Modeling Credit Risk and Pricing Credit Derivatives

by

Martin P. Wolf

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MODELING CREDIT RISK AND PRICING CREDIT DERIVATIVES

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von
Martin WOLF

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1 Introduction

Banks are financial intermediaries originating loans and consequently facing credit risk. Credit risk can be defined as the risk of losses caused by the default or by the deterioration in credit quality of a borrower. Default occurs when a borrower cannot meet his key financial obligations to pay principal and interest.

Banks increasingly recognize the need to measure and manage the credit risk of the loans they have originated not only on a loan-by-loan basis but also on a portfolio basis. A precondition for diversification after the origination of the loans is their transferability. But as it is wellknown transferring credit risk of loans is difficult due to severe adverse selection and moral hazard problems. That is why the use of existing tools like loan sales has not been very successful in transferring the credit risk on a broad scale. However, in recent years, the development of markets for credit securitization and credit derivatives has provided new tools for managing credit risk.

Credit derivatives are often described as "synthetic loans" which reflects only too narrowly their common use and enormous potential. More broadly defined credit derivatives are sophisticated financial instruments that enable the unbundling and intermediation of credit.

A risk seller, which is the party seeking credit risk protection, may want to reduce exposures while maintaining relationships that may be endangered by selling their loans, reduce or diversify illiquid exposures, or reduce exposures while avoiding adverse tax or accounting treatment. A risk buyer, the party assuming credit risk, may want to diversify credit exposures, get access to credit markets which are otherwise restricted by corporate statute or off-limits by regulation, or simply exploit arbitrage pricing discrepancies, for example resulting from perceived mispricing between bank loans and subordinated debt of the same issuer.

The pricing and management of credit derivatives requires more sophisticated credit risk models. With the advent of the market-based models the mathematical modeling of the pure interest-rate risk in the bond market is coming closer to a generally accepted benchmark (see Sandmann and Sondermann (1997), p.119). Of the remaining risk components in the bond market, credit risk is the largest unresolved modeling problem.

The valuation of credit derivatives changed the focus of many credit risk models. Instead of developing a pricing framework which yields the fair prices for defaultable bonds, now these bonds are to be taken as input to derive prices for more exotic derivative instruments. Therefore, models had to be developed that had this degree of flexibility. (see Schönbucher (2000), p.3)

The thesis for diploma (in the rest of this paper simply called thesis) starts with a short description of the credit derivatives' place in the credit risk management. Then it proceeds by outlining the basic forms of credit derivatives, their applications, and their contract elements. Chapter 4 gives a first impression of the two common pricing frameworks, whereas chapter 5 describes the Duffie-Singleton approach in more detail. Chapter 6 applies this framework and examines the importance of the different parameters on the outcomes of the simulation. Finally, chapter 7 gives examples for the valuation of credit-risky securities.

2 Credit Risk Management

Over the years, the importance of understanding credit risk has slowly spread from loan departments of various financial institutions to a broad array of capital market participants. Credit risk is the risk of loss on a financial or non-financial contract due to the counterparty's failure to perform on that contract. Credit risk's two components are default risk and recovery risk. Default risk is the possibility that a counterparty will fail to meet its obligation, and recovery risk is the possibility that the recovery value of the defaulted contract may be less than its promised value (see Skora (1998a), p.1).

Banks are not the only entities affected by credit risk. Investors who purchase corporate, municipal, or sovereign bonds also face credit risk. Even if the likelihood of default of a given bond issuer is small, an investor can still face the possibility of a bond being downgraded by a rating agency. Rating downgrades often result in an immediate drop in value of the bond. Note that this not only hurts the bondholders, it also increases the cost of financing for the issuer who has been downgraded. Given these risks, one might expect formal models of credit risk valuation to be prevalent in the various bond markets. However, this is not the case.

2.1 Credit Risk versus Market Risk

Credit risk has both similarities and differences to other risks such as interest rate risk or equity risk. These latter risks are usually referred to as market risk. Credit risk can be traded just as interest rate risk may be traded. A corporate bond or emerging market bond is an excellent mechanism for taking credit exposure to a particular issuer. The price of the bond is affected by changes in the credit risk or perceived credit risk of the issuer. Of course, a bond is not a perfect instrument for trading credit risk: its price is also affected by changes in the general level of interest rates.

