Pre-Course Reading for xVA

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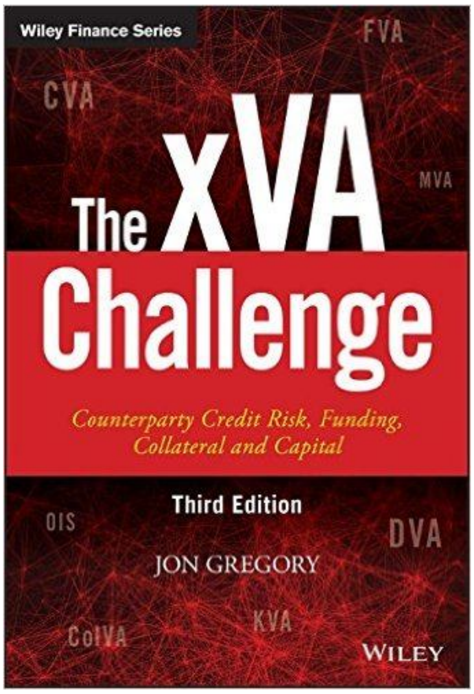
This is general pre-course reading for my xVA courses and aims to cover the more basic topics that will be either not covered or is discussed relatively briefly. It is highly recommended that a delegate has a reasonable understanding of the material here prior to the course.

Some of the content below has been taken from my book "The xVA Challenge" published by John Wiley and Sons.



Any queries or suggestions, please feel free to email me at jon@oftraining.com.

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1 DERIVATIVES

1.1 Overview

Derivatives contracts represent agreements either to make payments or to buy or sell an underlying security at a time or times in the future. Maturities may range from a few weeks or months (for example, futures contracts) to many years (for example, long-dated swaps). The value of a derivative will change with the level of one of more underlying assets or indices and possibly decisions made by the parties to the contract. In many cases, the initial value of a traded derivative will be contractually configured to be zero for both parties at inception. The credit risk of derivatives contracts is called counterparty risk.

1.2 Exchange traded and OTC derivatives

Many of the simplest derivative products are traded on exchanges. A derivatives exchange is a financial centre where parties can trade standardised contracts such as futures and options at a specified price. An exchange promotes market efficiency and enhances liquidity by centralising trading in a single place. Modern-day exchanges have a central clearing function that guarantees performance and therefore mitigates counterparty risk. Exchange-traded derivatives are usually assumed to have no counterparty risk but this due to the simplicity of the products as much as the central clearing function.

Compared to exchange-traded derivatives, OTC derivatives tend to be less standard and are typically traded bilaterally, i.e., between two parties. Hence, each party takes counterparty risk with respect to the other party. Many OTC derivatives are long-dated and many end-user counterparties are unable to post collateral: counterparty risk is therefore an unavoidable consequence. A relatively small number of banks are fairly dominant in OTC derivatives: these are generally large, highly interconnected and viewed as being “too big to fail”.

The OTC derivatives market has developed in the last two decades to be much larger than the exchange-traded market (Figure 1). This is due to the use of OTC products as customised hedging instruments and investment vehicles. The OTC market has also seen the development of completely new products (for example, credit default swaps). The relative popularity of OTC products is the ability to tailor contracts more precisely to client needs.

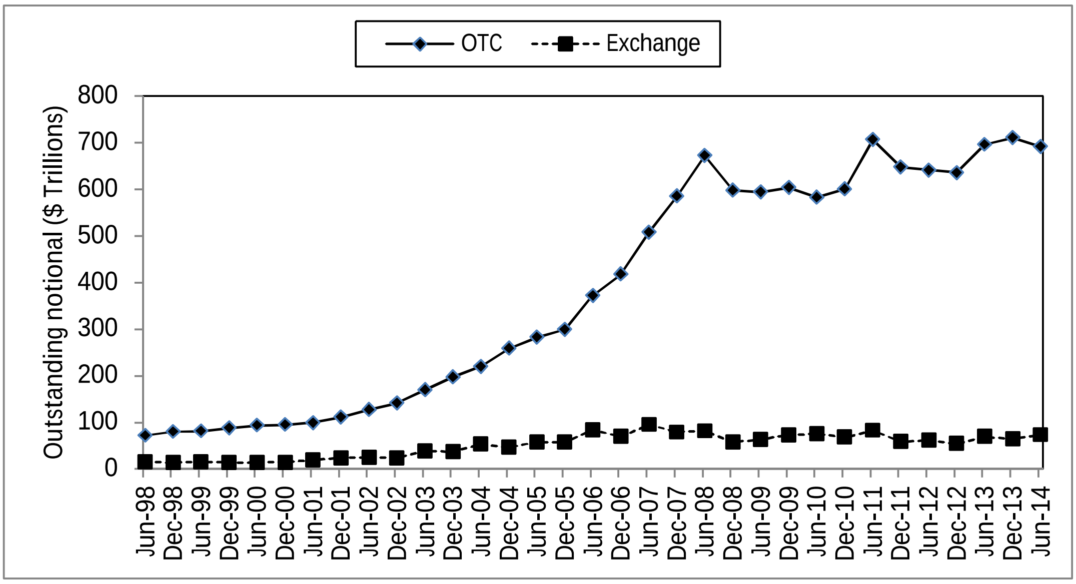

Figure 1. *Total outstanding notional of OTC and exchange-traded derivatives transactions. Note that this is only a guide to the amount of underlying risk. Source: BIS.*

A significant amount of OTC derivatives are collateralised with parties pledging cash and securities against the mark-to-market (MTM) of their derivative portfolio with the aim of neutralising the net exposure. Collateral can reduce counterparty risk but introduces additional legal and operational risks. Furthermore, posting collateral introduces liquidity risk as it is necessary to source the cash or securities to deliver.

Since the late 1990s, there has also been a growing trend to centrally clear some OTC derivatives, primarily aimed at reducing counterparty risk. Centrally cleared derivatives retain some OTC features (such as being transacted bilaterally) but use the central clearing function developed for exchange-traded derivatives. Central clearing does require an OTC derivative to have a certain level of standardisation and liquidity, and to not be too complex. This means that many types of OTC derivatives will never be suitable for central clearing.

Broadly speaking, derivatives can be classified into several different groups by the way in which they are transacted and collateralised. These groups, in increasing complexity and risk are:

- *Exchange-traded.* These are the simplest, liquid and short-dated derivatives that are traded on an exchange.
- *OTC centrally cleared.* These are OTC derivatives that are not suitable for exchange-trading due to being relatively complex, illiquid or non-standard but are centrally cleared.
- *OTC collateralised.* These are bilateral OTC derivatives that are not centrally cleared but where parties post collateral to one another in order to mitigate the counterparty risk.
- *OTC uncollateralised.* These are bilateral OTC derivatives where parties do not post collateral (or post less and/or lower quality collateral). This is typically because one of the parties involved in the contract (typically an end-user such as a corporate) cannot commit to collateral posting.

1.3 Lehman Brothers

The bankruptcy of Lehman Brothers in 2008 provides a good example of the difficulties created by OTC derivatives. Lehman had over 200 registered subsidiaries in 21 countries and around a million derivatives transactions. The insolvency laws of more than 80 jurisdictions were relevant. In order to fully settle with an OTC derivative counterparty, the following steps need to be taken:

- Reconciliation of the universe of transactions;
- Valuation of each underlying transaction; and
- Agreement of a net settlement amount.

As shown in Figure 2, carrying out the above steps across many different counterparties and transactions has been a very time consuming process.

