 | 0.0498 |
| 0.0825 | 0.1939 | 0.0778 | 0.0478 | 0.0465 |
| 0.0975 | 0.0723 | 0.0664 | 0.0458 | 0.0403 |
| **Senior Bond Loss (percent of par per bp)** | | | | |
| $\pi$ | $\rho = 0.00$ | $\rho = 0.30$ | $\rho = 0.60$ | $\rho = 0.90$ |
| 0.0075 | 0.0000 | 0.0018 | 0.0084 | 0.0190 |
| 0.0225 | 0.0000 | 0.0041 | 0.0140 | 0.0255 |
| 0.0375 | 0.0000 | 0.0081 | 0.0152 | 0.0229 |
| 0.0525 | 0.0000 | 0.0127 | 0.0170 | 0.0226 |
| 0.0675 | 0.0027 | 0.0159 | 0.0194 | 0.0228 |
| 0.0825 | 0.0117 | 0.0176 | 0.0220 | 0.0228 |
| 0.0975 | 0.0243 | 0.0198 | 0.0217 | 0.0220 |

Note that some of the default01 plots are not smooth curves, providing us with two related insights. The first is about the difficulty or "expense" of estimating the value and risk of credit portfolios using simulation methods. The number of defaults at each $t$ in each simulation thread

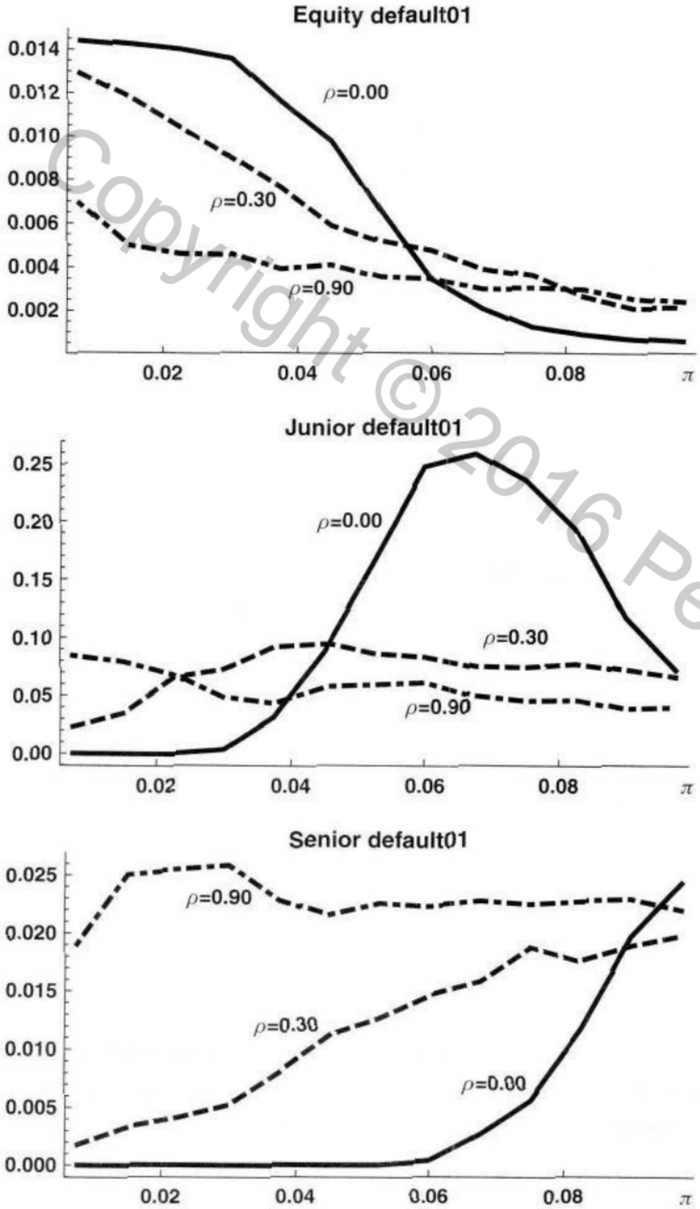


**FIGURE 8-5** Default sensitivities of CLO tranches.

Default01 as a function of default probability for different constant pairwise correlations. Equity in $ million per bp, bonds in percent of par per bp.

must be an integer. Even with 100 loans in the collateral pool, the distribution of value is so skewed and fat-tailed that simulation noise amounting to one or two defaults can make a material difference in the average of the simulation results. The curves could be smoothed out further by substantially increasing the number of simulations used in the estimation procedure. This would be costly in computing time and storage of interim results.

We have enough simulations that the fair value plots are reasonably smooth, but not so all the default01 plots. The lumpiness shows up particularly in the plots of the senior bond default01 plots and those for higher correlations for all tranches. The reason is intuitive. At higher correlations, the defaults tend to come in clusters, amplifying the lumpiness. A chance variation in the number of default clusters in a few simulation threads can materially change the average over all the threads.

The second insight is that because of the fat-tailed distribution of losses, it is difficult to diversify a credit portfolio and reduce idiosyncratic risk. Even in a portfolio of 100 credits, defaults remain "lumpy" events.

## Summary of Tranche Risks

We've now examined the risk of the securitization liabilities in several different ways: mean values, the distribution of values and Credit VaR, and the sensitivities of the values to changes in default behavior, all measured for varying default probabilities and correlations. As in the scenario analysis of the previous section, we've focused on the securitization's liability structure and waterfall, and less on the equally crucial credit analysis of the underlying loans.

On the basis of the example, we can make a few generalizations about structured credit product risk.

*Systematic risk.* Structured credit products can have a great deal of systematic risk, even when the collateral pools are well-diversified. In our example, the systematic risk shows up in the equity values and bond losses when default correlation is high. High default correlation is one way of expressing high systematic risk, since it means that there is a low but material probability of a state of the world in which an unusually large number of defaults occurs.

Most notably, even if the collateral is well-diversified, the senior bond has a risk of loss, and potentially a large loss, if correlation is high. While its expected loss may be lower than that of the underlying loan pool, the tail of the loss and the Credit VaR are high, as seen in the rightmost column of plots in Figure 8-4. In other words, they are very exposed to systematic risk. The degree of exposure depends heavily on the credit quality of the underlying collateral and the credit enhancement.

*Tranche thinness.* Another way in which the senior bond's exposure to systematic risk is revealed is in the declining difference between the senior bond's Credit VaRs at the 99 and 95 percent confidence levels as default probabilities rise for high default correlations. For the mezzanine bond, the difference between Credit VaR at the 99 and 95 percent confidence levels is small for most values of $\pi$ and $\rho$, as seen in Figure 8-3. The reason is that tranche is relatively thin. The consequence of tranche thinness is that, conditional on the tranche suffering a loss at all, the size of the loss is likely to be large.

*Granularity* can significantly diminish securitization risks. In Chapter 7, we saw that a portfolio of large loans has greater risk than a portfolio with equal par value of smaller loans, each of which has the same default probability, recovery rate, and default correlation to other loans. Similarly, "lumpy" pools of collateral have greater risk of extreme outliers than granular ones. A securitization with a more granular collateral pool can have a somewhat larger senior tranche with no increase in Credit VaR. A good example of securitizations that are not typically granular are the many CMBS deals in which the pool consists of relative few mortgage loans on large properties, or so-called *fusion* deals in which a fairly granular pool of smaller loans is combined with a few large loans. When the asset pool is not granular, and/or correlation is high, the securitization is said to have high *concentration risk.*

## STANDARD TRANCHES AND IMPLIED CREDIT CORRELATION

Structured credit products are claims on cash flows of credit portfolios. Their prices therefore contain information about how the market values certain characteristics of those portfolios, among them default correlation. In the previous section, we have seen how to use an estimate of the default correlation to estimate model values or securitization tranches. Next, we see how we can reverse engineer the modeling process, applying the model to observed market prices of structured credit products to estimate a default correlation. The correlation obtained in this way is called an *implied credit* or *implied default correlation.* It is a risk-neutral parameter that we can estimate whenever we observe prices of portfolio credit products.

### Credit Index Default Swaps and Standard Tranches

We begin by introducing an important class of securitized credit products that trades in relatively liquid markets. In Chapter 6, we studied CDS, the basic credit derivative, and earlier in this chapter we noted that CDS are often building blocks in synthetic structured products. *Credit index default swaps* or CDS indexes are a variant of CDS in which the underlying security is a portfolio of CDS on individual companies, rather than a single company's debt obligations. Two groups of CDS indexes are particularly frequently traded:

*CDX* (or CDX.NA) are index CDS on North American companies.

*iTraxx* are index CDS on European and Asian companies.

Both groups are managed by Markit, a company specializing in credit-derivatives pricing and administration. There are, in addition, customized credit index default swaps on sets of companies chosen by a client or financial intermediary.

CDX and iTraxx come in series, initiated semiannually, and indexed by a series number. For example, series CDX.NA.IG.10 was introduced in March 2008. Each series has a number of index products, which can be classified by

*Maturity.* The standard maturities, as with single-name CDS, are 1, 3, 5, 7, and 10 years. The maturity dates are fixed calendar dates.

*Credit quality.* In addition to the investment grade CDX.NA.IG, there is a high-yield group (CDX.NA.HY), and subsets of IG and HY that focus on narrower ranges of credit quality.

We'll focus on investment grade CDX (CDX.NA.IG); the iTraxx are analogous. Each IG series has an underlying basket consisting of equal notional amounts of CDS on 125 investment-grade companies. Thus a notional amount $125,000,000 of the CDX contains $1,000,000 notional of CDS on each of the 125 names. The list of 125 names changes from series to series as firms lose or obtain investment-grade ratings, and merge with or spin off from other firms.

Cash flows and defaults are treated similarly to those of a single-name CDS credit event. Given the CDS spread premiums on the individual names in the index, there is a fair market CDS spread premium on the CDX. One difference from single-name CDS is that the spread premium is fixed on the initiation date, so subsequent trading is CDX of a particular series generally involves the exchange of net present value. The buyer of CDX protection pays the fixed spread premium to the seller. If credit spreads have widened since the initiation date, the buyer of protection on CDX will pay an amount to the seller of protection.

In the event of default of a constituent of the CDX, the company is removed from the index. In general, there is cash settlement, with an auction to determine the value of recovery on the defaulting company's debt. The dollar amount of spread premium and the notional amount of the CDX contract are reduced by 0.8 percent (since there are 125 equally weighted constituents), and the CDX protection seller pays 0.8 percent of the notional, minus the recovery amount, to the protection buyer.

The constituents of a CDX series can be used as the reference portfolio of a synthetic CDO. The resulting CDO is then economically similar to a cash CLO or CDO with a collateral pool consisting of equal par amounts of bonds issued by the 125 firms in the index. There is a standard capital structure for such synthetic CDOs based on CDX:

| Assets | Liabilities |
|---|---|
| \$1 million notional long protection on each constituent of CDX.NA.IG, total \$125 million notional | Equity 0–3%<br>Junior mezzanine 3–7%<br>Senior mezzanine 7–10%<br>Senior 10–15%<br>Super senior 15–30% |

The liabilities in this structure are called the *standard tranches.* They are fairly liquid and widely traded, in contrast to *bespoke tranches*, generally issued "to order" for a client that wishes to hedge or take on exposures to a specific set of credits, with a specific maturity, and at a specific point in the capital structure. Similar products exist for the iTraxx, with a somewhat different tranching. The fair market value or spread of each tranche is tied to those of the constituent CDS by arbitrage.

The equity tranche, which is exposed to the first loss, is completely wiped out when the loss reaches 3 percent of the notional value. The weight of each constituent is the same, and if we assume default recovery is the same 40 percent for each constituent, then 9 or 10 defaults will suffice: 9 defaults will leave just a small sliver of the equity tranche, and 10 defaults will entirely wipe it out and begin to eat into the junior mezzanine tranche.

## Implied Correlation

The values, sensitivities, and other risk characteristics of a standard tranche can be computed using the copula techniques described in this and Chapter 6, but with one important difference. In the previous section, the key inputs to the valuation were estimates of default probabilities and default correlation. But the constituents of the collateral pools of the standard tranches are the 125 single-name CDS in the IG index, relatively liquid products whose spreads can be observed daily, or even at higher frequency. Rather than using the default probabilities of the underlying firms to value the constituents of the IG index, as in our CLO example in this chapter, we use their market CDS spreads, as in Chapter 6, to obtain risk-neutral default probabilities. In many cases, there is not only an observation of the most liquid five-year CDS, but of spreads on other CDS along the term structure. There may also be a risk-neutral estimate of the recovery rate from recovery swaps. CDS indexes and their standard tranches are therefore typically valued, and their risks analyzed, using risk-neutral estimates of default probabilities.

The remaining key input into the valuation, using the copula technique of this and the last chapter, is the constant pairwise correlation. While the copula correlation is not observable, it can be inferred from the market values of the tranches themselves, once the risk-neutral probabilities implied by the single-name CDS are accounted for. Not only the underlying CDS, but the tranches themselves, are relatively liquid products for which daily market prices can be observed. Given these market prices, and the risk-neutral default curves, a risk-neutral *implied correlation* can be computed for each tranche. Typically, the correlation computed in this fashion is called a *base correlation*, since it is associated with the attachment point of a specific tranche. Correlations generally vary by tranche, a phenomenon called *correlation skew.*

Since the implied correlation is computed using risk-neutral parameter inputs, the calculation uses risk-free rates rather than the fair market discount rates of the tranches. To compute the equity base correlation, we require the market equity tranche price (or compute it from the points up-front and running spread), and the spreads of the constituent CDS. Next, we compute the risk-neutral default probabilities of each of the underlying 125 CDS. Given these default probabilities, and a copula correlation, we can simulate the cash flows to the equity tranche. There will be one unique correlation for which the present value of the cash flows matches the market price of the equity tranche. That unique value is the implied correlation.

The CLO example of the previous section can be used to illustrate these computations. Suppose the observed market price of the equity is $5 million, and that we obtain a CDS-based risk-neutral default probability of the underlying loans equal to 2 percent. In the top panel of Table 8-3, we can see that a constant pairwise correlation of 0.3 "matches" the equity price to the default probability. If we were to observe the equity price rising to $5.6 million, with no change in the risk-neutral default probability, we would conclude that the implied correlation had risen to 0.6, reflecting an increase in the market's assessment of the systematic risk of the underlying loans.