On the other hand, credit risk has many properties that make it different from market risk – especially for modeling purposes. A US treasury bond is the quintessential example of a security that has interest rate risk, but no credit risk. The treasury bond markets are liquid, so the Treasury rate is set through the trading activities of thousands market-makers and

end-users. As a result one may take both long and short positions in the treasury bond market of almost any tenor while incurring small transaction costs.

In contrast to the treasury bond market, markets for credit risky debt are illiquid. The illiquidity is due in part to the size of the credit market. The market of credit risky debt is segmented – each corporation issues its own debt which trades at prices representing the investors' perceptions for that particular corporation. As a result, instruments that would allow one to assume the credit risk of a particular corporation at a particular tenor may simply not exist; sometimes those that do exist either do not trade or trade for large transaction costs.

A second difference between market risk and credit risk is that changes in credit risk often cause the price of the associated debt instrument to “jump”. Moreover, that jump can be very large, particularly when it is caused by default. At default the recovery value can be a small fraction of the face value of the debt instrument; furthermore, the recovery value is highly uncertain and may only be determined after a negotiation process (see Skora (1998a), p.3).

2.2 Methods of Credit Risk Management

In years past, the intuition of the participants in the corporate bond market provided an informal model of credit risk which dictated the spread over treasuries that bonds of differing credit ratings were traded at. Historically, banks have dealt with credit risk by requiring borrowers to meet certain underwriting standards. This is done so that the bank can acquire debt that has a low probability of default. In addition, banks slowly learned that they could diversify their credit risk exposure by making different types of loans in different geographic regions.

2.2.1 Risk Transfer in the Cash Market

Many types of credit risks cannot be sold in the cash market. Also when diversifying concentrations in a credit portfolio, suitable assets may not be readily available. Reasons why unacceptable credit risks cannot be discarded or diversified include the following (see Lloyd (1998), p.3):

- Lack of liquidity: Instruments such as private placements and receivables cannot easily be traded in the market.
- Relationship concerns: Selling exposures may be harmful to client relationships.
- Lack of availability of credit assets for all maturities.
- Inability to obtain the exact return and risk profile sought.
- High financing costs or risk of short squeeze associated with short sale of assets.
- Tax, accounting and regulatory issues.

2.2.2 Risk Transfer with Credit Derivatives

Managing credit risk with credit derivatives has the advantage that they can be held off balance sheet and do not require funding. Due to their high flexibility credit derivatives can be structured according to the endusers' needs. Furthermore, since derivatives are over-the-counter contracts, transactions are confidential. Finally speed of settlement and liquidity are reasons why credit derivatives are a better alternative to the reinsurance market (see Lloyd (1998), p.4). Chapter 3 gives a more detailed description of these instruments.

2.2.3 Regulatory Treatment of Credit Derivatives

In reviewing credit derivatives, examiners are considering the credit risk associated with the reference asset as the primary risk, as they do for loan participations or guarantees. A banking organization providing credit protection through a credit derivative can become as exposed to the credit risk of the reference asset as it would if the asset was on its own balance sheet. Because of that, banking organizations providing credit protection through a credit derivative should hold capital and reserves against their exposure to the reference asset. This broad principle holds for all credit derivatives, except for credit derivative contracts that incorporate periodic payments for depreciation or appreciation, including most total rate of return swaps. Here the guarantor can deduct the amount of depreciation

from the notional amount (see Board of Governors of the Federal Reserve System (1996), p.2).

Furthermore, examiners must ascertain whether the amount of credit protection a beneficiary receives by entering into a credit derivative is sufficient to warrant treatment of the derivative as a guarantee for regulatory capital and other supervisory purposes. Those arrangements that provide virtually complete credit protection to the underlying asset are considered effective guarantees for purposes of asset classification and risk-based capital calculations. If the reference asset is not identical to the asset actually owned by the beneficiary this incomplete protection has to be considered in the risk-based capital calculations. In addition, the banking organization offsetting the credit exposure is obligated to demonstrate to examiners that there is a high degree of correlation between the two instruments; the reference instrument is a reasonable and sufficiently liquid proxy for the underlying asset so that the instruments can be reasonably expected to behave in a similar manner in the event of default; and, at a minimum, the reference asset and underlying asset are subject to a mutual cross-default provisions amount (see Board of Governors of the Federal Reserve System, p.6).

