Best Practices in Credit Risk Management

Challenges to and Opportunities for Rebuilding Trust
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Credit Risk Management Challenges and Opportunities

It was the summer of 2007. The banking sector had only recently adopted Basel II regulations and begun to feel at ease with its credit risk management systems when the US subprime crisis erupted, subsequently spilling over into the most severe financial crisis since the Great Depression.

A March 2008 survey of the Senior Supervisors Group – a group of senior financial supervisors from 10 countries – noted: “Generally, management at the better performing firms had more adaptive (rather than static) risk measurement processes and systems that could rapidly alter underlying assumptions in risk measures to reflect current circumstances.”¹

Internal Rating Systems

Banks have been using internal ratings to assess customers’ creditworthiness for a long time. Over the years, different banks developed different rating schemes based on their own needs. With the advent of Basel II, however, the importance of internal rating systems was raised to a new level.

The Basel II Framework

In the area of credit risk, the Basel II framework allowed banks, for the first time, to use their own estimates of certain risk parameters to determine the regulatory capital required for an exposure. In the internal ratings-based (IRB) approach, a bank may base regulatory capital calculations on its internal rating systems, provided that the internal rating systems meet several minimum requirements. Using internal credit portfolio models to determine the necessary regulatory capital, however, is not allowed.

The Basel II definition of an internal rating system is very broad: “The term ‘rating system’ comprises all of the methods, processes, controls, and data collection and IT systems that support the assessment of credit risk, the assignment of internal risk ratings and the quantification of default and loss estimates.”² In general, an internal rating system has to assess the default risk independently from transaction-specific factors. Banks are expected to come up with their own estimates for a borrower’s probability of default (PD), and – in the advanced IRB approach – for loss given default (LGD) and exposure at default (EAD) of a transaction.

¹ SSG 2008, p. 4
² BCBS 2006, § 394
Regulatory Minimum Requirements

The aim of the minimum requirements is to make sure that an internal rating system is implemented consistently and that it can evaluate the credit risk in a transaction with sufficient accuracy. These requirements and their associated details, which were outlined in Basel II, set the bar very high both for data management and reporting systems and for model development, monitoring and validation capabilities.

As an example, Basel II stated that reporting to senior management “must include risk profile by grade, migration across grades, estimation of the relevant parameters per grade and comparison of realized default rates (and LGDs and EADs for banks on advanced approaches) against expectations.”

Similarly, the responsibilities of the credit risk control unit(s) include: “Production and analysis of summary reports from the bank’s rating system, to include historical default data sorted by rating at the time of default and one year prior to default, grade migration analyses, and monitoring of trends in key rating criteria.”

Furthermore, the minimum requirements set forth guidelines concerning both the structure and documentation of rating systems, the rating processes, the use test and senior management involvement.

Disclosure Requirements

In addition to the minimum requirements, the disclosure requirements of Pillar 3 must be met. They are also substantial and detailed, especially for IRB banks, and call for an integrated and comprehensive database system with sufficient analysis and reporting power on top.

Effects of Basel II

The Basel II requirements have led to the standardization of certain aspects of internal rating systems. Notably, internal rating systems in the post-Basel II realm:

- Tend to be more objective and repeatable, less expert- and more model-based, offer a greater number of distinct grades and enable consistent ratings.
- Must be calibrated on a long-run history of default and loss experience for internal or external ratings.
- Are part of a comprehensive rating and risk management process.

Basel II also recognizes that the development and validation of models is more than the production of statistics; it recognizes the essential subjective factor – the art of risk ratings.

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3 See BCBS 2006, Part 2, III.H
4 BCBS 2006, § 440
5 BCBS 2006, § 441
**Internal Ratings**

Although the following denominations and classifications are not unequivocal, an internal rating model in a restricted sense often refers only to the default risk component of a rating system. Internal ratings may be developed via empirical models (e.g., credit risk scorecards) or expert-based models. In addition, external ratings, as well as ratings from market-driven rating models, are widely employed. From a terminology perspective, “credit scoring” (which results in a “credit score”) is most often used in the retail banking segment, while the term “risk rating” is used in wholesale banking units to define the same process of producing risk ratings for counterparties.

**Credit Scoring**

Credit scoring is used extensively in the retail customer segment, and has been for several decades in the more mature banking markets. Typically, this segment comprises a large number of customers with similar characteristics or product requirements. The availability of large amounts of internal and external (i.e., credit bureau) data enables the development of scorecards using predictive modeling techniques and the performance of robust data mining. Several statistical methods may be used, with logistic regression being the most popular. Credit scorecards are usually developed, at minimum, for each product (e.g., a credit card). Depending on the amount of data available, further scorecards are created for product sub-segments (e.g., by origination channel, age, new/existing customer, etc.). Depending on whether or not there is prior knowledge about the customer or his/her use of a product, one distinguishes:

- Application scoring for new customers or for customers requesting a certain product for the first time.
- Behavioral scoring for customers who already have a credit history with the institution.