Implied credit correlation is as much a market-risk as a credit-risk concept. The value of each tranche has a distinct risk-neutral partial spread01, rather than a default01, that is, sensitivities to each of the constituents of the IG 125. The spread01 measures a market, rather than a credit risk, though it will be influenced by changing market assessments of each firm's creditworthiness. Each of these sensitivities is a function, *inter alia*, of the implied correlation. Conversely, the implied correlation varies in its own right, as well as with the constituent and index credit spreads. For the cash CLO example in this chapter, changes in default rates and correlation result in changes in expected cash flows and credit losses to the CLO tranches, that is, changes in fundamental value. For the standard tranches, changes in risk-neutral probabilities and correlations bring about mark-to-market changes in tranche values.

## Summary of Default Correlation Concepts

In discussing credit risk, we have used the term "correlation" in several different ways. This is a potential source of confusion, so let's review and summarize these correlation concepts:

*Default correlation* is the correlation concept most directly related to portfolio credit risk. We formally defined the default correlation of two firms over a given future time period as the correlation coefficient of the two random variables describing the firms' default behavior over a given time period.

*Asset return correlation* is the correlation of logarithmic changes in two firms' asset values. In practice, portfolio credit risk measurement of corporate obligations often relies on asset return correlations. Although this is in a sense the "wrong" correlation concept, since it isn't default correlation, it can be appropriate in the right type of model. For example, in a Merton-type credit risk model, the occurrence of default is a function of the firm's asset value. The asset return correlation in a factor model is driven by each firm's factor loading.

*Equity return correlation* is the correlation of logarithmic changes in the market value of two firms' equity prices. The asset correlation is not directly unobservable, so in practice, asset correlations are often proxied by equity correlations.

*Copula correlations* are the values entered into the off-diagonal cells of the correlation matrix of the distribution used in the copula approach to measuring credit portfolio risk. Unlike the other correlation concepts, the copula correlations have no direct economic interpretation. They depend on which family of statistical distributions is used in the copula-based risk estimate. However, the correlation of a Gaussian copula is identical to the correlation of a Gaussian single-factor factor models.

The normal copula has become something of a standard in credit risk. The values of certain types of securities, such as the standard CDS index equity tranches, as we just noted, depend as heavily on default correlation as on the levels of the spreads in the index. The values of these securities can therefore be expressed in terms of the implied correlation.

*Spread correlation* is the correlation of changes, generally in basis points, in the spreads on two firms' comparable debt obligations. It is a mark-to-market rather than credit risk concept.

*Implied credit correlation* is an estimate of the copula correlation derived from market prices. It is not a distinct "theoretical" concept from the copula correlation, but is arrived at differently. Rather than estimating or guessing at it, we infer it from market prices. Like spread correlation, it is a market, rather than credit risk concept.

## ISSUER AND INVESTOR MOTIVATIONS FOR STRUCTURED CREDIT

To better understand why securitizations are created, we need to identify the incentives of the loan originators, who sell the underlying loans into the trust in order create a securitization, and of the investors, who buy the equity and bonds. These motivations are also key to understanding the regulatory issues raised by securitization and the role it played in the subprime crisis.

### Incentives of Issuers

An important motive for securitization is that it provides a technology for maturity matching, that is, for providing term funding for the underlying loans. There are two aspects to this motive: first, whether lower cost of funding can be achieved via securitization, and, second, whether, in the absence of securitization, the loan originator would have to sell the loans into the secondary market or would be able to retain them on his balance sheet. The securitization "exit" is attractive for lenders only if the cost of funding via securitization is lower than the next-best alternative. If the loans are retained, the loan originator may be able to fund the loans via unsecured borrowing. But doing so is generally costlier than secured borrowing via securitization.

Securitizations undertaken primarily to capture the spread between the underlying loan interest and the coupon rates of the liabilities are sometimes called *arbitrage CDOs*, while securitizations motivated largely for balance sheet relief are termed *balance sheet CDOs.* However, while the motivations are conceptually distinct, it is hard to distinguish securitizations this way.

Among the factors that tend to lower the spreads on securitization liabilities are loan pool diversification and an originator's reputation for high underwriting standards. Originators that have issued securitization deals with less-than-stellar performance may be obliged by the market to pay higher spreads on future deals. Issuer spread differentials are quite persistent. These factors also enable the issuer to lower the credit enhancement levels of the senior bonds that have the narrowest spreads, increasing the proceeds the issuer can borrow through securitization and decreasing the weighted-average financing cost.

Idiosyncratic credit risk can be hard to expunge entirely from credit portfolios, limiting the funding advantage securitization can achieve for some lending sectors. This limitation is important for sectors such as credit card and auto loans, where a high degree of granularity in loan pools can be achieved. As noted, commercial mortgage pools are particularly hard to diversify. Residential mortgage pools can be quite granular, but both commercial and residential mortgage loans have a degree of systematic risk that many market participants and regulators vastly underestimated prior to the subprime crisis.

The interest rates on the underlying loans, the default rate, the potential credit subordination level, and the spreads on the bonds interact to determine if securitization is economically superior to the alternatives. If, as is often the case, the issuer retains the servicing rights for the loans, and enjoys significant economies of scale in servicing, securitization permits him to increase servicing profits, raising the threshold interest rates on the liabilities at which securitization becomes attractive.

Looking now at the originator's alternative of selling the loans after origination, secondary trading markets exist for large corporate and commercial real estate loans, in which purchasers take an ongoing monitoring role. It is more difficult to sell most consumer loans to another financial intermediary. One of the impediments to secondary-market loan sales is the twin problem of monitoring and asymmetric information. The credit quality of loans is hard to assess and monitor over the life of the loan. The mere fact that the originator is selling a loan may indicate he possesses information suggesting the loan is of poorer quality than indicated by the securitization disclosures—the "lemons" problem. The originator's superior information on the loan and the borrower often puts him in the best position to monitor the loan and take mitigating action if the borrower has trouble making payments.

These problems can be mitigated if equity or other subordinated tranches, or parts of the underlying loans themselves, are either retained by the loan originator or by a firm with the capability to monitor the underlying collateral. Their first-loss position then provides an incentive to exercise care in asset selection, monitoring and pool management that protects the interests of senior tranches as well. *Risk retention* has been viewed as a panacea for the conflicts of interest inherent in securitization and has been enshrined in the Dodd-Frank regulatory changes. Rules embodying the legislation have not yet been promulgated but will likely bar issuers of most securitizations from selling all tranches in their entirety. Other mitigants include legal representations by the loan seller regarding the underwriting standards and quality of the loans.

The loan purchaser has legal rights against the seller if these representations are violated, for example, by applying lower underwriting standards than represented. In the wake of the subprime crisis, a number of legal actions have been brought by purchasers of loans as well as structured credit investors on these grounds. These mitigants suggest the difficulty of economically separating originators from loans, that is, of achieving genuine *credit risk transfer*, regardless of how legally robust is the sale of the loans into the securitization trust. The ambiguities of credit risk transfer also arise in credit derivatives transactions and in the creation of off-balance sheet vehicles by intermediaries, and contribute to financial instability by making it harder for market participants to discern issuers' asset volume and leverage.

## Incentives of Investors

To understand why securitizations take place, we also need to understand the incentives of investors. Securitization enables capital markets investors to participate in diversified loan pools in sectors that would otherwise be the province of banks alone, such as mortgages, credit card, and auto loans.

Tranching technology provides additional means of risk sharing over and above diversification. Investors, not issuers, motivate credit tranching beyond the issuers' retained interests. Issuers' needs are met by pooling and securitization—they don't require the tranching. Tranching enables investors to obtain return distributions better-tailored to their desired risk profile. A pass-through security provides only the benefit of diversification.

Introducing tranching and structure can reduce default risk for higher tranches, though at the price of potentially greater exposure to systematic risk. Thinner subordinate tranches draw investors desiring higher risk and returns. Some securitization tranches provide *embedded leverage.* Thicker senior tranches draw investors seeking lower-risk bonds in most states of the economy, but potentially severe losses in extremely bad states, and willing to take that type of risk in exchange for additional yield.

However, these features are useful to investors only if they carry out the due diligence needed to understand the return distribution accurately. Some institutional investors, particularly pension funds, have high demand for high-quality fixed-income securities that pay even a modest premium over risk-free or high-grade corporate bonds. This phenomenon, often called "searching" or "reaching for yield," arises because institutional investors deploy large sums of capital, while being required to reach particular return targets. Securitization is founded to a large extent on institutional demand for senior bonds. In the presence of regulatory safe harbors and imperfect governance mechanisms, this can lead to inadequate due diligence of the systematic risks of securitized credit products.

Mezzanine tranches, as we have seen, are an odd duck. Depending on the default probability, correlation, and tranche size, they may behave much like a senior tranche. That is, they have a low probability of loss, but high systematic risk; expected loss in the event of impairment is high, and impairment is likeliest in an adverse scenario for the economy as a whole. They may, in a different structure and environment, behave more like an equity tranche, with a high probability of impairment, but a respectable probability of a low. A mezzanine tranche may also switch from one behavior to another. In consequence, mezzanine tranches have less of a natural investor base than other securitized credit products. One result was that many mezzanine tranches were sold into CDOs, the senior tranches of which could be sold to yield-seeking investors uncritically buying structured products on the basis of yield and rating.

Fees also provide incentives to loan originators and issuers to create securitizations. A financial intermediary may earn a higher return from originating and, possibly, servicing loans than from retaining them and earning the loan interest. Securitization then provides a way for the intermediary to remove the loans from its balance sheet after origination. This motivation is related to *regulatory arbitrage*. For example, an intermediary may be able to retain some of the risk exposure and return from a loan pool while drastically reducing the regulatory capital required through securitization.

Off-balance sheet vehicles, and thus, ultimately, money market mutual funds, were also important investors in securitizations.

## Further Reading

Rutledge and Raynes (2010) is a quirky, but comprehensive, overview of structured finance, with particularly useful material on legal and structure issues. Textbook introductions to structured credit products include the somewhat untimely-titled Kothari (2006) and (2009), and Mounfield (2009). Meissner (2008) is a useful collection of articles on structured credit. Many of the references following Chapters 6 and 7 are also useful here.

Gibson (2004) provides a similar analysis to that this chapter of a structured credit product, but focusing on synthetic CDOs and carrying out the analysis using the single-factor model. Duffle and Gârleanu (2001) is an introduction to structured product valuation. Schwarcz (1994) is an introduction from a legal standpoint, which is important in all matters pertaining to credit and particularly so where securitization is concerned.

Gibson (2004) and Coval, Jurek, and Stafford (2009) discuss the embedded leverage in structured products and the motivations of investors. Zimmerman (2007), Ashcraft and Schuermann (2008) and Gorton (2008) provide thorough discussions of the securitization markets for subprime residential mortgages. Ashcraft and Schuermann (2008) also provide a detailed accounting of the information cost, monitoring, and other conflict-of-interest issues arising at different stages of the securitization. The discussion is useful both for the risk analysis of securitizations and as an illustration of the role of information cost issues in credit transactions generally. Benmelech and Dlugosz (2009) describes the ratings process for a class of structured products,

Li (2000) was an early application of copula theory to structured credit modeling. Tranche sensitivities are explained in Schloegl and Greenberg (2003).

Belsham, Vause, and Wells (2005); and Amato and Gyntelberg (2005) are introductions to credit correlation concepts. O'Kane and Livesey (2004), Kakodkar, Martin, and Galiani (2003), and Kakodkar, Galiani, and Shchetkovskiy (2004) are introductions by trading desk strategists to structured credit correlations. Amato and Remolona (2005) discusses the difficulty, compared with equities, of reducing idiosyncratic risk in credit portfolios and applies this finding to the risk of structured credit.

# Defining Counterparty Credit Risk

# 9

## Learning Objectives

After completing this reading you should be able to:

- Describe counterparty risk and differentiate it from lending risk.
- Describe transactions that carry counterparty risk and explain how counterparty risk can arise in each transaction.
- Identify and describe institutions that take on significant counterparty risk.
- Describe credit exposure, credit migration, recovery, mark-to-market, replacement cost, default probability, loss given default, and the recovery rate.
- Identify and describe the different ways institutions can manage and mitigate counterparty risk.

*Excerpt is Chapter 3 of* Counterparty Credit Risk and Credit Value Adjustment, *Second Edition, by Jon Gregory.*

An expert is a person who has made all the mistakes that can be made in a very narrow field.

—Niels Bohr (1885–1962)

# INTRODUCING COUNTERPARTY CREDIT RISK

. . . probably the single most important variable in determining whether and with what speed financial disturbances become financial shocks, with potential systemic traits

—Counterparty Risk Management Policy Group (2005)

Counterparty credit risk (often known just as counterparty risk) is the risk that the entity with whom one has entered into a financial contract (the counterparty to the contract) will fail to fulfil their side of the contractual agreement (e.g., they default). Counterparty risk is typically defined as arising from two broad classes of financial products:

- OTC (over-the-counter) derivatives, some well-known examples being
  - interest rate swaps,
  - FX forwards, and
  - credit default swaps.
- Securities financing transactions, for example
  - repos and reverse repos,
  - securities borrowing and lending.

The former category is the more significant due to the size and diversity of the OTC derivatives market and the fact that a significant amount of risk is not collateralised.

Mitigating counterparty risk creates other financial risks. A complete understanding of counterparty risk requires knowledge of all financial risks, such as market, credit, operational and liquidity. Furthermore, the interaction of different financial risks is critical in defining the nature of counterparty risk. As has been shown in the market events of the last few years, counterparty risk is complex, with systemic traits and the potential to cause, catalyse or magnify serious disturbances in the financial markets. Hence, the need to understand, quantify and manage counterparty risk is crucial. Without this, the future health, development and growth of derivatives products and financial markets in general will be hindered.

## Counterparty Risk versus Lending Risk

Traditionally, credit risk can generally be thought of as lending risk. One party owes an amount to another party and may fail to pay some or all of this due to insolvency. This can apply to loans, bonds, mortgages, credit cards and so on. Lending risk is characterised by two key aspects:

- The notional amount at risk at any time during the lending period is usually known with a degree of certainty. Market variables such as interest rates will typically create only moderate uncertainty over the amount owed. For example, in buying a fixed-coupon bond with a par value of $1,000, the notional amount at risk for the life of the bond is close to $1,000. A repayment mortgage will amortise over time (the notional drops due to the repayments) but one can predict with good accuracy the outstanding balance at some future date. A loan or credit card may have a certain maximum usage facility, which may reasonably be assumed fully drawn[1] for the purpose of credit risk.
- Only one party takes lending risk. A bondholder takes considerable credit risk but an issuer of a bond does not face a loss if the buyer of the bond defaults.[2] This point does not follow for other contracts.