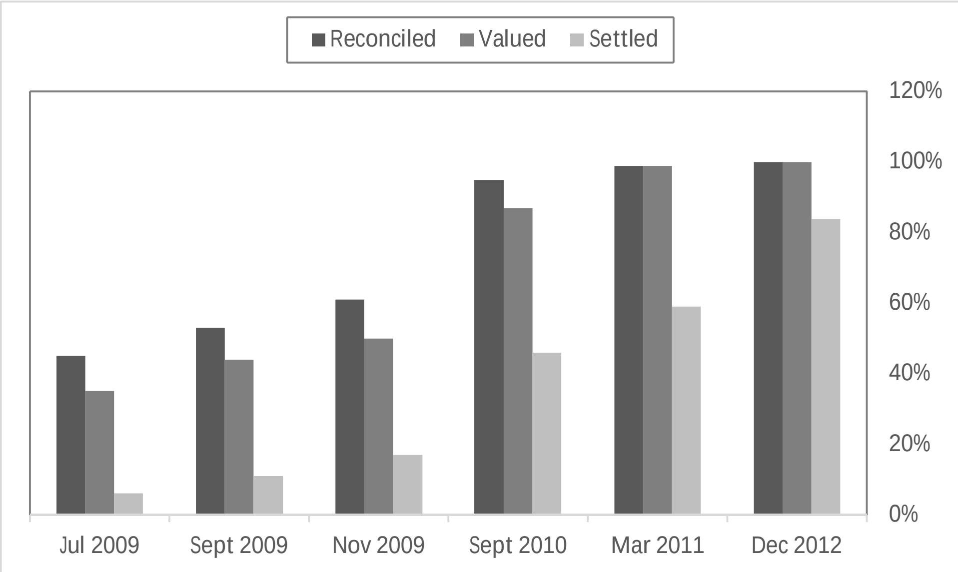

Figure 2. *Management of derivative transactions by the Lehman Brothers estate. Source: Fleming and Sarkar (2014).*[1]

2 COUNTERPARTY RISK

2.1 Definition

Counterparty credit risk (often known just as counterparty risk) is the risk that the entity with whom one has entered into a financial contract (the counterparty to the contract) will fail to fulfil their side of the contractual agreement (e.g., they default). Counterparty risk is typically defined as arising from two broad classes of financial products: OTC derivatives (e.g. interest rate swaps) and securities financial transactions (e.g. repos). The former category is the more significant due to the size of the OTC derivatives market, the fact that transactions are generally long-dated and also that many counterparties do not post collateral.

Two aspects differentiate contracts with counterparty risk from traditional credit risk:

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[1] Fleming, M. J., and A. Sarkar, 2014, "The Failure Resolution of Lehman Brothers", Federal Reserve Bank of New York Economic Policy Review, December, www.ny.frb.org

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

2.2 Mitigation

There are a number of ways of mitigating counterparty risk, some obvious examples being:

- *Netting.* Bilateral netting agreements allow cash flows to be offset and, in the event of default, for MTM values to be combined into a single net amount (Section 3.3).
- *Collateral.* Collateral agreements specify the contractual posting of cash or securities against MTM losses (Section 3.5).
- *Other contractual clauses.* Other features such as resets or additional termination events aim to periodically reset MTM values or terminate transactions early (Section 3.4).
- *Central counterparties.* Central counterparties (CCPs) guarantee the performance of transactions cleared through them and aim to be financially secure through the collateral and other financial resources they require from their members (Section 3.6).
- *Hedging.* Hedging counterparty risk with products such as credit default swaps (CDSs) aims to protect against potential default events and adverse credit spread movements and variability from other factors such as interest rates and FX.

2.3 Credit exposure

Credit exposure defines the loss in the event of a counterparty defaulting. It is also representative of other costs such as capital and funding that appear in other xVA terms. Exposure is characterised by the fact that a positive value of a portfolio corresponds to a claim on a defaulted counterparty, whereas in the event of negative value, a party is still obliged to honour their contractual payments. This means that if a party is owed money and their counterparty defaults then they will incur a loss, whilst in the reverse situation they cannot gain[2] from the default. More details are given in Section 4.1.

2.4 Default probability

When assessing counterparty risk, one must consider the credit quality of a counterparty over the entire lifetime of the relevant transactions. Such time horizons can be extremely long and the term structure of default is very important to consider.

Default probability may be defined as real-world or risk-neutral. In the former case, we ask ourselves what is the *actual* default probability of the counterparty, which often is estimated via historical data. In the latter case, we calculate the risk-neutral (or market-implied) probability from market credit spreads. It is worth emphasising that risk-neutral default probabilities have become virtually mandatory for CVA calculations in

[2] Except in some special and non-standard cases.

recent years due to a combination of accounting guidelines, regulatory rules and market practice. More details are given in Section 4.2.

2.5 Loss given default

Recovery rates typically represent the percentage of the outstanding claim recovered when a counterparty defaults. An alternative variable to recovery is loss given default (LGD), which in percentage terms is 100% minus the recovery rate. Default claims can vary significantly and LGD is therefore highly uncertain. In the event of a bankruptcy, the holders of OTC derivatives contracts with the counterparty in default would generally be *pari passu*[3] with the senior bondholders. OTC derivatives, bonds and CDSs generally reference senior unsecured credit risk and may appear to relate to the same LGD. However, there are timing issues: when a bond issuer defaults, LGD is realised immediately since the bond can be sold in the market. CDS contracts are also settled within days of the defined "credit event" via the CDS auction which likewise defines the LGD. However, OTC derivatives (unlike bonds) cannot be freely traded or sold, especially when the counterparty to the derivative is in default. This essentially leads to a potentially different LGD for derivatives. These aspects were very important in the Lehman Brothers bankruptcy of 2008.

2.6 Credit limits

Counterparty risk can be diversified by limiting exposure to any given counterparty, broadly in line with the perceived default probability of that counterparty (although such diversification is not always practical due to the relationship benefits from trading with certain key clients). The primary historical method of controlling counterparty risk was using limits as a means to cap the amount of risk to a given counterparty over time.

Credit limits are generally specified at the counterparty level as illustrated in Figure 3. The idea is to characterise the potential future exposure (PFE) to a counterparty over time and ensure that this does not exceed a certain value (the credit limit). The PFE (Section 4.1) represents a worst-case scenario and the credit limit will be set subjectively according to aspects such as the credit quality of the counterparty in question. Broadly speaking, the follow aspects must be accounted for when calculating the PFE (these also apply to CVA and other xVA terms):

- the transaction in question;
- the current relevant market variables (e.g. interest rates and volatilities);
- netting between the different transaction with the same counterparty;
- collateral terms with the counterparty (if any); and
- hedging aspects.

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

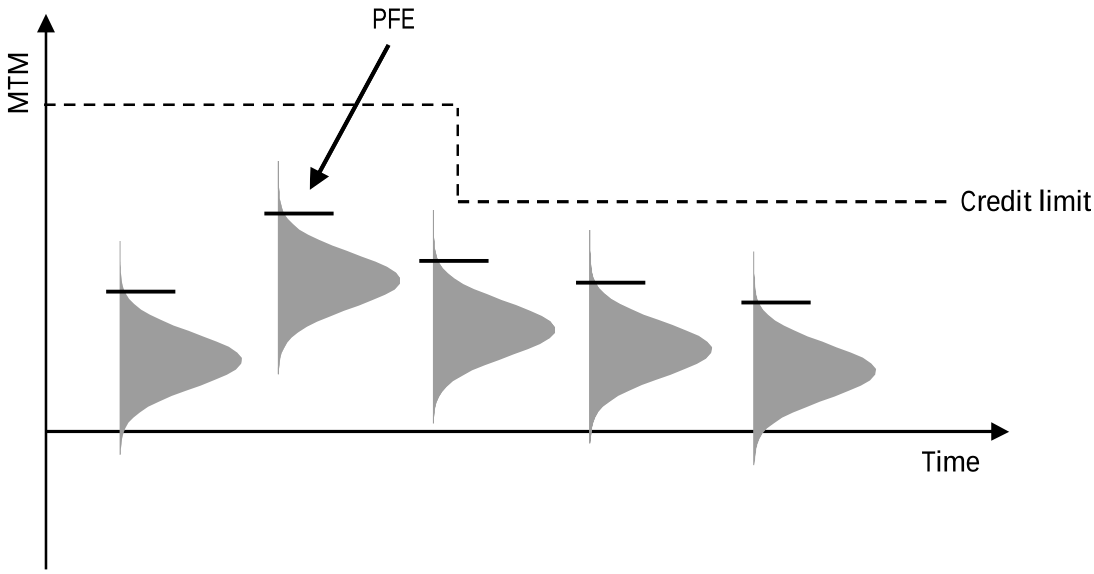

Figure 3. *Illustration of the use of PFE and credit limits.*

2.7 Regulation and accounting

Two key aspects around xVA are regulation and accounting. The most obvious regulatory component is rules on minimum capital standards, which are defined by the Basel Committee for Banking Supervision (BCBS). Accounting standards define the way in which the value of derivatives should be represented in financial statements, which has a significant impact on pricing and market practice.