The resulting score can be used in various credit risk management contexts. For example, application scoring is relevant for the following types of decisions:

- Risk-based pricing/down payment/deposit.
- Credit/loan limit.
- Cross-sell/up-sell offers.
- Product upgrade/downgrade.
- Due diligence optimization.
- ATM limits.
- Adjudication/collection workflow optimization.
- Quality of business/underwriting evaluation.
- Payment terms.
- Regulatory/economic capital.

On the customer side, ongoing behavior scoring is most often used for things such as:

- Ongoing credit-limit setting.
- Regulatory/economic capital.
- Credit card/phone usage monitoring.
• Renewal/reissue/re-pricing strategies.
• Credit card authorization strategy.
• Collections strategy.
• Direct marketing prequalification.
• Evaluating/pricing portfolios.
• Cross-selling to existing customers.

The credit score is linked to a probability of default, which can then be used for portfolio modeling, pricing and capital allocation purposes.

Generally, the scoring process itself is fully automated, which makes it inexpensive. For the most part, scorecards are easy to understand, and scoring outputs are easily interpreted.

Risk Rating

In the case of larger corporate customers, financial institutions, sovereigns, specialized lending or special products, a vast database of customers or deals in the respective business segment usually are not available. As a result, one often disposes of more information on an individual customer or a particular transaction, and expert judgment is used to complete the picture. Sometimes it is possible to obtain additional information from external providers.

Low default portfolios pose additional challenges. This becomes a major issue for most banks when they attempt to comply with Advanced and Foundation IRB. Approaches to overcoming low default portfolios include changing the definition of default and using roll rates (e.g., developing a model to predict 60 days past due and using roll rates to estimate 90), expanding performance/sample windows to get bigger development samples, Pluto-Tasche and using proxies, such as shadow ratings models.

As an example, consider an internal rating model for large corporate customers – one that comprises different elements with certain weights: e.g., balance sheet and cash flow ratios, peer and industry analysis, and the evaluation of management capabilities and the company’s strategic orientation. There are several potential issues with a rating system like this:

• This type of rating system does not have many adjusting levers.
• The significance of some of the criteria employed is not always evident.
• Arbitrary or expert-based weights may be applied to the individual criteria.
• The default database at hand often does not provide sufficient grounds for a statistical analysis with clear-cut results.

In this type of rating system, all elements that are not deducted automatically from reliable, hard-fact numbers imply the judgment of a credit expert. In addition, the possibility of overrides exists if certain criteria are satisfied. As a rule, a rating is reviewed when new information comes in, or at least once a year.
Market-Driven Rating Models

In order to track changes in credit quality more closely, banks have developed models that build on the market perception of a certain company's or a specific transaction's credit risk. Information about the market's view, if available, may come from various sources: share prices and credit spreads for the company, or market prices of comparable transactions. Of course, this kind of market information does not exist for many segments, such as small enterprises or private customers. Nevertheless, relationships deduced for large, international companies may – to some extent – be valid for smaller firms that have no presence in capital markets. For instance, they might give a good indication of the market's current risk appetite and may contain valuable information about industry correlations.

A class of models using share price data is based on an idea that traces back to seminal papers "The Pricing of Options and Corporate Liabilities" by Fischer Black and Myron Scholes and "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates" by Robert C. Merton. In the Black-Scholes-Merton model, the option pricing mechanism is used to derive a market value for a company's assets from observed values of equity prices and equity volatility. This, combined with balance sheet information on the firm's liabilities, enables the calculation of a probability of default. The basic idea here is that a company defaults when its asset value at the time horizon falls below a default threshold determined by the company's liabilities.

Figure 1 shows one possible path of an asset value starting at 100 today. The default barrier is 80, and the time horizon is assumed to be one year. In the model, a default occurs whenever the asset value settles below the default barrier after one year.

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6 Black and Scholes, 1973
7 Merton, 1974
The depicted path doesn’t lead to a default, since the asset value stays above the threshold. The default probability is indicated by the shaded area under the asset value distribution’s density curve. An obvious generalization of the Black-Scholes-Merton model is to determine defaults intra-year and to count every path that falls under the threshold during the year as a default.

In practice, these so-called asset value or structural credit risk models have to be calibrated to observed default histories in order to get the right order of the default probabilities. Default probability updates are possible with the frequency of available share price data. Practical implementations of asset value models range from their use as early-warning indicators of deterioration in credit quality to their use as benchmark or input parameters for an internal rating system, as well as building blocks for portfolio models.

Internal Rating System Validation

Considering how important internal rating system outputs are for assessing regulatory capital adequacy, as well as for performing internal risk, capital and pricing calculations, it is essential to scrutinize the performance of the employed rating models. Validating internal rating systems involves two different aspects:

- Verification of the design and discriminatory power of the rating model.
- Examination of the parameter calibrations.

It is important to note that validating internal ratings systems is a process rather than simply a reporting requirement involving the production of validation statistics. The robustness of the process and data used to arrive at the parameter estimates is just as important as the estimates themselves.