3 Credit Derivatives – Structures and Applications

3.1 Definition

Credit derivatives are off-balance sheet arrangements that allow one party (the beneficiary) to transfer the credit risk of a reference asset, which it often actually owns, to another party (the guarantor). This arrangement allows the guarantor to assume the credit risk associated with the reference asset without directly purchasing it. In exchange the guarantor receives a premium. The credit derivative's payoff depends on:

- the value of the reference asset or
- the entry of the credit event or
- the size of a predefined credit spread or
- a change in credit rating.

Credit derivatives can be based on a single or a number of borrowers or even a broad based index. In the case of the credit event, it can be agreed upon in the contract, if the payment is made in cash or in form of physical settlement of the underlying instrument (see Hüttemann (1998), p.55).

A more general description is given by Frank Iacono (1996): “A credit derivative is based on the credit performance of some credit sensitive asset or assets. Credit performance typically is measured

- by yield or price spreads relative to benchmarks,
- by credit ratings or
- by default status.”

3.2 Classification

For each type of credit risk, both option-based and forward-based (swap) products exist. One structural dimension unique to credit derivatives is the trigger or payoff variable, the other dimension is the type of the product (swap, forward or option contract) which is used to manage credit risk. The following table gives an overview classified by credit event and the structural dimension:

BASIC FORMS	Structural Dimension			
Credit Event	Options	Swaps	Forwards	Structured Notes
Changes in Credit Spread	Credit Spread Option	Credit Spread Swap/ Total Return Swap	Credit Spread Forward	Credit-Linked Note
Change in Market Value / Rating	Credit Event Option	Credit Event Swap/ Total Return Swap	Credit Event Forward	Credit-Linked Note
Default	Credit Default Option	Credit Default Swap		Credit-Linked Note

Table 1: Classification of Credit Derivatives[1]

3.2.1 The Transfer of Default Risk

Credit Default Option

Through a credit option, a bank or investor can take over the risk of a single company without having a credit relationship. It will receive an option premium in exchange. Depending on the compensation three types of put options can be distinguished:[2] a default digital put pays a lump sum in case of default, the default put pays the difference of the value of a defaulted asset to the reference asset, and the credit put enables the holder to sell a defaultable asset to a specified price also if no default took place.[3] The option is exercised by the referring party and pays a certain compensation. The following representation shows the structure of credit default options:

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1 Own illustration on basis of Kässbohrer (1998), p.14

2 See chapters 7.3, 7.5, and 7.8 for a description of the valuation of these instruments.

3 Therefore, the credit put option is also suitable to lay off both, credit spread risk and interest rate risk.

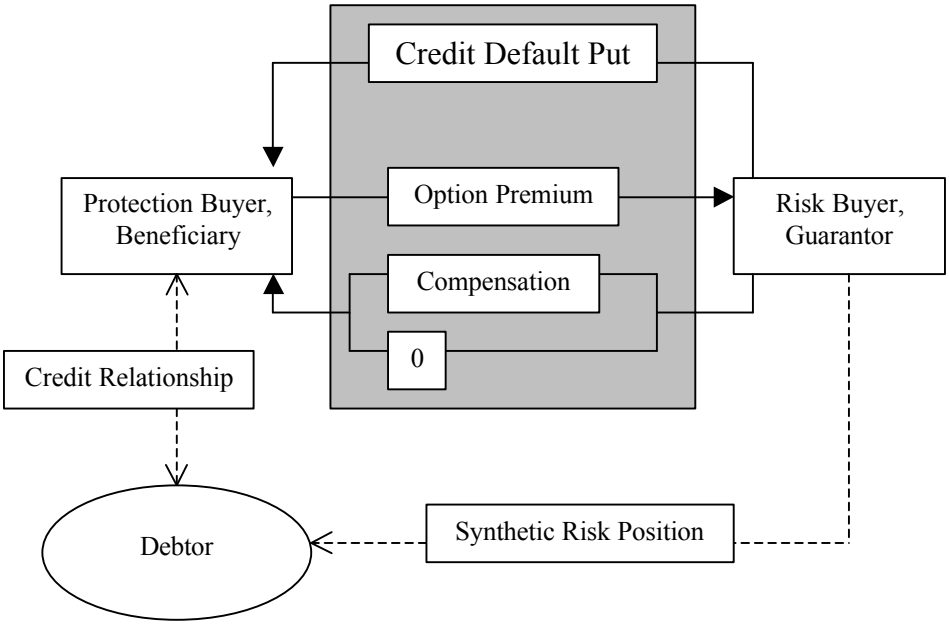

Illustration 1: Credit Default Option[4]