With counterparty risk, as with all credit risk, the cause of a loss is the obligor being unable or unwilling to meet contractual obligations. However, two aspects may differentiate contracts with counterparty risk from traditional credit risk:

- The value of the contract in the future is uncertain, in most cases significantly so. The value of a derivative at a potential default date will be the net value of all future cash flows required under that contract. This future value can be positive or negative and is typically highly uncertain (as seen from today).
- Since the value of the contract can be positive or negative, counterparty risk is typically *bilateral*. In other words, in a derivatives transaction, each counterparty has risk to the other.

[1] On the basis that an individual unable to pay their credit card bill is likely to be close to their limit.

[2] This is not precisely true in the case of bilateral counterparty risk (DVA), although we will show that conventions regarding closeout amounts can correct for this.

The primary distinguishing feature of counterparty risk compared with other forms of credit risk is that the value of the underlying contract in the future is uncertain, both in magnitude and in sign!

## Settlement and Pre-Settlement Risk

A derivatives portfolio contains a number of settlements equal to multiples of the total number of trades (for example, a swap contract will have a number of settlement dates as cash flows are exchanged periodically). Counterparty risk is mainly associated with pre-settlement risk, which is the risk of default of the counterparty prior to expiration (settlement) of the contract. However, we should also consider settlement risk, which is the risk of counterparty default *during* the settlement process.

- *Pre-settlement risk.* This is the risk that a counterparty will default prior to the final settlement of the transaction (at expiration). This is what counterparty risk usually refers to.
- *Settlement risk.* This arises at final settlement if there are timing differences between when each party performs on its obligations under the contract.

The difference between pre-settlement and settlement risk is illustrated in Figure 9-1.

Whilst settlement risk gives rise to much larger exposures, default prior to expiration of the contract is substantially more likely than default at the settlement date. However, settlement risk can be more complex when there is a substantial delivery period (for example, as in a commodity contract where one may be required to settle in cash against receiving a physical commodity over a specified time period).

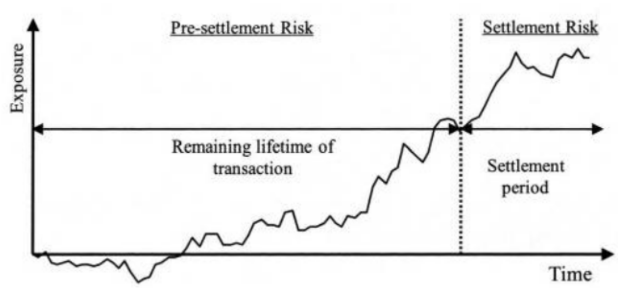


**FIGURE 9-1** Illustration of pre-settlement and settlement risk. Note that the settlement period is normally short (e.g., hours) but can be much longer in some cases.

Whilst all derivatives technically have both settlement and pre-settlement risk, the balance between the two will be different depending on the contract. Spot contracts have mainly settlement risk whilst long-dated swaps have mainly pre-settlement risk. Furthermore, various types of netting (see next chapter) provide mitigation against settlement and pre-settlement risks.

Unlike counterparty risk, settlement risk is characterised by a very large exposure, potentially 100% of the notional of the trade. Settlement risk is a major consideration in FX markets, where the settlement of a contract involves a payment of one currency against receiving the other. Most FX now goes through CLS[3] and most securities settle DVP,[4] but there are always exceptions and settlement risk should be recognised in such cases. Cash flows in a cross-currency swap may not go through CLS, so this may give rise to settlement risk. Settlement risk may also arise on securities financing transactions if the exchange of securities and cash is not DVP.

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**Example**

Suppose an institution enters into a forward foreign exchange contract to exchange €1m for $1.4m at a specified date in the future. The settlement risk exposes the institution to a substantial loss of $1.4m. which could arise if €1m was paid but the $1.4m was not received. Pre-settlement risk exposes the institution to just the difference in market value between the dollar and euro payments. If the foreign exchange rate moved from 1.4 to 1.45 then this would translate into a loss of $50,000. This type of cross-currency settlement risk is sometimes called Herstatt risk (see box on following page).

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Settlement risk typically occurs for only a small amount of time (often just days or even hours). To measure the period of risk to a high degree of accuracy would mean taking into account the contractual payment dates, the time zones involved, and the time it takes for the bank to

[3] The largest multi-currency cash settlement system; see http://www.cls-group.com.

[4] Delivery versus payment where payment is made at the moment of delivery, aiming to minimise settlement risk in securities transactions.

## Bankhaus Herstatt

The most well-known example of settlement risk is shown by the failure of a small German bank, Bankhaus Herstatt. On 26th June 1974, the firm defaulted but only after the close of the German interbank payments system (3:30pm local time). Some of Bankhaus Herstatt's counterparties had paid Deutschemarks to the bank during the day believing they would receive US dollars later the same day in New York. However, it was only 10:30am in New York when Herstatt's banking business was terminated and consequently all outgoing US dollar payments from Herstatt's account were suspended, leaving counterparties fully exposed.



perform its reconciliations across Nostro[5] accounts. Any failed trades should also continue to count against settlement exposure until the trade actually settles.

There are clearly circumstances where banks need to measure settlement risk, but it is important to avoid double counting this with pre-settlement or counterparty risk. Institutions typically set separate settlement risk limits and measure exposure against this limit rather than including settlement risk in the assessment of counterparty risk. It may be possible to mitigate settlement risk, for example, by insisting on receiving cash before transferring securities.

We also note that one of the recent initiatives to mitigate counterparty risk and some of its side-effects such as liquidity risk, the SCSA, does this at the cost of introducing more settlement risk.

## Exchange-Traded Derivatives

Some derivatives are exchange-traded where the exchange is a central financial centre where parties can trade standardised contracts such as futures and options at a specified price. Exchanges have been used to trade financial products for many years. An exchange promotes market efficiency and enhances liquidity by centralising trading in a single place. The process by which a financial contract becomes exchange-traded can be thought of as a long journey where a reasonable trading volume, standardisation, and liquidity must first develop.

Whilst an exchange provides efficient price discovery,[6] it also typically provides a means of mitigating counterparty risk. An exchange will also "clear" trades or have a central counterparty attached to it that will provide this clearing service. The clearing function guarantees the contract performance and eliminates counterparty risk. Indeed, when trading a typical exchange-traded derivative, the actual counterparty to the contract is the exchange. Derivatives traded on an exchange are therefore normally considered to have no counterparty risk since the only aspect of concern is the solvency of the exchange itself. However, this point requires much further analysis.

## OTC-Traded Derivatives

Due to the need for customisation, a much greater notional amount of derivatives are traded OTC (over the counter). OTC derivatives are typically traded bilaterally and each party takes counterparty risk to the other. The market for OTC derivatives has grown dramatically in the last decade and is significantly larger than the exchange-traded market, as illustrated in Figure 9-2. The strong growth of OTC derivatives against exchange-traded derivatives is partly due to exotic contracts and new markets such as credit derivatives (the credit default swap market increased by a factor of 10 between the end of 2003 and the end of 2008). However, the more important factor influencing the popularity of OTC products is the ability to tailor contracts more precisely to client needs, for example, by offering a particular maturity date. Exchange-traded products, by their very nature, do not offer customisation.

The total notional amount of all derivatives outstanding was $601 trillion at 2010 year-end. The curtailed growth towards the end of the history can be clearly attributed to the global financial crisis where firms have reduced balance sheets and reallocated capital and clients have been less interested in derivatives, particularly as structured products. However, the reduction in recent years is also partially due to compression exercises that seek to reduce counterparty risk via removing offsetting and redundant positions (discussed in more detail in the next chapter).

The split of OTC derivatives by product type is shown in Figure 9-3. Interest rate products contribute the majority

[5] This is a bank account held in a foreign country, denominated in the currency of that country. Nostro accounts are used for settlement of foreign exchange transactions.

[6] This is the process of determining the price of an asset in a marketplace through the interactions of buyers and sellers.

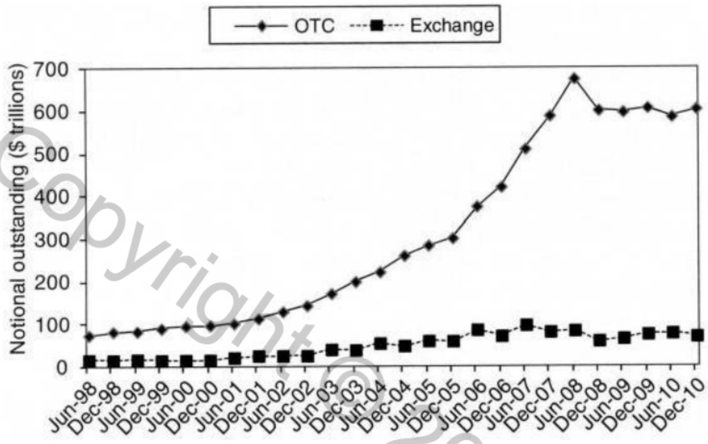



**FIGURE 9-2** Total outstanding notional of OTC- and exchange-traded derivatives transactions.

The figures cover interest rate, foreign exchange, equity, commodity and credit derivative contracts. Note that notional amounts outstanding are not directly comparable to those for exchange-traded derivatives, which refer to open interest or net positions whereas the amounts outstanding for OTC markets refer to gross positions, i.e., without netting.

*Source:* BIS.

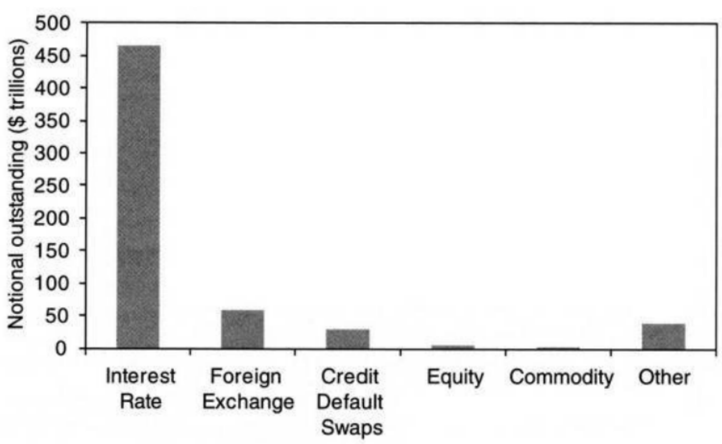



**FIGURE 9-3** Split of OTC gross outstanding notional by product type as of end 2010.

*Source:* BIS.

of the outstanding notional, with foreign exchange and credit default swaps seemingly less important. However, this gives a somewhat misleading view of the importance of counterparty risk in other asset classes, especially foreign exchange and credit default swaps. Whilst most foreign exchange products are short-dated, the long-dated nature and exchange of notional in cross-currency swaps means they carry a lot of counterparty risk. Credit default swaps not only have a large volatility component but also constitute significant "wrong-way risk" (discussed in detail in Chapter 16). So, whilst interest rate products make up a significant proportion of the counterparty risk in the market (and indeed are most commonly used in practical examples), one must not underestimate the important (and sometimes more subtle) contributions from other products.[7]

A key aspect of derivatives products is that their exposure is substantially smaller than that of an equivalent loan or bond. Consider an interest rate swap as an example; this contract involves the exchange of floating against fixed coupons and has no principal risk because only cash flows are exchanged. Furthermore, even the coupons are not fully at risk because, at coupon dates, only the difference in fixed and floating coupons or *net* payment will be exchanged. If a counterparty fails to perform, then an institution will have no obligation to continue to make coupon payments. Instead, the swap will be unwound based on independent quotations as to its current market value. If the swap has a negative value for an institution, then they stand to lose nothing if their counterparty defaults. For this reason, when we compare the actual total market of derivatives against their total notional amount outstanding, we see a massive reduction as illustrated in Table 9-1. For example, the total market value of interest rate contracts is only 3.1% of the total notional outstanding.

## Repos and Securities Lending

A repurchase agreement or *repo* is a mechanism to reduce the cost of financing although, as the repo market has grown, the application and strategies have also developed. In a repo transaction, one party exchanges

[7] Indeed, in a survey of banks I carried out in 2009, "Credit value adjustment and the changing environment for pricing and managing counterparty risk," banks were asked which asset classes they felt their counterparty risk came from. Interest rate products were indeed most significant overall (52%), but foreign exchange (18%) and credit derivatives (21%) were significant. This survey can be found at www.cvacentral.com.

**TABLE 9-1** Comparison of the Total Notional Outstanding and the Market Value of Derivatives ($ trillions) for Different Asset Classes as of December 2010

| | Gross Notional Outstanding | Gross Market Value* | Ratio |
|---|---|---|---|
| Interest rate | 465.3 | 14.6 | 3.1% |
| Foreign exchange | 57.8 | 2.5 | 4.3% |
| Credit default swaps | 29.9 | 1.4 | 4.5% |
| Equity | 5.6 | 0.6 | 11.5% |
| Commodity | 2.9 | 0.5 | 18.0% |

*This is calculated as the sum of the absolute value of gross positive and gross negative market values, corrected for double counting.

*Source:* BIS



securities in return for cash with an agreement to repurchase the securities at a specified future date. The securities essentially act as collateral for a cash loan. The repurchase price is greater than the original sale price with the difference effectively representing the repo rate, which equates to an interest rate on the transaction plus any counterparty risk charge. The collateral tends to be liquid securities (traditionally bonds, although other securities are also used) of stable value. A haircut is applied to mitigate the counterparty risk arising due to the chance that the borrower will fail to pay back the cash *and* the value of the collateral will fall. Repos are of great importance in international money markets and the market has been growing and developing substantially in recent years. A *reverse repo* is simply the same transaction from the other party's point of view.

A repo is essentially a loan with collateral taken against it to mitigate the otherwise substantial credit risk. However, some residual counterparty risk will remain. The seller of securities may default by failing to repurchase them at the maturity date. This means that the buyer may liquidate the securities in order to recover the cash lent. There is a risk that the securities may have lost value due to market movements and not cover this amount. To mitigate this risk, repos are often overcollateralised (via the haircut) as well as being subject to daily mark-to-market margining. Hence, the residual risk is essentially a "gap risk" in that the market moves quickly or "gaps" in a short space of time prior to the default of the seller. Conversely, if the value of the security rises, the borrower in a repo transaction may experience credit risk. The greater the degree of overcollateralisation, the greater this risk will be. The counterparty risk in a repo is subject to many factors such as the term (maturity), liquidity of security and the strength of counterparties involved.