For the first aspect, it is important to confirm that the rating model takes all material factors into account in order to differentiate between different levels of credit quality. In particular, the value distributions of rating criteria should be sufficiently distinct for customers who default and for those who do not. Different measures of discriminatory power, such as ROC curves and Gini coefficients, are used in practice.\(^8\)

For the second aspect, the PDs assigned to the rating grades must be compared with the realized default rates in the respective rating classes. The same holds true for the LGD and EAD estimates. Due to the scarcity of defaults in many business segments, and the fact that defaults generally do not occur independently, the validation of the PD calibrations appears to be quite complex. In a Basel II working paper, the Validation Group of the Basel II Research Task Force stated: “Due to correlation between defaults in a portfolio, observed default rates can systematically exceed the critical PD values if these are determined under the assumption of independence of the default events. This can happen easily for otherwise well-calibrated rating systems.”\(^9\)

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9 BCBS 2005 c, p. 3
The paper concluded that “… statistical tests alone will be insufficient to adequately validate an internal rating system” and proposed benchmarking with external sources as a complementary technique. Working Paper 14 offers a good example of the many different statistical and other measures used in the industry for model validation.

Challenges

The development, refinement, calibration and validation of an internal credit scoring or risk rating model are ongoing issues for banks. Among the challenges are:

• Obtaining a clean and consistent database as a basis for model development and validation.
• Coming up with creative and plausible solutions in the case of business segments with scarce default histories.
• Conceiving intelligent ways to deal with the problem of material biases/reject inference in scoring models.
• Creating forward-looking estimates with historical data that does not conform to expected economic performance.
• Integrating forward-looking indicators into the rating models.
• Finding the right balance between mechanically derived rating components and expert judgment, and defining clear rules for judgmental overrides.
• Objectifying soft factors and arbitrary settings in the rating systems as much as possible.
• Creating rating mechanisms that will remain stable over the course of time, yet be able to predict well in changing times.
• Devising feasible techniques for validating the accuracy of PD estimates.
• Coming up with more accurate models after analyzing models’ past performance.
• Considering alternative techniques, such as Bayesian inference, for parameter estimation.

LGD Modeling

In case of a default, the money invested in credit instruments is usually not completely lost. Depending on the type and seniority of the instrument, existing collateral, the liquidation value of the obligor’s assets, the prevailing bankruptcy laws and other factors, a smaller or larger part of the outstanding money can be recovered. The complement of the recovery rate is the loss given default (LGD), which describes the percentage loss of the outstanding money at the time of default. In its April 2006 guidelines, the Committee of European Banking Supervisors issued a noncomprehensive list of drivers that should be considered in the context of LGD estimation.\footnote{See CEBS 2006, § 273.}
One important observation is that, in an economic downturn, not only are higher-than-average PDs realized, but LGDs for many products also increase. In other words, there is often a positive correlation between the PD and the LGD of a certain credit instrument. However, a Basel II LGD working group came to the conclusion back in July 2005 that there was not yet a standard for making allowances for these dependencies: "The extent and manner by which potential dependencies between default rates and recovery rates are reflected in internal economic capital models varies considerably across institutions."12 In the Basel II provisions concerning the LGD estimation, it is therefore required that the LGD be calibrated to a downturn scenario.

One possibility for achieving a downturn bias involves estimating a static downturn LGD from losses observed in times of economic distress. In the context of portfolio modeling it is, however, not sufficient to work with a fixed number for the LGD, even if it is a higher-than-average value. An appropriate approach should consider the dependencies between PD and LGD in a stochastic framework.

An advanced LGD model will, therefore, be based on a stochastic modeling of factors that predict actual recovery rates and, in part, actual defaults. The factors should also reflect current and projected economic conditions.

Challenges

Determining the average historically realized LGDs is complicated.13 Nonetheless, it is still more difficult to come up with a stochastic LGD model as outlined above. Exacting tasks involve:

- Obtaining quantitative and qualitative improvements regarding the institution’s loss database.
- Collecting all relevant data to accurately calculate economic loss.
- Identifying the variables that have an impact on the LGD and serve as good predictors.
- Establishing an estimation methodology that includes relevant historical data, as well as pertinent market information.
- Formulating a clear procedure for achieving the downward adjustment.
- Setting up a stochastic model for the LGD – ideally one that goes beyond assuming a distribution with the same mean as the average observed LGDs.
- Considering correlations between PD and LGD in the portfolio model context.

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12 BCBS 2005 a, p. 1
13 See CEBS 2006, Chapter 3.3.3.2.
Exposure Calculation

For many credit products, the future exposure is a known quantity. Examples include bullet loans and loans with fixed installment schemes. Uncertainty concerning the height of a bank’s future credit exposure comes mainly in two guises:

- First, in the form of revolving credit facilities.
- Second, in the form of counterparty exposure in connection with derivatives contracts.