IFRS 13 accounting guidelines were introduced from 2013 to aim to provide a single framework for guidance around fair value measurement for financial instruments. IRFS 13 uses the concept of exit price which implies the use of risk-neutral (market implied) information as much as possible. This is particularly important in default probability estimation where market credit spreads tend to be used instead of historical default probabilities (Section 4.2). Exit price also introduces the notion of own credit risk and leads to DVA (Section 5.4). Exit price is an important concept for xVA in general since any valuation adjustment that is generally seen in market prices should also apparently become an accounting adjustment. This is exactly what has happened with FVA (Section 5.4) in recent years.

A key form of regulation is determining the minimum amount of capital that a given bank must hold. There is clearly a balance in defining the capital requirements for a bank; it must be high enough to contribute to a very low possibility of failure and, yet, not so severe as to unfairly penalise the bank and have adverse consequences for their clients and the economy as a whole. Capital is important since banks generally aim for a minimum return on capital when pricing transactions.

The definition of quantitative rules for regulatory capital is difficult. A simple approach will be transparent and easier to implement but will not capture any more than the key aspects of the risks arising from a complex web of positions at a bank.

Basel III defines two capital charges in relation to counterparty risk which are:

- The CCR capital charge (sometimes known as the default risk capital charge); and
- The CVA capital charge.

There are different methodologies for computing these requirements. Banks with internal model method (IMM) approval can use their own models for this purpose. All other banks must use simpler regulatory formulas which are not as risk sensitive and tend to be more conservative.

New methodologies are also being introduced, in particular:

- *SA-CCR (standardised approach for counterparty credit risk).* This will be the CCR capital charge methodology for non-IMM banks from 2017 (and may represent a floor for IMM banks).
- *FRTB-CVA (fundamental review of the trading book for CVA).* This will represent new methodologies for the CVA capital charge from 2019.

There are other aspects that impact capital requirements such as the leverage ratio. On a related point, regulation over liquidity, such as the liquidity coverage ratio (LCR) is important for xVA.

3 CONTRACTUAL ASPECTS

A given party may have hundreds or even thousands of separate derivatives transactions with a counterparty. They need a mechanism to terminate their transactions rapidly and replace (re-hedge) their overall position in the event of a default. This section reviews some important contractual terms that are generally applied to OTC derivatives transactions.

3.1 The ISDA Master Agreement

The market standard for OTC derivative documentation is the ISDA Master Agreement. The Master Agreement comprises a common core section and a schedule containing adjustable terms to be agreed by both parties. This specifies the contractual terms with respect to aspects such as netting, collateral, termination events, definition of default and the close-out process. The commercial terms of individual transactions are documented in a trade confirmation, which references the Master Agreement for the more general terms.

From a counterparty risk perspective, the ISDA Master Agreement has the following key features:

- events of default and the mechanics of the resulting close-out process;
- the application of netting with respect to different transactions in the event of default; and
- the contractual terms regarding the posting of collateral.

3.2 Close-out amount

The close-out amount represents the quantity that is owed by one party to another in a default scenario. If this amount is positive from the point of view of the surviving party, then they will have a claim on the estate of the defaulting party. If it is negative, then they will be obliged to pay this amount to the defaulting party. Although the defaulting party will be unable to pay the claim in full, establishing the size of the claim is important. The determination of the appropriate close-out amount is complex as parties will inevitably disagree. The surviving party will likely consider their value of executing replacement transactions. The defaulting party will likely disagree with this assessment since it will reflect charges such as bid-offer costs.

The concept of replacement cost led to the development of "Market Quotation" as a means to define the close-out amount in the 1992 ISDA Master Agreement with an alternative known as the "Loss Method". These are characterised as follows:

- *Market Quotation.* The determining (surviving) party obtains a minimum of three quotes from market-makers and uses the average of these quotations in order to determine the close-out amount.
- *Loss Method.* This is the fallback mechanism in the event that it is difficult for the determining party to use Market Quotation. The determining party is required to calculate its loss in good faith and using reasonable assumptions.

Market Quotation generally works well for non-complex transactions in relatively stable market conditions. However, since 1992 there have been an increasing number of more complex and structured OTC derivative transactions. This led to a number of significant disputes. Furthermore, the Loss Method was viewed as too subjective and as giving too much discretion to the determining party. This was further complicated by contradictory decisions made by the English and US courts. The 2002 ISDA Master Agreement replaced the concepts of market quotation and loss method with a single definition of "Close-out Amount". Close-out amounts are essentially a diluted form of market quotation as they do not require actual tradable quotes but can instead rely on indicative quotations, public sources of prices and market data and internal models to arrive at a commercially reasonable price.

Note that the contractual definition regarding close-out is crucial in defining the economics of a counterparty default and as such is a key element in defining credit exposure and related aspects such as CVA. For example, under the Close-out Amount definition in the 2002 ISDA, the determining party's own credit worthiness and costs of funding and hedging may be included.

3.3 Netting

OTC derivatives markets have historically developed netting methods whereby parties can offset what they owe to one another. The following two mechanisms, which apply in both bilateral and centrally cleared markets, facilitate this:

- *Payment netting.* This gives a party the ability to net cash flows occurring on the same day sometimes even if they are in different currencies. This typically relates to settlement risk since it mitigates intraday risk.

- *Close-out netting*. This allows the offsetting of all transaction values (both in a party's favour and against it) in a default scenario. This typically relates to counterparty risk.

Close-out netting gives a surviving party the right to offset the value[4] across all relevant transactions and determine a *net balance*, which is the sum of positive and negative values, for the final close-out amount. In essence, all covered transactions (of any maturity whether in- or out-of-the-money) collapse to a single net value. If the surviving party owes money, then it makes this payment or if it is owed money then it makes a claim for that amount. Close-out netting allows the surviving party to immediately

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

realise gains on transactions against losses on other transactions and effectively jump the bankruptcy queue for all but its net exposure, as illustrated in Figure 4.

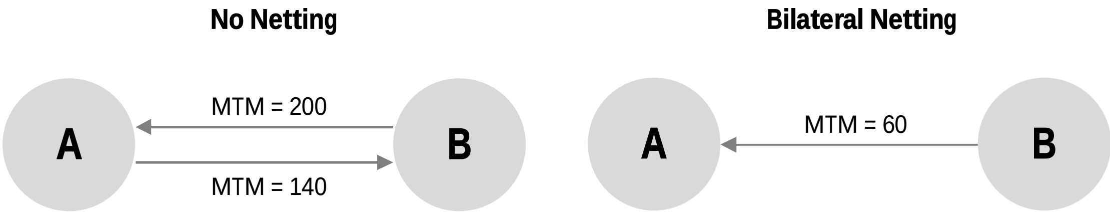

Figure 4. *Illustration of the impact of close-out netting. In the event of default of party A, without netting, party B would need to pay 200 to party A and would not receive the full amount of 140 owed. With netting, party B would simply pay 60 to party A and suffer no loss.*

In OTC derivatives markets, surviving parties will usually attempt to replace defaulted transactions. Without netting, the total number of transactions and their notional value that surviving parties would attempt to replace may be larger and hence may be more likely to cause market disturbances.

In centrally cleared markets, netting is potentially more efficient by being multilateral, rather than bilateral. However, bilateral markets do achieve multilateral netting via trade compression. Initiatives such as TriOptima's TriReduce service[5] provide compression services covering major OTC derivatives products. This is done via a coordinated reduction in the number and gross notional of transactions between major market participants but without materially changing their net market positions. Since compression services reduce the number and gross notional of derivatives transactions, they are also complimentary to central clearing environments.