Securities lending transactions involve one party borrowing securities from another and providing collateral of comparable value. This is similar to a repo transaction except that securities are exchanged for collateral rather than cash for collateral. Whilst a repo transaction always involves cash on one side, securities lending does not since the collateral used may be bonds or other securities. In addition to the collateral, securities lending typically involves a mark-to-market margining as for repo.

## Mitigating Counterparty Risk

Counterparty risk can be reduced by various means. Netting and collateral agreements have been common tools to achieve this. These are often bilateral and therefore aim to reduce the risk for *both* parties. In the event of default, netting allows the offset of amounts owed to and by a counterparty. However, the impact of netting is finite and heavily dependent on the type of underlying transactions involved. Collateral can reduce counterparty risk further and, in theory, eliminate it but creates significant operational costs and other risks, such as liquidity and legal. Chapter 10 examines these points in more detail.

Central counterparties, such as exchanges and clearing houses, can allow the centralisation of counterparty risk and mutualisation of losses. This at first seems like a simple solution to the problem raised by significant bilateral risks in the market, which can lead to a systemic crisis whereby the default of one institution creates a "domino effect." However, central counterparties can create moral hazard and asymmetric information problems by eliminating the incentive for market participants to monitor carefully the counterparty risks of one another.

The growth of the credit derivatives market has made hedging of counterparty risk a viable option. Credit derivatives products called contingent credit default swaps (CCDSs) have even been developed specifically for this purpose. Credit derivatives also create the opportunity to diversify counterparty risk by reducing counterparty exposure to the clients of a firm, taking instead exposure to other parties who may be clients only of a competitor. However, hedging can be expensive and creates wrong-way risk (Chapter 16).

We emphasise strongly that *any* mitigation of counterparty risk is a double-edged sword since it will not necessarily reduce overall risks and could potentially allow financial markets to develop too quickly or to reach a dangerous size. A very simple example can explain this. Suppose there are 100 units of risk in a market dominated by 10 dealers. The market cannot develop further since the 10 dealers are unable or unwilling to increase their positions and further market participants are unable, or simply do not see it as being profitable for them, to enter the market. Now, suppose some form of risk mitigation is developed, and allowed by regulators, which reduces the total amount of risk to 25 units. The market is now likely to develop strongly due to existing dealers increasing their exposures and new entrants to the market. Eventually, the market may increase in size and return to the situation of 100 units of risk. The risk mitigation has been extremely efficient since the market size (in terms of the original risk taken) has quadrupled. However, suppose the risk mitigation has some weaknesses and its impact has therefore been overstated, either due to dealers' over-optimistic assessments of their risks and/or regulators allowing too aggressive a reduction in capital. In this case, the overall risk in the market has actually increased due to the risk mitigation. Worst still, market participants and regulatory bodies are blind to these risks.

Understanding the balance between good and bad risk mitigation has not been easy for markets exposed to counterparty risk. We will devote separate chapters to understanding the full impact of collateralisation and netting, central counterparties, hedging and regulatory aspects.

## Counterparty Risk Players

The range of institutions that take significant counterparty risk has changed dramatically over recent years (or more to the point, institutions now fully appreciate the extent of counterparty risk they may face). Let us characterise these institutions generally:

- Large derivatives player
  - typically a large bank, often known as a dealer;
  - will have a vast number of OTC derivatives trades on their books;
  - will trade with each other and have many other clients;
  - coverage of all or many different asset classes (interest rate, foreign exchange, equity, commodities, credit derivatives);
  - will post collateral against positions (at least as long as the counterparty will make the same commitment and sometimes even if they do not).
- Medium derivatives player
  - typically a smaller bank or other financial institution such as a hedge fund or pension fund;
  - will have many OTC derivatives trades on their books;
  - will trade with a relatively large number of clients;
  - will cover several asset classes although may not be active in all of them (may, for example, not trade credit derivatives or commodities and will probably not deal with the more exotic derivatives);
  - will probably post collateral against positions with some exceptions.
- Small derivatives player
  - typically a large corporate or sovereign with significant derivatives requirements (for example, for hedging needs or investment) or a small financial institution;
  - will have a few OTC derivatives trades on their books;
  - will trade with potentially only a few different counterparties;
  - may be specialised to a single asset class (for example, some corporates trade only foreign exchange products, a mining company may trade only commodity forwards, a pension fund may only be active in interest rate and inflation products);
  - typically, will be unable to commit to posting collateral or will post illiquid collateral.

Historically, the large derivatives players have had much stronger credit quality than the other participants. However, some small players, such as sovereigns and insurance companies, have had very strong (Triple-A) credit quality and have used this to obtain favourable terms such as one-way collateral agreements. Historically, a large amount of counterparty risk has been ignored simply because large derivatives players (the credit spreads of large, highly rated financial institutions prior to 2007 amounted to just a few basis points per annum[8]) or Triple-A entities were assumed default-free.

[8] Meaning that the market priced their debt as being of very high quality and practically risk-free.

However, the above has since 2007 been very clearly seen as a myth and hence the bilateral nature of counterparty risk is ever-present. The impasse between derivatives counterparties caused by the bilateral nature of the risk has caused significant problems with previously liquid-trading activity becoming log-jammed. Now, all institutions facing counterparty risk *must* take it seriously and build their abilities in quantification, pricing and hedging aspects. No institution has such poor credit quality that they need not concern themselves with counterparty risk and no institution has such strong credit quality that their potential bankruptcy at some future date can be ignored.

Aside from the parties taking counterparty risk through their trading activities, other major players in the market are third parties. Third parties offer, for example, collateral management, software, trade compression and clearing services. They allow market participants to reduce counterparty risk, the risks associated with counterparty risk (such as legal) and improve overall operational efficiency with respect to these aspects.

## COMPONENTS AND TERMINOLOGY

### Credit Exposure

Credit exposure (hereafter often simply known as exposure) defines the loss in the event of a counterparty defaulting. Exposure is characterised by the fact that a positive value of a financial instrument corresponds to a claim on a defaulted counterparty, whereas in the event of negative value, an institution is still obliged to honour their contractual payments (at least to the extent that they exceed those of the defaulted counterparty). This means that if an institution is owed money and their counterparty defaults then they will incur a loss, whilst in the reverse situation they cannot gain[9] from the default by being somehow released from their liability.

Exposure is clearly a very time-sensitive measure since a counterparty can default at any time in the future and one must consider the impact of such an event many years from now. Exposure is needed in the analysis of counterparty risk since, for many financial instruments (notably derivatives), the creditor is not at risk for the full principal amount of the trade but only the *replacement cost*. A measure of exposure should encompass the risk arising from actual claims (current claims and those a financial institution is committed to provide), potential claims (possible future claims) as well as contingent liabilities. Essentially, characterising exposure involves answering the following two questions:

- What is the current exposure (the maximum loss if the counterparty defaults today)?
- What is the exposure in the future (what could be the loss if the counterparty defaults at some point in the future)?

The second point above is naturally far more complex to answer than the first, except in some simple cases. We emphasise that all exposure calculations, by convention, will ignore any recovery value in the event of a default. Hence, the exposure is the loss, as defined by the value or replacement cost that would be incurred assuming zero recovery value.

Finally, a very important point:

| Exposure is conditional on counterparty default. |
|---|

Exposure is relevant only if the counterparty defaults and hence the quantification of exposure should be "conditioned" upon this event, i.e.,

- What is the exposure in 1 year assuming the counterparty will default in 1 year?
- What is the exposure in 2 years assuming the counterparty will default in 2 years?
- And so on.

Having said this, we will often consider exposure independently of any default event and so assume implicitly no "wrong-way risk." Such an assumption is reasonable for most products subject to counterparty risk, although the reader should keep the idea of conditional exposure in mind if possible. We will then address wrong-way risk, which defines the relationship between exposure and counterparty default, in more detail in Chapter 16.

### Default Probability, Credit Migration and Credit Spreads

When assessing counterparty risk, one must consider the credit quality of a counterparty over the entire lifetime of the relevant transactions. Such time horizons can be extremely long. Ultimately, there are two aspects to consider:

[9] Except in some special and non-standard cases that we will consider later.

- What is the probability of the counterparty defaulting[10] over a certain time horizon?
- What is the probability of the counterparty suffering a decline in credit quality over a certain time horizon (for example, a ratings downgrade)?

Credit migrations or discrete changes in credit quality, such as due to ratings changes, are crucial since they influence the *term structure* of default probability. They should also be considered since they may cause issues even when a counterparty is not yet in default. Suppose the probability of default of a counterparty between the current time and a future date of, say, 1 year is known. It is also important to consider what the same annual default rate might be in 4 years, in other words the probability of default between 4 and 5 years in the future. There are three important aspects to consider:

- Future default probability,[11] as defined above, will have a tendency to decrease due to the chance that the default may occur before the start of the period in question. The probability of a counterparty defaulting between 20 and 21 years in the future may be very small. Not because they are very creditworthy (potentially quite the reverse), but rather because they are unlikely to survive for 20 years!
- A counterparty with an expectation of deterioration in credit quality will have an increasing probability of default over time (although at some point the above phenomenon will reverse this).
- A counterparty with an expectation of improvement in credit quality will have a decreasing probability of default over time, which will be accelerated by the first point above.

**SPREADSHEET 9-1** Counterparty Risk for an FX Forward

To download Spreadsheet 9-1, visit http://www.cvacentral.com/books/credit-value-adjustment/spreadsheets and click Chapter 3 exercises.

There is a well-known empirical mean-reversion in credit quality, as evidenced by historical credit ratings changes.

A trader has to assess the expected loss on a new FX forward trade due to counterparty risk. The potential loss at the maturity of the trade is estimated to be \$10m, whilst the default probability of the counterparty over the 5-year period is 10%. The trader argues that since the current exposure of the trade is zero, then the average loss over the life of the trade will be half the final value and hence the expected loss will be

$$\$10\text{m} \times 50\% \times 10\% = \$0.5\text{m}$$

This is not a very accurate calculation. Firstly, the estimate of average exposure is not 50% of the final value because the exposure does not increase linearly. Worse than this, there is an implicit assumption that the default probability is homogeneous through time. If the default probability actually increases through time, the actual expected loss can be considerably higher (see the example in Spreadsheet 9-1 where it is \$0.77m). The counterparty may be more likely to default closer to the 5-year point (where the loss is \$10m) than today (when the loss is zero).

This means that good (above-average) credit quality firms tend to deteriorate and vice versa. Hence, a counterparty of good credit quality will tend to have an increasing default probability over time whilst a poor credit quality counterparty will be more likely to default in the short term and less likely to do so in the longer term. The term structure of default is very important to consider, as the above example (box) demonstrates.

We note finally that default probability may be defined as real-world or risk-neutral. In the former case, we ask ourselves what is the *actual* default probability of the counterparty, which often is estimated via historical data. In the latter case, we calculate the risk-neutral (or market-implied) probability from market credit spreads. The latter case is relevant when hedging counterparty risk and the former otherwise.[12] The difference between real-world and risk-neutral default probabilities is discussed in detail in Chapter 14. When considering counterparty risk via credit spreads, then credit spread volatility is an important consideration in addition to credit migration and default risk.

## Recovery and Loss Given Default

Recovery rates typically represent the percentage of the outstanding claim recovered when a counterparty

[10] We will for now use the term default to refer to any "credit event" that could impact the counterparty. Such credit events will be described in greater depth in Chapter 14.

[11] Here we refer to default probabilities in a specified period, such as annual.

[12] We note that Basel III regulatory capital rules advocate the risk-neutral approach even though hedging may often be difficult.

defaults. An associated variable to recovery is *loss given default,* which is linked to recovery rate on a unit amount by the simple relationship *loss given default = 1 − recovery rate.*

Recovery rates can vary substantially, which is important because, for example, a recovery of 60% of a claim will result in only half the loss compared to a recovery of 20%. Credit exposure is traditionally measured gross of any recovery (and hence is a worst-case estimate) but recovery rates play a critical role in the quantification of counterparty risk via credit value adjustment (CVA).

In the event of a bankruptcy, the holders of OTC derivatives contracts with the counterparty in default would normally be *pari passu*[13] with the senior bondholders. OTC derivatives, bonds and credit default swaps (CDSs) therefore reference senior unsecured credit risk and therefore may appear to relate to the same recovery value. However, there are two complexities around such aspects. Firstly, whilst CDS contracts are designed as hedges for bonds and loans, they do not necessarily correspond to exactly the same recovery values. This is due to structural features of CDS contracts such as cheapest-to-deliver optionality and delivery squeezes. Whilst recent changes to the CDS market, such as the "big bang protocol," have minimised their impact, these must be understood to fully appreciate hedging of counterparty risk through CDS contracts. Secondly, there is a timing issue. When a bond issuer defaults, the recovery rate can be realised immediately as the bond can be sold in the market. CDS contracts are also settled within days of the defined "credit event" via the CDS auction. However, OTC derivatives (unlike bonds) cannot be freely traded or sold, especially when the counterparty to the derivative is in default. This essentially leads to a different recovery value for derivatives. These recovery aspects, very important in the Lehman Brothers bankruptcy of 2008, are discussed in more detail in Chapter 14.

## Mark-to-Market and Replacement Cost

The mark-to-market (MtM) with respect to a particular counterparty defines what could be potentially lost today. However, this is dependent on the ability to net the trades in the event the counterparty defaults. Furthermore, other aspects that will reduce the exposure in the event of default, such as collateral legally held against the contracts and possibly hedges, must be considered. These considerations are discussed in more detail in Chapter 10.

Current MtM does not constitute an *immediate* liability by one party to the other but rather is the present value of all the payments an institution is expecting to receive, less those it is obliged to make. These payments may be scheduled to occur many years in the future and may have values that are strongly dependent on market variables. MtM may therefore be positive or negative, depending on whether a transaction is in an institution's favour or not.

Contractual features of transactions, such as closeout netting and termination features, refer to *replacement costs*. Risk-free MtM is clearly closely related to replacement cost, which defines the entry point into an equivalent transaction(s) with another counterparty. Models tend to assume, for reasons of simplicity, that the two are the same. However, the actual situation is more complicated.