Unfunded revolving credit facilities can have an important share in the bank’s credit portfolio. Especially in times of difficult access to funding, a concurrent drawing of many customers under these facilities can put further strain on a bank’s liquidity situation. There are a number of reasons why a company would make use of its revolving credit lines. The most obvious is that a company falling into financial distress will be prone to drawing upon its lines. Thus, the uncertainty regarding the usage of committed revolving credit facilities has a liquidity risk as well as a credit risk aspect. A bank must gain a qualitative and quantitative understanding of the possible future fluctuations of its credit exposure related to revolving credit facilities.

A derivative contract may also lead to a credit exposure in a case where the market value of the contract assumes a positive value from the bank’s perspective, and no – or insufficient – offsetting risk mitigants, such as collateral or netting agreements, are in place. Implied counterparty credit risk became a particular focus as a result of the highly publicized Lehman bankruptcy in September 2008: Lehman was the derivatives counterparty for many banks, which were suddenly confronted with unexpected write-downs due to their Lehman exposure.

As was pointed out in a Basel II paper on economic capital practices in banks, counterparty credit risk poses a number of particularly difficult problems: “The measurement and management of counterparty credit risk creates unique challenges for banks. Measurement of counterparty credit risk represents a complex exercise, potentially millions of transactions (including an increasingly significant percentage that exhibit optionality) spanning variable time horizons ranging from overnight to 30 or more years; tracking collateral and netting arrangements; and categorizing exposures across thousands of counterparties.”

From a credit default risk point of view, the interesting quantity is the exposure at the time of the default, which is usually denoted by exposure at default (EAD). A convenient way to describe EAD in the case of committed lines is via the so-called credit conversion factor (CCF), which stands for the fraction of the currently undrawn amount of the commitment that is expected to be drawn at the time of default. In the Basel II context, CCFs are also used for the exposure calculation of a number of other off-balance-sheet items.
Challenges

In the area of exposure calculation, the following actions must take place:

- Establishment of a database with historical drawings of defaulted customers. Record the drawings at default and at different time horizons before default.
- Identification of important drivers for drawings of committed lines.
- Implementation of a stochastic model for drawings under revolving credit lines. The model should, among other things, reflect the higher probability of a drawing with deteriorating credit quality, and allow for different time-to-default horizons.
- Correct calculation of the credit exposures arising from derivatives, which requires a database with all the contractual details, including collateral provisions.
- Counterparty credit risk calls for joint modeling of market and credit risks.
- In an integrated risk calculation, the interdependencies between market, liquidity and credit risk also must be addressed for the exposure component.

Internal Credit Portfolio Models

Internal models for market risk have been used in the banking industry for a long time. In 1995, the Basel Committee decided that internal models could also be the basis for calculating minimum capital requirements for market risk. This document introduced important concepts, such as quantitative and qualitative standards, back-testing, stress testing and scenario analysis. Up until now, however, there have been no comparable approaches on the part of the supervisors in the area of credit risk.

Many banks use internal models to calculate their credit portfolio risk, but these models may not be used to determine regulatory capital for credit risk. Instead, the Basel II minimum capital requirements for credit risk are expressed in the form of rules and tables with some risk differentiation if an external rating (standardized approach) exists, or they are calculated according to prescribed formulas that are based on a simple credit portfolio model (IRB approach). Nevertheless, in the IRB approach, the bank’s own estimates determine important parameters in the supervisory formulas.

Approaches to Modeling Credit Portfolios

Currently, many banks have implemented a number of different credit portfolio models for calculating credit risk economic capital, credit risk stress testing and allocating credit risk for funds transfer pricing. The classical portfolio models are generally divided into:

- Structural multifactor models based on the Merton (1974) framework, such as Moody’s KMV and CreditMetrics of RiskMetrics Group (originally JPMorgan).
- The actuarial approach with CreditRisk+ of Credit Suisse.
- The reduced form macroeconomic approach by CreditPortfolioView of McKinsey and its generalization to multiple rating categories and pooling approximations for large portfolios.

15 BCBS 1995
16 Nyström and Skoglund, 2006
Although implemented credit portfolio models are generally quite complex, a basic setup with idealized assumptions allows the derivation of a loss distribution that captures the most important characteristics of real-life credit portfolio loss distributions. Since defaults in this model are described in the framework of an asset value default model, it falls into the class of asset value credit portfolio models.

**One-Factor Asset Value Model**

Default rates change very much with the state of the economy. In a simplifying approach, this observation can be translated into the modeling world by letting the defaults be driven by only one factor – which, consequently, can be thought of as describing the overall state of the economy. Assuming further that the credit portfolio includes many homogeneous credits with the same values for PD, LGD and exposure, a distribution for the percentage portfolio loss, whose shape depends on two parameters, obtains the asset correlation and the probability of default (see Appendix 1). The most striking feature of this loss distribution is that it becomes very skewed and fat-tailed with increasing asset correlation. Skewed, fat-tailed distributions are typical of credit portfolio loss distributions.

