CREDIT RISK

Estimation Techniques

TABLE OF CONTENTS

Introduction

Measurement of credit risk is an important exercise for financial institutions, more so because of regulatory requirements. Credit risk can be classified under two categories – issuer risk and counterparty risk. *Issuer risk* is the risk that the issuer/obligor defaults and is unable to fulfil payment obligations. On the other hand, *counterparty risk* includes *default risk* – risk that counterparty defaults without any payment/incomplete payment on the transaction; *replacement risk* – risk that, after default occurs, replacing the deal under the same conditions is not possible; *settlement risk* – risk that parties involved in the settlement fails before the transaction is fully settled.

Under Base II, banks are expected to employ the standardized approach to estimate their economic capital for credit risk. In Basel II, banks are allowed to use their own credit risk models, which enable them to better segregate risk and include diversification effects of the bank's portfolio. Basel II.5 and III require banks to implement Credit Valuation Adjustment charge, an OTC derivative concept.

The integral components of credit risk, as recognized by the Bank of International Settlements (BIS), are:

- *Probability of Default (PD)*: Probability that the obligor will default within a given time horizon
- *Exposure at Default (EAD)*: Amount outstanding with the obligor at the time of default
- *Loss given Default (LGD)*: Percentage loss incurred relative to the EAD
- *Maturity (M)*[1]: Effective maturity of the exposure

This document focuses on issuer risk and the associated parameter estimation techniques applicable to retail and wholesale banks. Therefore, the term credit risk used in this document is meant to imply issuer risk. Issuer risk is applicable to loans, exchange-traded products, and OTC-traded products[2].

The document takes into account the regulatory framework prescribed by the BIS as the foundation for exploring the calculation structure of credit regulatory capital and the various parameter estimation techniques that are to be considered. The three credit capital calculation approaches suggested by the BIS are discussed – *Standardized*, *Internal Ratings Based-Foundation*, and *Internal Ratings Based-Advanced*. The scope of each of these three approaches is explored with specific emphasis on the estimation techniques required for the two Internal Ratings-Based approaches.

Apart from the regulatory structure associated with credit risk, the estimation techniques of the three primary parameters of credit risk are explored. The standardized approach to calculate risk weights is discussed. The internal model techniques for estimating PD and LGD are explored – these techniques fall under the IRB approaches. For EAD, apart from the internal models for IRB, the methods applicable for the standardized approach are also discussed.

Once these risk/parameter-estimation models are implemented, it is mandatory by regulations to perform validation exercise of these models. The last section of this document discusses how integral model validation is to the development of a robust risk estimation framework. The section also outlines the processes and steps employed to validate a model.

---

[1] The estimation procedure/formula for this parameter is provided by the Basel regulations; no internal models explored.
[2] For specific products – credit default swaps, bonds.

irevna   The best people to work with

Regulatory Framework

Under Basel I, the risk weights depend on the categorization of obligors. They do not consider the actual obligor risk rating or the tenor of the facility and do not recognize any form of collateral. Therefore, the credit risk capital required as a percentage of exposure will be a constant 8% across all facility ratings.

Under Basel II, the credit risk measurement techniques proposed under capital adequacy rules can be classified under:

- *Standardized Approach*: This approach uses a simplistic categorization of obligors, without considering their actual credit risks; external credit ratings are used
- *Internal Ratings-Based (IRB) Approach*: In this approach, banks that meet certain criteria are permitted to use their own estimated risk parameters to calculate regulatory capital required for credit risk

The IRB approach can be further classified into:

- *Foundation-IRB*: Banks are allowed to calculate the probability of default (PD) for each asset; while the regulator will determine Loss Given Default (LGD) and Exposure at Default (EAD). Maturity (M) can be assigned by either
- *Advanced-IRB*: Banks are allowed to use their internal models to calculate PD, LGD, EAD, and M

The primary objective of employing these models is to arrive at the total risk weighted assets (RWA), which is used to calculate the regulatory capital. The RWA calculation is based on either 'Standardized' or 'IRB' approach.

To determine the minimum capital required for credit risk, banks are required to categorize their claims into groups mentioned in regulatory guidelines. These categories are used to calculate/determine their respective risk weights. The risk weights required for the calculation of credit capital can either be 'regulator determined' or calculated using credit risk parameters, estimated using 'internal models'. The means of calculating risk weights and EAD under each of the three approaches is mentioned below:

	PD	LGD	M	EAD
Standardized	Regulator determined – Risk weights		Regulator determined	Regulator determined
Foundation - IRB	Internal model	Regulator determined	Regulator determined	Regulator determined
Advanced - IRB[3]	Internal model	Internal model	Formula provided	Internal model

Note: For the 'Regulator Determined' cases, the type of obligor and the type of credit facility determine the risk-weight table or formula to be used.

According to the standardized approach, the categorizations are used to determine regulator-prescribed risk weights. To determine the EAD for on-balance sheet items, the balance sheet values of the items are used as exposures. Collateral, haircut, and netting adjustments are made wherever applicable. For off-balance sheet items, the undrawn commitment is multiplied by a regulator-prescribed CCF[4].

For the IRB approaches, the risk parameters are inputs to the respective risk weight formulas. To determine the EAD, on-balance sheet items use the balance-sheet values and the off-balance sheet items use CCFs suggested by the regulators. For the foundation approach, the CCFs are the same as those for the standardized approach, but with a few exceptions. For the advanced approach, the CCFs can be the bank's own internal estimates.

---

[3]It should be noted that for *retail exposures*, there is no separate classification of the IRB – Foundation and Advanced; for this facility, all the three parameters (PD, LGD, and EAD) need to be estimated using internal models.

[4] Credit Conversion Factor – discussed in section *Exposure at Default*

Both Basel and Dodd-Frank regulations require banks to gradually stop their reliance on external credit ratings. Banks are encouraged to build their own internal models to calculate regulatory capital which aligns with their credit risk.

Process Flow: Credit Capital Calculation (Basel II)
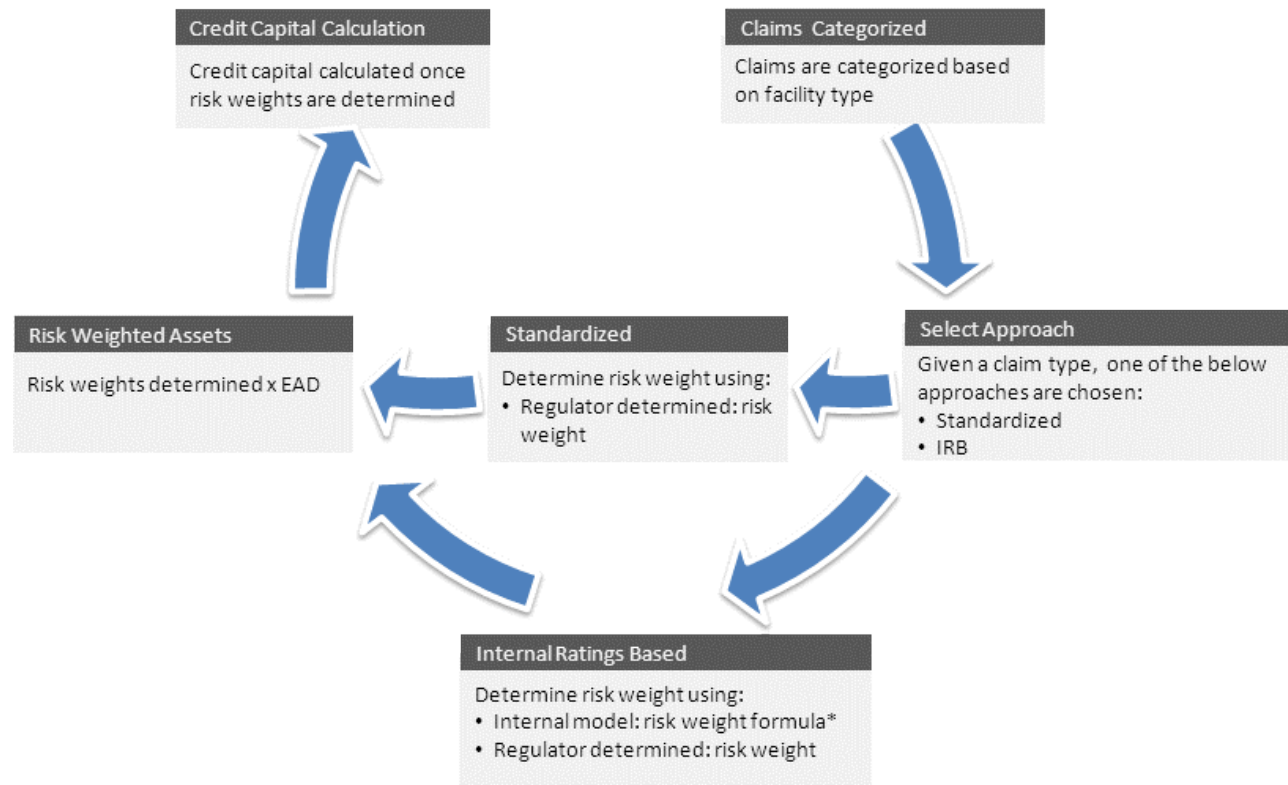
* The risk weight formula depends on the 'claim type' chosen and is a function of internal estimates of PD, LGD, and EAD

As the Basel II guidelines suggest, banks are allowed to use a variety of 'internal models' using advanced credit risk estimation techniques, thereby raising concerns of potential estimation differences across banks. Therefore, those banks that wish to implement the IRB approach must first apply to the regulators for accreditation. To get a go-ahead from the regulators, banks' internal estimation techniques should meet some stringent quantitative and qualitative requirements as follows:

- Internal models are expected to be risk-sensitive to the portfolio of the bank
- The internal model should be able to capture obligor characteristics and should have sufficient information to estimate the key risk parameters within statistical confidence levels
- There should be proper corporate governance and internal controls
- The modeling and capital estimation framework should be linked to the day-to-day operations of the bank
- There should be an appropriate validation and testing process, ensuring the estimation of the precise PD, LGD, EAD, and capital estimates for credit risk

The following sections discuss the standardized approach, the IRB approach, and the various internal models that can be employed to estimate credit risk capital.

