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VALUATION AND TRADING STRATEGIES OF CDS

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Abstract

One of the most important risk for financial institutions is credit risk. Most financial institutions devote considerably resources to the measurement and management of credit risk. Regulators have for many years required banks to keep capital to reflect the credit risks they are bearing. Credit risks arises from the possibility that borrowers and counterparties in derivatives transactions may default. Credit derivatives enable banks and other financial institutions to manage their credit risk. They can be used to transfer credit risk from one company to another and to diversify credit risk by swapping one type of exposure for another. This paper discuss about the approach we apply on stripping credit curve, survival analysis and displaying the probability that a company will default and if the investors should be worried about CDS. For this we have developed a tool which set up and built the credit curves using the CDS spreads, and then calculates hazard rates and default probabilities. We finish by discussing the common risk factors by shifting inputs or model parameters that affect directly in our results, and present the possible usage of the extended probability of default vector on measuring other counterparty risks.

Keywords: CDS spread, probability of default, hazard rates, interpolation

1. Introduction

Credit risk is an important risk for financial institutions. Most of financial institutions devote considerable resources to the measurement and management of credit risk. Regulators have for many years required banks to keep capital to reflect the credit risks they are bearing. Credit risk arises from the possibility that borrowers and counterparties in derivatives transactions may default. The most exciting developments in derivatives markets since the late 1990s have been in the credit derivatives area. In 2000 the total notional principal for outstanding credit derivatives contracts was about $800 billion. By June 2007 this had grown to over $42 trillion and just for CDS at the end-December of 2015 $1.137 trillion (EMTA Survey). Credit derivatives are contracts where the payoff depends on the credit worthiness of one or more companies or countries. This paper explains how credit derivatives work, discuss an approach for estimating the probability that a company will default and some valuation issues. Credit derivatives allow companies to trade credit risk in much the same way that they trade market risks. Banks and other financial institutions used to be in the position where they could do little once they had assumed a credit risk except wait (and hope for the best). Now they can actively manage their portfolios of credit risks, keeping some and entering into credit derivatives contracts to protect themselves from others. Banks have been the biggest buyers of credit protection and insurance companies have been the biggest sellers. Credit derivatives can be categorized as "*single name*" or "*multiname*". The most popular single-name credit derivative is a credit default swap. The payoff from this instrument depends on what happens to one company or country. There are two sides to the contract: the buyer and seller of protection. There is a payoff from the seller of protection to the buyer of protection if the specified entity (company or country) defaults on its obligations. The most popular multiname credit derivative is a collateralized debt obligation. In this, a portfolio of debt instruments is specified and a complex structure is created where the cash flows from the portfolio are channelled to different categories of investors. Multiname credit derivatives increased in popularity relative to single-name credit derivatives up to June 2007. In December 2004 they accounted for about 20% of the credit derivatives market, but by June 2007 their share of the market had risen to over 43%. In July 2007 investors lost confidence in the subprime mortgage market in the United States. Interest in multiname structered credit products, whether they involved subprime mortgages or not, declined. Single-name credit derivatives continued to be actively traded after July 2007 and they are derivative contracts that implicitly allow investors to trade credit protection. In the event of a deterioration in credit quality, the buyer of credit protection gains and the seller loses. CDS contracts may represent the most significant and challenging financial innovation of the last two decades: volumes have grown enormously in recent years. Furthermore, after the recent financial crisis, trading in CDS contracts has become controversial and some government regulators have recently advocated a ban on so-called ‘naked’ long positions in CDS contracts. Anyway a new set of ISDA definitions made the CDS market function more effectively. According to the recent regulation process CDS are ready to tackle government bail-ins of banks, Greek default experience has incentivised better sovereign credit event mechanism. In this paper we will show some results generated from a CDS tool we have built to set up credit curves for use in the CDS model. Our tool creates credit curves from CDS spread inputs, and calculates hazard rates and default probabilities from them then it provides the possibility of pricing CDS's. In section 2 we start with a general discription of the mechanics of the CDS market and the advantages and shortcomings of trading CDS's. Section 3 discusses the stripping process of credit curve, and what is more crutial to be defined before we price a new CDS. Section 4 discuss how credit default swaps are valued, the entire schema we use during pricing process ilustrated by an example. Section 5 and 6 explains the risk manangment process and the risk variables we must analyse and on which we should take decisions. We are concentrated on the shape of the credit curves and also in a perturbation analysis which shift any possible factor that affects our results.