![Figure 2: Density of the loss distribution for a homogeneous portfolio.](image)

In Figure 2, the density of the loss distribution is shown for a PD of 2 percent, LGD of 100 percent and two values of the asset correlation, 16 percent and 8 percent. The vertical lines also indicate the 99.9 percent quantiles for the two cases. The density for $p = 16$ percent especially exhibits a striking skew with the 99.9 percent quantile being way out in the tail at a value of 18.62 percent.
Model Behind Basel II

The Basel II minimum capital requirements for credit risk in the IRB approach are based on a one-factor asset value model. By making specific choices on the asset correlation for different asset classes, the model can account, to a certain extent, for the variety of borrowers and transactions in real-life portfolios. It is interesting to note that the asset correlations used in Basel II for corporate exposures (including the firm-size adjustment for small and medium-sized companies) cover a range from 8 percent to 24 percent.

The nice property of the Basel II capital allocation mechanism derived from the model is that the capital required for a single transaction is determined only by the parameters of the transaction - i.e., notably by PD, LGD and EAD. The total regulatory capital for the credit portfolio is obtained by summing up the regulatory risk capital for all transactions.

Due to its simplicity and its standardization, the credit portfolio model underlying Basel II does not offer the basis for a fine-grained picture of portfolio risk based on the best assumptions a bank can make about the risk parameters. In particular, it does not account for regional and industry diversification, and single name or industry concentrations are not penalized.

Complex Credit Portfolio Models

According to Basel II, in addition to regulatory requirements and reporting, many banks use their own credit portfolio model for risk management, capital allocation and pricing. The risk capital deduced from the bank's own credit portfolio model is usually referred to as economic capital. After the allocation of economic portfolio capital to individual transactions, risk-adjusted pricing can be established. For most of the internal credit models, economic portfolio capital can no longer be determined in an analytic way. Instead, Monte Carlo simulations may be used.

In general, there are two ways to look at credit risk. The more traditional and simpler way is to consider only losses due to defaults for the valuation of instruments where a market value is not readily available - e.g., a loan would be valued at par as long as the customer is not in default. This view does not take into account a gradual deterioration in credit quality, which could manifest itself in a downgrade of an external or internal rating or in a widening of a credit spread, if available.

The second way is to determine a market value for each credit instrument. Since many credit markets are still rather illiquid, a model value is often taken as a proxy. To obtain the value distribution of the credit portfolio in the first case, it is sufficient to simulate defaults. In the second case, the whole spectrum of possible market values must be simulated.

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A common measure for the risk quantification of a portfolio is the portfolio’s value at risk (VaR). VaR is defined as the portfolio loss that is not exceeded with a high probability – the confidence level – over a given time horizon. In credit risk, the portfolio VaR is usually evaluated over a one-year time horizon, with confidence levels typically greater than 99 percent. The economic capital is read off from the loss distribution as the difference between the expected loss and the VaR of the portfolio.

For the purpose of enterprisewide risk management, banks must determine economic capital on a firmwide level over all business lines and risk types. This poses further problems regarding a consistent risk aggregation. In 1997, JP Morgan published the CreditMetrics model, which acted as a prototype and trendsetter for a number of in-house solutions for evaluating credit portfolio risk. It employs a multifactor model, calculates a market value distribution and proposes a computation scheme for the determination of the risk contributions of individual transactions. In the CreditMetrics model, changes in credit quality are expressed via rating migrations and defaults, which are both described in the framework of an asset value model.

In credit portfolio models using an asset value model for the generation of correlated changes in credit quality, a crucial point is the level of asset correlations between the customers. The shape of the loss distribution changes radically with increasing asset correlation; so does the portfolio risk (see Figure 2). One of the main differences among various models involves the modeling of the asset correlations – in particular, in the correlation level and the factor model. The appropriate level of the asset correlations is still a matter of dispute.

Credit portfolios are difficult to back-test. In contrast to market risk VaR calculations with time horizons from one to 10 days, the typical one-year horizon of a credit VaR implies that the back-testing history is very short.

Challenges

Credit portfolio modeling is still an open field with significant ongoing development. Challenges include:

- Implementing the portfolio model on clean data.
- Designing a good factor model that can take hold of the correlations in the portfolio, and using copula functions to investigate the added value of dependency structures other than the standard Gaussian.
- Including forward-looking and business-cycle-dependent indicators, while also considering market risk indicators and tackling problems connected to the determination of economic capital on a firmwide level.
- Taking contagion effects into account.
- Allowing for alternative risk measures, such as expected shortfall.
- Devising intelligent ways to back-test parameters and portfolio model outputs.

Incremental Risk Charge

The incremental risk to the Basel market risk requires banks to estimate, separately, the default and migration risk of their trading portfolios that are exposed to credit risk. The regulation requires that total regulatory charges for trading books be computed as the sum of the market risk capital and the incremental risk charge for credit risk. In contrast to Basel II models for the banking book, no model is prescribed, and banks can use internal models to calculate the incremental risk charge. The incremental risk charge for traded credit risk is, in effect, a market risk charge, but it is computed using the bank’s internal model for portfolio credit risk.

