A Guide to the CDS Package

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1 Introduction

Over the past three decades, **credit derivatives** have become increasingly common tools for finanical institutions that wish to pass on **credit risk** to investors who accept that risk for a premium, or fee. To put it simply, credit risk is the possibility that a borrower will default on his or her loan. In the modern financial world, there are many types of credit derivatives, including collaterized debt obligations (CDOs) and collaterized loan obligations (CLOs). In this vignette, we will focus on **credit default swaps** (CDSs), a type of credit derivative that has become quite popular among pension funds, hedge funds, and investment banks, among other financial institutions (see Figure 1). We will explain the mechanics of this financial product and show how the **CDS** package can be used to manipulate and calcuate relevant CDS information.

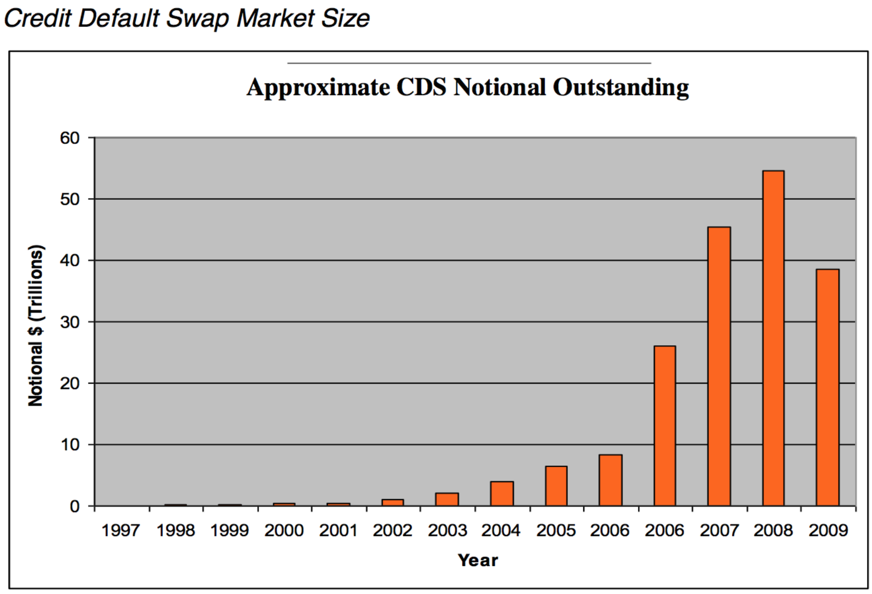

Figure 1: CDS notional outstanding from 1997-2009.

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CDSs originated in the late 1980s and were popularized by a team at J.P. Morgan that included Blythe Masters (Lenzner, 2009; Lanchester, 2009). The CDS markets have grown exponentially over the past decade when financial institutions used CDSs to hedge against credit risk exposure. Many different types of CDSs have since emerged including basket default swaps (BDSs), index CDSs, credit-linked notes, etc. (Kallianiotis, 2013). In the **CDS** package, we focus on calculations related to single-name, or corporate, credit default swaps.

2 Fixed Income Securities and Credit Risk

CDSs are used for the purpose of hedging against the **credit risk** associated with **bonds** or **fixed income**. Before we approach understanding how CDSs work, we must understand the mechanics of a standard coupon bond and its associated risks.

2.1 Bond Basics

Consider the following example: let's say that there exists a pension fund manager who has to allocate her clients' money (a total sum of $10 million dollars). Pension funds are usually risk-averse investors who seek to minimize their losses, even if that ultimately creates lower returns on investments. Pension funds also have to constantly return money to their clients, so they strive to hold assets that pay regular interests to the owner. Pension funds also want to invest in assets that are **liquid** i.e. whose sales do not affect their prices. In such a scenario, coupon bonds seem like an attractive investment.

A **coupon bond** is an agreement in which one party lends money to another party in exchange for that same sum of money, plus period **coupon payments**, at a future date. Since the bond pays a regular interest to the bondholder, it can also be termed as **fixed income**. A major advantage of holding bonds over shares (also known as equity) is that bondholders are compensated before shareholders in the case of liquidiation. Furthermore, bonds can be categorized as "senior" or "junior"; there exist many other classifications, but we'll stick to these two for now. As the terms suggest, senior bonds usually have the greatest seniority in the issuer's capital structure and are repaid before junior bonds in the case of default.

To understand the different variables used to determine cash flows and bond pricing, let's look at actual data for an Alcoa Inc. bond that will mature, or be paid out, five years from now—in other words, the bond has a **maturity date** of five years. This data has been retrieved from Bloomberg, one of the most widely used sources of financial data.

Figure 2: Bloomberg data for Senior Bonds of Alcoa Inc., maturing on February 23, 2019. This figure displays some essential information that a potential investor would need to consider such as the company (name), industry, seniority (rank), coupon, maturity, coupon payment dates and credit ratings.

2.2 Risk-free Bonds

Bonds issues by the U.S. Government (known as treasury bonds) are generally considered to be **risk-free** since the probability of the U.S. Government failing to meet its debt obligations is almost negligible. Bonds issued by Japan (Japanese Government Bonds or JGBs) and Britain (Gilts) are also considered to be risk-free. Therefore, the interest paid by sovereign bonds is an important benchmark for the pricing of corporate bonds or even the bonds of other governments.

Bonds from Alcoa Inc., or any corporation, are generally riskier than bonds issued by the U.S. Government. A rational investor would want a riskier bond to pay a higher interest rate than a U.S. reasury bond, since otherwise she could get the same interest payment at no risk at all. She would want the expected return of a corporate bond to be the same as the expected return of a risk-free bond. For this to be the case, the riskier bond would have to pay more than the risk-free asset, and the amount to which the riskier bond's expected profit exceeds that of a risk-free bond is known as the **risk premium**. So, the interest premium that an investor would want from a bond would change as the risk-free rate changes. It is important to understand the intuition behind this before we explain how bonds are priced.

2.3 Bond Pricing

Present Value (PV)

Present value refers to the current value of a future payment. For example, if an investor has $1 million dollars, that asset (if invested) it is worth more today than $1 million dollars ten years from now. If this person invests his $1 million dollars in, say, a risk-free asset earning 5% a year (compounded semi-annually), that initial amount will become $1.63 million in ten years. So, the present value of that $1.63 million (that will accumulate over ten years) is $1 million. The 5% interest rate that we are using to discount the future value is known as the **discount rate**.

Present Value of Bonds

A bond's price is essentially the sum of the present values of its cash flows i.e. the sum of the present values of coupon payments and principal. Basically, we have to pretend as though we are investing the coupon payments and principal at different time periods. So for our $1 million bond with a discount rate of 5% paid semi-annually (2.5% every six months), the present value of the first coupon of $25,000 is $25,000/1.025, that of the second coupon is $25,000/1.025 and so on. The present value (and price) of a bond can be calculated using the equation below:

$$\text{Price} = C * \frac{1 - \frac{1}{(1+i)^n}}{i} + \frac{M}{(1+i)^n} \tag{1}$$

"M" represents the principal payment and "C" refers to the coupon payment of $25,000. "i" is the discount rate and is also called the **yield to maturity (YTM)** or just **yield**. It is the required interest or discount rate for the present value of a future payment to be equal to the bond price.