2. The definition of credit default swap

The most popular credit derivative is a credit default swap (CDS). This is a contract that provides insurance against the risk of a default by particular company. The company is known as the *reference entity* and a default by the company is known as a *credit event*. In brief, a CDS is used to transfer the credit risk of a reference entity from one party to another. The buyer of the CDS is said to buy protection. The buyer usually pays a premium (which is called CDS spread) and profits if the reference entity has a credit event, or if the credit worsens while the swap is outstanding. Buying protection has a similar credit risk position to selling a bond short, or “going short risk”. The seller of the credit default swap is said to sell protection. The seller collects the payments and profits if the credit of the reference entity remains stable or improves while the swap is outstanding. Selling protection has a similar credit risk position to owning a bond or loan, or "going long risk". As shown in Figure 2.1, Investor A, the buyer of protection, pays Investor B, the seller of protection, a regular stream of payments knowing as premium leg. This size of these premium payments is calculated from a quoted default swap spread which is paid on the face value of the protection. These payments are made until a credit event occurs or until maturity, whichever occurs first. If a credit event does occur before the maturity date of the contract, there is a payment by the protection seller, known as the protection leg. This payment equals the difference between par and the price of the cheapest to deliver asset of the reference entity on the face value of the protection and compensates the protection buyer for the loss. It can be made in cash or physically settled format.

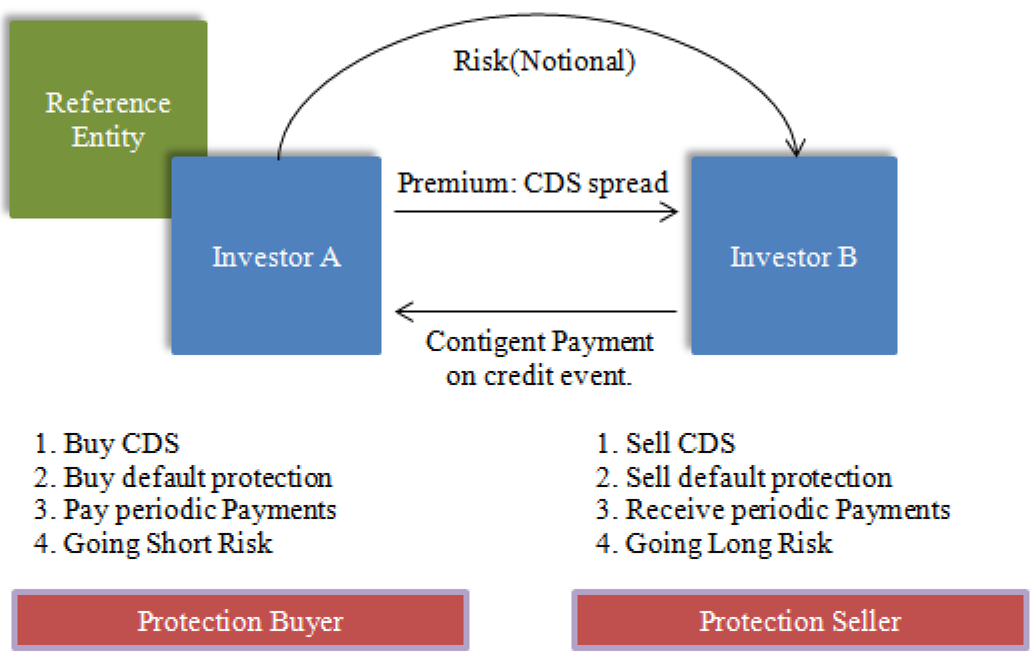

Figure 2.1. Mechanics of the CDS's premium leg and protection leg.

The good and the bad sides of CDSs?