3.4 Termination features and resets

In addition to netting, some other risk mitigating features that are applied, typically at the transaction level, are:

- *Termination events.* An Additional Termination Event (ATE), allows a party to terminate an OTC derivative transaction(s) in certain situations, the most common being in relation to a rating downgrade (for example, below investment grade) although they can also be mandatory or optional. ATEs are obviously designed to reduce counterparty risk by allowing a party to terminate transactions or apply other risk reducing actions (for example, receiving collateral) when their counterparty's credit quality is deteriorating. Variants of ATEs include "break clauses" or "mutual puts".
- *Resets.* A reset agreement is a clause which avoids a transaction becoming strongly in-the-money (to either party) by means of adjusting product-specific parameters that reset the transaction to be at-the-money. Reset dates may coincide with payment dates or be triggered by the breach of some market value. For example, in a resettable cross-currency swap, the MTM on the swap (which is mainly driven by FX movements) is exchanged at each reset time in cash and the FX rate is reset to (typically) the prevailing spot rate. The reset means that the notional on one leg of the swap will change. Such a reset is similar to the impact of closing out the transaction and executing a replacement transaction at market rates and consequently reduces the exposure. An example of the impact

[5] www.trioptima.com

of such a reset is shown in Figure 5. It can also be seen as a first step towards collateralisation.

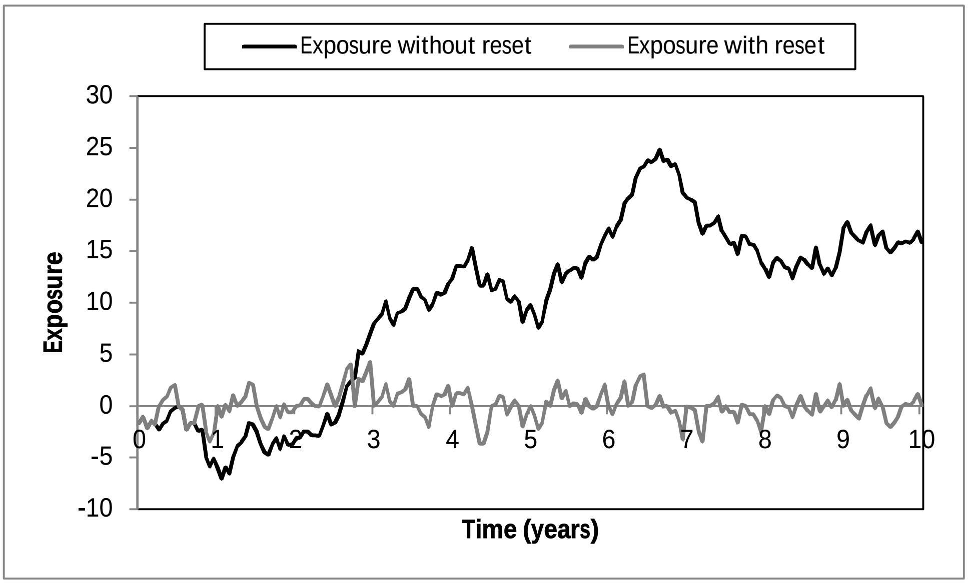

Figure 5. *Illustration of the impact of reset features on the exposure of a long-dated cross-currency swap. Resets are assumed to occur quarterly.*

3.5 Collateral

Collateral is an asset supporting a risk in a legally enforceable way. The fundamental idea of derivatives collateralisation (Figure 6) is that cash or securities are passed (with or without actual ownership changing) from one party to another as a means to reduce counterparty risk. Whilst break clauses and resets can provide some risk mitigating benefit in these situations, collateral is a more dynamic and generic concept.

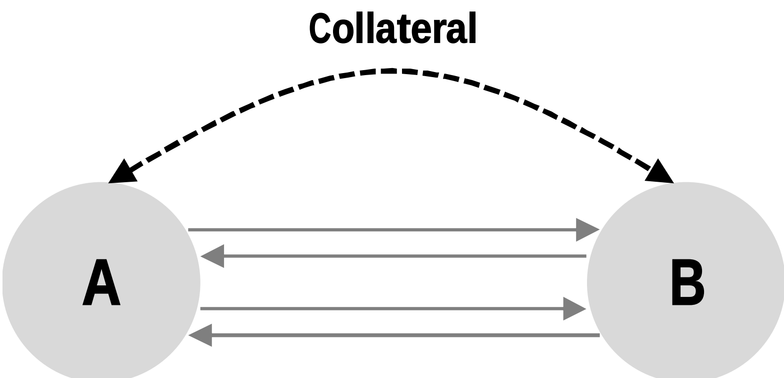

Figure 6. *Illustration of the basic role of collateral in OTC derivatives.*

A collateral agreement reduces risk by specifying that collateral must be posted by one counterparty to the other to support such an exposure. In the event of default, the surviving party may use the collateral to offset any losses. Note that, since collateral agreements are often bilateral, collateral must be returned or posted in the opposite direction when exposure decreases. Hence, in the case of a positive MTM, a party will call for collateral and in the case of a negative MTM they will be required to post collateral themselves (although they may not need to return if their counterparty does not make a request). Posting collateral and returning previously received collateral are not materially very different. One exception is that when returning, a party may ask for specific securities back.

Some important terms in collateral agreements are:

- *Threshold.* The threshold is an amount below which collateral is not required, leading to *undercollateralisation*. Above the threshold, only the *incremental* amount of collateral can be called for (for example, a threshold of 5 and MTM of 8 would lead to collateral of 3 being required). Thresholds limit the risk reduction benefit of collateral but reduce the operational burden and liquidity costs. Zero thresholds are increasingly common for financial counterparties.
- *Minimum transfer amount (and rounding).* A minimum transfer amount is the smallest amount of collateral that needs to be transferred. It is used to avoid the workload associated with a frequent transfer of insignificant amounts of collateral. A collateral amount may also be rounded to a multiple of a certain size to avoid dealing with awkward quantities. Note that minimum transfer amounts and rounding quantities are relevant for non-cash collateral where transfer of small amounts is problematic. In cases where cash only collateral is used (e.g. central clearing) then these terms are generally zero.
- *Haircuts.* A haircut is a reduction in the value of an asset to account for the fact that its value may fall when it is liquidated. As such the haircut is theoretically driven by the volatility of the asset, and its liquidity. Haircuts are primarily used to account for market risk stemming from the price volatility of the type of collateral posted although collateral with significant credit or liquid risk is generally avoided.

The margin period of risk (MPR) is the term used to refer to the *effective* time between a counterparty ceasing to post collateral and when all the underlying transactions have been successfully closed-out and replaced (or otherwise hedged) as illustrated in Figure 7. Such a period is crucial since it defines the effective length of time without receiving collateral where any increase in exposure (including close-out costs) will remain uncollateralised. It is often used when modelling the effects of collateral.

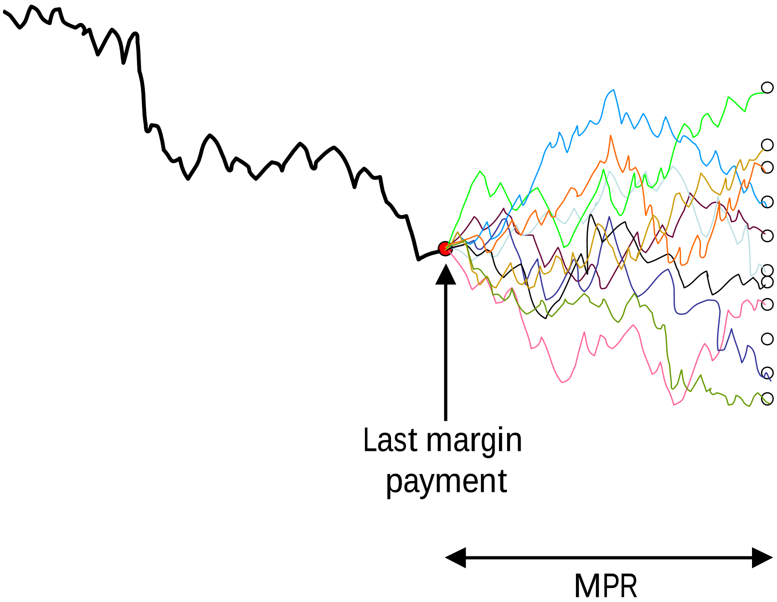

Figure 7. *Illustration of the role of the margin period of risk (MPR).*

There are two fundamentally different types of collateral. In derivatives, collateral would most obviously reflect the MTM of the underlying transactions, which can generally be positive or negative from each party’s point of view. This idea forms the basis of *variation margin*. However, in an actual default scenario, the variation margin may be insufficient due to aspects such as delays in receiving collateral and close-out costs (e.g. bid-offer). For these and other reasons, additional collateral is sometimes used in the form of *initial margin*. Figure 8 shows conceptually the roles of variation and initial margins. Clearly the MPR concept is related to the initial margin amount.