If we look at the top of Figure 2.1, we see that bonds for Alcoa Inc. on June 24, 2014 have a coupon of 5.72%, a price of $112.063 and a yield of 2.928%. The **Cpn Freq** (Coupon Frequency) is quoted as "S/A" which stands for "semi-annually." So, if our pension fund manager were to purchase Alcoa Inc. bonds that have a principal of $10 million dollars and that pay a coupon of $286,000 semi-annually, it would cost her $11,206,300. If we substitute "i" in the above equation with 0.014514, "C" with $2.86, "M" with $100 and "n" with 10, we would get the bond price quoted in the Bloomberg screenshot in Figure 2.1: $112.063.

When our portfolio manager has to purchase a bond, she has to determine what a fair yield, or discount rate, for that specific bond would look like. The factors affecting the yield include the risk-free rate, as explained earlier, and the credit health of the company, represented partly by the credit rating. If we look at the equation above or even think of these concepts intuitively, we can see that the bond yield has an inverse relationship with its price. Moreover, the difference between the yield of a bond and the yield of a risk-free bond of the same maturity is a common measurement of the company's credit risk.

2.4 Credit Risk Associated with Bonds

If we look to the right of Figure 2.1, under "Bond Ratings," we can see certain symbols representing **credit ratings** that are provided by rating agencies such as Moody's, S&P and Fitch. These symbols are indicators of a company's **creditworthiness** and its **credit risk**. When a company like Alcoa Inc. issues bonds, there is always a possibility that it may not be able to meet its debt obligations. That possibility, or risk, is known as the credit risk. Naturally, if a company's credit risk goes up, investors would demand a higher yield and consequently, a lower price.

A risk-averse investor, like our pension fund portfolio manager, would naturally want to purchase senior bonds from a company that has a low credit risk—a company like Alcoa Inc., which has a rating of BBB- from S&P and Ba1 from Moody's. We will not go into the details of how these ratings are determined, since those details are beyond the scope of this vignette. What we should note is that companies that have credit ratings of BBB- or higher from S&P or Baa3 or higher from Moody's can be classified as **Investment Grade** bonds. Such companies, at least from the viewpoint of the rating agencies, have a low credit risk. Bonds that have a rating below this are termed as **speculative grade** bonds or **junk** bonds, and have a higher yield than IG bonds. We can see a complete list of classifications from Moody's and S&P in Figure 2.4:

Investment Grade					Speculative Grade				
S&P	Fitch	Moody's	Interpretation	Numeric Scale	S&P	Fitch	Moody's	Interpretation	Numeric Scale
AAA	AAA	Aaa	Very high credit quality	1	BB+	BB+	Ba1	It has speculative elements and it is subject to substantial credit risk	11
					BB	BB	Ba2		12
					BB-	BB-	Ba3		13
AA+	AA+	Aa1	High credit quality	2	B+	B+	B1	It is considered speculative and it has high credit risk	14
AA	AA	Aa2		3	B	B	B2		15
AA-	AA-	Aa3		4	B-	B-	B3		16
A+	A+	A1	Medium-high grade, with low credit risk	5	CCC+	CCC+	Caa1	Bad credit conditions and it is subject to high credit risk	17
A	A	A2		6	CCC	CCC	Caa2		18
A-	A-	A3		7	CCC-	CCC-	Caa3		19
					CC	CC	Ca		20
BBB+	BBB+	Baa1	Moderate Credit Risk	8					
BBB	BBB	Baa2		9	C	C	C	Very close to default or in default	22
BBB-	BBB-	Baa3		10	SD	DDD	-		22
					D	DD			22
					-	D			22

Figure 3: Credit rating classifications from Moody's and S&P for long-term debt obligations.

Another important term associated with credit risk is a **credit event**. A credit event can signify the risk of a company's bankruptcy and resulting default, but the term can also expand to include failure to pay out debt within a certain amount of time, a credit downgrade and the confiscation of assets, among other events. In a later section, we will see the exact events that constitute a credit event.

3 CDS Basics

3.1 CDSs as Hedging Tools

Let's assume that our portfolio manager buys bonds of Alcoa Inc. with a face value of $10 million and with a maturity of five years. Six months after the she makes this trade, her confidence in the creditworthiness of Alcoa Inc. begins to waiver. Of course, she could simply sell the bonds. However, that may be premature or even unprofitable. Instead, she could **hedge** her position by purchasing a financial product whose value rises with a drop in the bonds' value. In other words, she could take a position that allows her to *profit* from increased credit risk. **Hedging** is a process that allows you to profit from both a rise and a drop in an asset's value. When an investors hedges, she takes two opposite positions on an asset such that in the case of a rise or drop, her downside is limited and one position offsets the losses from the other. When the asset in question is a bond, one has the options to be **long** in which you simply own the bond and profit when its price increases (or yield drops). The opposite position is to be **short** bonds. Shorting is the process of borrowing and selling a security with the obligation to repurchase it in the future and return it to the lender. Clearly, this is profitable if the value of the security drops by the time it is repurchased in the future. It is a convenitional technique of hedging against credit risk is **shorting** of bonds. However, there are several issues associated with this method. It is difficult to short bonds that are not **liquid**. The portfolio manager may not be able to find enough bonds that will mature at the same time. Moreover, she would have to spend $10 million to hedge her entire portfolio of $10 million, which is a substantial opportunity cost.

3.2 CDS Mechanics

CDSs were invented in order to resolve these issues associated with hedging against credit risk (as described in Section 3.1).

As shown in Figure 3.2, a CDS is an agreement between two **counterparties**, or opposing groups, in which the buyer (in this case, the portfolio manager) pays a **fixed periodic coupon** to the seller in exchange for protection against a credit event associated with the buyer's bond.

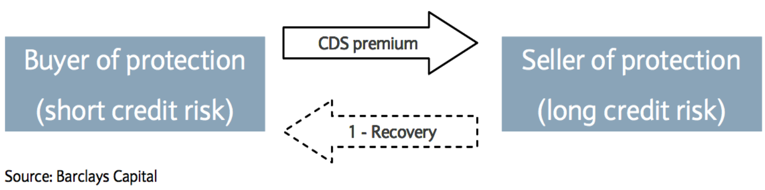


Figure 4: Cash flows in a single name CDS contract.

In our example, the portfolio manager is the **protection buyer**. Let's say that the **protection seller** is a hedge fund. The hedge fund sells protection to the portfolio manager for $10 million of senior debt. This amount is known as the **notional amount**. In return, she has to pay the hedge fund an annual coupon rate of over 1%, or 100 basis points, for a period of five years. These $100,000 payments are made quarterly, so she would have to pay 0.25% every quarter until the maturity date.