The "good" side of a CDS – it provides protection against non-payment to one party and a return for providing this protection to the other party. However, there is a possible cause of the "bad" side of a CDS – neither party has to be directly involved in the underlying loan. CDS contracts are widely used from financial institutions to diversify their credit risks. Their goal is to share their risks among the members of the market in a well-diversified way, in order to eliminate the possibility that the protected risk is closely related with the protection seller's credit rate. Companies use the CDSs in order to eliminate or reduce their risk exposure on reference assets without having to sell these assets. It is true that the holder of a reference asset can avoid its credit risk by simply selling the asset to another company. However, this is often not preferable for a number of reasons. But CDS market enables the investors to speculate on the credit rating. Each one of the companies are involved in the CDS market have their ways to value credit ability of other firms. These values are reflected to the CDS prices. If a company estimates that the CDS price on a reference asset is low (because it believes that the credit rate of the reference entity is underrated), it would be willing to buy the protection at this (low) price. It is a well-known fact that the prices of the CDSs reveal a great deal of information about the market's perspective on the companies and governments' credit risk. Speculation trading has increased the liquidity of the CDS markets a lot. As we emphasized above the CDS market aims to provide efficient tools for hedging and taking credit positions. In general, it does this very well. But there were shortcomings in the documentation, as shown by the SNS and Greek credit events. A new set of ISDA definitions will make the CDS market function more effectively. Financial CDS, in particular, should benefit from the changes. Liquidity in the subordinated market has been constrained by the uncertainty around credit events. The new, modern CDS contract should see more participants enter the market. CDS is now ready to tackle events in the troubled post-crisis era.

3. Stripping credit curves

We talk about credit curves because the spread demanded for buying or selling protection generally varies with the length of that protection. In other words, buying protection for 10 years usually means paying a higher period fee (spread per year) than buying protection for 5 years (making an upward sloping curve). We plot each spread against the time the protection covers (1Y, 2Y,..., 10Y) to give us a credit curve, as in Figure 3.1.

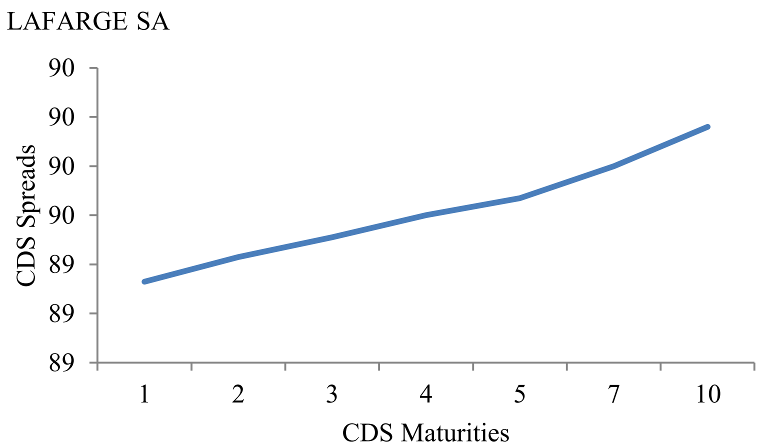

Figure 3.1. The shape of CDS Spreads

Each point along this credit curve represents a spread that ensures the present value of the expected spread payments (Premium Leg) equals the present value of the payment on default (Protection Leg), as it is shown in the section 4 (equality (*)). The valuation of CDS can be thought of as a scenario analysis where the credit survives or defaults. As CDS spreads move with the market and as time passes, the value of the contract may change. So, it is important to focus on bootstrapping process of credit curves. In our case, the credit event process is modeled directly by modeling the probability of the credit event itself. We have characterized a credit event as the first event of the Poisson [3] counting process which occurs at some time τ with a probability defined as

$$P(\tau < t + dt | \tau \geq t) = \lambda(t)dt \quad (3.1)$$

i.e, probability of a default occuring within the time interval $[t, t + dt)$ conditional on surviving to time t, is proportional to some time dependent function $\lambda(t)$, known as the hazard rate, and the length of the time interval dt. The probability of surviving to at least time, $T > t$, (assuming no default has occured up to time t) is given by

$$V(t,T) = P(\tau > T | \tau > t) = E(I_{\tau > T} | F_t) = e^{-\int_t^T \lambda(s)ds} \quad (3.2)$$

where $I_{\tau > T}$ is the indicator function which is 1 if $\tau > T$ and 0 otherwise. It should be noted that the intensity here does not represent a real-world probability of default. Up until this point we have assumed that the intensity is deterministic. If it is extended to be a stochastic process, then the survival probability is given by

$$V(t,T) = E^P(e^{-\int_t^T \lambda(s)ds} | F_t) \quad (3.3)$$

It is quite clear that the survival probability $V(t,T)$ is playing the same role as the discount factor $P(t,T)$, as is the intensity $\lambda(t)$ and the instantaneous short rate $r(t)$. Defining $Q(t,T)$ as the probability of default by time t, so that $Q(t,T) = 1 - V(t,T)$, gives

$$Q(t,T) = 1 - e^{-\int_t^T \lambda(s)ds} \quad (3.4)$$

The survival probability curve $V(t,T)$ and the hazard rate curve $Q(t,T)$ are equivalent, and we refer to them generically as credit curves. In the Table 3.1, there are five on-market CDS quotes for the reference entity, with maturities from 1 to 5 years. With a given risk-free rate term structure and an assumption for the recovery rate (in our case it is 50%), from our credit tool we can bootstrap the hazard rates and survival rates for year 1 to year 5.