The replacement cost of a transaction, whilst closely coupled to the MtM value of a transaction, will not be the same. To replace a transaction, one must consider costs such as bid–offer spreads, which may be significant for highly illiquid securities. Note that even a standard and liquid contract might be non-standard and illiquid at the default time. In such a case, one must then decide whether to replace with an expensive non-standard derivative or with a more standard one that does not match precisely the original one. Documentation suggests that such cost can essentially be passed on via the replacement cost concept, therefore ignoring transaction costs when quantifying counterparty risk seems reasonable.[14]

Unfortunately, counterparty risk *itself* causes further complication here. Documentation suggests that the creditworthiness of the surviving (or exercising in the case of a contractual termination) party can also be considered in a replacement cost. This means that the future counterparty risk (via CVA and DVA components) actually defines the future replacement cost. This creates a recursive problem since we cannot define counterparty risk without knowing the future counterparty risk and vice versa. For now, we

[13] This means they have the same seniority and therefore should expect to receive the same recovery value.

[14] This is still not perfect since, whilst documentation suggests that by using a replacement cost concept, transactions costs can be claimed from the counterparty, if the counterparty is in default then only a proportion of these costs will be received.

emphasise that basing replacement cost on risk-free valuation is a reasonable approximation to the more complicated, actual situation.

## Mitigating Counterparty Risk

The many ways to mitigate or limit counterparty risk are discussed in more detail in the next chapter. Some are relatively simple contractual risk mitigants, whilst other methods are more complex and costly to implement. No risk mitigant is perfect and there will always be some residual counterparty risk, however small. It is therefore important to consider carefully the benefit of risk mitigants when quantifying counterparty risk. Chapter 13 covers this extensively. In addition to the residual counterparty risk, it is important to keep in mind that risk mitigants do not remove counterparty risk *per se* but instead convert it into other forms of financial risk, some obvious examples being:

- *Netting.* Being legally able to offset positive and negative contract values with the same counterparty, in the event of their default, reduces exposure at the counterparty level. However, this also creates legal risk in cases where a netting agreement cannot be legally enforced in a particular jurisdiction.
- *Collateral*. Holding cash or securities against an exposure can clearly reduce that exposure. However, this leads to operational and liquidity risks through the necessity to run a complex collateral management function. Indeed, many counterparties cannot agree to collateral terms due to these risks and their inability to handle them effectively.
- *Central counterparties*. Create operational and liquidity risks, for the reasons above, and systemic risk since the failure of a central counterparty could amount to a significant systemic disturbance.
- *Hedging*. Hedging clearly has the aim of reducing counterparty risk but may lead to additional market risks through the mark-to-market volatility of the hedging instruments.

# CONTROL AND QUANTIFICATION

It is important for an institution to control the counterparty risk that they face. This must recognise the fact that counterparty risk varies substantially depending on aspects such as the transaction and counterparty in question. In addition, it is important to give the correct benefit arising from the many risk mitigants (such as netting and collateral) that may be relevant. Control of counterparty risk has been traditionally the purpose of credit limits, used by most banks for well over a decade.

However, *credit limits* only limit counterparty risk and, whilst this is clearly the first line of defence, there is also a need to correctly quantify and ensure an institution is being correctly compensated for the counterparty risk they take. This is achieved via *credit value adjustment* (CVA), which has been used increasingly in recent years as a means of putting a value or price on the counterparty risk faced by an institution.

An institution is faced with counterparty risk from many counterparties and must control the portfolio impact and link this to capital requirements, regulatory or economic. Finally, the hedging of a counterparty must also be considered. Let us examine these components and how they fit together.

## Credit Limits

Let us consider the first and most basic use of exposure, which is as a means to control the amount of risk to a given counterparty over time. The basic idea of diversification is to avoid putting all your eggs in one basket. Market participants can achieve this by limiting credit exposure to any given counterparty, in line with the default probability of that counterparty. This is the basic principle of credit limits (or credit lines). By trading with a greater number of counterparties, an institution is not so exposed to the failure of any one of them. Diversification is not always practical due to the relationship benefits from trading with certain key clients. In such cases, credit exposures can become excessively large and must be mitigated by other means.

Attribute a credit limit specific to each counterparty as illustrated in Figure 9-4. The idea is to characterise the potential future exposure (PFE) to a counterparty over time and ensure that this does not exceed a certain value (the credit limit). The PFE represents a worst-case scenario and is similar to the well-known VaR measure. PFE will be described in more detail in Chapter 10. The credit limit will be set arbitrarily according to the risk appetite of the institution in question. It may be time-dependent, reflecting the fact that exposures at different times in the future may be considered differently.

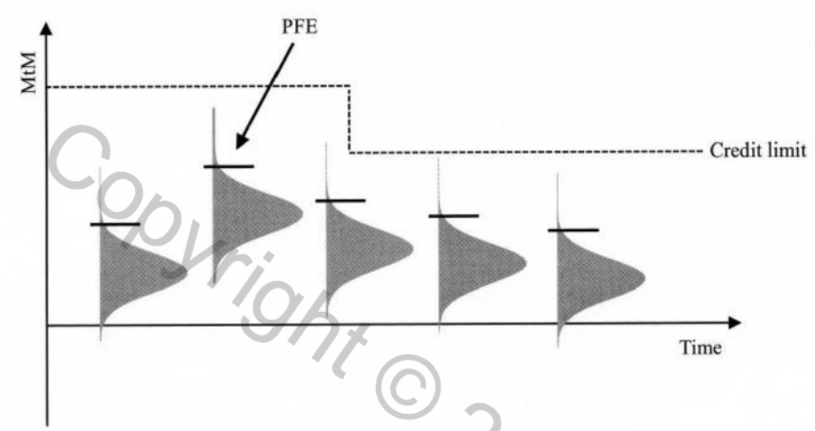



**FIGURE 9-4** Illustration of the use of potential future exposure to control counterparty risk.

Credit limits will often be reduced over time, effectively favouring short-term exposures over long-term ones. This is due to the chance that a counterparty's credit quality may deteriorate over a long horizon. Indeed, empirical and market-implied default probabilities for good quality (investment grade) institutions tend to increase over time (see Chapter 14 for more details). Such an increase in default probability justifies the reduction of a credit limit. The credit limit of a counterparty with poor credit quality (sub-investment grade) arguably should increase over time since, if the counterparty does not default, then its credit quality will be expected to improve eventually.

Any trade that would breach a credit limit at any point in the future is likely to be refused. Credit limits allow a consolidated view of exposure with each counterparty and represent a first step in portfolio counterparty risk management.

When assessing PFE against credit limits, possible future transactions are not considered. However, it is possible for changing market conditions (spot rates and volatilities, for example) to increase PFEs and cause credit limits to be breached. An institution must have not only a policy regarding credit limits, which defines the ability to transact further, but also a rule about the circumstances under which existing positions must be adjusted when a credit limit is breached due to market moves. For example, a credit limit of \$10m ("soft limit") might restrict trades that cause an increase in PFE above this value and may allow the PFE to move up to \$12m ("hard limit") as a result of changes in market conditions. In the event of a triggering of the higher limit, it may be necessary to reduce the PFE to within the original \$10m limit by adjusting positions or using credit derivatives to hedge the exposure.

A credit limit controls exposure in a rather binary way, without any dynamic reference to the relevant variables below:

- default probability of counterparty;
- expected recovery rate of counterparty;
- downgrade probability (worsening credit quality) of counterparty;
- correlation between counterparties (concentrations).

All of the above variables are likely to be built into the defined credit limit in some way. For example, a low default probability or high recovery may lead to a larger limit, whilst a significant chance of downgrade may lead to a decreased credit limit over time (as is the case in Figure 9-4). Finally, a counterparty that is highly correlated to others should have a lower credit limit than an equivalent counterparty, which is less correlated. However, such decisions are made in a qualitative fashion and the nature of credit limits leads to either accepting or rejecting a new transaction with reference to exposure alone and not the actual profitability of the transaction. This is a key motivation for the pricing of counterparty risk via CVA.

## Credit Value Adjustment

Traditional counterparty risk management, as described above, works in a binary fashion. The use of credit limits, for example, gives an institution the ability to decide whether to enter into a new transaction with a given counterparty. If there were a breach of the credit limit then a transaction would be refused (except in special cases). The problem with this is that the risk of a new transaction is the only consideration whereas the return (profit) should surely be a factor also.

By pricing counterparty risk, one can move beyond a binary decision-making process. The question of whether to do a transaction becomes simply whether or not it is profitable once the counterparty risk component has been "priced in." As we will show in Chapter 15, the risky price of a derivative can be expressed as the risk-free price (the price assuming no counterparty risk) less a component to correct for the counterparty risk. The latter component is often called CVA (credit value adjustment). Ensuring that the profitability of a transaction exceeds the CVA is a first hurdle to the proper treatment of counterparty risk. The CVA "charge" should be calculated in a sophisticated way to account for all the aspects that will define the CVA:

- the default probability of the counterparty;
- the default probability of the institution;
- the transaction in question;
- netting of existing transactions with the same counterparty;
- collateralisation;
- hedging aspects.

CVA moves beyond the binary nature of credit limits and prices counterparty risk directly. A transaction is not refused or accepted directly but an institution needs to make a profit that more than covers the incremental CVA of the transaction, i.e., the increase in CVA taking into account netting effects due to any existing trades with the counterparty. Other aspects, such as collateral, should also be considered. Such pricing aspects are considered in detail in Chapter 15.

CVA is not the be-all and end-all of counterparty risk, though. Broadly speaking, there are three levels to assessing the counterparty risk of a transaction:

- *Trade level*. Incorporating all characteristics of the trade and associated risk factors. This defines the counterparty risk of a trade at a "stand-alone" level.
- *Counterparty level*. Incorporating the impact of risk mitigants such as netting and collateral for each counterparty individually. This defines the incremental impact a trade has with respect to existing transactions.
- *Portfolio level*. Consideration of the risk to all counterparties knowing that only a small fraction may default in a given time period. This defines the impact a trade has on the total counterparty risk faced by an institution.

CVA only addresses the first two components above.

## CVA or Credit Limits?

Both.

CVA focuses on evaluating counterparty risk at the trade level (incorporating all specific features of the trade) and counterparty level (incorporating risk mitigants). In contrast, credit limits essentially act at the portfolio level by limiting exposures to avoid concentrations. When viewed like this, we see that CVA and credit limits act in a complementary fashion, as illustrated in Figure 9-5. Indeed, CVA encourages *minimising* the number of counterparties an institution would trade with, since this maximises the benefits of netting whilst credit limits encourage *maximising* this number. Hence, CVA and credit limits are typically used together as complementary ways to quantify and manage counterparty risk.

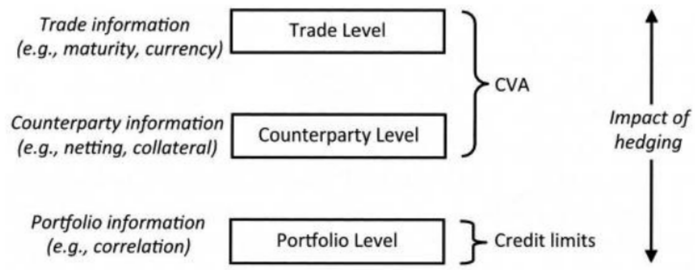



**FIGURE 9-5** High-level illustration of the complementary use of CVA and credit limits to manage counterparty risk.

## What Does CVA Represent?

Since counterparty risk has a price via CVA, then an immediate question is what defines this price. The price of a financial instrument can generally be defined in one of two ways:

- The price represents an expected value of future cash flows, incorporating some adjustment for the risk being taken (the risk premium). We will call this the *actuarial price*.
- The price is the cost of an associated hedging strategy. This is the *risk-neutral* (or market-implied) price.

A price defined by hedging arguments may often differ dramatically from one based on expected value + risk premium. Hence, it is natural to ask ourselves into which camp CVA falls. The answer is, unfortunately, both since CVA can be partially but not perfectly hedged. If we have a current exposure of $10m, we may not be able to hedge the resulting loss if the counterparty defaults. Even if we can hedge this current exposure, we might not be able to hedge the future variability of that exposure.

Hence, we must understand the *hedging* implications but also the *portfolio-level* considerations of the residual risks (that cannot be hedged). It is important to emphasise at this point that, whatever the viability of hedging and the extent of an institution's wish to hedge their CVA, Basel III

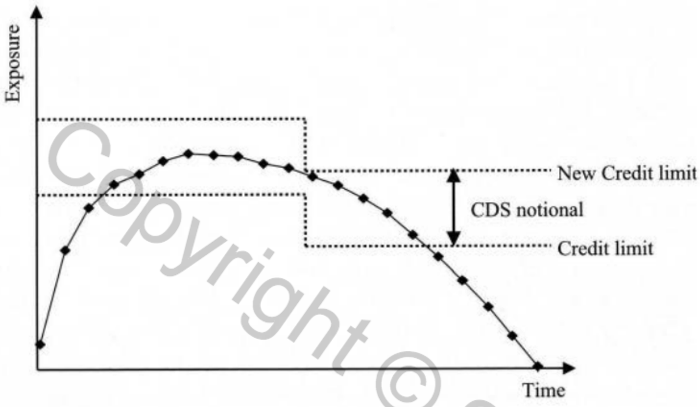



**FIGURE 9-6** Illustration of CDS hedging in order to increase a credit limit.

regulatory capital rules advocate a risk-neutral approach to CVA. CVA quantification, hedging, portfolio aspects and regulatory capital rules are all important considerations for properly dealing with counterparty risk.

## Hedging Counterparty Risk

The growth of the credit derivatives market has facilitated hedging of counterparty credit risk. Suppose an institution has a \$10m netted exposure (uncollateralised), which is causing concern and furthermore preventing any further trading activity with the counterparty. Buying \$10m notional of CDS protection referenced to this counterparty will hedge this credit exposure. The hedging depends on the ability to trade CDSs on the counterparty in question and comes at a cost. However, hedging enables one to reduce the exposure and hence provides a means to transact further with the counterparty. It can be considered that CDS hedging therefore increases a credit limit by the notional of the CDS protection purchased.[15] This provides a means to use CDS protection to hedge the extent to which a transaction exceeds a credit limit. The combination of hedging some portion of the exposure may be considered the most economically viable solution to trading with some counterparties. This is illustrated in Figure 9-6.

More tailored credit derivative products such as CCDSs have been designed to hedge counterparty risk even more directly. CCDSs are essentially CDSs but with the notional of protection indexed to the exposure on a contractually specified derivative. They allow the synthetic transfer of counterparty risk linked to a specific trade and counterparty to a third party. Suppose institution A trades a contract with party X and has counterparty risk. If A now buys CCDS protection from a party Y referencing both counterparty X and the underlying contract involved, then it has effectively passed the counterparty risk to Y (without X needing to be involved in the arrangement).