In the case of default, the hedge fund would have to pay a compensation equal to the notional amount minus the company's **recovery rate**. The recovery rate is defined as the amount that the company is able to give back to its debt holders after default. When a company goes into bankruptcy and is forced to default on its debt, whatever remains in the company's assets is paid out according to the firm's capital structure. This transaction protects the portfolio from the bonds' associated credit risk without forcing the owner to sell the bonds. The hedge fund, on the other hand, receives a fee and walks away without any losses if there is no credit event.

Our example above can be described as a single-name CDS contract, in which the transfer of credit risk takes place between two parties. The protection buyer of a CDS contract transfers the credit risk to the CDS protection seller by paying a series of coupons until the contract terminates. In other words, the protection buyer is **short credit** by selling the credit risk of an underlying bond to the protection seller, who is **long credit** since she believes that the bond will meet its debt obligations. Note that there is no direct involvement of the Alcoa Inc. in the transaction; this exchange only takes place between the two counterparties.

4 CDS Terminology and Cash Flows

Although the cash flows involved in a CDS seem pretty simple in Figure 3.2, the underlying mechanics of a CDS are a bit more complex. To understand this, let's look at actual CDS data from Bloomberg for Alcoa Inc. Bloomberg and Markit are the two most commonly used sources for CDS related data; we will discuss these sources extensively in a later section. Figure 4 below displays many different variables such as RED Pair Code, REF Entity, Trade Date, Debt Type etc. for the CDS of Alcoa Inc. for June 02, 2014. These are standard terms of CDS contracts that were set by the **International Swaps and Derivatives Association (ISDA)**, the organization that regulates over-the-counter derivatives such as CDSs. Let's understand what these variables are and how they are important for understanding the cash flow[1].

[1]Some of the definitions come from *Credit Derivatives Glossary* (Markit, 2009), *Standard Corporate CDS Handbook* (Leeming et al., 2010), *Credit Derivatives* (Green and Witschen, 2012), and *The Pricing and Risk Management of Credit Default Swaps, with a Focus on the ISDA Model* (White, 2013).

Figure 5: CDS figures from Bloomberg for Alcoa Inc. Note that this **REF Obligation** (Reference Obligation) matches the ISIN in Figure 2.1.

4.1 Entity-Specific Variables

Some of these variables seem self-explanatory. **REF Entity** (Reference Entity) refers to the name of the company (Alcoa Inc., in this case) that the buyer wants protection against. The **ticker** is an abbreviated reference symbol for the Reference Entity, which is "AA" for Alcoa Inc. Moreover, the **Trade Date** is the date on which we are making the trade—June 02, 2014.

The **RED Pair Code** is a Markit product that stands for Reference Entity Database. Each entity/seniority pair has a unique six-digit RED Pair Code that matches the first six digits of the nine-digit RED Pair Code. Each entity also has a "preferred reference obligation," which is the default reference obligation for CDS trades. A user can input either the six-digit RED Pair Code or the nine-digit RED Pair Code. The input "014B98" is the six-digit RED Pair Code for "Alcoa Inc.".

We can also note the label **Debt type**, marked as "Senior." Clearly, this refers to the seniority of the debt. The **notional amount** is printed as "10" or \$10 million USD (US Dollars). The "MM" between the amount and the currency refers to the type of restructuring of the contract—in this case, "Modified Modified" Restructuring (explained further in Section 4.3). The **REF Obligation** (Reference Obligation) refers to the bond involved in the CDS. Since our portfolio manager is purchasing protection on the bonds she previously purchased, this **REF Obligation** (Reference Obligation) matches the ISIN in Figure 2.1.

Maturity refers to the **tenor**, or length, of the contract. The most commonly traded contracts have maturities of five years. The Bloomberg screenshot displays the length of the contract, as well as the implied maturity date. Interestingly, the maturity date for the CDS of Alcoa Inc. on June 02, 2014 is June 20, 2019. This seems odd since we would expect it to be on June 02, 2019, exactly five years from the Trade Date. However, the maturity date always falls on one of the four **roll dates**: March 20, June 20, September 20 and December 20. Therefore, the maturity date for this contract will be on the roll date after June 02, 2019, which is June 20, 2019. Also note that this contract is of the type **SNAC** or Standard North American Contract, which is a convention that specifies how North American single-name CDSs are supposed to trade. In European markets, CDSs belong to the **STEC** category, or Standard European Contract.

4.2 Premium Leg

The stream of cash flows from the protection buyer to the seller, when there is no default, is known as the **premium leg**. To understand the premium leg, we must look at the **Trd Sprd** (Trade Spread) and **Coupon** in Figure 4. In section 3.2, we stated that the protection buyer pays the protection seller a fixed coupon for purchasing protection. Until 2009, the two counterparties in a CDS contract would agree on the coupon level before the trade. Then, as the market moved, this tradable coupon would vary. So if our portfolio manager was purchasing a CDS before 2009, she would have had to negotiate a fixed coupon—which would then vary as the company's credit risk varied—with the hedge fund.

In April 2009 in North America, the ISDA introduced a series of mandatory modifications to the CDS contract known as the "Big Bang Protocol". Under the new rules, coupon rates were standardized in North America in Europe from June 2009 on. Dealers now had to quote **standard coupons** of 100bps or 500bps in North America, or 25bps, 100bps, 500bps or 1000bps in Europe, and all coupons were paid quarterly on one of the four roll dates. The coupon printed in the figure above is the fixed coupon for Alcoa Inc., which is 100bps, or 1% of the notional amount. However, the dealers may not feel that this is the fair premium for protection. For instance, the hedge fund selling protection to the portfolio manager may feel that the fair premium should be 160bps, and not 100bps. This fair premium rate is known as **trade spread** (or **par spread**, or just **spread**), labeled as 160 in the figure above.

Naturally, if the hedge fund believes that the fair premium should be 160bps, it would like to be compensated for receiving just 100bps. As a result, the portfolio manager would have to make what is known as an **Upfront Payment** at the trade inception. Therefore, in the absence of a credit event, the cash flow between the two parties, over the life of the contract, would look like Figure 4.2.