Standardized Approach

In the standardized approach (Basel II), the risk weights for different exposures are specified by the Basel committee. To determine the risk weights for the standardized approach, the bank can take the help of external credit rating agencies that are recognised as eligible by national supervisors in accordance to the criteria specified by the Basel committee.

The following are the different types of claims on which risk weights are specified by Basel:

Sovereign Loan	Public Sector Entities	Multilateral Development Banks	Banks
Securities Firms	Corporates	Regulatory Retail Portfolios	Residential Property
Commercial Real Estate	Past Due Loans	Higher Risk Categories	Other Assets
Off-Balance Sheet Items	Securitized Exposures	Securitized Financing Transactions	OTC Derivatives

The risk-weights for each of these claim categories are mentioned below:

- *Sovereign loan, public sector entities, multilateral development banks, banks, securities firms, and corporates*: These categories have different risk weights, specified according to their ratings e.g. (A+ rated sovereign claim has a risk weight of 20%). The ratings should be from an external party that satisfies the criteria set out by Basel committee. Each of the six categories has tables mentioning the risk weights to be used for different ratings and other points that should be taken into consideration while deciding on the risk weights
- *Regulatory retail portfolio*: Claims falling under this category are given risk weight of 75%. The rules for classifying a portfolio into a retail portfolio are mentioned in the Basel norms
- *Residential property*: Minimum risk weight of 35% is advised by the Basel committee
- *Commercial real estate*: Risk weight of 100% is advised by the Basel committee
- *Past due loans*: Only the unsecured portion of the loan, which is more than 90 days are considered and different risk weights are assigned depending on the outstanding amount
- *Higher risk categories*: These claims are given risk weight of 150%
- *Other assets*: These claims are given risk weight of 100%
- *Off balance sheet items*: These are converted into credit exposure equivalents by using credit conversion factors (CCF). Basel norms have given different conversion factors for all the possible different type balance sheet items
- *Securitized transactions*: Risk weights are assigned according to their ratings and maturity
- *OTC transactions*: Specified guidelines (mathematical formula) are provided to calculate the exposure

Classifying the securities into different categories and then determining the risk weights of the instrument is a critical task. This requires an in-depth understanding of all the products of the bank, and also the Basel norms specifying guidelines for the classification. Furthermore, while dealing with OTC derivatives, it is essential to go through the terms and conditions of these products. Sound knowledge of the business as well as legal aspects of the products is essential.

Once the risk weights are determined, the capital required could be calculated as:

Capital Requirement|$_{\text{category, rating}}$ = Asset Value x Risk-Weight x 8%

Calculation of credit capital requirement under Standardized Approach for *Sovereign Loan* is shown below:

	AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to B-	Below B-	Unrated
Risk weight	0%	20%	50%	100%	150%	100%
Asset value	$100m	$100m	$100m	$100m	$100m	$100m
Risk-weighted asset	$0m	$20m	$50m	$100m	$150m	$100m
Capital required	$0m	$1.6m	$4m	$8m	$12m	$8m

Note: The ratings mentioned in the Basel II document are of S&P's. However, the BIS mentions that it does not show any preference to these ratings; the bank can choose equivalent rating from any other agency.

Basel has provided guidelines for specifying the instruments that are eligible for financial collateral. Further, collaterals are subject to haircut for which Basel provides the guidelines as to how much haircut should be applied to calculate the final exposure. Basel also provides guidelines for other mitigation techniques to reduce the exposure for the capital requirement.

Banks are allowed to use credit risk mitigation (CRM) techniques to reduce their capital requirement. Below are the CRM techniques that banks can use:

- Collateralized transactions
- On-balance sheet netting
- Guarantees and credit derivatives
- Maturity mismatch
- Miscellaneous

To apply the credit risk mitigation techniques, it is essential to understand the products and clause mentioned in the terms and conditions that can be used to reduce exposure to the counterparty.

Internal Ratings-Based Approach

The Internal Ratings-Based (IRB) Approach of Basel II allows banks to use their internal estimates of risk parameters to calculate the required capital related to the exposure. However, only banks meeting certain minimum requirements are allowed to employ this approach.

From the bank's perspective, the IRB approach allows it to use internal models to calculate credit capital, enabling more sensitivity to the credit risk in the bank's portfolio. Furthermore, incorporating better risk management techniques on its portfolio will show its effect on minimizing the regulatory capital required. Another incentive to move to the IRB approach is that the IRB-based regulatory capital is 'lower than' the standardized approach for higher credit rated banks and 'higher than' for lower credit rated banks, thus providing a better alternative for investment grade banks.

The IRB approach estimates risk parameters under:

■ *Foundation approach:* Banks estimate PD using internal models, while the other parameters take supervisory estimates
■ *Advanced approach*: Banks provide their own estimate of PD, LGD, and EAD and their calculation for M is subject to the supervisory requirements

Under the IRB approach, banks are required to categorize their banking book exposures into the following asset classes:

■ Corporate
■ Sovereign
■ Bank
■ Retail
■ Equity

Basel provides *risk weight formulas* for the IRB approach; the PD, LGD, and M are inputs to these formulas. The formula varies depending on the exposure category. Under the IRB–Foundation, the formula assumes a value for LGD and M, while under the IRB–Advanced, all parameters are estimated using internal models.

The risk weight formulas represent only unexpected loss (UL) and do not include expected loss (EL). EL is the average loss that the bank expects from an exposure over a fixed time period, while UL is the loss that the bank incurs over and above the average loss expected from an exposure over a certain time period.

Banks generally cover their ELs on a continuous basis through provisions and write offs. ULs occur less frequently and consist of large losses; banks are required to keep capital for ULs.

Under the IRB approach, general provisions are not included in Tier 2 capital as previously done according under the 1988 Accord. The banks following the IRB approach are not required to keep capital for EL as long as they keep sufficient provisions for the EL. In case the EL exceeds the total eligible provisions then banks must deduct the difference – 50% of the difference is deducted from Tier 1 and 50% is deducted from Tier 2 capital. If EL is less than the provisions, then banks may adjust the difference in Tier 2 capital subject to the 0.6% limit of credit risk weighted assets.

Probability of Default – IRB

Probability of default (PD) is an estimate of the likelihood that the obligor will be unable to meet its debt obligation over a certain time horizon. PD is integral to estimating credit risk and its associated economic capital/regulatory capital. According to Basel II, a default event on an obligation would occur if either or both of the following conditions meet:

- The obligor is unlikely to be able to repay its debt without giving up any pledged collateral
- The obligor has passed more than 90 days without paying a material credit obligation

Given the requirement or constraints, PD can be calculated for a single obligor or a group of obligors with similar credit risk features. The former method is more prevalent in corporate banking and the latter in retail banking.

Estimation of PD depends on two broad categories of information:

- Macroeconomic – unemployment, GDP growth rate, interest rate
- Obligor specific – financial ratios/growth (corporate), demographic information (retail)

PD can be categorized as unstressed/stressed PD and through-the-cycle/point-in-time PD. If the PD is estimated considering the current macroeconomic and obligor-specific information, it is known as unstressed PD. Stressed PD is estimated using current obligor-specific information and "stressed" macroeconomic factors (independent of the current state of the economy). Point-in-time PD estimates incorporate macroeconomic and the obligor's own credit quality, whereas through-the-cycle PD estimates are mainly determined by factors affecting the obligor's long-run credit quality trends.

Any of the following four modeling techniques can be used to estimate PD:

- *Pooling* – estimated empirically using historical default data of a large universe of obligors
- *Statistical* – estimated using statistical techniques through macro and obligor-specific data
- *Reduced-form* – estimated from the observable prices of CDSs, bonds, and equity options
- *Structural* – estimated using company level information

PD Estimation Techniques
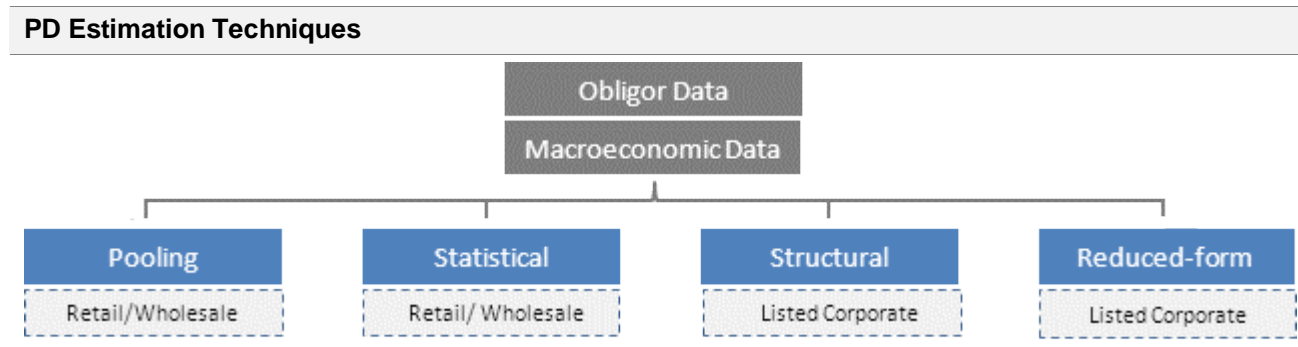
Each of these techniques has their own pros and cons. A certain bank may use different techniques for different obligor types, facility types, and regions. Pooling and statistical techniques are more widely used in retail and wholesale banks because of their precision vs structural and reduced-form techniques. However, for liquid obligors trading in secondary markets, structural and reduced-form techniques are better alternatives.