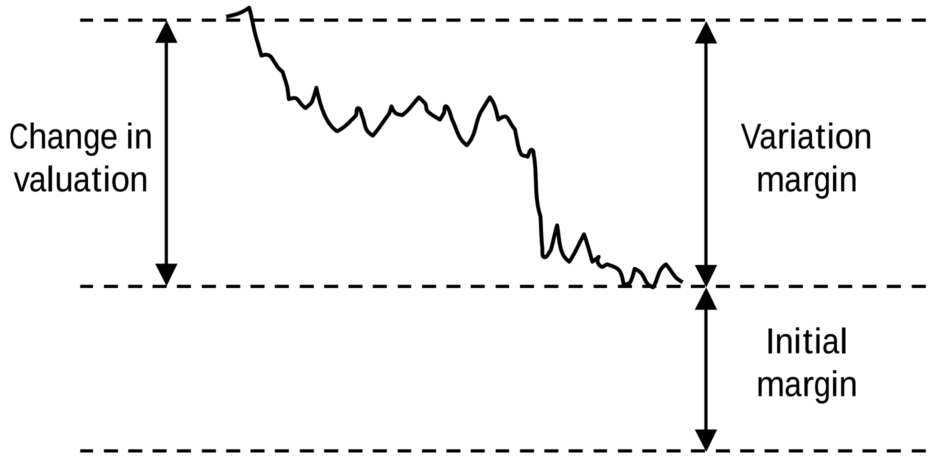

Figure 8. *Illustration of the difference between variation and initial margins. Variation margin aims to track the MTM of the relevant portfolio through time whilst initial margin represents a buffer that may be needed due to delays and close-out costs.*

Initial margin (or independent amount as it is sometimes known in bilateral markets) defines an amount of extra collateral that must be posted irrespective of the MTM of the underlying portfolio. The general aim is to give the added safety of *overcollateralisation* to provide a cushion against potential risks such as delays in receiving collateral and costs in the close-out process. Initial margin has been relatively uncommon in bilateral market although future regulatory rules will change this. Note that thresholds and initial margins essentially work in opposite directions and an initial margin can be thought of (intuitively and mathematically) as a negative threshold.

Historically, OTC derivative markets have sometimes also linked collateral requirements to credit quality (most commonly credit ratings). An example of this is shown in Table 1.

Table 1. *Example of rating linked collateral parameters.*

Rating	Initial margin	Threshold
AAA / Aaa	0	Infinity
AA+ / Aa1	0	\$100m
AA / Aa2	0	\$50m
AA- / Aa3	0	\$25m
A+ / A1	0	0
A / A2	\$25m	0
A- / A3	\$50m	0
BBB+ / Baa1	\$75m	0

Two other important concepts in collateral management are:

- *Rehypothecation.* For funding reasons, it is useful to re-use collateral although this tends to create counterparty risk. The right of rehypothecation means that the collateral receiver can use the collateral (for example, in another collateral agreement or a repo transaction). In some situations (such as posting cash variation margin), rehypothecation rights are not required since the collateral is intrinsically reusable.

- *Segregation.* Segregation of collateral is designed to reduce counterparty risk and entails collateral posted being legally protected in the event that the receiving counterparty becomes insolvent. In practice, this can be achieved either through legal terms or alternatively by a third party custodian holding the initial margin. Segregation is contrary and incompatible with the practice of rehypothecation.

In general, variation margin (since it is an amount owed) is not segregated and can be rehypothecated. Initial margin (since it is an additional amount) is usually segregated and cannot therefore be rehypothecated.

3.6 Central counterparties and bilateral margin rules

The global financial crisis from 2007 onwards triggered grave concerns regarding counterparty risk, catalysed by events such as the Lehman Brothers bankruptcy, the failure of monoline insurers and the default of Icelandic banks. Counterparty risk in OTC derivatives, especially credit derivatives, was identified as a major risk to the financial system. As a result of this, regulation is now requiring that all standardised OTC derivatives be cleared via central counterparties (CCPs).

The main function of an OTC CCP is to interpose itself directly or indirectly between counterparties to assume their rights and obligations by acting as buyer to every seller and vice versa (Figure 9). This means that the original counterparty to a trade no longer represents a direct risk, as the CCP to all intents and purposes becomes the new counterparty. CCPs essentially reallocate default losses via a variety of methods including netting, collateralisation and loss mutualisation. Obviously, the intention is that the overall process will reduce counterparty and systemic risks.

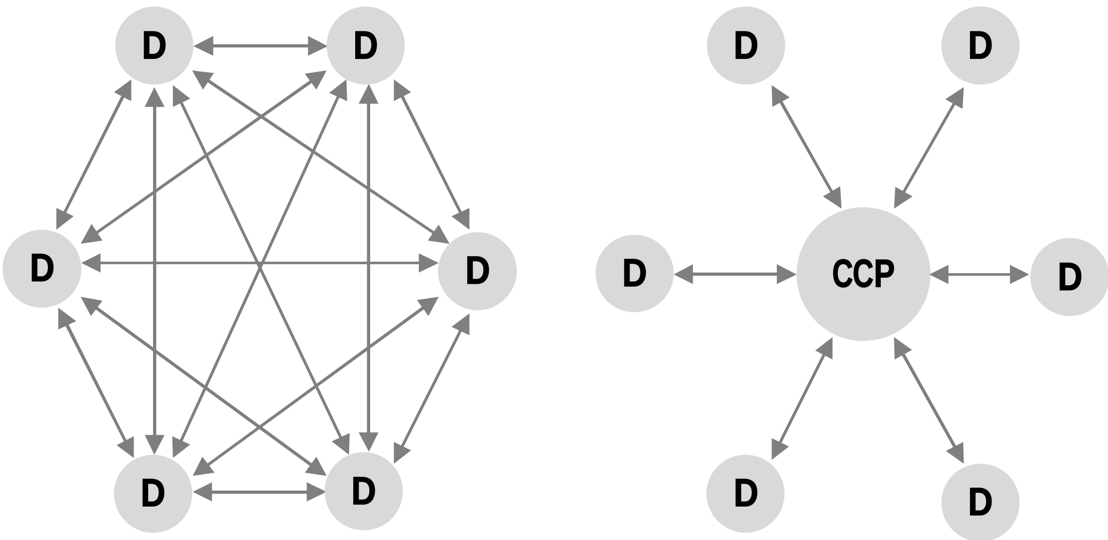

Figure 9. *Illustration of bilateral markets (left) compared to centrally cleared markets (right).*

It is important to note that some banks and most end-users of OTC derivatives (e.g. pension funds) will access CCPs through a clearing member and will not become members themselves. This is due to the membership, operational and liquidity requirements related to being a clearing member. In particular, participating in regular "fire drills" and bidding in a CCP auction are the main reasons why a party decides against being a clearing member at a given CCP.

Related to the clearing mandate, regulators are also requiring that major OTC derivatives users will be subject to bilateral margin rules governing how they post collateral to each other. These rules, which phase in from September 2016, basically mean that financial counterparties will need to post variation margin (with zero thresholds) and initial margin to each other. The intention seems to be to make the bilateral collateral rules quite close to those required by CCPs.

4 CREDIT VALUE ADJUSTMENT

Credit value adjustment (CVA) involves the calculation of two components, credit exposure and default probability. We will describe these components separately, introduce CVA calculations and also the topic of wrong-way risk.