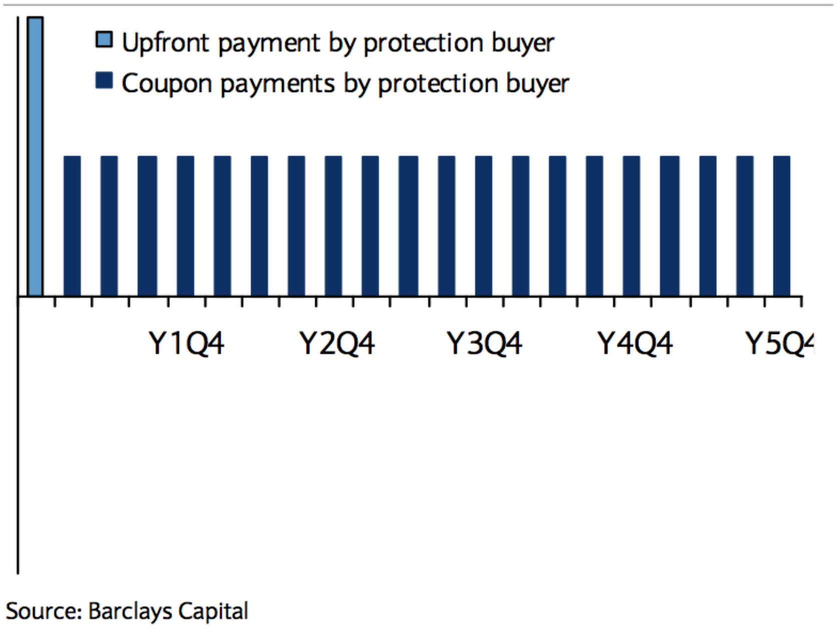


Figure 6: CDS cash flows when there is no credit event.

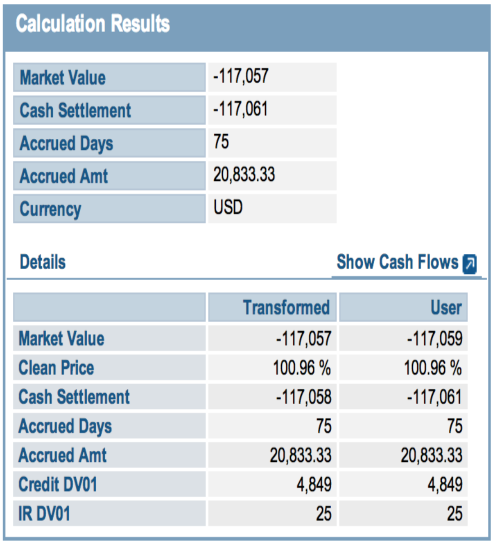
The ISDA protocol, since April 2009, specifies that all premium payments, by default, start on the roll date before the Trade Date. So if the Trade Date is June 02, 2014, the **Accrual Begin Date** is, by default, March 20, 2014. Now if the Accrual Begin Date is 75 days before the Trade Date, the portfolio manager would not want to pay interest for the 75 days she has not received protection for.

$$\text{Accrued} = \frac{75}{360} * \frac{1}{100} * \$10000000 = \$20,833 \tag{2}$$

We must note that we are dividing 75 by 360 instead of 365 in the above calculation. This has to do with the **Day Count Convention** (**Day Cnt** in Figure 4) of the contract, which specifies that the accrual factor between two dates is ACT/360, or Actual/360.

If we subtract the **Accrued Interest** over the past 75 days from the upfront payment, we get the **Dirty Upfront** or **Cash Settlement Amount**. With the information for Alcoa Inc. given in the Figure 4, the dirty upfront value for this contract is $258,478. **Clean Upfront**, on the other hand, is the dirty upfront minus any accrued interest payment, and is also called the **Principal**. In this case, it is $27,9311. Moreover, we can also note a variable called **Pts Upf** in Figure 4. This is the **Points Upfront**, or simply **points**, which is the clean upfront expressed as a percentage of the notional amount.

As we can see, the upfront and points upfront values are positive, since the spread of the CDS is higher than the fixed coupon rate. If instead, the portfolio manager and hedge fund agree that the fair premium should be 60bps, the upfront value would be negative i.e. the hedge fund would pay the portfolio manager a compensation for receiving a coupon higher than the fair premium or spread. The cash flows would then look like the values in Figure 4.2. The clean and dirty values are now both negative.



Calculation Results

Market Value	-117,057
Cash Settlement	-117,061
Accrued Days	75
Accrued Amt	20,833.33
Currency	USD

Details — Show Cash Flows

	Transformed	User
Market Value	-117,057	-117,059
Clean Price	100.96 %	100.96 %
Cash Settlement	-117,058	-117,061
Accrued Days	75	75
Accrued Amt	20,833.33	20,833.33
Credit DV01	4,849	4,849
IR DV01	25	25

Figure 7: CDS cash flows for Alcoa Inc. when spread is equal to 60bps and the coupon is equal to 100bps. These have been calculated using the calculator provided by Markit.

4.3 Protection Leg

So far we have only discussed the stream of payments for a contract in which a credit event does not occur. The stream of payments that would be have to be made in the case of a credit event is known as the **protection leg** or **contingent leg**. If, however, there is a credit event, the cash flow would look like Figure 4.3.

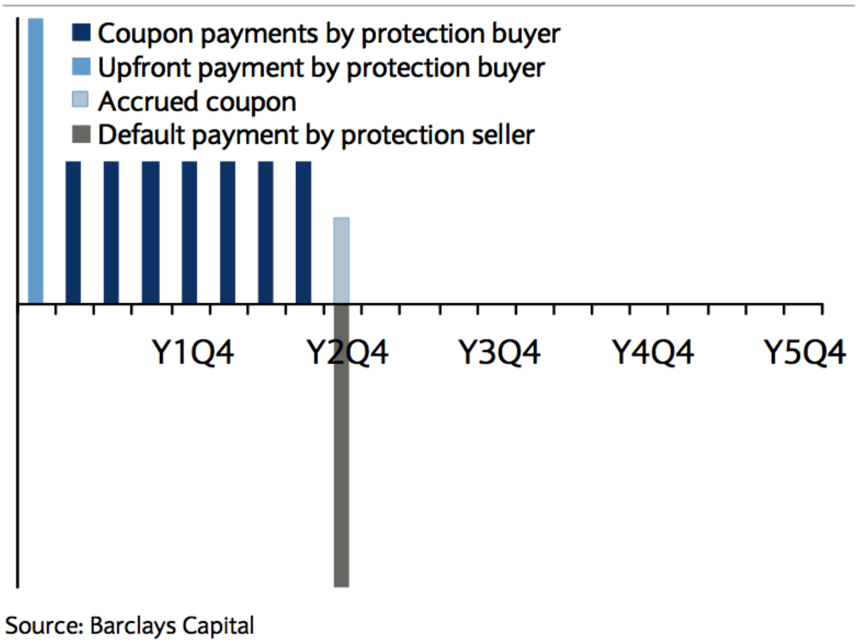


Figure 8: CDS cash flows when there is a credit event.

When a default does occur, the protection seller would owe the protection buyer the notional amount minus any money recovered from the company. It must be noted that the protection is effective for the credit events that have taken place since 60 days *before* the trade date; this date is known as **backstop date**. Before the "Big Bang" Protocol, this date used to be one day *after* the trade date. The advantage of the new system is that if there is a delay in the credit event becoming known, the two dealers have sufficient time to process the information.