The payment profile of a plain credit put option can be plotted as follows:

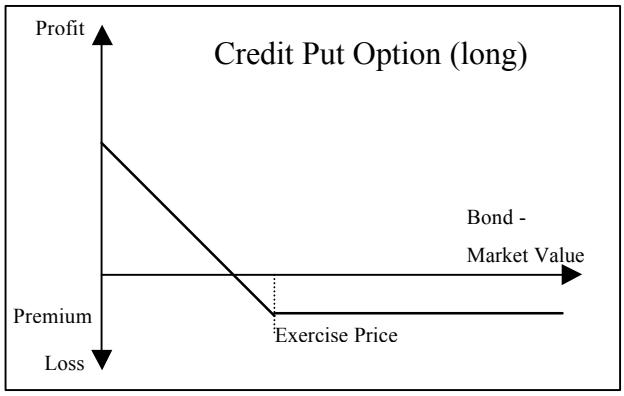

Illustration 2: Payment Profile of a Credit Put Option[5]

Credit Default Swap

The credit default swap is the most straightforward type of a credit derivative. It is an agreement between two counterparties that allows one counterparty to be long a third-party credit risk, and the other counterparty to be short the credit risk. Explained another way, it is a transaction where one party makes periodic payments in exchange for receiving a specified payment if a predetermined credit event occurs (see Lloyd (1998), p.3). In the

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4 Own illustration on basis of Bank of England (1996), p.6 and Kässbohrer (1998), p.15

5 Own illustration on basis of Kässbohrer (1998), p.15

event of the specified credit default, the hedger delivers to the swap counterparty a pre-specified reference asset (for example a bond issued by the defaulted borrower though it can also be loans, swaps, trade receivables, ...) and the counterparty pays the hedger par.

While there is no default event, the hedger pays the swap counterparty a spread derived from the Libor spread received by an investor in the underlying obligation in the cash or asset-swap market. The construction of a credit default swap looks similar to an option with the difference that the risk seller has to pay the premium periodically.[6]

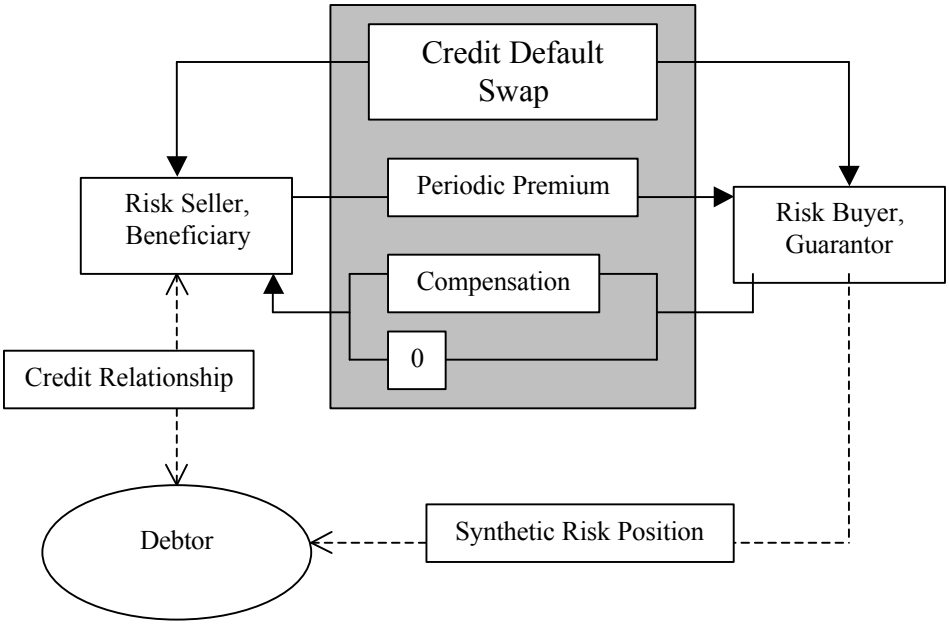

Illustration 3: Credit Default Swap[7]

Strongly related to this instrument are the letter of credit (LC) and the bond insurance. Under a LC, the issuer pays the bank an annual fee in exchange for the bank's promise to make debt payments on behalf of the issuer, should the issuer fail to do so. Since a bond insurance is also undertaken by the issuer of a bond, again the issuer pays the insurer the premium, who guarantees performance on the bond.