In the calculation of incremental risk charges, the choice of the liquidity horizon for traded credits is a key component. The incremental risk charge calculations required by regulators represent a substantial challenge for banks in adapting their current portfolio credit risk models for traded credits to incorporate assumptions about liquidity horizons. The assigned liquidity horizon for any particular credit represents the bank’s view on the time required to fully hedge or sell the credit without any significant negative liquidity effects on the price.

Moreover, the assigned liquidity horizon should, according to regulators, be valid even under stressed conditions. Using the experience of the financial crisis, this requirement has the practical implication that only investment-grade credits can, in effect, be considered to have relatively short liquidity horizons, whereas medium-grade credits should have fairly long liquidity horizons. And, finally, noninvestment- or speculative-grade credits should be considered as buy-and-hold securities. In the calculation of IRC, two important effects determine the IRC for a particular credit rating and liquidity horizon: first, the mitigation effect of preventing the bond from further downgrades by trading it frequently, and second, the multiple default effect obtained from frequent trading.

Risk-Adjusted Performance Measurement and Pricing

Another benefit of an internal portfolio model is that it can be used as the basis for risk-adjusted performance measurement (RAPM). A ratio used in this context is the risk-adjusted return on capital (RAROC), which relates risk-adjusted net revenues to economic capital. Originally developed by Bankers Trust in the late 1970s for use in a trading environment, the concept was subsequently extended and adopted by many banks in different variations. Other denominations – like return on risk-adjusted capital (RORAC) or risk-adjusted return on risk-adjusted capital (RARORAC) – are also used. A typical definition is:

\[ RAROC = \frac{\text{Revenues} - \text{EL} - \text{Costs}}{\text{Economic Capital}} \]

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19 Basel 2009
20 See Skoglund and Chen (2011) for a practical application of IRC with a multifactor portfolio credit risk model.
21 Guill, 2009
Revenues include margins, provisions and fees, EL stands for the expected loss, and costs are all attributable to direct operating costs. A RAROC measure can be determined for the whole portfolio, down to individual transactions. The calculations can be made ex ante with expected revenues and costs or ex post with the actual values. In a full-fledged implementation for the bank’s total portfolio, the economic capital would include all types of risks. Here, the focus is on credit risk in the credit portfolio.

For the calculation of a RAROC number for an individual transaction or a subportfolio, all income, cost and economic capital components must be determined at that level. Since the VaR and the economic capital are computed for the whole portfolio in the first instance, an important step is the allocation of total economic capital to individual transactions.

RAROC can be used to identify which business segments, business units and individual deals create value. To this end, RAROC must be compared with the hurdle rate, which is a strategic benchmark set by senior management. For instance, if the RAROC of a deal is equal to or greater than the hurdle rate, the deal should be done from a RAROC perspective. Thus, during the deal negotiation, the RAROC can be an incentive for obtaining higher margins or additional collateral, or for entering into a cross-selling dialogue.

Given the risk profile of a customer and further transaction-specific information, the hurdle rate is a determining factor for a transaction’s minimum margin. To calculate the minimum margin, it is important that you take into account the possibility of rating migrations, during which time the margin cannot be renegotiated. This will lead, in general, to higher margin requirements for medium- and long-term transactions. The calculation of a minimum margin is of particular importance for segments in which a market price is not readily available.

Another benchmark for pricing is a market-driven price, which may be based on CDS spreads and zero-coupon curves for a certain risk category or counterparty, if available. This type of benchmark is useful at the time of origination, as well as any time later for the purpose of a revaluation.

Challenges

Although the idea of RAPM to relate risk-adjusted revenue to economic capital is simple, the consistent implementation of a performance measurement and pricing practice throughout the whole organization may be difficult. Important steps in this demanding task include:

• Implementing a procedure for allocating economic capital to individual transactions that is consistent with the risk measure used to determine the portfolio risk.
• Determining a hurdle rate based on economic considerations, and devising a set of principles for using this benchmark in day-to-day business situations.
• Defining the interplay among available capital, bound regulatory capital and required economic capital.
• Deducing a fair price for credit risk, and implementing this price in pricing tools. One must solve possible conflicts arising from divergences between model prices and observed market prices, as well as establish an efficient pricing mechanism for the transfer of loans from originating business units to a credit portfolio management unit.

• Allowing for optionalities embedded in certain credit instruments.

**Stress Testing**

Considerable skepticism regarding the merits of sophisticated risk management models arose as a result of the immense write-downs in the banking sector and the financial distress suffered by many banks during the financial crisis. One of the lessons learned is that a risk model can only make loss predictions based on implemented risk factors and the existing parameter calibration, which often relies on historical data. These limitations can result in a severe underestimation of risk, especially in the case of new or complex products and new or rapidly changing market conditions.