Table 3.1. An example of hazard rates and survival probabilities.

Year	CDS Premium (bps)	Hazard Rate (%)	Survival Probability (%)	Cumulative default probability
0	28.73	0.58%	99%	0.58%
1	27.42	0.53%	99%	1.11%
2	26.20	0.48%	98%	1.59%
3	25.06	0.44%	98%	2.03%
4	24.00	0.40%	98%	2.42%

Calculating the default probability default curve

Given a curve of par spreads (spreads of CDSs of various maturities, each with net present value of zero), the system calculates an implied default probability curve by using a bootstrap procedure. Thus, it finds a default probability curve such that all given CDS contracts have zero value.

Other usage of probability of default

As we know a big problem in the over-the-counter derivatives market is the risk of counterparty default. All the financial institutions need to measure the counterparty risk and they do this by calculating XVA's. In this case they need to have calculated the default probability, so our credit tool could be used as a generator of a dense vector of default probabilities. For example, CVA is the expected value of credit losses over the lifetime of the trade and it is calculated by the following formula:

$$CVA = PV * (EAD * (1 - Recovery\ Rate) * Probability\ of\ Default)$$

where probability of default derived through market CDS spreads (by the market's view of how likely it is that default will occur before the reference entity matures).

Recovery Rate Curve

It is clear that the recovery rate's impact on CDS valuation is more subtle. Recovery rates effect default probabilities, and thus effect the valuation of cash flows. They are determined through an CDS auction process [5] according to the ISDA Agreement, which is aimed at identifying a fair recovery rate for the defaulted instrument in question so as to facilitate cash-settlement of the contracts. The relationship between CDS spread and Recovery rate is shown as follow:

$$CDS\ spread\ \approx (1 - \text{Recovery rate}) * \text{Probability of default}$$

In other words, CDS spreads are equal to the potential loss in default multiplied by the probability of default. Re-arranging the terms gives:

$$\text{Probability of default} \approx CDS\ spread/(1 - \text{Recovery rate})$$

Therefore, for a given CDS spread, the higher the recovery rate assumption the higher the default probability assumed. In our tool we have reserved a space to set up the recovery rate assumptions for credit curves for use in the CDS model. Table 3.2 provides historical data on average recovery rates for different seniorities, but also it is possible to set up a term structure recovery rate curve (it is an optional choice).

Table 3.2. Recovery rates according seniorities.

Seniority	Rates
Senior - C	0.4
Subordinated - C	0.1
Senior - B	0.5
Subordinated - B	0.0
Sovereign	0.2

4. CDS Valuation

We now present a discrete form pricing approach that we use in our tool, using market-observed parameter inputs. We started earlier that a CDS has two cash flow legs; the premium leg and the protection (contigent cash flow) leg. We wish to determine the par spread or premium of the CDS, remembering that for a par spread valuation, in accordance with no - arbitrage principles, the net present value of both legs must be equal to zero (that is, they have the same valuation). The valuation of the premium leg is given by the following relationship:

$$PV\ of\ No\text{-}default\ fee\ payments = s_N * Annuity_N$$

which is given by

$$PV = s_N \sum_{i=1}^{N} DF_i * PnD_i * A_i \qquad (4.1)$$

where,

s_N is the par spread (CDS premium) for maturity N
DF_i is the risk − free discount factor from time T_0 to time T_i

PnD_i is the no − default probability from T_0 to T_i

A_i is the accrual period from T_{i-1} to T_i

Note that the value for *PnD* is for the specific reference entity for which a CDS is being priced. If the accrual fee for the CDS is paid upon default and termination, then the valuation of the premium leg is given by the relationship:

$$PV\ of\ no-default\ fee\ payments + PV\ of\ Default\ accruals$$
$$= s_N * Annuity_N + s_N * Default\ accrual_N$$

which is given by

$$PV_{NoDefault+DefaultAccrual} = s_N \sum_{i=1}^{N} DF_i * PnD_i * A_i + s_N \sum_{i=1}^{N} DF_i * (PnD_{I-1} - PnD_i) * \frac{A_i}{2} \quad (4.2)$$

where,

$(PnD_{i-1} - PnD_i)$ is the probability of a credit event occuring during the period T_{i-1} to T_i

$A_i/2$ is the average accrual amount from T_{i-1} to T_i.