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6 This is also true for the valuation as it can be seen in sections 7.4 and 7.5.

7 Own illustration

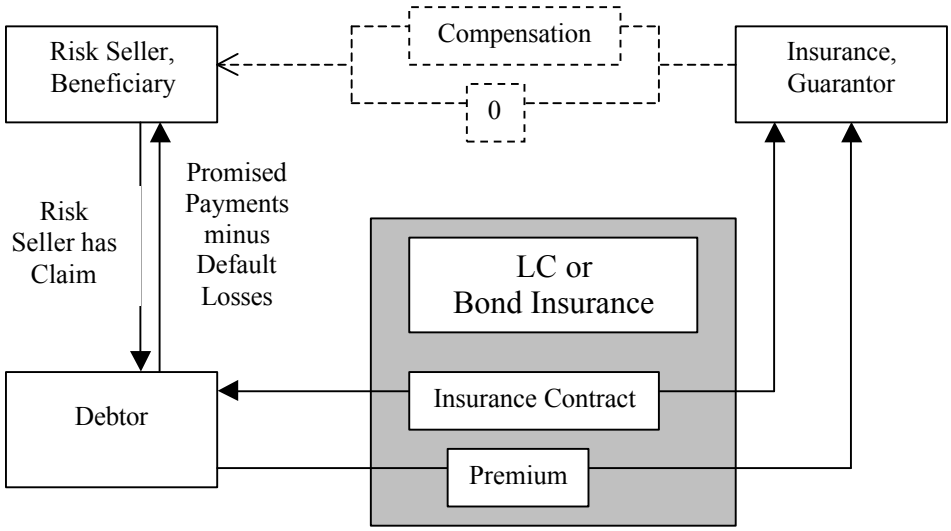

Illustration 4: Letter of Credit and Bond Insurance[8]

Credit Linked Note

A credit linked note is a structured note with an embedded credit derivative. Unlike a credit derivative, a credit linked note is an on-balance sheet transaction. An investor holding a bond can purchase a credit linked note in which the coupon payments and the amount of principal paid at the note's maturity are linked to default events. The buyer of the credit linked note holds a short put option on the defaultable debt. For this additional risk the investor receives Libor plus a premium. With this credit linked note, the investor takes over the synthetic risk position of the reference credit. However, he is also subject to the credit risk of the issuer of the credit linked note.

The advantage for the seller of the risk in this contract is, that she has no exposure to the institution that assumes the default risk. The buyer of the notes simply gets less principal back or a lower coupon. The risk seller holds a long put on the defaultable bond when selling the credit linked note.

Because of the higher risk of the risk buyer a company with its own capital equipment which distributes the credit linked notes can be set up, which then is called special purpose vehicle. In this case issuer and risk seller do not have to be identical persons.