## Portfolio Counterparty Risk

Take the above example of counterparties X and Y. Institution A now has risk to only the joint default or "double default" of counterparties X and Y. This means one needs to consider the joint likelihood of these counterparties defaulting. More generally, we should consider the impact of the default probability of all counterparties. For a typical bank, the number of counterparties with whom they have exposure is in the thousands and so this is a difficult but important task.

The concept of assigning capital against financial risks is done in recognition of the fact that unexpected losses are best understood at the portfolio, rather than the transaction, level. Capital requirements may be economic (calculated by the institution in question for accurate quantification of risk) or regulatory (imposed by regulators). Either way, the role of capital is to act as a buffer against unexpected losses. Hence, while pricing counterparty risk via CVA involves assessment of expected losses at the counterparty level, the concept of capital allows one to make decisions at the portfolio level (for example, all counterparties an institution trades with) and consider unexpected as well as expected losses.

The computation of capital for a credit portfolio is a rather complex issue since the correlation (or more generally dependency) between the defaults of different counterparties must be quantified. A high positive correlation (strong dependency) means that multiple defaults are possible, which will therefore increase the unexpected loss and associated capital numbers. Assessment of capital for counterparty risk is even more important due to the asymmetric nature of exposure. One must not only understand the correlation between counterparty default events, but also the correlation between the resulting exposures. For example, suppose an institution has a transaction with counterparty A and hedges that transaction with

[15] There are some technical factors that should be considered here, which may mean that the hedge is not effective. Chapter 14 will discuss these aspects in more detail.

counterparty B. This means the MtM positions with the two counterparties will always offset one another and *cannot* therefore both be positive. Hence, default of both counterparties A and B will create only a single loss in relation to whichever counterparty the institution has exposure to at the default time. Essentially, the negative correlation of the exposures reduces the overall risk. In case the MtM values of transactions with counterparty A and B were positively correlated, joint default would be expected to give rise to a greater loss.

Finally, it is important to consider regulatory capital. Whilst this should be aligned with economic capital, the necessity for relatively simple regulation tends to restrict this. Furthermore, with the creation of the Basel III capital requirements, the variability of CVA itself must be capitalised, alongside the more traditional measure of the default component of counterparty risk.

## SUMMARY

In this chapter, we have defined counterparty risk, introducing the key components of credit exposure, default probability and recovery, and outlining the risk mitigation approaches of netting and collateralisation. We have discussed various ways of quantifying and managing counterparty risk from the traditional approach of credit limits to the more sophisticated approaches of pricing via CVA and the consideration of portfolio and hedging aspects.

The next section of this book will deal in depth with the mitigation of counterparty risk.

# Netting, Compression, Resets, and Termination Features

10



## Learning Objectives

After completing this reading you should be able to:

- Explain the purpose of an ISDA Master Agreement.
- Summarize netting and close-out procedures (including multilateral netting), explain their advantages and disadvantages, and describe how they fit into the framework of the ISDA Master Agreement.
- Describe the effectiveness of netting in reducing credit exposure under various scenarios.
- Describe the mechanics of termination provisions and trade compressions and explain their advantages and disadvantages.

*Excerpt is Chapter 4 of* Counterparty Credit Risk and Credit Value Adjustment, *Second Edition, by Jon Gregory.*

One ought never to turn one's back on a threatened danger and try to run away from it. If you do that, you will double the danger. But if you meet it promptly and without flinching, you will reduce the danger by half.

—Sir Winston Churchill (1874–1965)

## INTRODUCTION

### The Origins of Counterparty Risk

The classic counterparty credit risk problem is illustrated in Figure 10-1, supposing an institution executes a trade with counterparty A and hedges this with counterparty B.[1] For example, the institution could be a bank providing an OTC derivative trade to a customer (A) and hedging it with another bank (B). In this situation, the institution has no volatility of their overall profit and loss (PnL) and, consequently, no market risk. However, they do have counterparty risk to both counterparties A and B since, if either were to default, then this would leave exposure to the other side of the trade.

### The ISDA Master Agreement

The International Swaps and Derivatives Association (ISDA) is a trade organisation for OTC derivatives practitioners. The ISDA Master Agreement is a bilateral framework, which contains terms and conditions to govern transactions between parties. It is designed to eliminate legal uncertainties and to provide mechanisms for mitigating counterparty risk. It specifies the general terms of the agreement between parties with respect to general questions such as netting, collateral, definition of default and other termination events. Multiple transactions can be subsumed under this general Master Agreement to form a single legal contract of indefinite term, covering many or all of the transactions traded. Individual transactions are incorporated by reference in the trade confirmation to the relevant Master Agreement. Trading then tends to occur without the need to update or change any aspect of the relevant ISDA agreement.

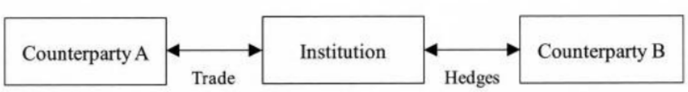



**FIGURE 10-1** Illustration of the typical situation in which counterparty risk arises.

[1] Note that the hedge may, in fact, be a series of trades.

## NETTING

Consider a holder of a debt security from a bankrupt company. Not only do they expect to make a substantial loss due to the default, but they also must expect it to be some time (often years) before they will receive any recovery value linked to the notional amount of their claim. Whilst this is problematic, it has not been considered a major problem, for example, in the predominantly buy-to-hold, long-only, cash bond market.

Derivatives markets are fast moving, with participants regularly changing their positions and where many instruments offset (hedge) one other. When a counterparty defaults, the market needs a mechanism whereby participants can replace (re-hedge) their position with other counterparties. Furthermore, it is desirable for an institution to be able to offset what it owes to the defaulted counterparty against what they themselves are owed. The following two mechanisms facilitate this:

- *Payment netting.* This gives an institution the ability to net cash flows occurring on the same day. This typically relates to settlement risk.
- *Closeout netting.* This allows the termination of all contracts between the insolvent and a solvent counterparty, together with the offsetting of all transaction values (both in an institution's favour and against it). This typically relates to counterparty risk.

Netting legislation covering derivatives has been adopted in most countries with major financial markets. ISDA has obtained legal opinions supporting the closeout and netting provisions in their Master Agreements in most relevant jurisdictions. (At the time of writing, they currently have such opinion covering 54 jurisdictions.) Thirty-seven countries have legislation that provides explicitly for the enforceability of netting. However, there remain jurisdictions where netting is not allowable.

### Payment Netting

Payment netting covers the situation where an institution will have to make and receive more than one payment during a given day. The Bankhaus Herstatt example from the 1970s, illustrates the risks of such a situation. Payment netting allows an institution to combine same-day cash flows into a single net payment. This reduces settlement risk and enhances operational efficiency. For example, if a $305m floating swap payment is to be made and a $300m fixed payment received (on the same day), then the institution in question would simply make a net payment of $5m with the $300m payment having no associated risk.

Payment netting would appear to be a simple process, which gives the maximum reduction of any risk arising from payments made on the same day. However, it does leave operational risk, which has been illustrated in a recent high-profile case during the financial crisis (see box below).

The KfW Bankengruppe transaction, giving rise to the problem outlined below, was a regular currency swap with euros being paid to Lehman and dollars paid back to KfW. On the day Lehman Brothers declared bankruptcy, KfW made an automated transfer of €300m despite the obvious fact that the stricken Lehman Brothers would not be making the opposite dollar payment.

## The Need for Closeout Netting

It is not uncommon to have many different trades with an individual counterparty. Such trades may be simple or complex and may cover a small or wider range of products across different asset classes. Furthermore, trades may fall into one of the three following categories:

- Trades may constitute hedges (or partial hedges) so that their values should naturally move in opposite directions.
- Trades may constitute unwinds in that, rather than cancelling a transaction, the reverse (or mirror) trade may have been executed. Hence two trades with a counterparty may have equal and opposite values, to reflect the fact that the original trade has been cancelled. Although compression exercises can sometimes reduce such exposures (see later), such trades can otherwise exist for many years.
- Trades may be largely independent, e.g., from different asset classes or on different underlyings.

In light of the above points, it is rather worrying that from a legal point of view the loss on a counterparty defaulting is the *sum* of the exposures. Consider the case of a trade (trade 1) being cancelled via executing the reverse transaction (trade 2). Suppose there are two scenarios in that trade 1 and trade 2 can take the values +10 and −10, respectively, or vice versa. Table 10-1 shows the possible outcomes.

Whilst the total value of the two trades is zero (as it should be, since the aim was to cancel the original trade), the total exposure is +10 in both scenarios. This means that if the counterparty defaults, in either scenario there would be a loss due to having to settle the trade with the negative MtM but not being able to claim (either directly or via offsetting) the trade that has a

### The Case of KfW Bankengruppe ("Germany's Dumbest Bank")

As the problems surrounding Lehman Brothers grew ever-more apparent, most of Lehman's counterparties stopped doing business with the company. However, government-owned German bank KfW Bankengruppe made what they described as an "automated transfer" of €300m to Lehman Brothers literally hours before the latter's bankruptcy. This provoked an outcry, with one German newspaper calling KfW "Germany's dumbest bank." Two of the bank's management board members* and the head of the risk-control department were suspended in the aftermath of the mistake. Since the bank was government-owned, the transfer would have cost each German person around €4. The bank's total loss, including other deals with Lehman Brothers, was calculated to be nearer €600m.

*One has since successfully sued the bank for his subsequent dismissal.

**TABLE 10-1** Illustration of the Exposure of Two Equal and Opposite Trades with and without Netting

| | Scenario 1 | Scenario 2 |
|---|---|---|
| Trade 1 value | +10 | −10 |
| Trade 2 value | −10 | +10 |
| Total value | 0 | 0 |
| Trade 1 exposure | +10 | 0 |
| Trade 2 exposure | 0 | +10 |
| Total exposure (without netting) | +10 | +10 |

positive MtM. This is a rather perverse situation since any valuation system would show the above position as having zero MtM value, and furthermore, a market risk system would show the position as having zero market risk. Yet the counterparty credit exposure of the position is far from zero.

Bankruptcy proceedings are, by their nature, long and unpredictable processes. During such proceedings, likely counterparty risk losses are compounded by the uncertainty regarding the termination of proceedings. A creditor who holds an insolvent firm's debt has a known exposure, and while the eventual recovery is uncertain, it can be estimated and capped. However, this is not the case for derivatives where constant rebalancing is typically required to maintain hedged positions. Once a counterparty is in default, cash flows will cease and an institution will be likely to want or need to execute new replacement contracts.

## Closeout Netting

Closeout netting comes into force in the event of the default of a counterparty. Its aim is to allow a timely termination and settlement of the net value of all trades with that counterparty. Essentially, this consists of two components:

1. *Closeout.* The right to terminate transactions with the defaulted counterparty and cease any contractual payments.
2. *Netting.* The right to offset amounts[2] due at termination of individual contracts to determine a *net balance,* which is the sum of positive and negative transaction values, to determine a final closeout amount.

Closeout netting permits the immediate termination of all contracts between an institution and a defaulted counterparty and to offset the amount it owes a counterparty against the amount it is owed to arrive at a net payment. If the institution owes money, then it makes this payment, whilst if it is owed money, then it makes a bankruptcy claim for that amount. Closeout netting allows the surviving institution to *immediately* realise gains on transactions against losses on other transactions and effectively jump the bankruptcy queue for all but its net exposure, as illustrated in Figure 10-2. Without the ability to closeout their positions at the time a counterparty becomes insolvent, market participants would find themselves locked into contracts that fluctuate in value and are impossible to hedge (due to the uncertainty of future recovery).

Whilst payment netting reduces settlement risk, closeout netting is relevant to counterparty risk since it reduces pre-settlement risk. Netting allows counterparties to reduce the risk to each other via a legal agreement that becomes active if either of them defaults. Netting agreements are crucial in order to recognise the benefit of offsetting trades with the same counterparty.

Netting is a critical way to control the exposure to a counterparty across two or more transactions. Without netting, the loss in the event of default of a counterparty is the sum of the value of the transactions with that counterparty that have *positive MtM value.* This means that derivatives with a negative value have to be settled (cash paid to the defaulted counterparty) whilst those with a positive value will represent a claim in the bankruptcy process. Perfectly offsetting derivatives transactions or "mirror trades" with the same counterparty (as arises due to cancellation of a trade) will *not* have zero value if the counterparty is in default. The argument that the purpose of a trade was to cancel a previous one does not justify the netting of their values.

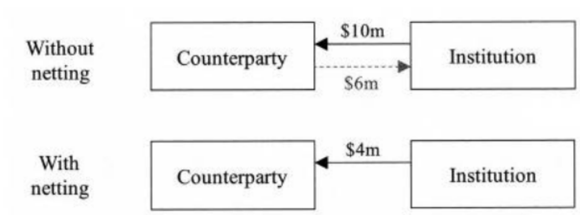



**FIGURE 10-2** Illustration of the benefit of closeout netting.

Without netting, the institution must pay $10m to the defaulted counterparty whilst losing some or all of the owed $6m. With netting, the institution is allowed to pay only the net amount of $4m, thereby gaining the $6m owed in entirety.

[2] The calculations made by the surviving party may be disputed later via litigation. However, the prospect of a valuation dispute and an uncertain recovery value does not affect the ability of the surviving party to immediately terminate and replace the contracts with a different counterparty.

**Example**

Consider five different transactions with a particular counterparty with current MtM given by +7, −4, +5, +2, −4. The total exposure is

+14 (without netting)
+6 (with netting)

**SPREADSHEET 10-1**

Simple Netting Example

To download Spreadsheet 10-1, visit http://www.cvacentral.com/books/credit-value-adjustment/spreadsheets and click Chapter 5 exercises.

Note that "set-off" is similar to closeout netting and involves obligations between two parties being offset to create an obligation that represents the difference. Typically, set-off relates to actual obligations whilst closeout netting refers only to a calculated amount. Set-off can be treated differently in different jurisdictions but is sometimes used interchangeably with the term closeout netting.

## Netting Sets and Subadditivity

We will use the concept of a "netting set," which will correspond to a set of trades that can be legally netted together in the event of a default. A netting set may be a single trade and there may be more than one netting set for a given counterparty. Across netting sets, exposure will always be additive, whereas within a netting set MtM values can be added.

A very important point is that within a netting set, quantities such as expected exposure and CVA are non-additive. Whilst this is beneficial, since the overall risk is likely to be substantially reduced, it does make the quantification of exposure and CVA (Chapter 15) more complex. This complexity arises from the fact that a transaction cannot be analysed on its own but must be considered with respect to the entire netting set.