Types of Settlements in the Case of a Default

In the event of a default, there are two ways this transaction could take place. The first is a **physical settlement** where the buyer will actually deliver the defaulted bonds to seller and the seller will then pay the face value of those bonds. The disadvantage of this is that in the case of a default the buyers of protection who do not own those bonds will have to find the bonds to deliver to the seller and this may artificially drive up the price of the bonds. This is especially the case when there are a large number of outstanding CDS contract.

The alternative to physical settlements is a **cash settlement**, in which the seller simply pays the buyer the notional amount*(1-recovery rate). Clearly, determining a recovery rate is a problem. One approach the ISDA has been using lately is an **auction** style process in which major dealers submit their bids for the value they place on a company's debt. CDS contracts for corporate bonds generally assume a 40% recovery rate for valuation purposes.

What Constitutes a Default?

Another problem that we face is determining what constitutes a default. A default does not have to be outright bankruptcy. Often companies **restructure** their debt instead of declaring for bankruptcy. In debt restructuring, companies basically renegotiate the terms of their debt. In some CDS contracts, restructuring does not constitute a default. In Figure fig:CDSalcoa, if we look between the notional amount and the currency, we will see a text box printed as 'MM'. This stands for 'Modified Modified' restructuring and implies that debt restructuring does constitute a default for this contract. So if Alcoa Inc. decides to restructure this specific debt, the portfolio manager will have to be paid by the hedge fund.

Counterparty Risk

When a counterparty like the hedge fund sells protection on a bond, there is always the possibility that, in case of a default, the counterparty may not be able to pay the notional amount to the protection buyer. Or it could so happen that our portfolio manager is unable to make her periodic payments. The risk of either of these eventualities taking place is known as **counterparty risk**.

5 CDS Pricing

The ISDA has created the "Standard Model," which allows market participants to calculate cash settlement from conventional spread quotations, convert between conventional spread and upfront payments, and build the spread curve of a CDS. In this section we will lay out the assumptions made by the standard model, and explain the methods and formulas used to calculate certain information related to CDSs.

5.1 Mark-to-Market Calculations

Let's say our portfolio manager wants to sell her CDS contract, for whatever reasons. Finding the market value of a CDS contract, for the protection buyer, is known as **Marking-to-market (MTM)** and the value is known as the **mark-to-market** value. Theoretically, the value of this Alcoa CDS for the portfolio manager is:

Money she is expected to receive – Money she expected to pay.

Clearly if she is expected to receive more than she expects to pay, the value of the contract will be positive. So if the fair spreads for this CDS contract rise, the market value of her CDS will increase. If Alcoa's credit risk increases and the fair spreads actually rise, she will be in a **mark-to-market profit**. If on the other hand, the credit risk and fair spreads drop, she would be in a **mark-to-market loss**.

The Standard Model assumes that the mark-to-market value is computed by discounting the expected protection leg and premium leg cashflows to the trade date. Clearly, an important part of determining the mark-to-market value is determining how likely the bond is to default. This is known as the **probability of default**. Before we understand how to determine the probability of default, we must understand how we are pricing both the premium and the protection leg and why the .

5.2 Present Value of CDSs

In Section 2.3 we explained the concept of **present value** and how a bond's price is the present value of its future cash flows. This concept applies in the pricing of CDSs as well. We know that one of the central components in determining the price of a CDS is the spread. When the spread is different from the standard coupon of the contract, an upfront payment has to be made as a compensation. This upfront value is the present value of the extra cash flows that will be made on top of the standard coupon payments. So if we have a five-year contract for the CDS of Alcoa Inc., in which the standard coupon is 100bps and the fair spread is 160bps, the upfront value paid by the portfolio manager to the hedge fund is the present value of the extra 60bps payments made quarterly (15 bps per quarter) over a period of five years.

Present Value of the Premium Leg

The present value of the premium leg is the present value of future coupon payments

Present Value of the Protection Leg

The present value of the protection leg is the present value of an expected contingent payment.

5.3 Present Value 01 and its determinants

At this point it is important to understand **PV01** or **present value 01** since it used to calculate the cash flows and risk measures of a CDS. PV01 is the present value of a stream of 1 basis point payments at each CDS coupon date. It is sometimes referred to as the **CDS duration** or **risky duration**. Analytically, PV01 can be calculated by

$$PV01 = \sum_t Df(t_i)S(t_i)B(t_i),$$

- $i =$ coupon index,
- $t_i =$ coupon date,
- $B(t_i) =$ day count fraction at t_i.
- $Df(f_i) =$ discount factor until t_i,
- $S(t_i) =$ survival probability until t_i,

As we can see in the equation above, we need the coupon index, coupon dates, the day count fraction, discount factor for each date, and survival probability until the date of the respective coupon payment.Before go into the details of how PV01 is used in determining the market price or the risk measures, it is essential to understand the different components used to calculate it. Coupon dates refer to the dates on which coupon payments are made. Day count fraction is the fraction of the day on which the coupon payment is made upon 360 or 365, depending on the day count convention of that CDS. While the first three components of the above equation seem straightforward, the other two - survivial probability and discount factor require more explanation.

Discount factor: Using the Swap Curve or Risk-Free Curve

The risk free rates are the discount factor used in the calculation of PV01. If we look at Figure 5.3, we can see the yields for different treasury bonds, at 8pm UTC, June 23 2014.

Yield Curve

Date 23-Jun-2014

Snap 1600 **TimeZone:** New York

Recalculate

Period	Type	Rate
1M	Deposit	0.1520 %
2M	Deposit	0.1963 %
3M	Deposit	0.2326 %
6M	Deposit	0.3253 %
1Y	Deposit	0.5471 %
2Y	Swap	0.6190 %
3Y	Swap	1.0630 %
4Y	Swap	1.4665 %
5Y	Swap	1.7930 %
6Y	Swap	2.0570 %
7Y	Swap	2.2725 %
8Y	Swap	2.4450 %
9Y	Swap	2.5880 %
10Y	Swap	2.7110 %
12Y	Swap	2.9085 %
15Y	Swap	3.1110 %
20Y	Swap	3.2915 %
25Y	Swap	3.3710 %
30Y	Swap	3.4100 %

Interest Rate Conventions

Spot Date: 26-Jun-2014	**Swap DCC:** 30/360
MM DCC: A/360	**Swap Interval:** 6M
Floating DCC: A/360	**Holidays:** none
Floating Interval: 3M	**Bad Day Conv:** MF

Figure 9: Risk-free rates with their day count conventions on June 23 2014, at 4pm EST. These are the rates that will be used to price the CDS of Alcoa Inc. on June 24, 2014.

Bond yields are directly proportional to the maturity of the bond. This is because the risk of default for a government, or any other entity, is higher over a long period than over a short one. The risk that a government may default on its debt over 30 years is higher than the risk that it defaults in six months. In rare cases, the short-term yields are higher than long term yields; this can often be a sign of a recession. If, for a given date, we plot the maturities of different bonds on the x-axis and their corresponding yields on the y-axis, we get the **Swap Curve**.