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8 Own illustration

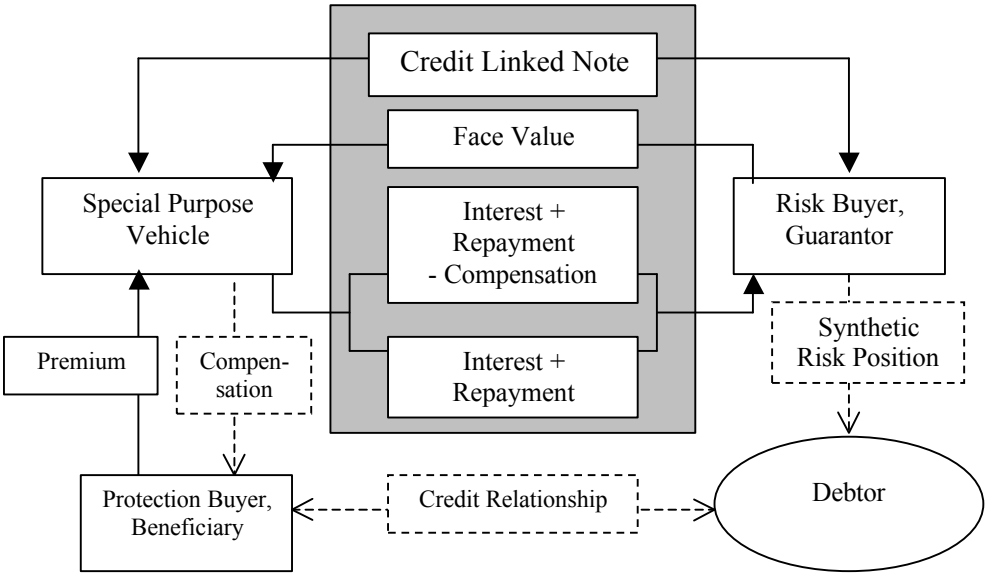

Illustration 5: Credit Linked Note and Special Purpose Vehicle[9]

3.2.2 The Transfer of Credit Spread Risk

Credit Spread Options

Credit spread options, also called differential options, protect the insuring party against an unfavorable development of the credit spread of two assets with same maturity but different credit risk. In a spread put option, one party pays a premium for the right to sell a bond to a counterparty at a certain spread at a certain time in the future. The credit spread is the yield differential between the reference credit and a predetermined benchmark rate (see Lloyd (1998), p.12). Thus, in a credit spread derivative, the payment is based on the movement of the value of one reference credit against another.

The buyer of a credit spread put makes a profit if the credit spread increases as a result of a decline in credit quality.[10] The buyer of a credit spread call believes in a future improvement in credit quality. If the credit spread contracts he will make a profit.

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[9] Own illustration on basis of Kässbohrer (1998), p.19

[10] Equation (88) on page 93 describes the payoff function of a credit spread put option.

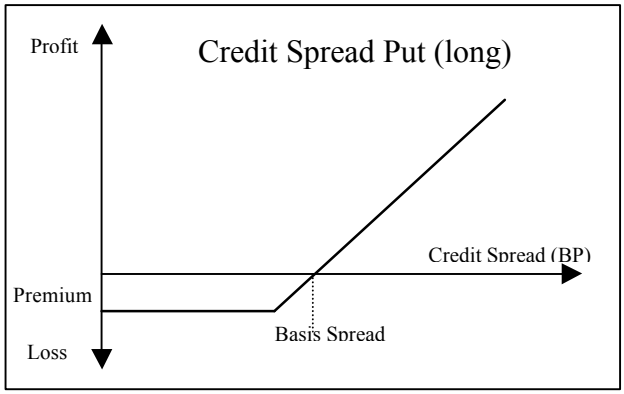

Illustration 6: Credit Spread Put Option[11]

A ratings downgrade option is sometimes embedded in bond structures. If a specified company's rating is downgraded the option pays out a specific amount. However, the relationship between spread and rating is unstable and does not guarantee enough compensation for the reduction in bond price.

Credit Spread Swaps and Forwards

In a credit spread forward contract, one party agrees to buy an asset from another party at a certain spread on a given date in the future. Whereas, an option needs not to be exercised, a swap or forward is a binding contract. The difference between a credit spread option and swap is how the premium is paid. Options on the one hand require an up-front payment, the premium of the swaps on the other hand consists of periodic payments.

Total Return Swap

The total return swap is an agreement in which the coupon and any capital appreciation on an instrument such as a bond are exchanged for a Libor-linked payment plus any depreciation in the capital value of the underlying asset. Hence, a total return swap periodically marks to market the underlying loan or bond. There is no exchange of principal or ownership and funding of the underlying asset is unchanged. This is also the difference to a repro which involves initial and final exchange of securities. If the swap maturity matches that of the reference asset it is simply a synthetic version of the asset that

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11 Own illustration on basis of Kässbohrer (1998), p.15

allows the holder to go long or short easily and without funding. If it is not, then the swap is a synthetic asset (see Parseley (1997), p.83).