## The Impact of Netting

Netting has been critical for the growth of the OTC derivatives market. Without netting, the current size and liquidity of the OTC derivatives market would be unlikely to exist. Netting means that the overall credit exposure in the market grows at a lower rate than the notional growth of the market itself. This has historically allowed dealers to build a large book on a limited capital base. The expansion and greater concentration of derivatives markets has increased the extent of netting steadily over the last decade such that netting currently reduces exposure by close to 90% (Figure 10-3). Note that netted positions are inherently more volatile than their underlying gross positions, which can create systemic risk.

Netting has some subtle effects on the dynamics of derivative markets. Suppose an institution wants to trade out of a position. OTC derivatives are often not liquid and readily tradable. If the institution executes an offsetting position with another market participant, whilst removing the market risk as required, they will have counterparty risk with respect to the original and the new counterparty. Netting means that executing the reverse position with the original counterparty offsets not only the market risk but also the counterparty risk. A counterparty knowing that an institution is heavily incentivised to trade out of the position with them may offer unfavourable terms to extract the maximum financial gain. The institution can either accept these unfavourable terms or

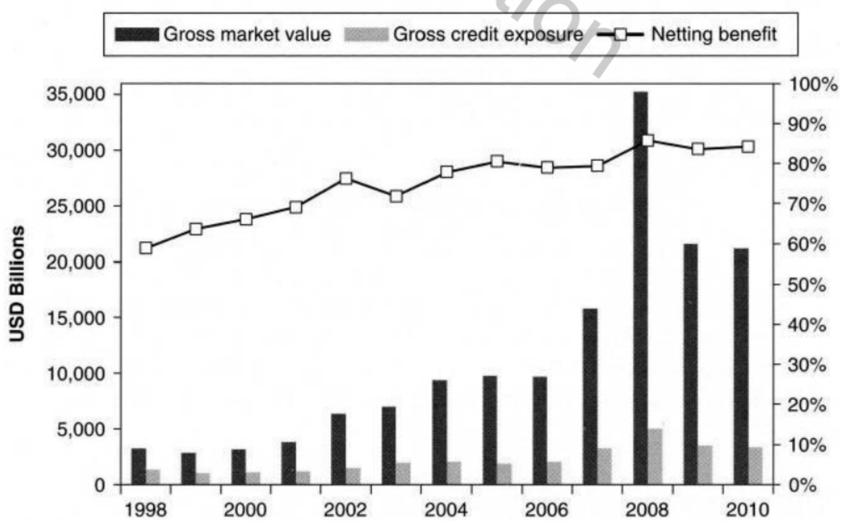



**FIGURE 10-3** Illustration of the impact of netting on OTC derivatives exposure.

The netting benefit is defined by dividing the gross credit exposure by the gross market value and subtracting this result from 100%.

*Source:* ISDA and BIS.

trade with another counterparty and accept the resulting counterparty risk.

The above point extends to establishing multiple positions with different risk exposures. Suppose an institution wants both interest rate and foreign exchange hedges. Since these trades are imperfectly correlated, by executing the hedges with the same counterparty the overall counterparty risk generated is reduced. This institution may obtain more favourable terms (for example, via a smaller CVA charge).

An additional implication of netting is that it can change the way market participants react to perceptions of increasing risk of a particular counterparty. If credit exposures were driven by gross positions then all those trading with the troubled counterparty would have strong incentives to attempt to terminate existing positions and stop any new trading. Such actions would likely result in even more financial distress for the troubled counterparty. With netting, an institution will be far less worried if there is no current exposure (MtM is negative). Whilst they will be concerned about potential future exposure and may require collateral, netting reduces the concern when a counterparty is in distress, which may in turn reduce systemic risk.

## Product Coverage

Some institutions trade many financial products (such as loans and repos as well as interest rate, foreign exchange, commodity, equity and credit products). The ability to apply netting to most or all of these products is desirable in order to reduce exposure. However, legal issues regarding the enforceability of netting arise due to trades being booked with various different legal entities across different regions. The legal and other operational risks introduced by netting should not be ignored.

Bilateral netting is generally recognised for OTC derivatives, repo-style transactions and on-balance-sheet loans and deposits. Cross-product netting is typically possible within one of these categories (for example, between interest rate and foreign exchange transactions). However, netting across these product categories (for example, OTC derivatives and repos) is usually not possible.

# TERMINATION FEATURES AND TRADE COMPRESSION

Whilst netting reduces OTC derivative exposure by almost an order of magnitude, there is still a need to find ways of reducing it still further. Typical ISDA netting agreements by their very nature operate bilaterally between just two counterparties. One idea is to take netting further and gain *multilateral* netting benefits via the cooperation of three or more counterparties. The first way in which this can be achieved is via trade compression.

Long-dated derivatives have the problem that, whilst the current exposure might be relatively small and manageable, the exposure years from now could have easily increased to a relatively large, unmanageable level. An obvious way to mitigate this problem is to have a contractual feature in the trade that permits action to reduce a high exposure. This is the role of break clauses and reset agreements.

## Reset Agreements

A reset agreement avoids a trade becoming strongly in-the-money by means of readjusting product-specific parameters that reset the trade to be more at-the-money. Reset dates may coincide with payment dates or be triggered by the breach of some market value. For example, in a resettable cross-currency swap, the MtM on the swap (which is mainly driven by FX movements on the final exchange of notional) is exchanged at each reset time in cash. In addition, the FX rate is reset to (typically) the prevailing spot rate. The reset means that the notional on one leg of the swap will change. Such a reset is similar to the impact of closing out the transaction and executing a replacement transaction at market rates and consequently reduces the exposure. An example of the impact on exposure is shown in Figure 10-4.

## Additional Termination Events

Additional termination events (ATEs) or so-called break clauses are useful in giving the possibility for an institution to terminate a trade prior to their counterparty's creditworthiness deteriorating to the point of bankruptcy. Under ISDA documentation, break clauses can be defined via "Additional Termination Events." A break clause may occur at one or more pre-specified dates in the future and may be used by one or both counterparties to the transaction. If the break is exercised, then the exercising party can terminate the transaction at its current replacement value. This introduces a complexity in terms of the definition of the replacement cost and whether it, for example, incorporates the credit quality

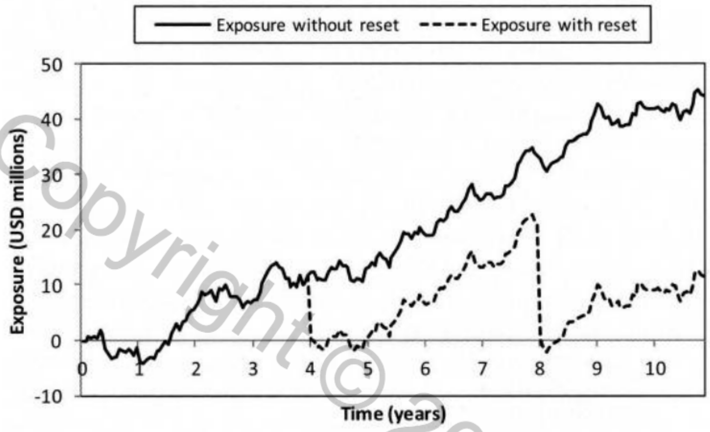



**FIGURE 10-4** Illustration of the impact of reset features on the exposure of a long-dated cross-currency swap. Resets can be seen to occur at 4 and 8 years.

of the replacement counterparty[3] and other aspects as discussed in Chapter 9.

A break clause may be considered particularly useful when trading with a relatively good credit quality counterparty on a long-maturity transaction (for example, 10 years or greater). Over such a time horizon, there is ample time for both the MtM of the transaction to become significantly positive and for the credit quality of the counterparty to decline. A *bilateral* break clause will often be relevant since both parties to the transaction may be in the same situation. The break clause will typically only be possible after a certain period (for example, 3 years) and possibly at pre-specified dates (for example, annually) thereafter.

A break clause goes one step further than a refix and actually specifies the termination of transactions. However, they are not always freely exercisable. Typically, such events can be defined to fall into three categories:

- *Mandatory.* This means that the transaction will definitely terminate at the date of the break clause.
- *Optional.* This means that one (unilateral break clause) or both (bilateral break clause) counterparties have the option to terminate the transaction at the pre-specified date(s).
- *Trigger-based.* This means that a trigger (typically a ratings downgrade[4]) must occur before the break clause(s) may be exercised. There is no ISDA standard ATE and events are therefore a result of negotiations between the parties concerned.

A mandatory break clause is simple to understand and is just a natural continuation of a reset feature (see Figure 10-5). However, as discussed in Chapter 9, there is a complexity in terms of the definition of the replacement cost and whether it, for example, incorporates the credit quality of the replacement counterparty. Optional and trigger-based break clauses lead to more subtle problems in terms of defining their benefits. The problem with optional break clauses is that they need to be exercised early before the counterparty's credit quality declines significantly and/or exposure increases substantially. Exercising them at the "last minute" is unlikely to be useful due to systemic risk problems.[5] However, clients do not generally expect break clauses to be exercised (especially before the aforementioned changes in credit quality and exposure) and banks, for relationship reasons, very rarely do choose to exercise them. Hence, banks have historically avoided exercise for the good of the relationship with the counterparty in question and, in hindsight, many bilateral break clauses have been gimmicks, which have not been utilised when they should have been. This is essentially part of a moral hazard problem, where front-office personnel may use the presence of a break clause to get a trade done but then later argue against the exercise of the break to avoid a negative impact on the client relationship. Banks should have clear and consistent policies over the exercise of option break clauses and the benefit they assign to them from a risk reduction point of view.

Trigger-based break clauses, typically using credit ratings,[6] create further problems. Firstly, unlike default

[3] This in turn should incorporate the value of any break clause in the replacement contract and so on to infinity.

[4] They may be based on as little as a 1-notch downgrade in a credit rating or a more substantial downgrade, for example, to sub-investment grade status.

[5] By this point, the counterparty is usually in severe financial distress and the exercise of the break clause achieves no more than catalysing a failure. This is especially problematic if many parties have similar types of break clause and exercise at similar times.

[6] Alternatives include decline in net asset value of funds, mergers, changes of management or "key person" events.

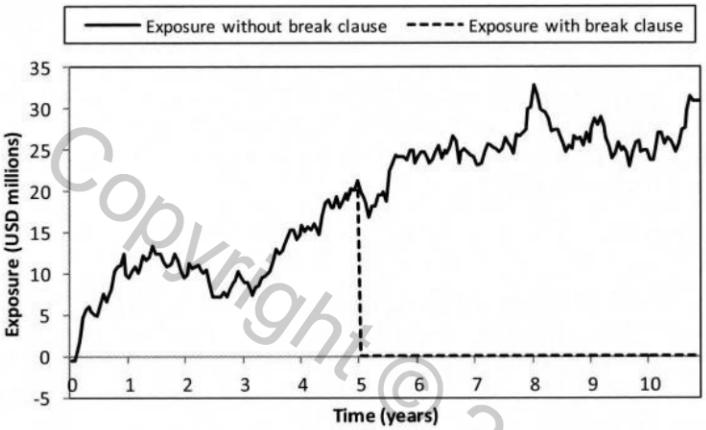



**FIGURE 10-5** Illustration of the impact of a reset feature on the exposure of a long-dated cross-currency swap which occurs at the 5-year point.

This example is relevant for a mandatory reset since it assumes termination will definitely occur.

probability, rating transitions probabilities cannot be implied from market data. This means that historical data must be used which is, by its nature, scarce and limited to some broad classification. Secondly, ratings have in many circumstances, especially during the financial crisis, been shown to be extremely slow in reacting to negative credit information.[7] Indeed, under the Basel III rules for capital allocation, no positive benefit for ratings-based triggers is allowed.

Prior to the financial crisis, break clauses were typically required by banks trading with some non-collateral-posting counterparties. More recently, various counterparties (for example, asset managers and pension funds) have demanded break clauses linked to banks' own credit ratings due to the unprecedented credit quality problems within the banking sector.

## Walkaway Features

A final point of note is that some OTC derivatives have been documented with "walkaway" or "tear-up" features. Such a clause effectively allows an institution to cancel transactions in the event that their counterparty defaults. They would clearly only choose to do this in case they were in debt to the counterparty. Whilst a feature such as this does not reduce credit exposure, it does allow an institution to benefit from ceasing payments and not being obliged to settle amounts owed to a counterparty. These types of agreements, which were common prior to the 1992 ISDA Master Agreement, have been less usual since and are not part of standardised ISDA documentation. However, they have sometimes been used in transactions since 1992. Whilst walkaway features do not mitigate counterparty risk *per se*, they do result in potential gains that offset the risk of potential losses.

Walkaway agreements were seen in the Drexel Burnham Lambert (DBL) bankruptcy of 1990. Interestingly, in this case counterparties of DBL decided not to walk away and chose to settle net amounts owed. This was largely due to relatively small gains compared with the potential legal cost of having to defend the validity of the walkaway

### The Dangers of Credit Rating Triggers

Certain debt contracts may contain an *acceleration* clause that permits the creditor to accelerate future payments (for example, repayment of principal) in the event of a rating agency downgrade, default or other adverse credit event. Acceleration features are clearly aimed at protecting creditors. However, the acceleration of required payments can precipitate financial difficulties and catalyse the insolvency of a firm. As such, these triggers can increase systemic risk.

Consider the case of American International Group Inc. (AIG), which failed in September 2008 due to liquidity problems. The liquidity problems stemmed from the requirement for AIG to post an additional $20 billion[8] of collateral (relating to CDS trades) as a result of its bonds being downgraded. An institution trading with AIG may have thought the requirement for AIG to post collateral due to a downgrade would provide a safety net. However, since the downgrade was linked to the extremely poor performance of AIG's positions and collateral would be required to be posted to many institutions, in retrospect it is unlikely that a feature such as this would do anything more than catalyse a counterparty's demise. Luckily (for them and their counterparties, if not the US taxpayer), AIG was bailed out but this story illustrates the limitation of any trigger linked to a credit rating change.

[7] One obvious extension of this idea is to create triggers based on more continuous quantities such as credit spreads. However, this can lead to death spiral effects.

[8] AIG 2008 Form 10-K.

agreements or the reputational cost of being seen as taking advantage of the DBL default.

Even without an explicit walkaway agreement, an institution can still attempt to gain in the event of a counterparty default by not closing out contracts that are out-of-the-money to them but ceasing underlying payments. Another interesting case is that between Enron Australia (Enron) and TXU Electricity that traded a number of electricity swaps that were against TXU when Enron went into liquidation in early 2002. Although the swaps were not traded with a walkaway feature, ISDA documentation supported TXU avoiding paying the MtM owed to Enron (AUD3.3 million) by not terminating the transaction (closeout) but ceasing payments to their defaulted counterparty. The Enron liquidator went to court to try to force TXU effectively to settle the swaps but the (New South Wales Supreme) court found in favour of TXU in that they would not have to pay the owed amount until the individual transactions expired (i.e., the obligation to pay was not cancelled but it was postponed).