4.1 Exposure

The main defining characteristic of credit exposure (hereafter referred to just as exposure) is related to whether the effective value of the contracts (including collateral) is positive (in a party's favour) or negative (against them), as illustrated in Figure 10:

- *Negative value.* In this case, the party is in debt to its counterparty and is still legally obliged to settle this amount. A party does not[6] generally gain or lose from their counterparty's default in this case.
- *Positive value.* When a counterparty defaults, they will be unable to undertake future commitments and hence a surviving party will have a claim (typically as an unsecured creditor). They will then expect to recover some fraction of their claim, just as bondholders receive some recovery on the face value of a bond.

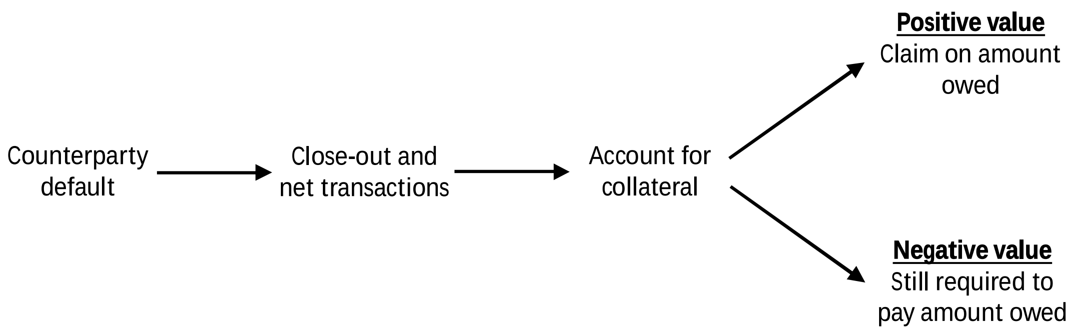

Figure 10 *Illustration of the impact of a positive or negative value in the event of the default of a counterparty.*

We can define exposure simply as:

$$Exposure = \max(value, 0) \tag{1}$$

The amount represented by "value" in the above discussion represents the effective value of the relevant contracts at the default time of the counterparty, including the impact of risk mitigants such as netting and collateral. Due to the difficulties around the close-out process, this is impossible to model precisely but the clean MTM (i.e. with no valuation adjustments) is generally used as a proxy.

[6] This is not completely true due to the complexity of the close-out process.

The exposure can also be seen to be similar to an option payoff. This means that volatility is an important component and that exposure quantification is a difficult task, akin to pricing options on derivatives. Quantifying exposure is extremely complex due to the long periods involved, the many different market variables that may influence the exposure, and risk mitigants such as netting and collateral (Figure 11).

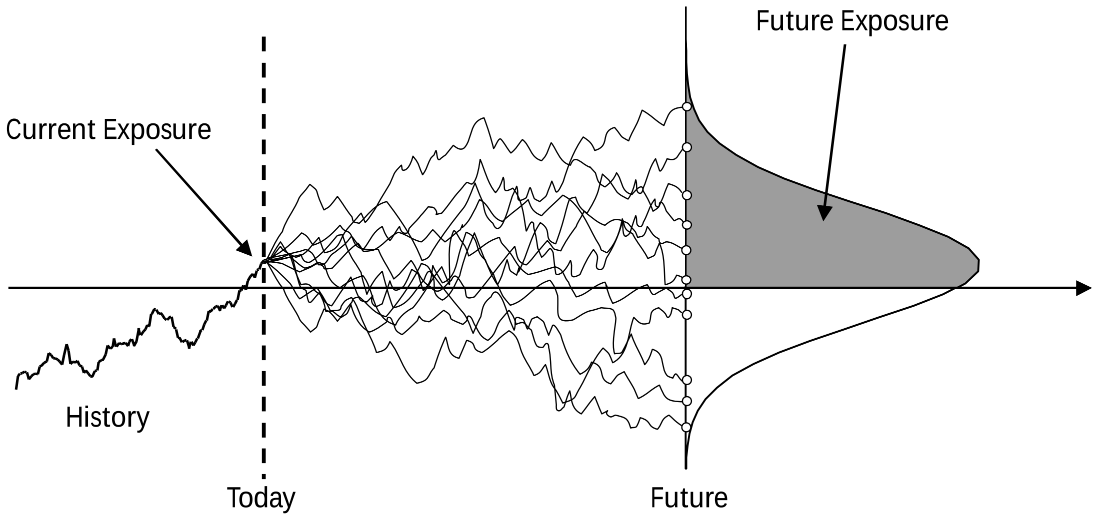

Figure 11. *Illustration of future exposure.*

There are a number of important metrics used when quantifying exposure which all based on the distribution of future value:

- *Expected future value (EFV).* This component represents the forward or expected value.
- *Potential future exposure (PFE).* As discussed in Section 2.6, PFE represents the worse (highest) exposure at a certain confidence level. PFE is a similar metric to Value-at-Risk (VAR).
- *Expected exposure (EE).* EE is the average of all exposure values. Note that only positive values give rise to exposures which means that the expected exposure is above the EFV. Note that EE is sometimes called EPE by banks.
- *Expected positive exposure (EPE).* EPE is defined as the average exposure across all time horizons and is therefore be the (weighted) average of the EE across time, as illustrated in Figure 12. This single EPE number is often called a “loan equivalent”, and is the average amount effectively lent to the counterparty.

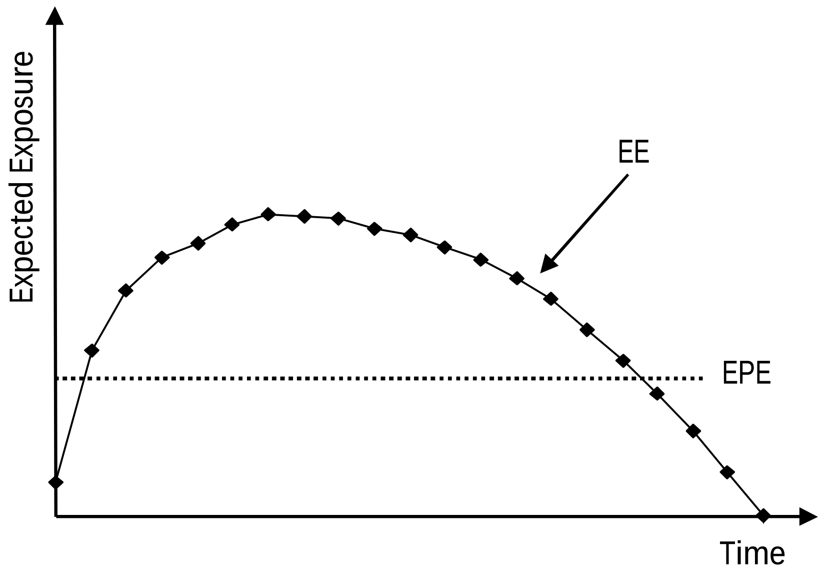

Figure 12. *Illustration of EPE.*

Exposure is represented by positive future values. Conversely, we may define negative exposure as being represented by negative future values. This will represent the exposure from a counterparty's point of view. We can define measures such as negative expected exposure (NEE) and expected negative exposure (ENE), which are important when computing metrics such as DVA and FVA.

4.2 Default probability

Broadly speaking, there are two types of default probability, real-world and risk-neutral. A real-world default probability is typically estimated from historical default data via some associated credit rating. A risk-neutral default probability is derived from market prices such as CDSs. Risk-neutral default probabilities are typically larger than real-world probabilities due to an embedded premium that investors require when taking credit risk (Figure 1).