For example, any positive change in value is paid by the premium payer (the bank) to the default risk holder (the swap counterparty). Any negative change is paid by the default risk holder to the premium payer. The bank paying the premium in this kind of swap is effectively warehousing a loan, renting out its balance sheet while transferring the economic value of the loan to a third party. The motivation behind this type of transaction is a need to get rid of an asset without entering a physical transaction that might upset the borrower (see Parseley (1996), p.31).

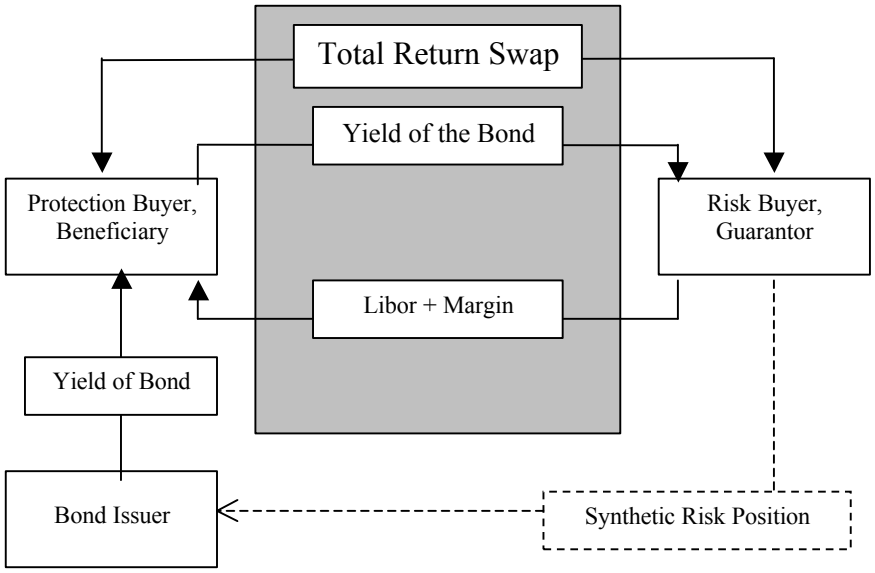

Illustration 7: Total Return Swap[12]

3.2.3 Exotic and Hybrid Instruments

Basket Credit Swap and Note

In addition to the standard credit derivative products, such as credit default swaps and total return swaps based upon a single underlying credit risk, many new products are now associated with a portfolio of credit risks. A typical example is the product with payment contingent upon the time and identity of the first or second-to-default in a given credit risk

12 Own illustration on basis of Kässbohrer (1998), p.16

portfolio. Variations include the instruments with payment dependent upon the cumulative loss before a given time in the future.

Basket Credit Derivatives can be classified into three broad categories (see Li, p.1):

a) Payment associated with the total loss over a fixed period of time:
This product has a contingent payment based upon the total loss of a given credit portfolio over a fixed time horizon, such as one year. Suppose L_t is the cumulative total loss of a given credit portfolio at a prefixed time t in the future, such as 1 year, and D is the deductible. The payoff function for this instrument at time t is

$$P = \begin{cases} 0, & \text{if} \quad L_t \le D, \\ L_t - D, & \text{if} \quad L_t \ge D. \end{cases}$$

b) Payment is associated with the cumulative loss across time:
Here the payment starts if the cumulative loss becomes larger than a lower limit L, and the payment continues after this point whenever new loss occurs until the cumulative loss reaches an upper limit H. Here an example for a basket derivative over five years with a lower limit of L = \$15m and H = \$30:

	Year 1	Year 2	Year 3	Year 4	Year 5
Loss	\$10m	\$13m	\$8m	\$0m	\$19m
Cumulative loss	\$10m	\$23m	\$31m	\$31m	\$50m
Payment	\$0m	\$8m	\$8m	\$0m	\$14m

Table 2: Basket Credit Derivative with Cumulative Loss across time

c) Payment is associated with the time and identity of the default:
The payment of this product depends upon the time and identity of the first or the first few defaults of a given credit portfolio, i.e. a Portfolio manager chooses a portfolio of three credit risks of face values \$100, \$150 and \$200 million, respectively, and buys credit protection against the first-to-default of the portfolio. If one of the credit defaults, she receives the face amount of the defaulted asset, delivers the defaulted asset to the first-to-default protection seller, and the credit default swap terminates.