In calculating the price of a CDS we use the swap curve of the *previous day*, and use the rates for the corresponding currency. So for CDSs denominated in USD, we will use the US treasury rates, for those in GBP we will use UK Government bond yields and so on.

The ISDA also standardizes the interest rates used by the Standard Model in valuing a CDS contract. There are two types of rates used in valuing a USD-denominated CDS contract: cash rates and swap rates. Cash rates are of the following maturities: one, two, three, and six month(s), and one year. They are provided by the British Bankers' Association (BBA). Swap rates are of maturity 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25, and 30 years, and are provided by ICAP (Markit, 2013). The Standard Model follows the conventions below for interpolation of the entire USD yield curve:

- The day count convention (DCC) for money market instruments and the floating legs of the swaps is **ACT/360**.
- DCC for floating legs of the swaps is **30/360**.
- Payment frequency for fixed legs of the swaps is 6 months.
- Payment frequency for floating legs of the swaps is 3 months.[2]
- A business day calendar of weekdays (Monday to Friday) is assumed. Saturdays and Sundays will be the only non-business days.
- If a date falls on a non-business day, the convention used for adjusting coupon payment dates is **M** (Modified Following).
- Recovery Rate is the estimated percentage of par value that bondholders will receive after a credit event. It is commonly reported in percentage of notional value. CDS contracts for corporate bonds assume a 40% recovery rate for valuation purposes.

CDS mark-to-market = T - 60 Calender Days.

Survivial Probability

5.4 Principal Amount (Clean Upfront)

Now that we understand the intuition and the mathematics behind the formula for PV01, we can use it to calculate the principal amount (clean upfront payment) paid from the protection buyer to the seller using the following formula:

$$\text{Principal Amount} = (\text{Par Spread - Coupon}) \times \text{PV01}.$$

The Standard Model allows market participants to convert between the par spread and the upfront payment, and compute the cash settlement amount for a standard contract.

5.5 Risk Measures of a Standard CDS Contract

The PV01 can be used to compute certain risk measures related to interest rates, spread and the default probability.

Spread DV01

Using the concept of PV01, we show the calculation of the main risks (exposures) of a CDS position, **Spread DV01**. Spread DV01 reflects the risk duration of a CDS trade, also known as **Sprd DV01**, **Credit DV01**, **Spread Delta**, and just **DV01**.

[2] See `http://www.fincad.com/derivatives-resources/wiki/swap-pricing.aspx` for details on floating and fixed legs calculation.

It measures the sensitivity of a CDS contract mark-to-market to a parallel shift in the term structure of the par spread. DV01 should always be positive for a protection buyer since he or she is short credit, and a rising spread is a sign of credit deterioration. Starting with PV01 and taking the derivative with respect to the spread gives us:

$$\begin{aligned} PV &= (S - C) * PV01 \\ DV01 &= \frac{\partial PV}{\partial S} \\ &= PV01 + (S - C)\frac{\partial PV01}{\partial S}, \end{aligned}$$

where S is the spread of the contract and C is the coupon.

Both DV01 and PV01 are measured in dollars and are equal if the spread equals the coupon.

IRDV01 or Interest Rate Dollar Value 01

The **IR DV01** is the change in value of a CDS contract for a 1 bp parallel increase in the interest rate curve. IR DV01 is, typically, a much smaller dollar value than Spread DV01 because moves in overall interest rates have a much smaller effect on the value of a CDS contract than does a move in the CDS spread itself.

`Price` refers to the clean dollar price of the contract and is calculated by

$$\begin{aligned} \text{Price\&} &= (1 - \text{Principal}/\text{Notional}) * 100 \\ \& &= 100 - \text{Points Upfront}. \end{aligned}$$

Default Probability or Probability of Default (PD)

Default Probability refers to the default probability which is the estimated probability of default for each maturity by a given time. It can be approximated by

$$\text{Default Prob} \approx \left[1 - exp\left(\frac{rt}{1-R}\right)\right],$$

where r is the spread, t is the time to maturity, and R is the recovery rate.

Default Exposure

"Default Expo" refers to the expoure to the default of a CDS contract based on the formula below.

$$\text{Default Exposure} = (1 - \text{Recovery Rate}) * \text{Notional} - \text{Principal}.$$

6 CDS Indices

Holding a portfolio of a disproportionate number of Alcoa Inc. bonds is naturally a risky idea. It is akin to putting all your eggs in one basket, as the saying goes. In the real world, most successful portfolio managers prefer to distribute their risk by holding a portfolio with hundreds, if not thousands, of different positions. Instead of holding a 10 million USD of Alcoa Inc. bonds, let's say our portfolio manager decides to take less risk by holding bonds of 100 different Investment Grade companies. This is known as **diversification**. Although this strategy reduces her exposure to the credit risk of any particular company, she hasn't reduced her exposure to factors that might affect a wide variety of assets simulatenously, such as interest rate risk or political risk. Fortunately, in the modern financial world, she has the option of purchasing multi-name CDSs, or CDS indices, which contain a basket of CDSs.

Moreover, if our portfolio manager has a high-risk appetite and wants to earn a higher return for her investors, she may invest a portion of her portfolio in bonds that have a lower credit rating but provide a higher yield. She may consider investing in a tranche of CDS indices known as CDX.NA.HY. These index products trade in high volumes and are very liquid.

7 Pricing Sources

Bloomberg and Markit are the most widely used sources for data related to pricing of CDSs. We compared the results from our package with results from Bloomberg and Markit. Interestingly, the results from Markit and Bloomberg were not always identical.