The valuation of the protection leg is approximated by:

$$PV\ of\ Contigent\ = Contigent_N$$

which is given by

$$PV_{Contigent} = (1 - R) \sum_{i=1}^{N} DF_i * (PnD_{i-1} - PnD_i)$$

where *R* is the recovery rate of the reference obligation. For a par credit default swap, we know that

Valuation of Premium leg = Valuation of protection leg (*)

and therefore we can set

$$s_N \sum_{i=1}^{N} DF_i * PnD_i * A_i + s_N \sum_{i=1}^{N} DF_i * (PnD_{i-1} - PnD_i) * \frac{A_i}{2} = (1 - R) \sum_{i=1}^{N} DF_i * (PnD_{i-1} - PnD_i)$$

which may be rearranged to give us the formula for the CDS premium *s* as follows:

$$s_N = \frac{(1-R)\sum_{i=1}^{N} DF_i*(PnD_{i-1}-PnD_i)}{\sum_{i=1}^{N} DF_i*PnD_i*A_i+DF_i*(PnD_{i-1}-PnD_i)*\frac{A_i}{2}} \qquad (4.3)$$

All the valuation process of a CDS in our tool is represented by the following general schema:

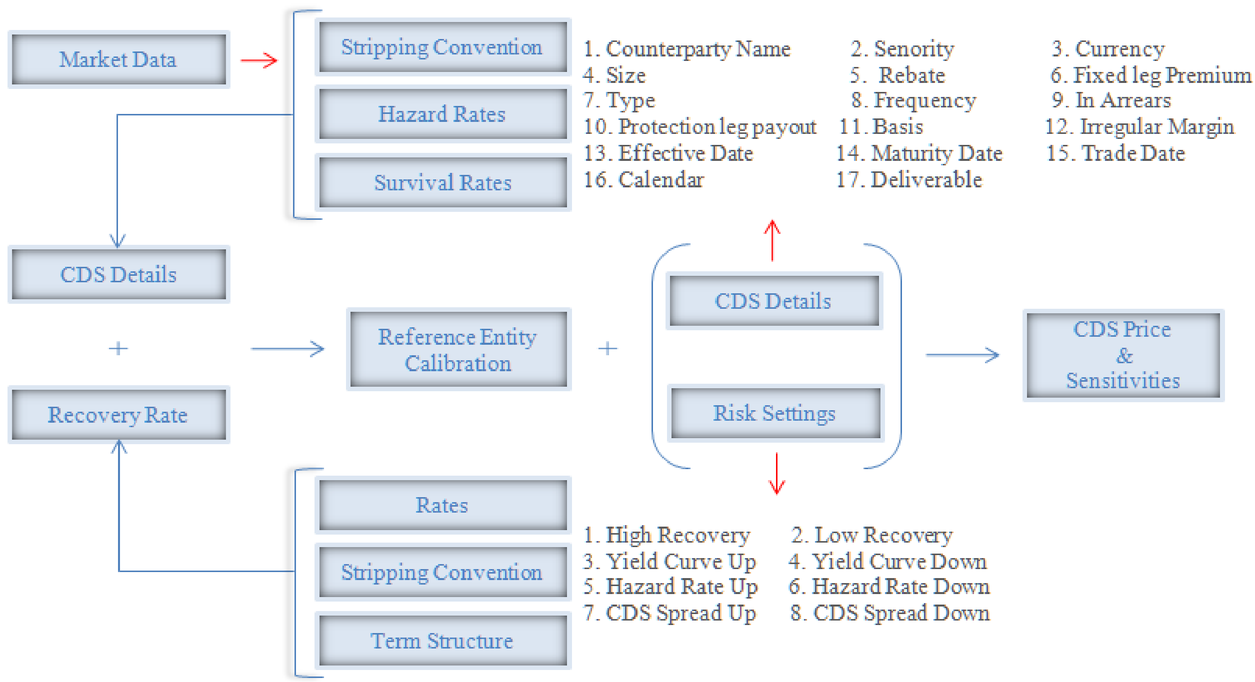

Figure 4.1. The entire process of generating the valuation output of a CDS.