The following sections discuss the estimation techniques in detail.

Pooling Approach

Corporate Exposures

Empirical survey takes into consideration all the historical defaults that have occurred in the past. Historical PD is calculated by taking the ratio of the bonds that have defaulted to the total bonds issued in the past, provided the bonds taken into consideration are identical in nature. A bond with specific characteristics will have a different PD.

Bonds having similar characteristics are grouped together and divided into categories/pools. Then, PD for each category corresponding to the age of each bond/loan is calculated. This will be equal to the ratio of the bonds which have defaulted to the total number of the bonds in that group. PD for each category will be the average of all the individual bonds/loan PD in that category. Calculation for this method is divided into two categories:

- Cohort method
- Duration (intensity)-based method

Under the cohort method, the ratio of default bonds to the total bonds are taken without considering the time taken to default; only the status at the end of period is taken into consideration. However, under the duration-based method, the time taken by the bond to default is also included in the calculation. Therefore, in the duration-based method, the numerator is the proportion of bond years defaulted and the denominator is the total number of bond years.

Another point which needs to be considered is the time horizon over which the default is considered. For calculating the one-year default rate, one can calculate the default rates for each year in the past and take the weighted average (weighted by the total bonds) to calculate the one-year default rate. For time horizons of two years or more, one can calculate the PD by taking all the defaults within that time span or calculate the marginal PD for each year and then calculate the cumulative PD for the mentioned time horizon.

For calculating the PD, the universe of bonds taken at the start of observation should remain the same. PD corresponds to a specific time horizon, so inclusion of more bonds between the start and end of observation will not provide the intended PD as the new bonds would not have covered the time required for calculation.

As mentioned above, calculation of PD would also require the list of all the bonds that have defaulted in the past and their characteristics. The market price of bond trading in the market after the default gives its default price. The other data required would be the characteristics of the defaulted bond, such as its rating, maturity, issuance date, seniority, issuer's rating, covenants, and country. This methodology is adopted by rating agencies. The probability of default mentioned in the default transition matrix is calculated based on actual historical defaults.

Retail Exposures

For retail exposures, the *facilities* that have defaulted in the past are considered. Historical PD is calculated by taking the ratio of the facilities that have defaulted to the total facilities that existed in the concerned time frame. In this method, the facilities are divided into different categories/pools based on their risk drivers.

The risk drivers chosen for categorization depend on the bank, based on the availability of the data. The primary risk drivers are facility types, delinquency in payment, customer score, geographical location, etc. The PD for each category is calculated by taking the average PD of all the loans in that category. To determine the PD for retail exposures, they are mapped to one of the categories discussed above. The PD calculated for that category is assigned to the exposure whose PD is to be determined. Similar to the methodology for corporate exposures, in retail exposures, too, the time horizon for which the default is considered is fixed.

The drawback of this technique is that it does not capture the effects of economic cycles and the high conditional correlation of defaults during downturns. Furthermore, market information is not employed in determining the PD using this technique.

Statistical Approach

Historical data on characteristics of retail obligors and corporate obligors can be used to estimate their respective probability of defaults. Various statistical techniques can be employed on the data to estimate PD for defined time horizons. The statistical model specifies the relationship between the inputs and the outcome – PD. The parameters determined depend on the data used to develop the model.

Many statistical techniques can be used to estimate and classify PD of an obligor. Regression (linear/logit/probit), discriminant analysis, neural networks, hazard model, decision trees are some of them. PD estimation using logistic regression is explained in this section.

One of the most recommended statistical techniques to estimate PD is logistic regression. This method of regression is applicable when the dependent variable is binary i.e. takes one of the two available values. This variable indicates whether or not the loan/debt has gone into default over a certain time horizon.

The wide usage of logit regression over other statistical models is attributed to the following reasons:

■ The output of the regression is bounded between 0 and 1 – just the way we need them

■ Logit regression has the flexibility to capture non-linear relationships

The first step of logistic regression is to define the dependent variable – definition of default, and the performance window – the time over which the obligor can enter default status. The next steps include selection of relevant predictive variables, their graphical inspection, finding correlation among them, handling missing data, and transforming the data to achieve better model fitment statistics.

Flow: Logistic Regression Process
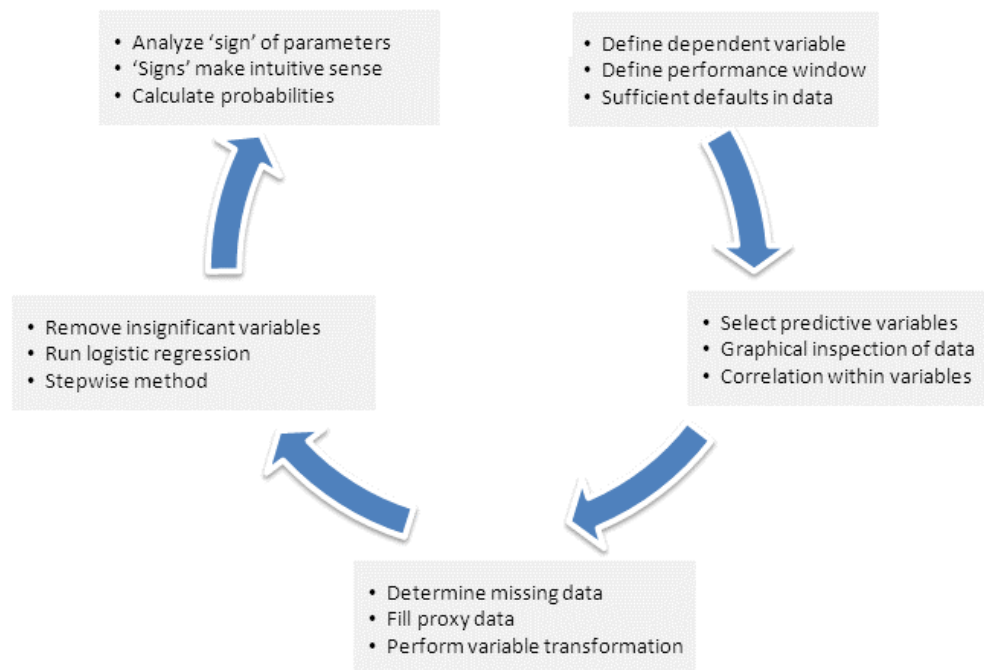
Some of the common variable sources used to estimate the PD of a corporate are financial statements, owner's data, type of loan, size of loan, and industry of the company. Similarly, for retail obligors, variable sources could be customer demographics, income statistics, age of loan, and the number of late payments.

Insignificant variables are removed and a step-wise logistic regression is run on the remaining independent variables and the dependent variable. The model involves multivariate regression analysis where the

dependent variable is restricted to the values of zero or one, where one indicates bad loan and zero indicates good loan. After performing regression analysis, we consider only those independent variables that are significantly related to the dependent variable.

Once the model is developed, the signs of the parameter estimates associated with each variable need to be analysed for intuitive clarity. Each sign suggests the relationship (positive/negative) of an independent variable with the dependent variable.

Equations for the model are given below:

$$\frac{\pi(x)}{1 - \pi(x)} = \exp(\beta_0 + \beta_1 * X1 + \beta_2 * X2)$$

where,

$\pi(x)$ is the PD
β_i (i=0, 1, 2) are the parameter estimates
X_i (i = 1, 2) are the independent variables

$$PD = \pi(x) = \frac{\exp(\beta_0 + \beta_1 * X1 + \beta_2 * X2)}{1 + \exp(\beta_0 + \beta_1 * X1 + \beta_2 * X2)}$$

To analyse a new loan or an existing loan, we use the output from the model and compare it with two threshold levels (predetermined), which are used to determine whether the loan is good, bad, or needs brief evaluation. The two threshold levels ($0 < T_1 < T_2 < 1$) are chosen such that it minimizes the cost of evaluation. Normally, T_1 and T_2 are chosen such that the proportion of bad loans classified as good should not be more than 5% and the proportion of bad loans correctly classified as bad should be at least 75% of the total bad loans. The following are the rules for predicting the default:

- If the output of the regression is $\pi(x) < T_1$ then loan is considered to be of good quality

- If the output is $\pi(x) > T_2$ then the loan is most likely to default

If the output of the regression Y_i is between T_1 and T_2, then there are less chances of default and needs more evaluation

Logistic regression is a widely used technique for estimating PD for retail, SME, and wholesale obligors. However, a lot of activities are involved, right from arranging data and cleaning them to filling for missing data – all requiring advanced statistical techniques. Then, deciding on the universe of independent variables, relationships between them, their applicability, and mathematical transformations on the variables to improve the model fitment require as much subjective analysis as quantitative. Furthermore, validating the model with out-of-sample data is an important step to determine the robustness of the model.