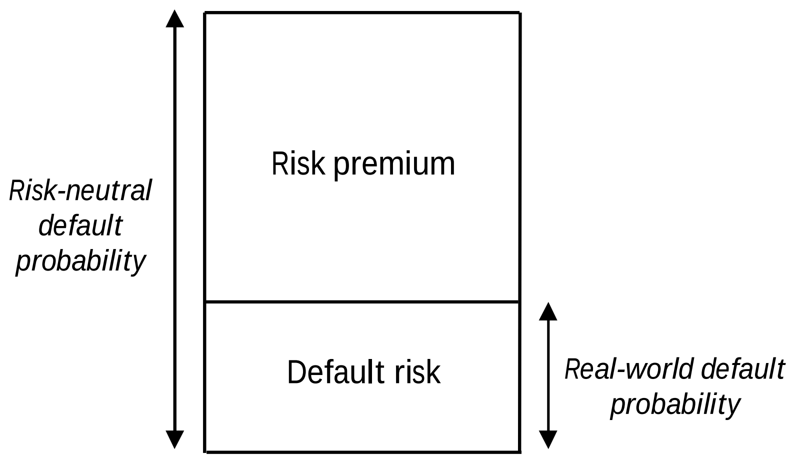

Figure 13. *Illustration of the difference between real-world and risk-neutral default probabilities.*

One empirical example showing the difference between real-world and risk-neutral default probabilities is given in Table 2. The differences are large, especially for strong quality credits.

Table 2. *Comparison between real-world and risk-neutral default probabilities in basis points. Source: Hull et al (2005)*[7].

	Real-world	*Risk-neutral*	*Ratio*
Aaa	4	67	16.8
Aa	6	78	13.0
A	13	128	9.8
Baa	47	238	5.1
Ba	240	507	2.1
B	749	902	1.2
Caa	1690	2130	1.3

In the past, it was common for banks to use real-world default probabilities (based on historical estimates) in order to quantify CVA. Now, it is standard for risk-neutral default probabilities to be used. This move has been catalysed by accounting requirements and Basel III capital rules and regulation in general. For example, EBA (2015)[8] states:

> *"The CVA data collection exercise has highlighted increased convergence in banks' practices in relation to CVA. Banks seem to have progressively converged in reflecting the cost of the credit risk of their counterparties in the fair value of derivatives using market implied data based on CDS spreads and proxy spreads in the vast majority of cases. This convergence is the result of industry practice, as well as a consequence of the implementation in the EU of IFRS 13 and the Basel CVA framework."*

Some smaller and regional banks still use real-world default probabilities and justify this with arguments that they have no credit spread data with which to benchmark parameters and that this conforms to the practice in their region. However, this position has become increasingly untenable in recent years.

Since many counterparties do not trade in the CDS market, risk-neutral default probabilities need to be defined via relevant proxies. This is typically done based on some mapping based on the rating, region and sector of the counterparty in question. Liquid credit spread information from single-name CDS, index CDS and other traded credit spreads is used.

Assuming the relevant spread can be calculated then a common approximate formula for risk-neutral default probabilities is:

$$PD(0, t_i) \approx 1 - \exp(-S_i t_i / LGD) \tag{2}$$

Where $PD(0, t_i)$ is the default probability up to t_i, S_i is the credit spread at time t_i and LGD is the assumed loss given default (Section 2.5).

4.3 Calculating CVA

The standard formula for CVA is:

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[7] Hull, J., M. Predescu, and A. White, 2005, "Bond Prices, Default Probabilities and Risk Premiums", Journal of Credit Risk, Vol. 1, No. 2 (Spring), pp. 53-60.

[8] European Banking Authority (EBA), 2015, "On Credit Valuation Adjustment (CVA) under Article 456(2) of Regulation (EU) No 575/2013 (Capital Requirements Regulation - CRR)", February, www.eba.europe.eu.

$$CVA = -LGD \sum_{i=1}^{m} EE(t_i) \times PD(t_{i-1}, t_i) \quad (3)$$

CVA depends on the following components:

- *Loss given default (LGD).* This is the percentage amount of the exposure expected to be lost if the counterparty defaults (Section 2.5).
- *Expected exposure (EE).* This term is the discounted expected exposure (EE) for the relevant dates in the future (Section 4.1).
- *Default probability (PD).* This requires the default probability which can be calculated via equation (3) since $PD(t_{i-1}, t_i) = PD(0, t_i) - PD(0, t_{i-1})$.

There is also a quicker way to estimate the above result that is useful for simple calculations. This formula assumes that the EE is constant over time and equal to its average value (EPE) which yields the following approximation:

$$CVA \approx -EPE \times Spread, \quad (4)$$

where the CVA is expressed in the same units as the credit spread, which should be for the maturity of the instrument in question, and EPE is as defined in Section 4.1.

4.4 Wrong-way risk

In the quantification of CVA, wrong-way risk (WWR) is sometimes ignored as above. WWR is the phrase generally used to indicate an unfavourable dependence between exposure and counterparty credit quality: the exposure is high when the counterparty is more likely to default which will clearly increase CVA. Incorporation of WWR in the CVA formula is probably most obviously achieved simply by representing the exposure *conditional* upon default of the counterparty. WWR is difficult to identify, model and hedge due to the often subtle macro-economic and structural effects that cause it.

One classic example of WWR is a cross-currency swap where a potential weakening of the currency and simultaneous deterioration in the credit quality of the counterparty is dangerous. This would obviously be the case in trading with a sovereign and paying their local currency (or more likely in practice hedging this trade with a bank in that same region). Alternatively, the default of a sovereign, financial institution or large corporate counterparty may itself precipitate a currency weakening.

Whilst it may often be a reasonable assumption to ignore WWR, its manifestation can be potentially dramatic. In contrast, “right-way” risk can exist in cases where the dependence between exposure and credit quality is a favourable one. Right-way situations will reduce counterparty risk and CVA. Regulators have identified both general (driven by macro-economic relationships) and specific (driven by causal linkages between the exposure/collateral and default of the counterparty) WWRs as critical to measure and control.

5 BEYOND CVA

5.1 The starting point

Pricing derivatives has always been relatively complex. However, prior to the global financial crisis, pricing of vanilla products was understood and most attention was on exotics. Credit, funding and liquidity were ignored, since their effects were viewed as negligible. This old-style framework is undergoing a revolution in order to address the shortcomings highlighted by the crisis and properly incorporate aspects such as funding and collateral agreements.

One change has been the move away from the use of LIBOR to discount future cash flows. For many years, LIBOR was seen as a good proxy for the risk-free rate. Now, the OIS (overnight indexed swap) is seen as the most obvious risk-free rate and can be shown to be the correct discount rate for a “perfectly collateralised transaction”. Perfect collateralisation means that the amount of collateral held (posted) will be at all times identical to the MTM (negative MTM) of the transaction and denominated in the same currency. Whilst this is never perfectly achieved in practice, it is a reasonable starting point and some transactions are considered by the industry to be close to this theoretical ideal, notably:

- centrally cleared trades - from the CCP point of view; and
- interbank trades (due to CSAs with zero thresholds, low MTAs and daily collateral posting).

Hence OIS discounting can be seen as a base case and xVA components can then be added/subtracted as relevant.

5.2 The birth of xVA

If the aftermath of the global financial crisis, CVA attracted huge interest due to the problems associated with counterparty risk, the reaction of regulators with the Basel III CVA capital charge and accounting changes with IFRS 13. However, related to these changes, other aspects started to gain considerable interest all of which are connected to CVA. The xVA terms arise from assessing rigorously the lifetime cost of an OTC derivative, including all economically relevant terms as illustrated in Figure 14. The explanation of the different aspects is as follows:

- *Positive MTM*. When the transaction is in-the-money (above the centre line), then the uncollateralised component gives rise to counterparty risk and funding costs. If some or all of the MTM is collateralised, then the counterparty can choose what type of collateral to post.
- *Negative MTM*. When the transaction is out-of-the-money then there is counterparty risk benefit from the party’s own default and a funding benefit to the extent their counterparty is uncollateralised. If collateral is posted, then the party can choose the type to post.
- *Overall*. Whether or not the transaction has a positive or negative MTM then there are costs from the capital that must be held against the transaction and any initial margin that needs to be posted.