This is a schema that shows the whole steps we should follow to obtain the CDS premium. Starting from the Market Data and Stripping Conventions of Credit Curves and ending with CDS premium and Risk details. Table 4.1 shows CDS valuation outputs for CDS's in different maturities (in our case from (1Y,...,10Y)), which are CDS premium (PV) and other details related to that. At first you will find the AM that shows the accrued premium in basis points, this associated by BPF that is the value of the protection leg of the CDS, i.e. the payoff on default, in basis points. NPV is another output from our tool that shows the fair premium for a new trade with the same details and zero NPV, while PoV is the net value of the transaction for the given transaction size (and direction), i.e. the value of the protection leg minus the value of the premium, expressed in the currency of the CDS.

Table 4.1. Example of pricing a CDS.

Term	AM (bps)	BPF (bps)	NPV (bps)	PoV	PrV (bps)	**PV (bps)**
1Y	0.00	28.92	38.38	22312.57	51.23	22.31
2Y	0.00	26.25	35.31	24302.62	50.55	24.30
3Y	0.00	23.63	31.87	26787.04	50.41	26.79
4Y	0.00	21.45	28.94	28953.32	50.41	28.95
5Y	0.00	19.13	26.09	30730.43	49.86	30.73
6Y	0.00	16.29	22.36	33263.47	49.56	33.26
7Y	0.00	16.17	22.30	33136.09	49.31	33.14
8Y	0.00	12.87	17.88	36082.66	48.95	36.08
9Y	0.00	12.71	17.64	36270.17	48.98	36.27
10Y	0.00	12.67	17.64	36155.07	48.82	36.16

Moreover, we show some details about Premium leg payments: PrV shows the value of the premium payments in basis points (including Accrued Margin). At the end we show you the **PV** value which is the net value of the transaction in basis points, with the direction of the transaction determined by the sign of the size of the trade in the currency of the trade the user choose to deal with, i.e. if size of the trade is positive this is the value of the protection leg minus the value of the premium. If size of the trade is negative, this is the value of the premium minus the value of the protection.

5. Analysing the shape of Credit Curves

The concepts of Survival Probability, Default Probability and Hazard Rates that we have seen so far help us to price a CDS contract and also to explain the shape of credit curves. Many CDS curves slope upwards because investors demand greater compensation (Spread), for giving protection for longer periods as the probability of defaulting increases over time. However, whilst it's true that the cumulative probability of default does increase over time, this by itself does not imply an upward sloping credit curve, flat or even downward sloping curves also imply the (cumulative) probability of default increasing over time. The reason why the curves usually are upward sloping curves is to look at the hazard rate implied by the shape of the curve: we know that flat curves imply constant hazard rates (the conditional probability of default is the same in each period). In other words, if the hazard rate is constant, spreads should be constant over time and credit curves should be flat.

An upward sloping curve, such as shown in Figure 3.1, implies a survival probability as shown in Figure 5.2, which declines at an increasing rate over time. This means that we have an increasing hazard rate for each period as shown in Figure 5.3.

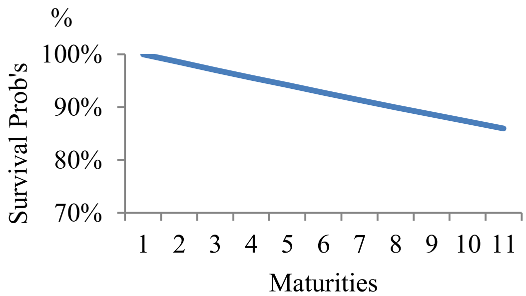

Figure 5.2. Upward Sloping CDS spreads.

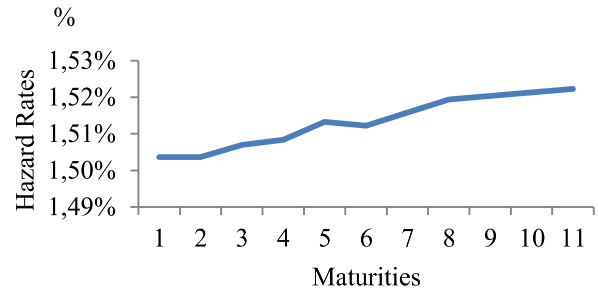

Figure 5.3. Hazard Rates for Upward Sloping Curve.

For curves that slope upwards, is expected that the hazard rate to be increasing over time. Intuitively, this means that the probability of defaulting in any period (conditional on not having defaulted until then) increases as time goes on. Upward sloping curves mean that the market is implying not only that companies are more likely to default with every year that goes by, but also that the likelihood in each year is ever increasing. Credit risk is therefore getting increasingly worse for every year into the future.

