Since counterparty risk has a price (CVA as defined in Chapter 7) then an immediate question is what defines this price. The price of a financial instrument can generally be defined in one of two ways:

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

A price defined by hedging arguments may often differ dramatically from one based on expected value + risk premium. Hence, it is natural to ask ourselves into which camp CVA falls. The answer is, unfortunately, both since CVA can be partially but not perfectly hedged. In the above example, we considered hedging a current exposure of $10m, but in this case future changes in exposure would not be hedged. Hence, one must account for any hedging possibilities or requirements when assessing counterparty risk but realise that pricing counterparty risk is not a totally "risk-neutral problem". An institution must also assess the residual risk that will always exist and ensure that this is correctly understood, managed and priced (i.e. the return of a transaction provides adequate compensation for the risk it ultimately creates). Hedging aspects in relation to counterparty risk are discussed in Chapter 9.

### 2.4.4 Capital requirements and counterparty risk

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

The computation of capital for a credit portfolio is a rather complex issue since the correlation (or more generally dependency) between the defaults of different counterparties must be quantified. A high positive correlation (strong dependency) means that multiple defaults are possible which will therefore increase the unexpected loss and associated capital numbers. Assessment of capital for counterparty risk is even more important due to the asymmetric nature of exposure. One must not only understand the correlation between counterparty default events, but also the correlation between the resulting exposures. For example, suppose an institution has a transaction with counterparty *A* and hedges that transaction with counterparty *B*. This means the MtM positions with the two counterparties will always offset one another and *cannot* therefore be both positive. Hence, default of both counterparties *A* and *B* will create only a single loss in relation to whichever counterparty the institution has exposure to at the default time. Essentially, the negative correlation of the exposures reduces the overall risk. In case the MtM values of transaction with counterparty *A* and *B* were positively correlated then joint default would be expected to give rise to a greater loss. These ideas will be covered in more detail in Chapter 10.

## 2.5 METRICS FOR CREDIT EXPOSURE

In this section, we define the measures commonly used to quantify exposure. There is no standard nomenclature used and some terms may be used in other contexts elsewhere. We follow the Basel Committee on Banking Supervision (2005) definitions, which are probably the most commonly used although, unfortunately, not the most intuitively named.

In mainstream financial risk management, value-at-risk (VAR) has proved to be a popular single metric to characterise risk. However, the characterisation of future exposure for counterparty risk will require the definition and use of several metrics. There are several reasons for the increased complexity of definition:

- Unlike tradition single-horizon risk measures such as VAR, credit exposure needs to be defined over multiple time horizons to fully understand the impact of the time and specifics of the underlying contracts.
- Counterparty risk is looked at from both a pricing and risk management viewpoint, which require different metrics.
- In looking at counterparty risk at a portfolio level (many counterparties), it is important to understand the effective exposure or "loan equivalent" exposure with respect to each counterparty.

We begin by defining exposure metrics for a given time horizon.

### 2.5.1 Expected MtM

This component represents the forward or expected value of a transaction at some point in the future. Due to the relatively long time horizons involved in measuring counterparty risk, the expected MtM can be an important component, whereas for market risk VAR assessment (involving only a time horizon of 10 days), it is typically not. Expected MtM may vary significantly from current MtM due to the specifics of cash flows. Forward rates are also a key factor when measuring exposure under the risk-neutral measure (discussed in more detail in Chapter 3).

### 2.5.2 Expected exposure

Due to the asymmetry of losses described above, an institution typically cares only about positive MtM values since these represent the cases where they will make a loss if their counterparty defaults. Hence, it is natural to ask what the expected exposure (EE) is since this will represent the amount expected to be lost if the counterparty defaults. By definition, the EE will be greater than the expected MtM since it concerns only the positive MtM values.

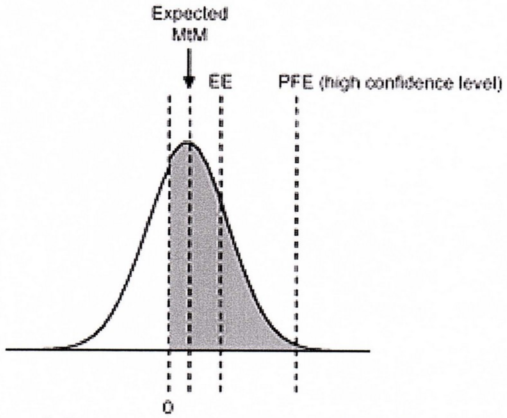


**Figure 2.6.** Illustration of the exposure metrics EE and PFE. The grey area represents positive MtM values or exposure.

### 2.5.3 Potential future exposure

In risk management, it is natural to ask ourselves *what is the worse exposure we could have at a certain time in the future?* A PFE will answer this question with reference to a certain confidence level. For example, the PFE at a confidence level of 99% will define an exposure that would be exceeded with a probability of no more than 1% (one minus the confidence level). We see that the definition of PFE is exactly the same as the traditional measure of value-at-risk (VAR) with two notable exceptions:

- PFE may be defined at a point far in the future (e.g. several years) whereas VAR typically refers to a short (e.g. 10-day) horizon.
- PFE refers to a number that will normally be associated with a gain (exposure) whereas traditional VAR refers to a loss.