As a consequence, risk models must be complemented by stress testing and model-independent risk analysis. The use of stress tests in particular has become much more important. In *Principles for Sound Stress Testing Practices and Supervision*, the Basel Committee states that stress testing practices before the crisis were insufficient in several respects. For example, prior to the crisis, stress tests:

• Were too mild, too inflexible and too limited in scope.

• Were uncoordinated and not aggregated across risk types and business lines.

• Were based too much on historically observed relationships.

• Failed to take into account specific risks connected with structured products and leveraged lending.

• Yielded results that afterward were not taken seriously or did not receive the necessary management awareness.

• Lacked senior management involvement.

Referring to the situation prior to the crisis, the Basel Committee said: “Stress testing frameworks were usually not flexible enough to respond quickly as the crisis evolved (e.g., inability to aggregate exposures quickly, apply new scenarios or modify models). Further investments in IT infrastructure may be necessary to enhance the availability and granularity of risk information that will enable timely analysis and assessment of the impact of new stress scenarios designed to address a rapidly changing environment.”

Based on their observations, the Basel Committee formulated 15 recommendations for improving stress testing programs, which we have summarized for you in the following section. 

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22 BCBS 2009 b, p.3
23 BCBS 2009 b, p. 8 - p. 16
**Basel Committee Recommendations for Improved Stress Testing**

According to the Basel Committee, stress testing should be applied to the firmwide portfolio in an integrated manner and should take the specific risk characteristics of the portfolio into consideration. Stress testing should include techniques such as:

- Sensitivity analysis of risk parameters.
- Scenario analyses based on historically observed relationships, as well as on conceived ones.
- The application of very severe but still plausible shocks.
- Reverse stress tests that identify events that could jeopardize the bank’s survival.

Stress tests can also deal with vulnerabilities that are not (yet) easily captured in common VaR models – e.g., reputational risk, basis risk in hedges or the unexpected drying up of liquidity in whole market segments. Innovative and creative stress tests go hand-in-hand with more judgmental deliberations and require a sound understanding of the perils lurking in products and portfolios.

Stress tests that focus specifically on credit risk include, among others, the stressing of default and recovery rates, a significant increase in correlations, collapsing collateral values, dramatic changes in interest rates and credit spreads, materializing concentration risks, widespread drawings in committed lines, and the unforeseen taking back of assets in off-balance-sheet vehicles onto the bank’s balance sheet. For those interested in reading more, see the following SAS white papers on stress testing: *Stress Testing: A Board-Level Issue* (sas.com/reg/wp/corp/30464) and *A Practical Approach to Firmwide Stress Testing* (sas.com/reg/wp/ca/25070).

**Challenges**

Reflecting on the shortcomings of pre-crisis stress testing, we can create a plan for improved stress testing that would include these key points:

- Extend stress tests to address the total risk of the firm and to embrace all business units and risk types. Ensure that the data management and analytic systems are in appropriate condition for this task.
- Devise more creative and forward-looking stress scenarios. Employ different stress testing techniques, including reverse stress testing. Enlarge the scope of existing stress tests, and also consider risks in new products, warehousing and basis risk in imperfect hedges.
- Anchor stress testing as a crucial element in the firm’s risk governance. Stress testing outcomes must be taken seriously and should have an impact on risk management practices – in particular, in current hedging and future investment and lending policies.
- Use stress tests as one element in the assessment of capital adequacy. Consider stress testing results in the context of determining to what extent an extra capital cushion above the regulatory minimum capital requirements, as well as above the calculated economic capital, is needed.
Credit Derivatives

Credit derivatives are a clever way to transfer credit risk. On the one hand, banks can take risks in markets where they are not commercially active. On the other hand, they can dispose of unwanted credit risks in their portfolios – for example, due to individual name or regional concentrations. The risk reduction can be achieved without harming customer relationships, since the customer’s access to bank funding is not affected. In this context, the use of credit derivatives can be regarded as a portfolio management hedging activity. Credit derivatives appear in many guises and can be classified into various categories. An important and widely used type is the credit default swap.

Credit Default Swaps

In a single-name credit default swap (CDS), the protection buyer obtains the right to fall back on the protection seller in case there is a credit event associated with the reference obligation of the reference entity – e.g., a third-party loan or bond. The documentation of credit default swaps, and credit derivatives in general, lays down precisely what kind of credit quality deterioration is considered a credit event and how such a credit event is identified. For instance, a credit event can be a failure to pay, bankruptcy or restructuring. The documentation also determines how the contract is settled: physical delivery of a so-called deliverable obligation in exchange for the face amount or cash settlement. The protection seller receives regular premium payments in return for the risk taken.

Thus, for a credit default swap, if no credit event occurs, only the protection premiums flow. If a credit event is triggered during the term of contract, the flow of protection premiums terminates, and the protection seller has to indemnify the protection buyer for the credit loss, according to the rules of the credit derivatives contract.