Some Lehman counterparties chose (like TXU) not to closeout swaps and stop making contractual payments (as the ISDA Master Agreement seems to support). Since the swaps were very out-of-the-money from the counterparties' point of view (and therefore strongly in-the-money for Lehman), there were potential gains to be made from doing this. Again, Lehman administrators challenged this in the courts. U.S. and English courts came to different conclusions with respect to the enforceability of this "walkaway event," with the U.S. court[9] ruling that the action was improper whilst the English court[10] ruled that the withholding of payments was proper.

Any type of walkaway feature is arguably rather unpleasant and should be avoided due to the additional costs for the counterparty in default and the creation of *moral hazard* (since an institution is potentially given the incentive to contribute to their counterparty's default due to the financial gain they can make).

[9] The Bankruptcy Court for the Southern District of New York.

[10] High Court of England and Wales.

## Trade Compression and Multilateral Netting

Standard netting arrangements such as described previously in this chapter are undertaken *bilaterally,* i.e., between two institutions only. Whilst bilateral netting has a significant impact on reducing overall credit exposure, it is limited to pairs of institutions within the market. Suppose that institution A has an exposure to institution B, whilst B has the same exposure to a third institution C that has another identical exposure to the original institution A. Even using bilateral netting, all three institutions have exposure (A has exposure to B, B to C and C to A). Some sort of trilateral (and by extension multilateral) netting between the three (or more) institutions would allow the exposures to be netted further, as illustrated in Figure 10-6. Even non-matching exposures could be reduced to their lowest level, as also shown.

However, implementation of multilateral netting is not trivial. In addition to the operational costs, it would give rise to questions such as how losses would be allocated between institutions A and B if, for example, institution C were to default. Problems such as this mean that some membership organisation needs to be at the centre of multilateral netting. Typically, such an entity will be an exchange or clearing house that will handle many aspects of the netting process such as valuation, settlement and collateralisation. A disadvantage of multilateral netting is that it tends to mutualise and homogenise counterparty risk, reducing incentives for institutions to scrutinise the credit quality of their counterparties.

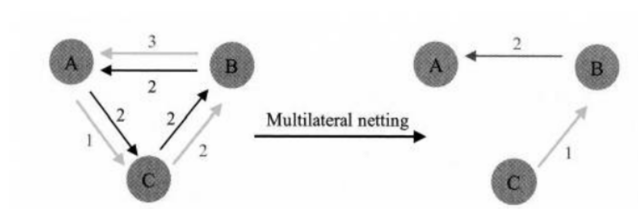



**FIGURE 10-6** Illustration of the potential exposure reduction offered by multilateral netting.

The black and grey exposures indicate positions in similar transactions, differing only in notional amount. The exposures in black are removed completely whilst those in grey are reduced by one unit.

A way to attempt multilateral netting without the complexity of a membership organisation such as an exchange or central counterparty is via trade compression. This has developed since OTC derivatives portfolios grow significantly through time but contain redundancies due to the nature of trading (e.g., with respect to unwinds). This suggests that the trades can be reduced in terms of number and gross notional without changing the overall risk profile. This will reduce operational costs but also minimise counterparty risk. A simple example is given in Table 10-2 for single-name CDS contracts.

Trade compression by its very nature needs the cooperation of multiple participants. Participants submit their relevant trades for compression, which are matched according to the counterparty to the trade and cross-referenced against a trade-reporting warehouse. Participants must also specify tolerances since, whilst the aim of compression is to be totally market risk- and cash-neutral, allowing some very small changes in PnL and risk profile can increase the extent of the compression possible. It is also important not to breach an institution's credit limit to a given counterparty. Based on trade population, redundancies and tolerances, unwinds are determined based on redundancies in the multilateral trade population. Once the proposed terminations and replacement trades are accepted by all participants, the process is finished and all trade terminations and replacements are legally binding.

Compression is subject to diminishing marginal returns over time as the maximum multilateral netting is achieved. It also relies to some degree on counterparties being readily interchangeable which implies they need to have comparable credit quality.

Companies such as TriOptima[11] provide compression services covering major OTC derivatives products such as interest rate swaps (in all global currencies), credit default swaps (single-name, indices and tranches) and energy swaps. This has been instrumental in reducing exposures in OTC derivatives markets, especially in rapidly growing areas such as credit derivatives.[12] The CDS market has made changes to promote compression, such as the adoption of standard coupons and maturity dates. We note that compression services can also be used in conjunction with central clearing.[13]

[11] www.trioptima.com

[12] For example, "TriOptima tear-ups cut CDS notional by $9 trillion," http://www.risk.net/risk-magazine/news/1505985/trioptima-tear-ups-cut-cds-notional-usd9-trillion. "CDS Dealers Compress $30 trillion in Trades in 2008," REUTERS, 12th January 2009.

[13] "TriOptima and LCH.Clearnet terminate SwapClear USD interest rate swaps with notional principal value of $7.1 trillion" http://www.lchclearnet.com/media_centre/press_releases/2011-08-04.asp.

**TABLE 10-2** Simple Illustration of Trade Compression for Single-name CDS Contracts

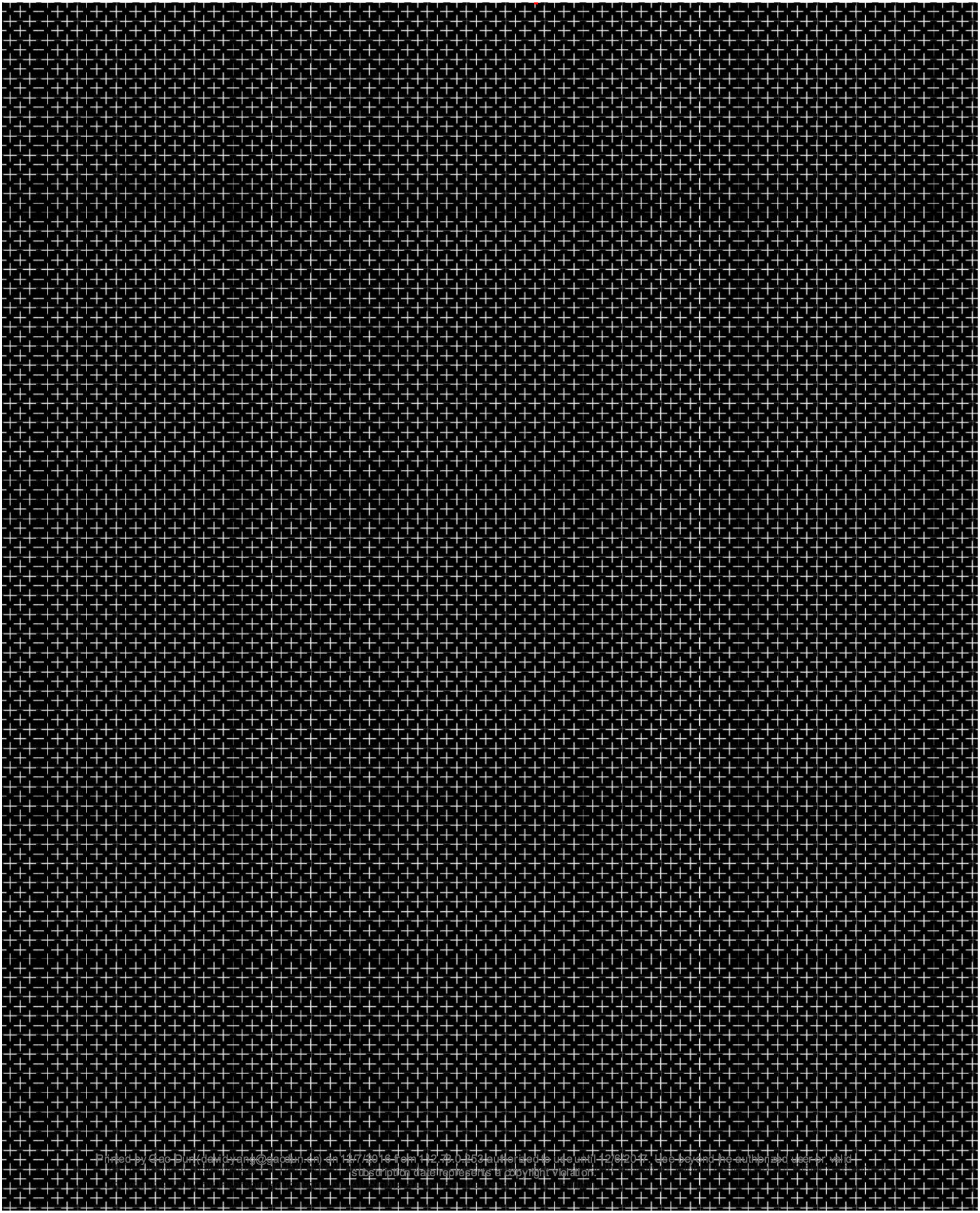
An institution has three contracts with the same reference credit and maturity but traded with different counterparties. It is beneficial to "compress" the three into a net contract, which represents the total notional of the long and short positions. This may most obviously be with counterparty A as a reduction of the initial trade although this may not be the case in practice. The coupon of the new contract is the weighted average of the three original ones. This can be also set to a standard value which will involve some PnL adjustment.

| Reference Credit | Notional | Long/Short | Maturity | Coupon | Counterparty |
|---|---|---|---|---|---|
| ABC Corp. | 40 | Long | 20/12/2015 | 200 | Counterparty A |
| ABC Corp. | 25 | Short | 20/12/2015 | 150 | Counterparty B |
| ABC Corp. | 10 | Short | 20/12/2015 | 325 | Counterparty C |
| **ABC Corp.** | **5** | **Long** | **20/12/2015** | **200** | **Counterparty A** |

## CONCLUSION

In this chapter, we have described the primary ways of mitigating counterparty risk via exposure. Closeout netting is a crucial way to control credit exposure by being legally able to offset transactions with positive and negative mark-to-market values in the event a counterparty does default. Reset features allow the periodic resetting of an exposure. Early termination events allow the termination of a transaction to mitigate an exposure combined with a deterioration of the credit quality of a counterparty, possibly linked to some event such as a credit ratings downgrade. Compression reduces gross notional and therefore also the associated net exposure.

In the next chapter, we discuss the use of collateral, which is the other main method for reducing credit exposure.



# Collateral

# 11



## Learning Objectives

After completing this reading you should be able to:

- Describe the rationale for collateral management.
- Describe features of a credit support annex (CSA) within the ISDA Master Agreement.
- Describe the role of a valuation agent.
- Describe types of collateral that are typically used.
- Explain the process for the reconciliation of collateral disputes.
- Explain the features of a collateralization agreement.
- Differentiate between a two-way and one-way CSA agreement, and describe how collateral parameters can be linked to credit quality.
- Explain how market risk, operational risk, and liquidity risk (including funding liquidity risk) can arise through collateralization.

*Excerpt is Chapter 5 of* Counterparty Credit Risk and Credit Value Adjustment, *Second Edition, by Jon Gregory.*

Distrust and caution are the parents of security.

—Benjamin Franklin (1706–1790)

# INTRODUCTION

Collateralisation (also known as margining) provides a further means to reduce credit exposure beyond the benefit achieved with netting and the other methods described in the previous chapter. Indeed, the use of collateral is essentially a natural extension of break clauses and resets. A break clause can be seen as a single payment of collateral and cancellation of the transaction. A reset feature is essentially the periodic payment of collateral to neutralise an exposure. Standard collateral terms simply take this further to much more frequent collateral posting. Collateral agreements may often be negotiated prior to any trading activity between counterparties or may be agreed or updated prior to an increase in trading volume or change in other conditions.

## Rationale for Collateral

Suppose that a netted exposure (sum of all the values of transactions with the counterparty) is large and positive. There is clearly a strong risk if the counterparty is to default. A collateral agreement limits this exposure by specifying that collateral must be posted by one counterparty to the other to support such an exposure. The collateral receiver only becomes the economic owner of the collateral if the collateral giver defaults. Like netting agreements, collateral agreements may be two-way which means that either counterparty would be required to post collateral against a negative mark-to-market value (from their point of view). Both counterparties will periodically mark all positions to market and check the net value. Then they will check the terms of the collateral agreement to calculate if they are owed collateral and vice versa. To keep operational costs under control, posting of collateral will not be continuous and will occur in blocks according to predefined rules.

> Collateral is an asset supporting a risk in a legally enforceable way.

Derivatives collateral is fundamentally different in both type and nature from the use of physical assets as security for debts. Secured creditors have a claim on particular assets, but their ability to realise the value of the assets is subject to delays in the bankruptcy process. It is possible for secured creditors to petition the bankruptcy court to release their security but this is a complicated process (e.g., see Baird, 2001). In contrast, collateral posted against derivatives positions is, in most cases, under the control of the counterparty and may be liquidated immediately upon an "event of default." This arises due to the laws governing derivatives contracts and the nature of the collateral (cash or liquid securities).

Exposure, in theory, can be completely neutralised as long as a sufficient amount of collateral is held against it. However, there are legal obstacles to this and issues such as rehypothecation (or relending, discussed in detail later). This was a significant issue in the Lehman Brothers bankruptcy of 2008.

The motivation for collateral management is clearly to reduce counterparty risk but can be summarised in more detail as follows:

- To reduce credit exposure so as to be able to do more business. To maintain exposures within credit lines and not have to cease trading with certain counterparties.
- To enable one to trade with a particular counterparty. For example, ratings restrictions may not allow uncollateralised credit lines to certain counterparties.
- To reduce capital requirements. For example, Basel regulatory capital rules give capital relief for collateralised exposures.
- To give more competitive pricing of counterparty credit risk.

The fundamental idea of collateral management is very simple in that cash or securities are passed from one counterparty to another as security for a credit exposure. However, effective collateral management is much harder than one might initially think, and there are many pitfalls along the way. In particular, it is important to note that, whilst collateral can be used to reduce credit exposure, it gives rise to new risks, such as market, operational and liquidity. All of these risks must be correctly understood, quantified and managed.

## Analogy with Mortgages

A collateralised position is analogous to a mortgaged house in many ways. As such, it is useful to consider the risks that a mortgage provider faces when making such a loan for their client to purchase a property. The risk that