This last point is important; VAR is trying to predict a worst-case *loss* whereas PFE is actually predicting a worst-case *gain*[10] since this is the amount at risk if the counterparty defaults.

The three exposure metrics discussed so far are illustrated in Figure 2.6.

### 2.5.4 EE and PFE for a normal distribution

In Appendix 2.A we give simple formulas for the EE and PFE for a normal distribution. These formulas are reasonably simple to compute and will be useful for some examples used throughout this book.

**Spreadsheet 2.2.** EE and PFE for a normal distribution.

### 2.5.5 Overview of exposure metrics

In Figure 2.6, we illustrated the EE and PFE exposure metrics with respect to a

[10] Unless in an extreme case the expected MtM is very negative so even the worst case exposure is zero.

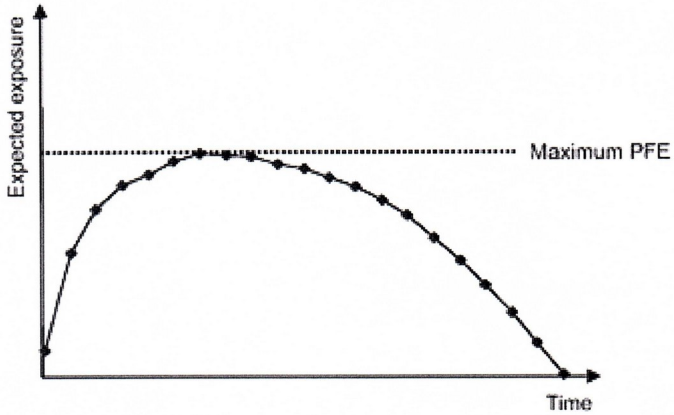


**Figure 2.9.** Illustration of maximum PFE.

approaches of netting and collateralisation. We have discussed various ways of quantifying and managing counterparty risk from the traditional approach of credit lines to the more sophisticated approaches of pricing and capital allocation. The concept of hedging as applied to counterparty risk has been introduced. Finally, some key definitions of potential future exposure (PFE), expected exposure (EE) and expected positive exposure (EPE) have been given. All of these aspects will be expanded upon heavily in the forthcoming chapters. Chapter 3 will deal in depth with the mitigation of counterparty risk.

## APPENDIX 2.A: CHARACTERISING EXPOSURE FOR A NORMAL DISTRIBUTION

Consider a normal distribution with mean $\mu$ (expected MtM) and standard deviation (of the MtM) $\sigma$. Let us calculate analytically the two different exposure metrics discussed. Under the normal distribution assumption, the MtM value of the portfolio in question (for an arbitrary time horizon) is given by:

$$V = \mu + \sigma Z,$$

where $Z$ is a standard normal variable.

### *(1) Potential future exposure (PFE)*

This measure is exactly the same as that used for value-at-risk calculations. The PFE at a given confidence level $\alpha$, $\text{PFE}_\alpha$, tells us an exposure that will be only exceeded with a probability given by no more than $1 - \alpha$. For a normal distribution, it is defined by a point a certain number of standard deviations away from the mean:

$$\text{PFE}_\alpha = \mu + \sigma\Phi^{-1}(\alpha).$$

where $\Phi^{-1}(.)$ represents the inverse of a cumulative normal distribution function (this is the function NORMSINV(.) in Microsoft Excel™). For example, with a confidence level of $\alpha = 99\%$, we have $\Phi^{-1}(99\%) = +2.33$ and the worst case exposure is 2.33 standard deviations above the expected MtM.

***(2) Expected exposure (EE)***

Exposure is given by:

$$E = \max(V, 0) = \max(\mu + \sigma Z, 0)$$

The EE defines the expected value knowing the MtM is positive so it represents the average of only the positive MtM values in the future. The expected exposure is therefore:

$$\text{EE} = \int_{-\mu/\sigma}^{\infty} (\mu + \sigma x)\varphi(x)\,dx = \mu\Phi(\mu/\sigma) + \sigma\varphi(\mu/\sigma),$$

where $\varphi(.)$ represents a normal distribution function (this is the function NORMDIST(.) in Microsoft Excel™ with additional parameters 0, 1 and "false") and $\Phi(.)$ represents the cumulative normal distribution function (this is the function NORMSDIST(.) in Microsoft Excel™). We see that EE depends on both the mean and the standard deviation; as the standard deviation increases so will the EE. In the special case of $\mu = 0$ we have:

$$\text{EE}_0 = \sigma\varphi(0) = \sigma/\sqrt{2\pi} \approx 0.40\sigma.$$

***(3) Expected positive exposure***

The above analysis is valid only for a single point in time. Suppose we are looking at the whole profile of exposure defined by $V(t) = \mu + \sigma\sqrt{t}Z$. Now we re-define $\sigma$ to be an annual standard deviation (volatility). The EPE, assuming a zero mean as above and integrating over time, would be:

$$\text{EPE}_0 = \frac{1}{\sqrt{2\pi}}\sigma \int_0^T \sqrt{t}\,dt/T = \frac{2}{3\sqrt{2\pi}}\sigma T^{1/2} = 0.27\sigma T^{1/2}.$$

All of these calculations are demonstrated in Spreadsheet 2.2.