Structural Approach

Structural models are used to calculate the probability of default for a corporate based on the value of its assets and liabilities. The central concept of structural model is that a company (with limited liability) defaults if the value of its assets is less than the debt of the company. This is because the value of equity becomes negative (asset value = equity value + liability value), which can be given away at zero cost.

As this technique involves valuation of the firm, these models are also known as "firm-value" models. Structural model was first suggested by Merton and after that many models with variations have been designed. The most widely used versions are:

- Merton Model
- KMV Model (a variant of the Merton's model)

Merton's Model – the basic set-up of Merton's model considers that the firm's liabilities consist of one zero-coupon bond with notional value L and maturing at T. So, there will be no payments until T, at which point the default decision is taken. Therefore, the PD is the probability that the value of the assets is below the value of liabilities, at time T.

The probability distribution of the asset value at time T is developed on the assumption that financial assets follow lognormal distribution as shown in the diagram below.

Merton Model: Probability of Default
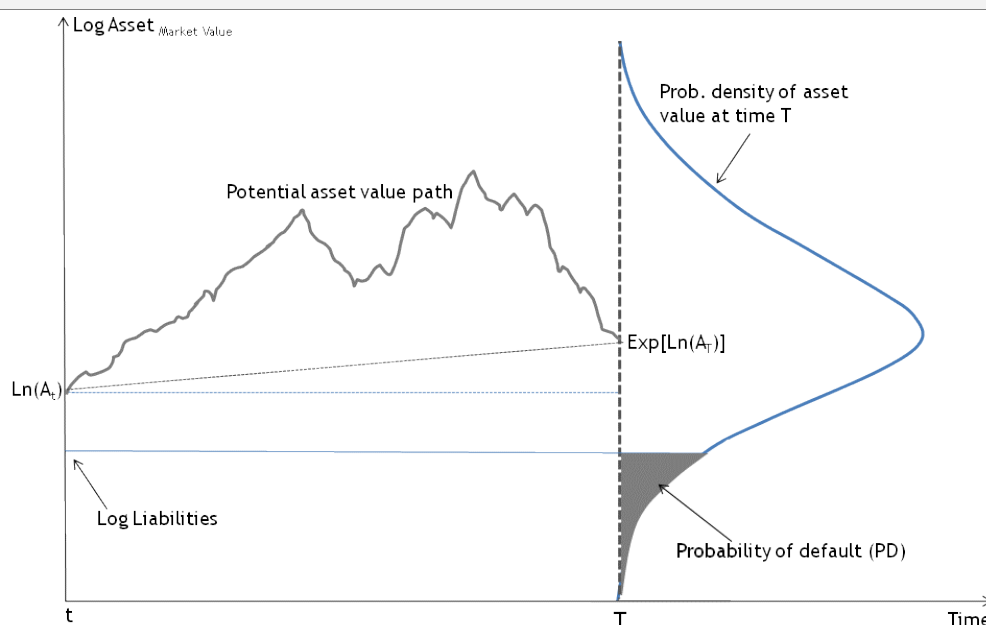
The log of the asset values follows a normal distribution at time T. Once we estimate the mean and the variance of the distribution, the PD can be calculated. Merton model uses an option theoretical framework (Black-Scholes) to model the default behavior. The payoff of the equity (shown in figure below) represents the payoff of a European call option.

In the Black-Scholes framework, the probability of default is the probability that this option expires out of the money, which is given by the following equation:

$$PD = \Phi[-\frac{\ln \frac{At}{L} + \ \mu_V - \sigma_V^2/2 \ *(T-t)}{\sigma_V \sqrt{(T-t)}}]$$

where,

$\Phi(.)$ = Cumulative standard normal distribution
A_t = Value of the firm at time t
L = Strike of the option which is the debt of the firm

μ_V = assets instantaneous expected rate of return on firm's value per unit time

σ_V = standard deviation of log of assets return

To calculate the PD, market value of assets and their volatility needs to be done. This is accomplished through the Black-Scholes option pricing formula, using an iterative approach.

The reason of using option pricing theory in the above formulations is to help form the relationship between unobservable variables (*future market values of the asset*, *standard deviation of the asset returns*), and observable variables.

At maturity T, we can form relationship between equity value and asset value. As long as the asset value is less than the value of liabilities, the equity's value will be zero because all the assets will be claimed by the bond holders. If the asset value is greater than the notional of the zero-coupon bond, the equity holders will receive the remaining value, and their pay-off behaves linearly with the asset value. The respective payoffs to the bond and equity-holders are shown below.

Payoffs: Bond and Equity-holders
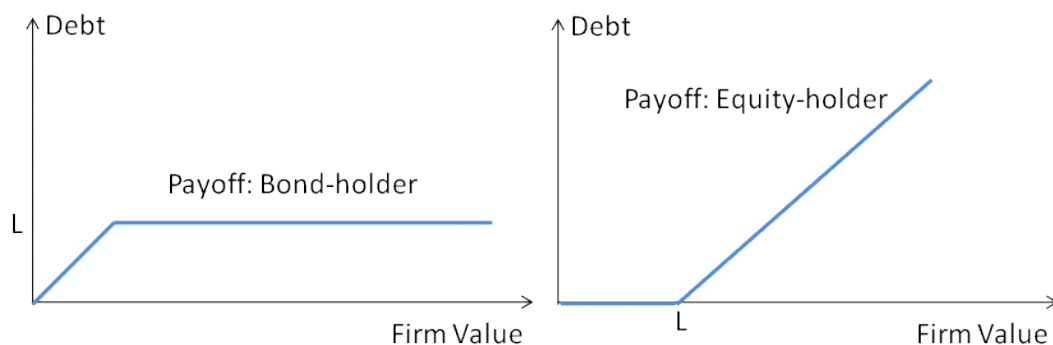
The payment at the maturity will be:

- Payment to bond holders = L – Max (L – A_t, 0)   (*payoff of a ZCB with notional L + short put with strike L*)
- Payment to equity holders = Max(A_t – L, 0) (*payoff of a European call option*)

This model adapts the dynamics of the firm's asset value process and the firm's capital structure to the requirements of Black-Scholes model, which takes the framework somewhat away from realism[5]. The calculated values of assets and its volatility are very sensitive to the value of inputs like equity volatility, which in turn is sensitive to the method used to calculate it. So, the methodology chosen to calculate equity volatility affects the probability of default significantly and can lead to incorrect PD. However, the structural model is easy to implement. Some extensions of this model such as KMV and Black-Cox have made more realistic assumptions.

---

[5] For 'asset value process': no possibility of early default before maturity date; assumption of lognormal distribution; continuous tradability. The 'capital structure' of a firm is more complicated than assumed

Reduced Form Approach

Reduced form PD is calculated using the credit spreads of non-defaulted risky bonds currently trading in the market. The spread above treasury bonds is the indicator of the risk premium demanded by the investors. However, this spread reflects the expected loss – which includes both PD and LGD – and liquidity premiums. Therefore, the modeling requires separating PD from the remaining parameters.

This section explores the *Jarrow-Turnbull* reduced form approach, which requires us to first construct a risk-free interest rate tree. The issuer's yield curve and recovery rate are taken from the market data. They can also be calculated using an internal model.

The value of the corporate bond for the first period is calculated using a 1-period interest rate tree by applying backward induction. The unknown first period's probability of default is a part of this formulation. Then, the value of the same corporate bond is calculated using the issuer's 1-period yield. This value is equated to the formulation developed from the interest rate tree. The probability of default is the value which solves this equation. Similarly, the same procedure can be extended to the following periods.

Reduced Form Model: Calculation Framework
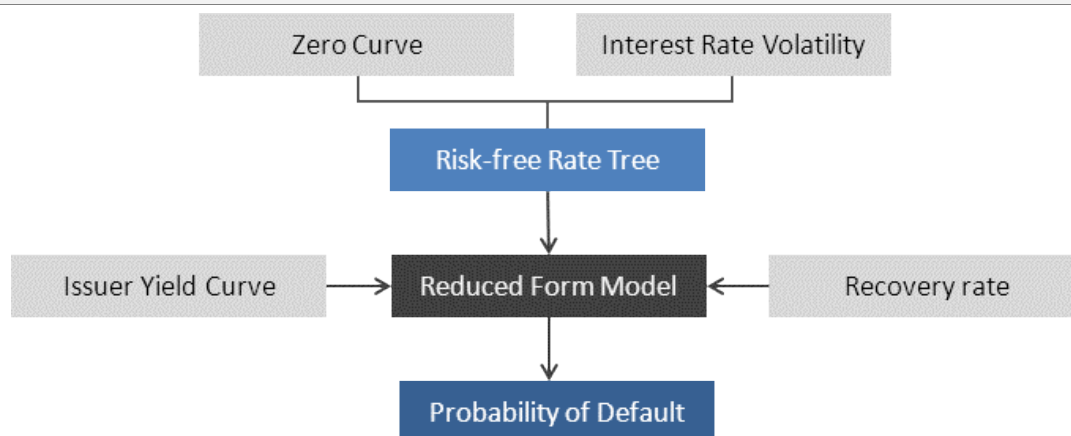
In the methodology mentioned above, the interest rate tree is calculated using the zero coupon curve and the volatility of the interest rate tree. This interest rate tree, the issuer's yield curve and the recovery rate are the inputs in the reduced form model. Probabilities for different periods can be calculated using this model. Let us assume the default probability for n^{th} period is p_n. The method to find the first period (between t=0 and t=1) default probability p_1 and all subsequent probabilities share the same intuition.