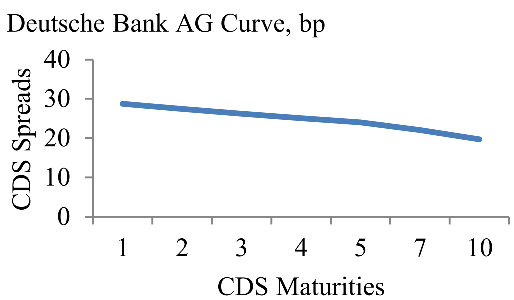

Figure 5.4. Downward Sloping CDS spreads.

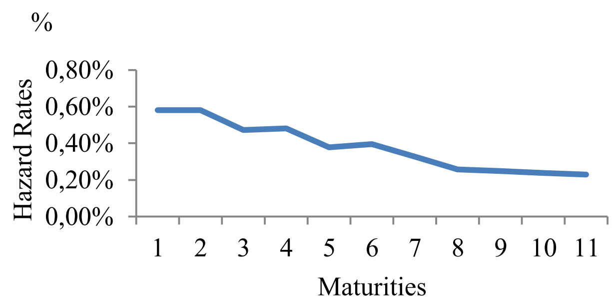

Figure 5.5. Hazard Rates for Downward Sloping Curve.

Companies with downward sloping curves have decreasing hazard rates, as can be seen when looking at Deutsche Bank AG (see Figure 5.4). This does not mean that the cumulative probability of default decreases, rather it implies a higher conditional probability of default (hazard rate) in earlier years with a lower conditional probability of default in later periods (see Figure 5.5). This is typically seen in lower rated companies where there is a higher probability of default in each of the immediate years. But if the company survives this initial period, then it will be in better shape and less likely to (conditionally) default over subsequent periods.

6. Sensitivity to CDS Premium.

The value of an existing CDS position depends on the recovery rate and credit curve perturbations and curve shape assumptions used in the calculation. In the tables below you will see the risk results, for all CDS's that the user have selected to deal with. Table 6.1 shows the change in PV of the CDS for each shift of inputs or model values (ex. the recovery rates, hazard rates, the yield curve, par CDS spread curve) as chosen in the Risk Settings (Figure 4.1) inputs section. The **PV** is the net value of the transaction in basis points, as shown in the Valuation outputs section (Table 4.1). PV High Recovery and PV Low Recovery tells about the sensitivity of the PV when we change recovery rate and in our case we have displayed the respective results for 60% and 0% recovery rates. While Average Hazard Rate, Average Yield Curve and Average CDS Spread shows the average change of the PV when the hazard rate curve, the yield curve and the par CDS spread curve, are perturbated, respectively.

Table 6.1. Risk details of CDS.

Term	PV High Recovery	PV Low Recovery	**PV** (bps)	Average Hazard Rate	Average Yield Curve	Average CDS Spread
1Y	-0.0202	0.0405	22.3126	-0.4985	-0.0011	-1.0093
2Y	-0.0536	0.1076	24.3026	-0.5008	-0.0013	-1.0136
3Y	-0.0895	0.1800	26.7870	-0.4994	-0.0013	-1.0099
4Y	-0.1266	0.2552	28.9533	-0.4993	-0.0015	-1.0082
5Y	-0.1621	0.3272	30.7304	-0.4984	-0.0016	-1.0044
6Y	-0.1997	0.4038	33.2635	-0.5001	-0.0017	-1.0052
7Y	-0.2267	0.4590	33.1361	-0.5013	-0.0017	-1.0070
8Y	-0.2663	0.5399	36.0827	-0.5080	-0.0019	-1.0171
9Y	-0.2918	0.5924	36.2702	-0.5081	-0.0019	-1.0165
10Y	-0.3147	0.6398	36.1551	-0.5106	-0.0019	-1.0206

In addition, there are some other more detailed outputs related to the sentitivites of the PV that are shown in the Table 6.2. For interest rate (IRL), hazard rate and spread shifts, the values shown are changes per basis point increase, calculated using the specified shifts (i.e. the actual change in PV (bps) divided by the shift). The Premium rebate shows the amount of the premium rebate to be made in case of default. The Default event risk columns show the value of the position in the case of default, with zero recovery (Default event risk R = 0%) and 100% recovery (Default event risk R = 100%).

Table 6.2. Other complementary risk details of CDS.