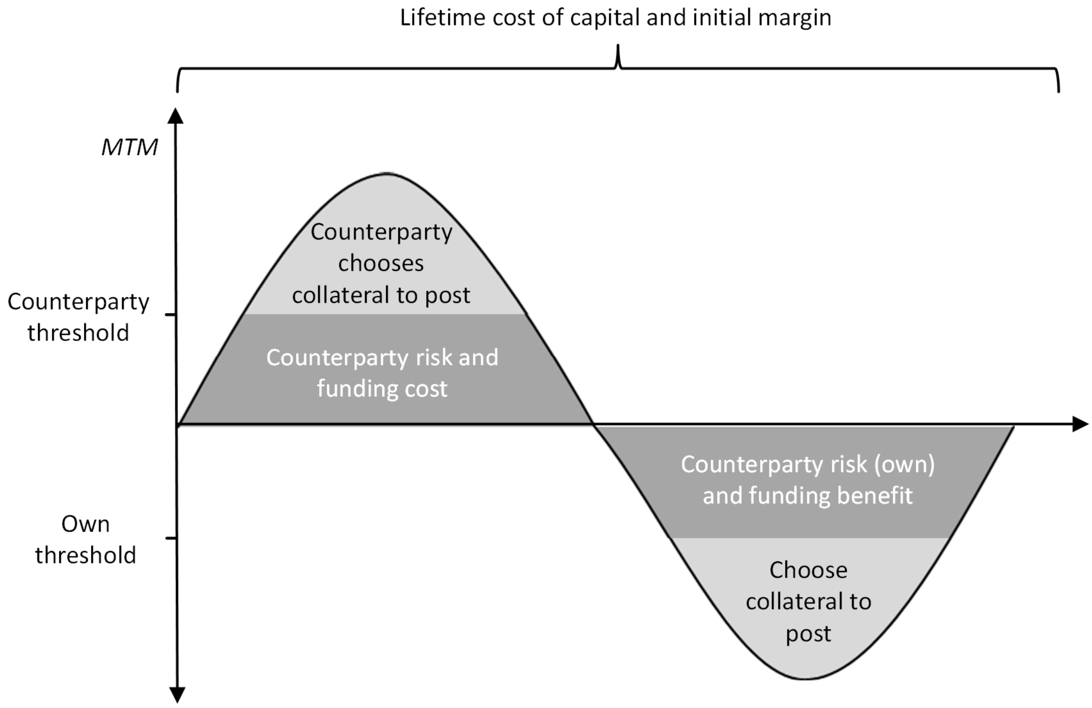

Figure 14. *Illustration of the lifetime cost of an OTC derivative. Note that this representation is general and in reality thresholds are often zero or infinity.*

5.3 Computing xVA

The general concept of any xVA term is illustrated in Figure 15. This quantifies the value of a component such as counterparty risk, collateral, funding or capital. Generally, the terms are associated with a cost but note that in some cases they can be benefits. In order to compute xVA we have to integrate the profile shown against the relevant cost or benefit such as a credit spread, collateral, funding or cost of capital metric.

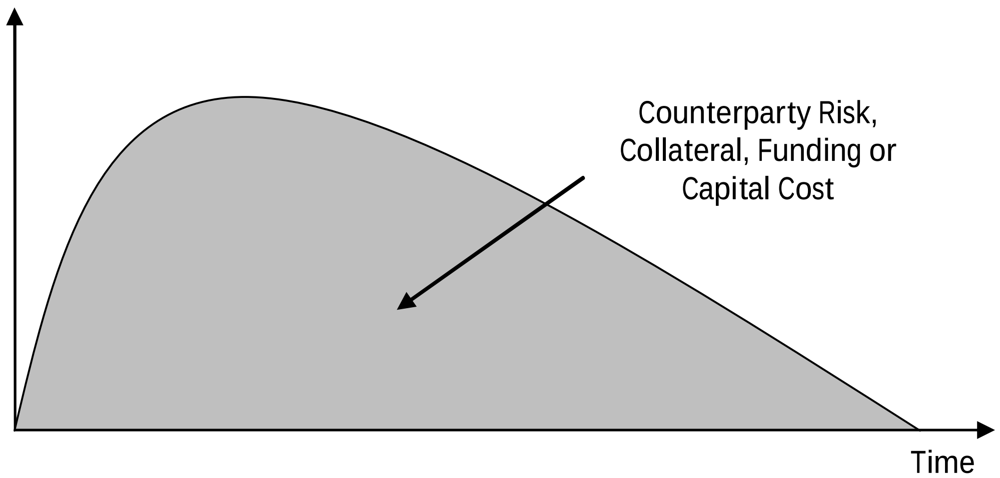

Figure 15. *Generic illustration of an xVA term. Note that the some xVA terms represent benefits and not costs and would appear on the negative y-axis.*

Calculating xVA involves integrating the relevant profile against the underlying cost or benefit such as a credit spread, collateral, funding or cost of capital metric. The quantification of the profile itself is generally a significant quantification challenge with issues over model choice, calibration and numerical tractability. In general, it requires the valuation of option-like payoffs. However, in certain special cases, the valuation collapses to essentially pricing forward contracts and is therefore largely model-independent. These special cases can be dealt with by changing discounting assumptions. There is also the problem of defining the cost component (credit spreads and funding, collateral and capital costs) which is a difficult qualitative problem.

5.4 xVA terms

Assuming, we start from a basic valuation such as OIS discounting, there are a variety of xVA terms defined as follows so as to achieve the correct valuation (Figure 16):

- *CVA and DVA.* Defines the bilateral valuation of counterparty risk. DVA (debt value adjustment) represents counterparty risk from the point of view of a party's own default.
- *FVA.* Defines the cost and benefit arising from the funding of the transaction.
- *ColVA.* Defines the costs and benefits from embedded optionality in the collateral agreement (such as being able to choose the currency or type of collateral to post) and any other non-standard collateral terms (compared to the idealised starting point).
- *KVA.* Defines the cost of holding capital (typically regulatory) over the lifetime of the transaction.
- *MVA.* Defines the cost of posting initial margin over the lifetime of the transaction.

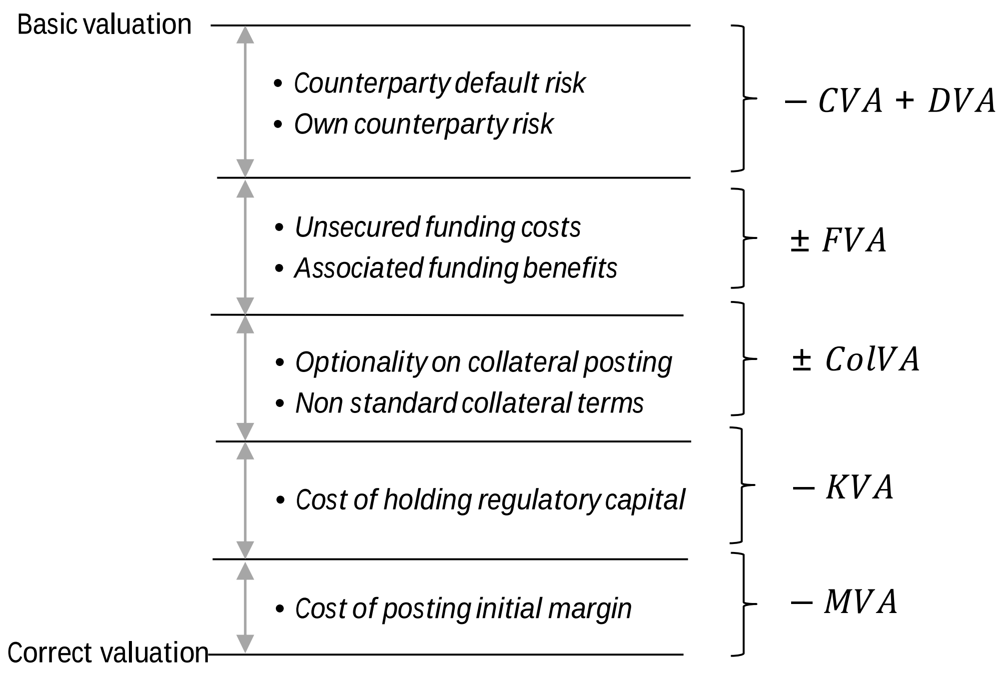

Figure 16. *Illustration of the role of xVA adjustments.*

It is also important to note that there are potential overlaps between the above terms. For example, between DVA and FVA where own default risk is widely seen as a funding benefit.

You are now ready for my course on xVA!