In case of p_1, as mentioned above, suppose the face value of the bond is 1\$ and the one-year risk-free rate is equal to R_1 and the recovery rate is δ. The value of the one-period corporate bond is shown as:

Equation 1: Value of the 1-period bond = $[1 * (1-p_1) + \delta p_1] * Exp(-R_1)$

The value of the corporate bond is also calculated from the issuer's yield curve – where, the one-period issuer's rate is RR_1– as:

Equation 2: Value of the 1-period bond = $Exp(-RR1)$

Since both values are supposed to be the same, we can equate equation 1 with equation 2:

$Exp(-RR_1) = [1 * (1-p_1) + \delta p_1] * Exp(-R_1)$

By iteration, we can find p_1. Similarly, we can repeat the same process to calculate the probabilities of following periods.

This model is applicable for only those companies whose bonds are actively traded on the market. Current market prices of the bonds may not reflect the riskiness of the company. Also, the liquidity risk premium in the spread is difficult to separate out.

Loss Given Default – IRB

A bank incurs a loss when a company to which the bank has lent money, or entered into a contract with, defaults on its payments. According to the Bank of International Settlements (BIS), a default on an obligor is said to have occurred when one or more of the following events have taken place:

- The obligor is past due more than 90 days on any credit obligation
- The obligor has filed for bankruptcy or similar protection from creditors

Loss Given Default (LGD) is defined as the percentage loss rate on EAD, given the obligor defaults. It provides the loss that a bank is bound to incur when a default occurs. The actual loss incurred will be the product of LGD and EAD. The components of the loss that will be incurred, given the obligor defaults are:

- Loss of principal – comprises of the major component of the loss and significantly impacts the LGD
- Carrying costs
- Workout expenses

Though a lot of attention is paid to PD modeling, LGD is assumed to be a constant in many studies and applications because it is not very straightforward to calculate. The estimation of LGD is crucial to the calculation of the required economic capital because the value of risk-weighted assets is more sensitive to changes in LGD than in PD. This implies the importance of precise estimation of LGD.

Value of LGD varies with the economic cycle, so the following variations in LGD are defined:

- Cyclical LGD (Point-in-Time LGD)
- Long-run LGD (Through-the-Cycle LGD)
- Downturn LGD

Cyclical LGD is calculated based on the recent data and its value depends on the economic cycle. Long-run LGD represents the average long-term LGD, corresponding to a non-cyclical scenario that is not dependent on the time the LGD is calculated. Downturn LGD represents the LGD at the worst time of the economic cycle. Basel ll requires that the LGD must reflect the downturn conditions wherever it is necessary to capture the relevant risks. For conditions when the credit losses for the respective asset classes are expected to be higher than the average, banks must use the downturn LGD.

Under the *IRB-Foundation approach*, senior claims on sovereigns, corporates, and banks not secured by accepted collateral are given an LGD value of 45% and the subordinated claims are given LGD value of 75%.

Under the *IRB- Advanced approach*, LGD needs to be estimated using internal models. Four broad modeling techniques can be employed for estimating LGD under this approach, as mentioned below:

- *Market LGD*: estimated using market prices of defaulted bonds/loans
- *Workout LGD*: estimated using cash-flows from workout process
- *Implied Market LGD*: estimated from market prices of non-defaulted bonds/loans
- *Statistical LGD:* estimated using regression on historical LGDs and facility characteristics

LGD: Estimation Techniques
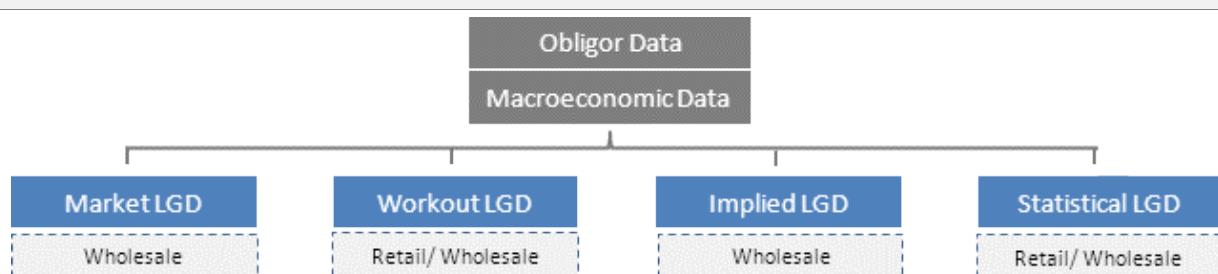
As discussed in the following sections, workout LGD gives a more precise estimate of LGD, though it is more calculation intensive. Market and Implied LGD are comparatively less computation intensive and work well for liquid market instruments.

It is suggested that the bank uses the market or implied LGD approach to estimate LGDs of liquid and traded instruments, whereas workout LGD is used for instruments that are illiquid or has no market. Another aspect that should be considered is the exposure of the transaction. If the exposure is large, it is suggested to employ a technique which calculates a more precise LGD value.

Furthermore, a model can be developed to forecast LGD, given the characteristics of the facility. We can achieve this by estimating historical LGDs (workout preferred for precision) for the instruments/facilities. Then, the statistical LGD technique is employed with various facility characteristics as the independent variables and the estimated LGDs as the dependent variable.

Market LGD

Market LGD is a historical-data-based method. In this technique, the observable *default price* of the bonds and loans that trade in the market after the firm has defaulted are used as the proxy for LGD. The actual prices of the bonds are based on par and thus can be easily converted into LGD as: {100% of par value - default price}. This technique reflects the investor's expectations about the recovery (i.e. 100% - LGD) through market prices of defaulted bonds and marketable loans.

The reason to use this method for calculating LGD is that the default price reflects the investor's expected recovery and thus is expected to include recoveries on both discounted principals and missed interest payments. Based on the default price of the bond and the corresponding characteristics of the bond, we can calculate the historical average of LGD associated with specific characteristics of the bond. Thereby, we can obtain the LGD for each type of bond.

Input data required would be the list of all the bonds that have defaulted in the past, their trading price in the market after the default and bond characteristics such as rating of the bond, maturity of bond, issuance date, age of the bond, seniority of the bond, issuer's rating, covenants, country's economic data, and collateral.

The methodology first involves grouping of the bonds having similar characteristics and then dividing them into different categories. LGD for each category, corresponding to the respective age of the loan, is calculated based on the default price. LGD for each category is the average of all individual bonds' LGD in that category. To calculate the LGD for a facility, we need to analyse the characteristics of the facility and decide in which category the facility falls; the corresponding LGD will be tagged to the facility.

Market LGD: Estimation Framework
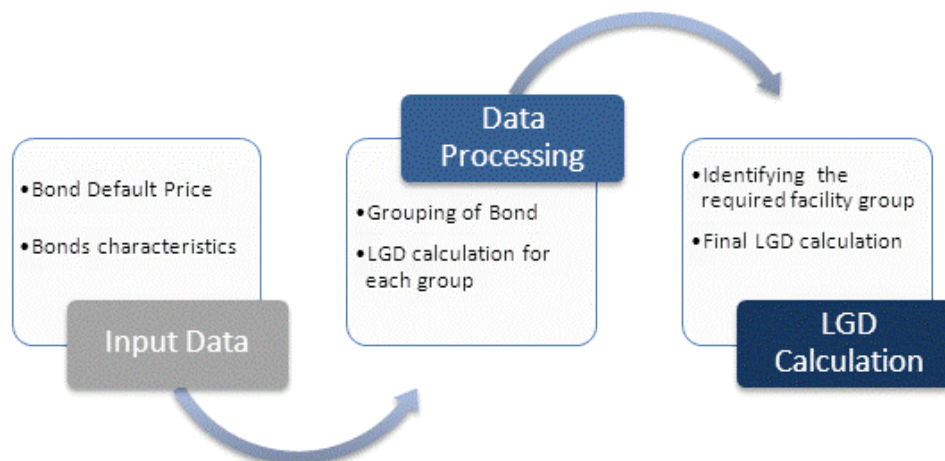
The primary advantage of this approach is that the data required for calculation can be observed immediately after a certain default. Furthermore, given that market price is used, it reflects the aggregate expected present value of the recovery. As the bond pieces are based on par, they can be easily converted into recovery percentage. Given the universe of data associated with historical bond defaults, calculating market LGD would be the preferred approach. Therefore, most rating agencies employ this method for estimating LGD.

The major disadvantage of this method is its issue with calculating LGD for instruments which are illiquid or have no market. For instance, defaulted bank loans do not trade; therefore, market LGD will not be applicable.
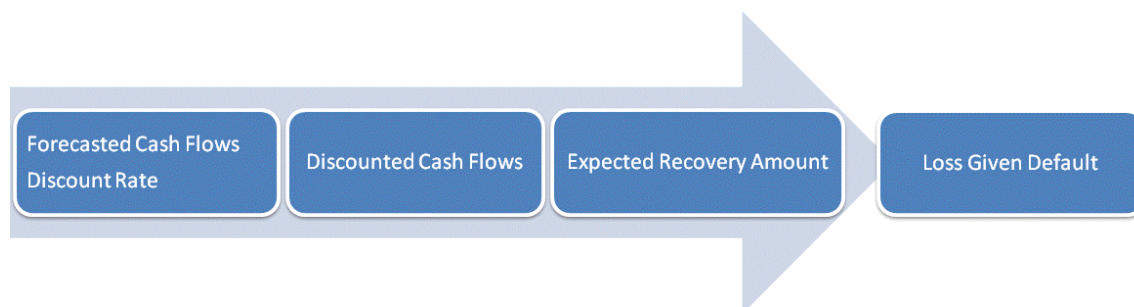
Workout LGD

Workout LGD calculates the LGD based on the actual cash flows that can be recovered from the firm by the workout process, once the firm has defaulted. The Workout LGD methodology involves prediction of the future cash flows that can be recovered from the company, after the company has defaulted on its payments. It takes into account all cash flows from the distressed asset linked to the recovery.