Term	Yield Curve Down	Yield Curve Up	Hazard Rate Down	Hazard Rate Up	CDS Spread Up	CDS Spread Down	Premium Rebate	Default Event R (0%)	Default Event R (100%)
1Y	-0.0011	-0.0011	-0.5010	-0.4960	-1.0080	-1.0106	5.4031	0	10000
2Y	-0.0013	-0.0013	-0.5083	-0.4933	-1.0103	-1.0170	4.8984	0	10000
3Y	-0.0013	-0.0013	-0.5118	-0.4870	-1.0046	-1.0152	4.4572	0	10000
4Y	-0.0015	-0.0015	-0.5166	-0.4820	-1.0009	-1.0155	4.1272	0	10000
5Y	-0.0016	-0.0016	-0.5205	-0.4763	-0.9951	-1.0137	3.7303	0	10000
6Y	-0.0017	-0.0017	-0.5271	-0.4731	-0.9940	-1.0165	3.2537	0	10000
7Y	-0.0017	-0.0017	-0.5331	-0.4695	-0.9938	-1.0202	3.3288	0	10000
8Y	-0.0019	-0.0019	-0.5450	-0.4710	-1.0018	-1.0324	2.7033	0	10000
9Y	-0.0019	-0.0019	-0.5499	-0.4663	-0.9993	-1.0337	2.7818	0	10000
10Y	-0.0019	-0.0019	-0.5573	-0.4639	-1.0015	-1.0398	2.8645	0	10000

We review the impact the recovery rate on CDS valuation. In the Figure 6.1 we show how CDS premium changes for a 5Y CDS using different recovery assumptions.

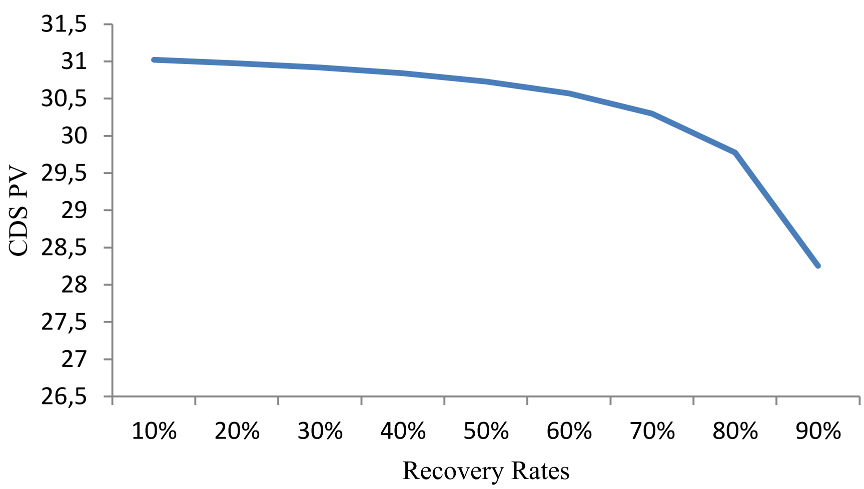

Figure 6.1. The sensitivity of CDS net value transaction in basis points to recovery assumptions.

As recovery rates increase the curve becomes steeper. As the recovery rate increases, this increases the default probability, which in turn decreases the CDS PV, although this only drops off sharply when recovery rates become very high which means that one is more likely to experience and settle at that recovery. CDS PV is also more sensitive to recovery at higher spreads for the same reason.

7. Conclusions

In this work we analyze CDS pricing and risk measures through an approach we have set-up and implemented in our tool. We explained the stripping process of credit curves and the role that survival curve, hazard rate curve and recovery curve plays in generating probability of default and pricing CDSs. Also, we analyzed the shape of the credit curves, and other risk factors which affect the CDS premium by applying a perturbation process by shifting model parameters and the yield curve of a specific economy. We concluded that the price of a credit default swap and the probability of default are directly connected. Quantifying the default probability and term structure is useful for hedging out credit risk inherent in fixed-income securities and is also helpful for calculating the risk-neutral prices of credit derivatives other than CDSs. As we know a big problem in the over-the-counter credit derivatives market is the risk of counterparty default. The protection seller may be unable to fully cover the loss it is insuring against. To mitigate this risk, the protection seller may have to post collateral. This market has perceived hazard rates which this pricing model computed can be integrated into more complicated models for multi-name credit derivative products, such as basket default swaps or CDOs. Other extensions of this project could be to incorporate stochastic recovery rates or stochastic hazard rates.

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