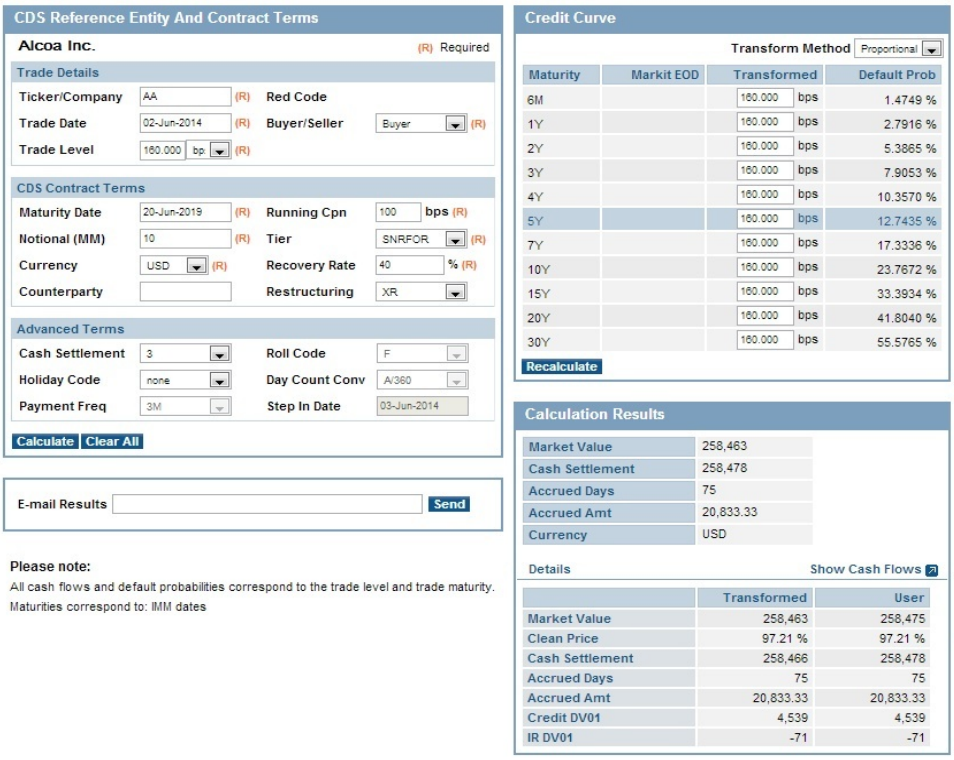


Figure 10: CDS figures from Markit.com

Figure 11: CDS figures from Bloomberg

The interest rate results were identical, at least until the fourth decimal place.

Yield Curve

Date 01-Jun-2014

Snap 1600 TimeZone: New York

Recalculate

Period	Type	Rate
1M	Deposit	0.1510 %
2M	Deposit	0.1908 %
3M	Deposit	0.2274 %
6M	Deposit	0.3219 %
1Y	Deposit	0.5344 %
2Y	Swap	0.5105 %
3Y	Swap	0.9095 %
4Y	Swap	1.2895 %
5Y	Swap	1.6175 %
6Y	Swap	1.8915 %
7Y	Swap	2.1165 %
8Y	Swap	2.2995 %
9Y	Swap	2.4525 %
10Y	Swap	2.5810 %
12Y	Swap	2.7885 %
15Y	Swap	2.9970 %
20Y	Swap	3.1825 %
25Y	Swap	3.2670 %
30Y	Swap	3.3055 %

Interest Rate Conventions

Spot Date: 04-Jun-2014	Swap DCC: 30/360
MM DCC: A/360	Swap Interval: 6M
Floating DCC: A/360	Holidays: none
Floating Interval: 3M	Bad Day Conv: MF

Figure 12: Interest Rate figures from Markit.com

Benchmark	S260 (USD ISDA Standard Curve - Mid)		
Date	06/02/2014		
Term	Rate	Term	Rate
1 Month	0.1510	12 Year	2.7885
2 Month	0.1908	15 Year	2.9970
3 Month	0.2274	20 Year	3.1825
6 Month	0.3219	25 Year	3.2670
12 Month	0.5344	30 Year	3.3055
2 Year	0.5105		
3 Year	0.9095		
4 Year	1.2895		
5 Year	1.6175		
6 Year	1.8915		
7 Year	2.1165		
8 Year	2.2995		
9 Year	2.4525		
10 Year	2.5810		

Figure 13: Interest Rate figures from Bloomberg

8 Using the CDS package

The **CDS** package implements the Standard Model, allowing users to value credit default swaps and calculate various risk measures associated with these instruments.

In the **CDS** package, we call the function `CDS` to construct an object of a class `CDS`. Below we show an example of how to construct a CDS contract in the package.

```
> library(CDS)
> cds1 <- CDS(entityName = "Alcoa Inc.",
+             RED = "49EB20",
+             TDate = "2014-04-15",
+             tenor = "5Y",
+             notional = 1e7,
+             coupon = 100,
+             parSpread = 50)
```

Here the user enters the CDS contract with "Alcoa Inc." as the underlying entity and sets the spread at 50 bps and the coupon at 100 bps. However, the valuation of a CDS contract requires neither the Reference Entity or the RED Code. She does not have to know that information to use the **CDS** package. As shown below, as long as she inputs the same `Trade Date`, `parSpread`, and `maturity` information, the valuation of the contract will be the same.

Besides `parSpread`, a market participant can choose to specify either `ptsUpfront` or `upfront` to construct a `CDS` class object.[3] `ptsUpfront` or `upfront` refer to points upfront (in %), and upfront payment (in dollar amount) of a CDS contract, respectively. One of the three arguments has to be specified in order to construct the `CDS` class object.

[3] See Section 4.2 for definitions on both terms.

Currently, a market participant can conduct CDS-related calculations by using the **CDSW Calculator** on a Bloomberg Terminal or the Markit CDS Calculator[4]. The **CDS** package provides tools for valuing a single-name CDS contract. The default setting allows a user to value a USD-denominated CDS contract following the Standard Model as mentioned before. She can also specify her own set of parameters to customize the calculation.

We have illustrated the construction of a CDS contract using the **CDS** package in previous sections. In this section, we will demonstrate the use of the **CDS** package in more detail and provide a series of examples.

Recall that in Section 'Using the CDS package', a `CDS` class object called `cds1` has been constructed. Its maturity is five years. Its spread is set at 50 bps and its coupon at 100 bps. The notional amount is $10 million. A user can call `summary` on a `cds1` to view essential information on the contract.

```
> summary(cds1)
Contract Type:                      SNAC   TDate:                   2014-04-15
Entity Name:                  Alcoa Inc.   RED:                         49EB20
Currency:                            USD   End Date:                2019-06-20
Spread:                               50   Coupon:                         100
Upfront:                        -256,577   Spread DV01:                  5,086
IR DV01:                           66.14   Rec Risk (1 pct):             90.03
```

In the summary output, it shows that the type of the CDS contract is "SNAC". `Trade Date` refers to the trade date and is April 15, 2014. Reference Entity (called `entityName` in the package) refers to the entity name of the CDS contract and is "Alcoa Inc.". The `RED` code is "48EB20" as specified by the user. `spread` shows that the quoted spread for the contract is 50 bps and the coupon is 100 bps as shown in the `coupon` field. `upfront` indicates the dirty upfront payment in dollars or the cash settlement amount. It is -256,577 dollars, which means that from a buyer's perspective, the net present value of the remaining expected cashflows is -$256,577.

The remaining three items from the `summary` output are `Spread DV01`, `IR DV01`, and `Rec Risk (1 pct)`. In `cds1`,the IR DV01 is $66.14. **Recovery Risk 01** or `Rec Risk (1 pct)` as shown in the `summary` output, is the dollar value change in market value if the recovery rate used in the CDS valuation were increased by 1%. It is $90.03 in `cds1`.

The default settings of valuing a CDS contract in the **CDS** package follow the Standard North American Corporate (SNAC) CDS Contract specifications.[5] Below we list the ISDA specifications implemented in the **CDS** package. Additional default settings in the package which are not specified by the Standard Model, such as the default notional amount, are also listed.