The following input data is required to calculate workout LGD:

Forecasted cash flows	Assets of firm	Risk-free rate	Spreads for risky assets
Legal cost	Foregone interest cost	Bond rating	Bond seniority
Volume of defaulted bonds	Backing of third party	Current macro. conditions	Distressed assets' demand/supply

The forecasted cash flows are discounted using an appropriate discount rate for the defaulted firm. These discounted cash flows are added to provide the expected recovery amount. The total exposure of the firm at the time of default minus the expected recovery amount gives the loss given default in absolute terms. The ratio of loss given default in absolute value to exposure at default gives the LGD in percentage terms.

Workout LGD: Estimation Framework

Forecasted Cash Flows
Discount Rate → Discounted Cash Flows → Expected Recovery Amount → Loss Given Default

Computation of workout LGD can be shown as below:

$$LGD\ \tau = \frac{EAD\ \tau - PV(\sum_{t=m}^{T} R(t)) + PV(\sum_{t=m}^{T} C(t))}{EAD\ \tau}$$

where,

- EAD is Exposure at Default
- τ is the default time
- m and T are the start and finish points of the workout process respectively
- PV(R(t)) is the recoveries during the workout process
- PV(C(t)) is the costs during the workout process

Though this formula looks simple, it is difficult to calculate. This is because there are subjective decisions involved such as timing of cash flows and discount rate to be considered (risk-free rate or a bank's hurdle rate). Furthermore, recoveries are not always in the form of cash, they can be illiquid securities or ones with no secondary market, leaving their values unclear. This means that, until all the recovered claims are sold – which could take a long time – an accurate estimation of LGD cannot be calculated. However, their expected values can be used for calculation.

Although the calculation process is difficult, workout LGD is considered to precisely reflect the losses post default. Banks generally use the workout approach to calculate LGD for illiquid loans and market LGD approach for observable market prices.

Implied LGD

Implied market LGD calculated LGD from market-observable information i.e. market prices. The assumption in these models is that the market prices incorporate all the risk parameters. So, by using these prices, the risk parameters such as PD and LGD can be extracted. The advantage of implied market LGD is that it is forward looking, as the prices incorporate the future expectation.

Implied LGD can be calculated by the following two methods:

■ Structural-form model
■ Reduced-form model

This section discusses the *structural model,* which is based on the framework developed by Merton. It uses the option pricing theory developed by Black and Scholes. Here the term structural is used as these models use the structural characteristics of the company, such as assets and their volatility, and leverage of the company. The basic idea behind these models is that the company will default if the company's assets value fall below its debt at maturity. So the company's default risk is driven by the asset's value and its volatility, which need to be estimated.

Bond holders have the primary right and the equity holders have the secondary right over the assets of the company, after the company has paid all of its debt. Now, if the value of assets is greater than the value of debt, then equity holders will get the excess amount over debt; if the value of assets is less than the debt value, then debt holders will get all the assets and equity holders will be left with nothing.

The payment to bondholders and equity holders can be shown by the following equation:

■ Payment to bond holders = $D - \text{Max}(D - A_t, 0)$(*payoff of debt D + short put with strike D and spot as assets A_t*)
■ Payment to equity holders = $\text{Max}(A_t - D, 0)$(*payoff of a European call option with D as strike and spot as assets A_t*)

Payoffs: Bond and Equity-holders
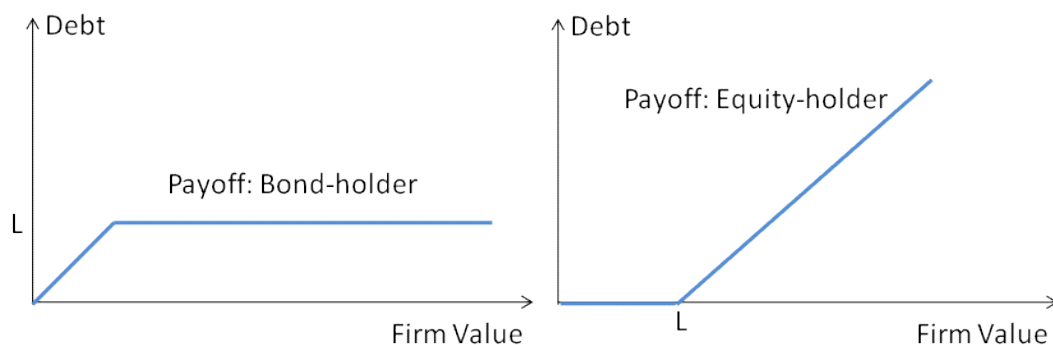
In the basic Merton model, the assumption is that the firm's debt is a zero coupon debt with notional D and specific maturity T and there will be no payments before this maturity. This maturity is the time over which LGD needs to be estimated. This implies that the default can occur only at maturity. The value of the firm is also assumed to be observable and following a lognormal diffusion process.

Payoff to the equity holders is similar to pricing a European call option with the spot as the asset price and debt as the strike. This value is calculated using Black Scholes and is compared with the market-observed price to estimate the model parameters required to estimate the LGD.

The value of LGD is calculated as 1 – Recover rate (RR). Recovery rate is the estimated value of assets in case of default i.e. the value of assets if it is less than the value of debt at maturity. Using the Black Scholes option pricing theory, recovery rate is given by:

RR = $\mathrm{E}\left(\frac{A_T}{\mathrm{D}} \mid A_T < D\right)$, therefore

RR = $\frac{A_0}{D} \exp(\mu_V T) \frac{\phi(-d_1)}{\phi(-d_2)}$

where,

$$d_1 = \frac{\ln \frac{A_t}{L} + \mu_V + \sigma_V^2/2 * T}{\sigma_V \sqrt{T}}, \quad d_2 = d_1 - \sigma_V \overline{T}$$

$\Phi(.)$ = Cumulative standard normal distribution

A_t = Value of the firm at time t
D = Strike of the option which is the debt of the firm

μ_V = assets' instantaneous expected rate of return on firm's value per unit time

σ_V = standard deviation of log of assets' return

The above equations can be modified to include dividends if the firm has a history of giving out dividends. By using asset's expected return, the LGD calculated is the real world LGD.

To calculate LGD, estimation of market value of assets and its volatility needs to be done. This is accomplished through the Black-Scholes option pricing formula, using an iterative approach.

Statistical LGD

Loss given default can be estimated with the help of statistical techniques using historical data. The statistical method estimates LGD by establishing a statistical relationship between LGD and factors that can affect the LGD of the facility. This relationship is then used to predict the LGD of the current facility. The most widely used statistical technique used to estimate LGD is regression.

In regression analysis, one dependent variable and one or more independent variables are used. The LGD will be the dependent variable and other factors that can change the value of LGD form the independent variables. LGD of the past facilities for the retail exposure or the default price for corporate exposure is used as a proxy for LGD. The independent variables consist of factors such as issuer's rating, rating of the facility, seniority of the facility, maturity, interest rates, labour market data, and business indicators such as gross domestic product, consumer price index, and inflation data.

LGD lies between 0 and 1, so transformation of output variable – LGD – is done to ensure that the output of the statistical model lies between 0 and 1. The following is the transformation done to LGD:

$$x_t = \log\left(\frac{LGD}{1 - LGD}\right)$$

Here, x_t is a linear equation formed by the linear combination of independent variables and is given by the following equation:

$$x_t = \alpha_0 + \alpha_1 * y_1 + \alpha_2 * y_2 + \cdots + \alpha_n * y_n$$

where,
   α (i= 0,1,2 … n) are the estimated parameters
   y (i= 0,1,2 … n) are the independent variables.

The current independent variables can be included and also with a time lag of one year or more. Once the model is calibrated, the LGD for a new facility can be calculated.

Following are the points to be kept in mind while implementing this model:

- Only the statistically significant variables should be considered in the final model
- Variables should have economic meaning in explaining the variation of LGD
- Independent variables should be able to explain the LGD significantly
- Data should be properly processed. For instance, removal of outliers to get the correct relationship

Exposure at Default

A key risk parameter to address the bank's exposure at the time of default is called exposure at default (EAD). The amount which the bank is expected to lose in the event of an obligor defaulting represents the EAD. According to the BIS, EAD must not be lower than the book value of balance sheet receivables and has to be calculated without considering provisions. EAD is calculated at the facility level.

Calculation of EAD according to the product type can be divided into two sections:

■ *Lines of credit*: This is a credit source provided to an entity (obligor) by a bank. Some types of 'lines of credit' are demand loan, term loan, revolving credit, and overdraft protection. Banks are required to estimate EAD for each facility type, which should reflect the chance of additional drawings by the obligor. The methods used to estimate the EAD for lines of credit and off-balance sheet items are:

  - *Credit Conversion Factor (CCF) Method*

■ *Derivatives*: These are vanilla and over-the-counter (OTC) instruments, the pay-outs of which depend on the movements of some asset class (underlying). The risk of default or counterparty credit risk is prevalent for OTC derivatives. The EADs of a few derivative products, such as interest rate swap, caps, floors, swaptions, cross currency swaps, equity swaps, and commodity swaps, are calculated in a different manner. EAD estimation methods for derivative products can be done by the below methods:

  - *Current Exposure Method (CEM)*
  - *Standardized Method (SM)*
  - *Internal Model Method (IMM)*

Under the internal ratings-based approach, calculation of EAD is further divided into the following two sections:

■ *Foundation Approach (F-IRB)*: In this approach, EAD associated with 'lines of credit' and 'off-balance sheet transactions' are to be calculated using the CCF method, where the CCFs are provided in the Basel guidelines; collaterals, guarantees or security are not taken into consideration while estimating EAD. To estimate EAD of derivatives, any of the abovementioned methods under the derivatives section can be chosen.