Sovereign Risk Option

These options allow investors to hedge all types of risks involving country or sovereign risks, such as currency restrictions, confiscation, civil war or expropriation. Banks function as intermediaries between companies seeking protection from these risks and investors, which want to invest off-balance in emerging markets. They can be modeled similar to credit default options (see Thym (1998), p.10).

Convertibility Risk Option

A convertibility risk option is generally based on emerging market currencies. This option gives the buyer the right to exchange a particular currency for dollars or some other hard currency, if events such as foreign exchange controls lead to inconvertibility of the local currency.

3.3 Contract Elements

3.3.1 Reference Asset

The contract has to include a reference asset, which is the criterion for the entry of a credit event as well as the measure for the amount of the compensation. A reference asset is only required when the deliverable obligations are limited to one asset and if there is cash settlement or materiality. In this case the asset must be liquid and widely traded. If the purpose of the credit derivative is mainly hedging of credit risk, the correlation between the actual loss of the beneficiary and the devaluation of the reference asset should be high i.e. a bank can reinsure the risk of default by buying puts on the borrowers bonds with a similar ranking.

3.3.2 Credit Event

The claim for a compensation emerges, if the specified credit event occurs within the term of the credit derivative. Credit events can be a failure to pay, waiver, restructuring, bankruptcy, cross-default, or a delayed payment. However, also a less significant decrease in credit quality can lead to the entry of the credit event, i.e. a rating downgrade or an

increase of the credit spread can be used as suitable measures. In this case a strike level for credit spreads that has to be exceeded may apply.

3.3.3 Compensation

On entry of the credit event, the compensation can be made in form of a cash or a physical settlement. The credit event payment in cash may be:

- payment of par value in exchange for delivering the reference asset
- payment of a pre-determined fixed amount
- payment of par less the recovery value.

If the contract parties agree on a physical settlement, the compensation in case of a credit event is made in the form of a delivery of a specified other asset in exchange of the defaulted asset.

3.3.4 Premium

In exchange for the guarantee a premium is paid by the beneficiary. In case of an option the payment is made at the beginning of the contract term, in case of a swap the premium is paid periodically until the time of the credit event or the maturity date of the credit swap, whichever is first (see Board of Governors of the Federal Reserve System (1996), p.2).

3.3.5 Notional Amount

The nominal value is determined by the amount of risk that is being transferred and thus, the nominal value is a result of the protection seeked by the one party and the risk exposure accepted by the other.

3.3.6 Term of the Contract

The term of many credit derivative transactions is shorter than the maturity of the underlying asset and, thus, provides only temporary credit protection to the beneficiary (see Board of Governors of the Federal Reserve System (1996), p.3). If the credit event

enters before the end of the term, depending on the contract, the positions can be settled immediately or can be kept up until maturity and finally settled.

3.4 Standardized Documentation

Until 1999, in Europe, only in Germany, France and the UK have regulators taken the trouble to lay down a framework for credit derivatives transactions. One major problem is the issue of documentation. Standardized and generally accepted documentation is useful and important in various ways: it can reduce legal risk, especially in cross-border transactions, i.e., by providing clear and precise terminology and definitions and reducing risk of incompatibility of laws of different jurisdictions, and it enhances market transparency by reducing confusing variety of documentation.

The International Swaps and Derivatives Association (ISDA), which, through various publications, has been considered a trendsetter in the derivatives arena by developing master agreements, has developed standard documentation for some types of credit derivatives. With eight different definitions of credit events that could have an impact on the transaction – bankruptcy, credit event upon merger, cross acceleration, cross default, downgrade, failure to pay, repudiation and restructuring – the documentation provides a framework for future transactions. One of the principal aims of ISDA in developing the definitions was to promote legal certainty in the market for credit default products. Nevertheless it has to be recognized, that credit involves more variables than, say, interest rates and thus the credit derivatives market will never be as uniform in its procedures as the interest rate derivatives market.

3.5 The Application of Credit Derivatives

3.5.1 Portfolio Diversification

Credit derivatives allow access to previously unavailable credits. They can be used to diversify across a range of borrowers in different regions to gain exposure to an asset without owning it. From a risk management perspective the optimal portfolio to aim for is well diversified and non-lumpy, but business strategies which focus on core clients create the exact opposite portfolio. Many financial institutions traditional approach to the credit