- Currency: USD.
- Trade Date (T): the current business day.
- CDS Date: Mar/Jun/Sep/Dec 20th of a year.

[4]The Markit CDS Calculator is available at `http://www.markit.com/markit.jsp?jsppage=pv.jsp`.

[5]See `http://www.cdsmodel.com/assets/cds-model/docs/Standard%20CDS%20Contract%20Specification.pdf` for details.

- Maturity: five years.
- Maturity Date (End Date): It falls on a CDS date without adjustment.
- Coupon Rate: 100 bps.
- Notional Amount (MM): 10MM.
- Recovery Rate (%): 40% for senior debts.
- Premium Leg:
  - Payment Frequency: quarterly
  - DCC: ACT/360
  - Pay Accrued On Default: It determines whether accrued interest is paid on a default. If a company defaults between payment dates, there is a certain amount of accrued payment that is owed to the protection seller. "True" means that this accrued will need to be paid by the protection buyer, "False" otherwise. The defalt is "True,"
  - Adjusted CDS Dates: "F." It means that it assumes the next available business day when a CDS date falls on a non-business day except the maturity date.
  - First Coupon Payment: It is the earliest Adjusted CDS Date after T + 1.
  - Accrual Begin Date (Start Date): It is the latest Adjusted CDS Date on or before T + 1.
  - Accrual Period: It is from previous accrual date (inclusive) to the next accrual date (exclusive), except for the last accrual period where the accrual end date (Maturity Date) is included.
- Protection Leg:
  - Protection Effective Date (Backdrop Date): T - 60 calendar days for credit events.
  - Protection Maturity Date: Maturity Date.
  - Protection Payoff: Par minus Recovery.

8.1 More on CDS pricing

`CS10` is a method which calculates the change in value of the CDS contract when the spread of the contract increases by 10%. `CS10` takes in a `CDS` class object formed by calling the `CDS` function. The CS10 of `cds1` is $25385.2.

```
> cds1.CS10 <- CS10(cds1)
> cds1.CS10
[1] 25385.2
```

A market participant can also update the `CDS` class objects she has constructed by calling the `update` method. It updates a `CDS` class object with a new spread and points upfront by specifiying the relevant input.

```
> cds3 <- update(cds1, spread = 55)
```

cds3 is a new CDS class object with a spread of 55 bps; all other specifications of the contract are the same as those in cds1 since it is updated from cds1. One can also specify upfront (in dollar amount) or ptsUpfront (in bps) in the update method.

Besides calling the summary method, one can type in the name of the CDS class object in the current **R** Session and obtain a full description of the CDS contract.

```
> cds3
CDS Contract
Contract Type:                    SNAC   Currency:                        USD
Entity Name:               Alcoa Inc.   RED:                          49EB20
TDate:                     2014-04-15   End Date:                 2019-06-20
Start Date:                2014-03-20   Backstop Date:            2014-02-14
1st Coupon:                2014-06-20   Pen Coupon:               2019-03-20
Day Cnt:                      ACT/360   Freq:                              Q

Calculation
Value Date:                2014-04-18   Price:                        102.24
Spread:                            55   Pts Upfront:                 -0.0224
Principal:                   -223,692   Spread DV01:                   5,064
Accrual:                       -7,500   IR DV01:                       59.35
Upfront:                     -231,192   Rec Risk (1 pct):              88.87
Default Prob:                   0.047   Default Expo:              6,223,692

Credit curve effective of 2014-04-15
 Term      Rate Term     Rate
   1M 0.001517   7Y 0.022630
   2M 0.001923   8Y 0.024580
   3M 0.002287   9Y 0.026265
   6M 0.003227  10Y 0.027590
   1Y 0.005465  12Y 0.029715
   2Y 0.005105  15Y 0.031820
   3Y 0.009265  20Y 0.033635
   4Y 0.013470  25Y 0.034420
   5Y 0.017150  30Y 0.034780
   6Y 0.020160
```

There are three parts of the output. The first part "CDS Contract" provides basic information on the contract including "Contract Type", "Currency", "Reference Name" (called Entity Name in the package), "RED", "Trade Date", various dates related to the contract, and the day count conventions for cds3.

The second part of the output contains relevant risks measures of cds3.

The price of cds3 is 102.24, greater than 100. A CDS will have a price greater than 100 if the points upfront are negative; that is, the CDS buyer needs to receive money to obtain protection because he promises to pay a coupon of, say, 100 even if the spread is 60. This is analogous to a bond investor paying more than the face value of a bond because current interest rates are lower than the coupon rate on the bond.

The last part of the output reports the interest rates used in the calculation. Calling the function `getRates` also produces the rates used in building a curve for CDS valuation.

```
> cds3Rates <- getRates(date = "2014-04-15")
```

The output consists of two list objects. The first list contains rates of various maturities. They are directly obtained from the Markit website based on the specifications (Markit, 2013).

```
   expiry matureDate     rate type
1      1M 2014-05-19 0.001517    M
2      2M 2014-06-17 0.001923    M
3      3M 2014-07-17 0.002287    M
4      6M 2014-10-17 0.003227    M
5      1Y 2015-04-17 0.005465    M
6      2Y 2016-04-17 0.005105    S
7      3Y 2017-04-17 0.009265    S
8      4Y 2018-04-17  0.01347    S
9      5Y 2019-04-17  0.01715    S
10     6Y 2020-04-17  0.02016    S
11     7Y 2021-04-17  0.02263    S
12     8Y 2022-04-17  0.02458    S
13     9Y 2023-04-17 0.026265    S
14    10Y 2024-04-17  0.02759    S
15    12Y 2026-04-17 0.029715    S
16    15Y 2029-04-17  0.03182    S
17    20Y 2034-04-17 0.033635    S
18    25Y 2039-04-17  0.03442    S
19    30Y 2044-04-17  0.03478    S
```

The second list reports the specific day count conventions and payment frequencies regarding the interest rate curve used.

```
                 text
effectiveDate    "2014-04-15"
badDayConvention "M"
mmDCC            "ACT/360"
mmCalendars      "none"
fixedDCC         "30/360"
floatDCC         "ACT/360"
fixedFreq        "6M"
floatFreq        "3M"
swapCalendars    "none"
```

9 Conclusion

In this paper, we describe the basics of a CDS contract and the ISDA Standard Model. We also provide a simple collection of tools to implement the Standard Model in **R** with the `CDS` package. Moreover, the flexibility of **R** itself allows users to extend and modify this package to suit their own needs and/or create their preferred models for valuing CDS contracts. An **R** package, `backtest` Campbell et al. (2007), provides facilities to explore portfolio-based conjectures about credit default swaps. It is possible to use the `backtest` package based on the output from the `CDS` package. Before reaching that level of complexity, however, `CDS` provides a good starting point for valuing credit default swaps.

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