■ *Advanced Approach (A-IRB)*: For this approach, banks are allowed to use their own models, and they have the flexibility in choosing their models. For the CCF method, the CCFs are not provided by the regulatory guidelines and have to be calculated.

Estimation Techniques: Exposure At Default
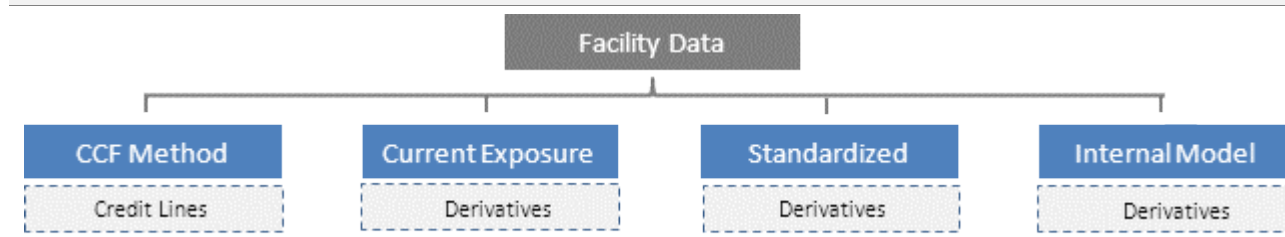
A bank's choice of internal model for estimating the exposure of OTC derivatives depends on its level of comfort with the complexity associated with the model. That apart, the choice also depends on the regulatory requirements met by the bank to implement complex internal models.

CCF Method

The amount which the borrower will owe to the bank at the time of default is the EAD. The following are the two types of credit exposures:

- *Fixed exposure*: Exposures for which the bank has not made any future commitments to provide credit in the future and the on-balance sheet value gives the value of exposure. The value of the exposure is given by the following formula:

  EAD = Drawn Credit Line

  EAD for the fixed exposures will equal to the current amount outstanding on the balance sheet and as a result no modeling is required for Basel ll requirements.

- *Variable exposure*: Exposures in which the bank provides future commitments, in addition to the current credit. Therefore, the exposure will contain both on- and off-balance sheet values. The value of exposure is given by the following formula:

  EAD = Drawn Credit Line + Credit Conversion Factor * Undrawn Credit Line

  where,

  > *Drawn Credit Line* = Current outstanding amount
  > *Credit Conversion Factor* = Expected future drawdown as a proportion of undrawn amount
  > *Undrawn Credit Line* = Difference between the total amount which the bank has committed and the drawn credit line

As the future drawdowns are not known, to estimate EAD we need to model for the CCF factor of each exposure.

Credit Conversion Factor (CCF) Modeling

The CCF is the ratio of the estimated extra drawn amount during 12 months before default over the undrawn amount at the time of estimation. It can be defined as the percentage of undrawn credit lines (UCL) which has not been paid out, but can be utilized by the borrower until the point of default. The CCF should lie between 0 and 1.

$$CCF = \frac{\text{Increase in exposure until default day}}{\text{Maximum possible increase exposure until default day}}$$

The CCF is calculated for the default exposures which are used to estimate the CCF for the non-default exposures.

The following steps are employed to estimate the CCF of non-default exposures:

- Exposures which had defaulted in the past are divided into pool on the basis of Exposure at default risk drivers(EADRD) – attributes of the exposure *viz.* factors affecting borrower's demand for funding/facilities, nature of particular facility
- Each individual default-exposure's CCF is estimated within the pools
- The average CCF for each pool is calculated – the CCF of the pool is defined as the weighted average of the CCF which were estimated for the defaulted individual exposures
- If the volatility of CCFs is low and lies around the average, it is advisable to use the average CCF; if the CCF values are volatile then it should represent the economic downturn conditions appropriately
- The average CCFs of default-exposure pools is used to estimate the CCFs for the non-default exposures using lookup tables
- The CCF obtained is checked whether it is appropriate for the current macroeconomic scenario and then used to calculate the EAD

Estimation Process: CCF Method
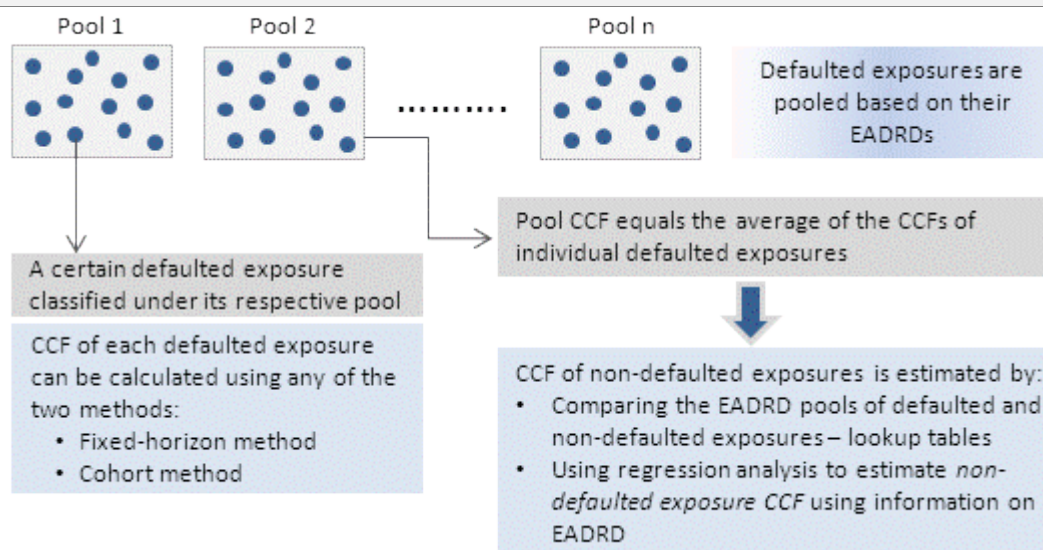
CCF Estimation for Defaulted Exposures

Estimation of the CCF for defaulted exposures is primarily done by two methods:

■ Fixed-horizon method
■ Cohort method

In both the methods, the observation time period is fixed (as fixed by the regulators) and is usually one year.

Fixed horizon method

This methodology assumes that all the exposures that are in non-default state will default at the same time over the time horizon chosen for the estimation. The CCF is calculated with respect to the time horizon that is always fixed.

The CCF is the ratio of the increase in the exposure until the default day to the maximum possible increase in exposure. These values are calculated with respect to the fixed time horizon. Therefore, the numerator indicates how much the exposure of the bank increased from the exposure at the fixed interval prior to default and the denominator indicates the maximum increase in the exposure that could have happened during the fixed interval.

Here the amount that will be drawn at the maturity is related to the drawn/undrawn amount at a fixed time prior to default. The CCF is given by the formula:

$$\text{CCF}_\text{fixed\_horizon} = \frac{\text{EAD} - \text{On\_balance}_\text{fixed\_horizon}}{\text{Limit}_\text{fixed\_horizon} - \text{On\_balance}_\text{fixed horizon}}$$

where,

EAD: Exposure at the time default occurred
On_balance (fixed horizon): *Exposure of the* bank at fixed time horizon (one year) prior to default
Limit (fixed horizon): Maximum exposure that the bank can have with the counterparty at the fixed horizon

Cohort method

The observed time horizon is divided into different short time windows (default can occur at any time in the time window). Therefore, the time horizon with respect to which the CCF is calculated is not fixed.

The CCF is the ratio of the increase in the exposure until the default day to the maximum possible exposure. These values are calculated with respect to the start of the time window. The numerator indicates how much the exposure of the bank increased from the exposure at the start of time window prior to default. The denominator indicates the maximum increase in the exposure that could have happened during the time window. As the default can occur at any time within the time window, the time interval between the start of window and the default is not fixed.

Here the amount that will be drawn at maturity is related to the drawn/undrawn amount at the beginning of the different time horizons. The CCF is given by the formula:

$$\text{CCF}_{\text{cohort}} = \frac{\text{EAD} - \text{On\_balance}_{\text{start of window}}}{\text{Limit}_{\text{start of window}} - \text{On\_Balance}_{\text{start of window}}}$$

where,

EAD: Exposure at the time default occurred

On_balance (start of window): Exposure of the bank at the start window period prior to default

Limit (start of window): Maximum exposure that the bank can have with the counterparty at the start of the time window

In the event of the CCF being negative or greater than 1, appropriate adjustment is made to make it applicable for calculation of EAD.

CCF Estimation for Non-Defaulted Exposures

The CCF for non-default exposure is calculated using the CCFs from the defaulted exposures. The current non-default EADRD pools are compared with the EADRD pools of the defaulted exposure – whose CCFs have been calculated. The lookup table method is employed to achieve this.

Apart from the approach discussed above, regression analysis can be used to estimate the non-default exposure CCFs. Once the CCFs for default exposures are calculated, the EADRDs can be grouped as independent variables and the CCFs calculated as dependent variable. A regression model for the universe of exposure data can be developed or regression models for each pool can also be calibrated. On entering the non-default exposure EADRD data, the corresponding CCF is estimated.

Current Exposure Method

The Current Exposure Method comprises of two components: Current Exposure (CE) and Potential Future Exposure (PFE). The formula for EAD under this method is given by the formula:

Equation 1: EAD = CE + PFE

where,

Current Exposure is the current market value of the contract or the replacement costs for a party if counterparty defaults today. It equals the market value if it is positive and zero if the market value is negative. Therefore, *CE = max {market value; 0}*

Potential Future Exposure is the maximum amount of exposure expected to occur on a future date with a high degree of statistical confidence.

The PFE is calculated by multiplying the notional values of the contracts with a fixed percentage which is the Credit Conversion Factor (CCF) as shown below:

Remaining	Interest rates	FX & gold	Equities	Precious metal (ex. gold)	Other commodity
< 1 year	0.0%	1.0%	6.0%	7.0%	10.0%
1-5 years	0.5%	5.0%	8.0%	7.0%	12.0%
> 5 years	1.5%	7.5%	10.0%	8.0%	15.0%

The effect of collaterals and netting on the EAD is mentioned below:

■ *Collateral*: In presence of a collateral agreement with counterparty, the EAD will be calculated as:

Equation 2: EAD = (CE+ PFE) - Collateral

Collateral deduction in the CEM method is allowed in Basel II, but it was not possible during Basel I. In the case of non-cash collateral, the value of the collateral is reduced subject to haircut. In the presence of collateral agreements, counterparties have to periodically mark to market their positions and in the event of exposure exceeding the pre-decided thresholds, they need to post more collateral by transferring the ownership of the assets.

■ *Netting*: Banks which employ CEM to calculate EAD are permitted to net the market value i.e. the current exposure with the counterparty if the contract is covered under the master agreement. All the contracts of a certain counterparty having positive and negative values can offset each other resulting in reduced exposure value.

CE (with netting): $CE = \max \{ \sum_k \text{market value}_k ; 0 \}$

For PFE, complete offsetting of negative and positive PFEs is not permitted. A PFE floor of 40% is maintained when contracts are netted. Therefore, the sum of PFEs of the various derivative contracts should be minimum 40% of total PFE. The remaining 60% depends on the "market value structure" of the bilateral derivative portfolio; the factor – current net exposure to the current gross exposure for all transactions within the netting set – which is also called NGR (net-to-gross replacement cost ratio) is incorporated.

PFE (with netting): $\text{PFE} = \{40\% * \sum_k \text{PFE}_k\} + \{60\% * \sum_k \text{PFE}_k * \frac{\max \{ \sum_k \text{market value}_k ; 0 \}}{\sum_k \max\{\text{market value}_k ; 0\}} \}$

Standardized Method

This method is employed by banks which are not capable of computing their OTC derivative exposures using the internal model method (discussed in the following section). However, this method is more risk sensitive than the Current Exposure Method. The Standardized method is used only for OTC derivatives.

Exposure at Default using the standardized method is calculated according to the following formula:

EAD = β * max [Current Exposure; $\sum_k (\text{NRP}_k * \text{CCF}_k)$]

where,

> *Current Exposure* is the mark-to-market value after netting and collateral reduction
>
> *NRP*s are the absolute value of the net risk positions in the hedging sets
>
> *CCF*s are the credit conversion factors applied for the k hedging sets
>
> *k* is the index that designates hedging sets
>
> *β* represents extra reserve for potential downturns in the economy and also captures model risk; its value is fixed by regulators at 1.4

For margined trades, standardized method does not account for future exchange of collateral; it only accounts for the current value of collateral posted in the CE. The current collateral value is subtracted from its corresponding position's notional to provide NRP. The CCFs corresponding to respective transactions are determined by the asset class it belongs.

The CCF values for the standardized method are provided in the following table:

Asset Class	CCF	Asset Class	CCF
Int. Rate Derivatives	0.2%	Gold	5%
Credit Derivatives	0.3%	Equity	7%
Debt Instruments	0.6%	Precious Metal w/o Gold	8.5%
Exchange Rate	2.5%	Other Commodities	10%
Electricity	4%	Other Derivatives	10%

Internal Model Method

The Internal Model Method (IMM) is the most risk-sensitive approach for EAD calculation available under the Basel II framework. A bank requires approval from local market regulators to use the IMM to calculate EAD. The IMM calculates the counterparty exposure of the bank at a future dates. These exposures are calculated for each *netting set*[6]. The exposure at default in IMM is given by the following formula:

$$\text{EAD} = \alpha * \text{Effective EPE}$$

where,

α: multiplier set by regulators to 1.4
Effective EPE: Effective Expected Positive Exposure

Alpha (α)[7] accounts for correlations between market and credit risk, credit portfolio assumptions, concentration risk and model risk. Banks can use their own estimates for α which is subject to floor value of 1.2. Effective EPE is the average of Expected Exposure (EE) for certain time interval at a future date. The formulas to calculate Effective EE and Effective EPE are:

$$\text{Effective EE}_{t_k} = \max(\text{Effective EE}_{t_{k-1}}, \text{EE}_{t_k})$$

$$\text{Effective EPE} = \sum_{k=1}^{\min(1\,\text{year},\text{maturity})} \text{Effective EE}_{t_k} * \Delta t_k)$$

where,

t_0 = Current date
$\Delta t_k = t_k - t_{k-1}$
$\text{Effective EE}_{t_k}$ = Current Exposure

Margined Exposures

In margined exposures, the contractual agreement states that counterparty-1 has to supply the collateral to counterparty-2 when the exposure of counterparty-2 exceeds the specified threshold level. EAD calculation for margined trades requires calculation of collateral value at a future date. A bank has the following methods to calculate the exposures for margined trades:

1. Calculate EPE without collateral adjustment
2. Calculate EPE equal to the sum of the threshold amount, MTA and the change in the expected exposure under margin period of risk
3. Calculate EPE by simultaneously simulating the collateral exposure

   Method 1

   In this method, EPE and collateral are calculated independently. The value of collateral is separately deducted from the EPE to calculate the effective EPE. The formula to calculate the EAD is:

   $$\text{EAD} = \alpha * \text{Effective EPE} - \text{Collateral}$$

   Method 2

   This method is for banks which are unable to model the EPE with margin agreements. This method calculates the EAD using the following formula:

   $$\text{Effective EPE}_{\text{margin}} = \min(\text{Threshold} + \text{MTA} + \Delta\text{EE}\,;\,\text{Effective EPE}_{\text{no margin}})$$

   where,

   Minimum Transfer Amount (MTA): the smallest amount of collateral that can be transferred
   Threshold: the amount of uncollateralized exposure
   ΔEE: change in expected exposure under the margin period of risk

---

[6] Netting set is defined as the group of transactions with a single counterparty to which the legal netting agreement is enforceable.
[7] It is the ratio of economic capital from a full simulation of counterparty exposure across counterparties and economic capital based on EPE with the assumption that they satisfy the requirements given by the Basel

Minimum transfer amount is used to avoid the workload associated with frequent transfer of insignificant amounts of collateral. A threshold is a level of exposure below which collateral will not be called.

Method 3

This methodology involves calculating the collateral along with the calculation of the exposure. This involves simultaneously simulating the exposures and the collateral. This method involves lot of complex calculations.

This methodology requires the approval of the local regulatory authority. If the regulatory authority finds flaws in the model that a bank uses, it can revoke the internal modeling license until the model has been re-calibrated. Depending upon the capability, the bank can chose any of the above mentioned models to calculate the EAD.

Model Validation

Once complete implementation of the risk framework – data integration, capital models, stress models, stress scenarios – takes place, a thorough validation and independent review of the relevant models is carried out. Also, all the methodologies, processes, system information, key assumptions, and suggested actions require proper documentation.

Regulatory Perspective

Model risk management is a key component. The regulatory guidelines such as those issued by the Office of the Comptroller of the Currency (OCC) in the US and Financial Services Authority (FSA) in the UK need to be strictly adhered to.

Banks are expected to have a robust system to validate the accuracy and consistency of various models used for capital and risk estimations. They should establish internal validation processes to assess the performance of such models. The suggested process cycle for models validation includes the following:

- Regular monitoring of model performance, which includes evaluation and rigorous statistical testing of stability of the model and its key coefficients
- Identifying and documenting individual fixed relationships in the model that are no longer appropriate
- Periodic testing of model outputs versus outcomes, at least on an annual basis
- Demanding change control process, which specifies procedures to be followed before making changes in the model, as a response to validation outcomes

Model Understanding

The models can be categorized as valuation models (of financial instruments), risk models (to model risk parameters and estimate risk), and econometric models (on modeling variable relationships). Typical models used in a retail or commercial banking setup include loan valuation models, default estimation models, LGD estimation models, EAD models, prepayment models and lending scorecards.

Proper checking of the models needs to be carried out to ensure that the models are appropriate, flexible and accurate. Limitations of the models need to be properly understood. Also, a proper documentation of all assumptions made during the process of modeling is required.

Validation Process

The outline of a typical model validation process is shown below:

Outline: Model Validation Process

Scoping	Model Theory	Model Implementation	Model Sensitivity	Model Limitations	Periodic Testing
• Scope of the validation exercise • Specific model from a larger group	• Theoretical background • All relevant model concepts	• Independent validation • Back-testing • Benchmarking	• Boundary testing • Input variable shocks / shifts	• Limitations in the pricing technique used • Limitations of the assumptions taken	• Re-calibrate the model • Back-testing of new data

irevna — The best people to work with