![Diagram of Single-name credit default swap with cash settlement.](image)

Although in principle, a counterparty’s credit risk can be hedged, there are a number of possible basis risks in credit derivatives contracts. For instance, the asset to be hedged could be a company’s loan, while the reference obligation is a bond from the same company. Another example would be a contract stipulating a fixed payment in case of a default event, where the eventually realized LGD after workout could be substantially different.
A generalization of the single-name credit default swap is the nth-to-default credit default swap. For example, a fourth-to-default credit default swap is typically defined in such a way that up to three entities in a predefined basket of reference entities can default without any compensation from the credit protection seller. Only the default of the fourth entity during the tenor of the swap can trigger the protection payment, after which the swap terminates. The value of an nth-to-default credit default swap is critically dependent on the default correlations of the entities in the basket.

Credit default swaps are also used in the context of securitizations. For instance, a synthetic collateralized debt obligation (synthetic CDO) usually makes use of CDS in order to achieve a risk transfer. Besides single-name credit default swaps, basket products and synthetic CDOs, there is a huge variety of credit derivative products – e.g., credit spread options, credit linked notes or credit derivatives indices.

Challenges

Important issues with credit derivatives that must be resolved include:

- Making use of state-of-the-art pricing algorithms and high-quality pricing data for the credit derivatives employed.
- Capturing the basis risks in credit derivative contracts, such as asset or maturity mismatches.
- Addressing the possibility of a failure of the protection due to a double default of reference entity and protection seller.
- Dealing with risks that aren’t easily captured by models, e.g., information asymmetry, documentation risk, changes in accounting or regulatory rules.
- Making sure that the organization understands the products, risks and models adequately, and that they correspond with the complexity of the credit derivative products used.

Securitizations and Asset-Backed Securities

There are many reasons for an institution to carry out a securitization – e.g., liquidity generation, balance sheet considerations, regulatory capital management, spread arbitrage, economic risk transfer or actions of credit portfolio management.

For instance, a bank with credit portfolio concentrations due to a strong regional presence or to a certain industry or customer focus may think securitization is an appropriate way to get rid of some of its concentration risk. Securitization can also be the basis for a self-contained business model: Assets are originated not with the intention to keep them on the bank’s balance sheet, but with the expectation of passing them directly through to other investors via securitization.
For an investor, securitizations offer the opportunity to invest in a certain portfolio segment with a specific risk profile determined by a combination of portfolio risk and structural provisions. In the past, investments in asset-backed securities (ABS) often promised a high return compared with the perceived risk; obviously, the risk perception was not always correct.

Asset-backed securities in the broader sense may be categorized into mortgage-backed securities (MBS), collateralized debt obligations (CDOs) and asset-backed securities referring to other asset classes, such as credit cards, auto loans or trade receivables (ABS in the restricted sense). Of particular importance for banks is the class of collateralized debt obligations.

Collateralized Debt Obligations

The collateral portfolio in a collateralized debt obligation typically comprises one or more of the following asset classes: loans, bonds, tranches of asset-backed securities including other CDOs, and credit default swaps.

In a securitization of loans sitting on a bank’s balance sheet, the risk of the underlying portfolio is, to a great extent, transferred to third-party investors. An important distinction is whether the risk transfer is achieved by a sale of the assets or by means of credit derivatives. The former case is called a cash CDO, the latter a synthetic CDO.

In a cash CDO, the bank gets rid of loans on its balance sheet by means of a true sale of the loans to a bankruptcy remote special purpose vehicle (SPV), which usually is created exclusively for the execution of the specific transaction. An important function of the SPV is to guarantee the complete separation of the assets from the bank in case of bankruptcy. The SPV refines the purchase by issuing notes with different risk characteristics to investors.

The different classes of notes are also referred to as tranches. In order to reduce the information asymmetry between the bank and an investor, an external rating agency usually assigns ratings to the senior and subordinated tranches. As for the equity tranche, the bank will often retain part of it.

Although there are more parties involved, and the actual legal construct may be quite sophisticated, the mechanics of a cash CDO can, for the most part, be described by means of the following simple picture:
Figure 4: Mechanics of a cash CDO.

Through the sale of the assets to the SPV and the issuance of notes, the risk of the asset pool is transferred to the investors. The cash flows from the assets are used to make the interest and amortization payments on the notes, and to pay administrative fees and fees to other parties involved. Defaults in the pool reduce the cash flow.

The transaction structure provides the details of the cash-flow waterfalls. In general, the effect of the structure is that interest and principal payments are made top-down from senior to junior tranches. Often, triggers based on different tests concerning a deterioration of the quality of the asset pool are implemented. They have the function of diverting cash flows in a way that senior tranches receive a higher protection with respect to promised interest payments and principal redemption. Additional credit enhancements may support the structure further.

As a result, losses in the asset pool work their way up in reverse order: from the equity tranche to the more senior tranches. In order to compensate investors in mezzanine and subordinated tranches for the increased risk, coupons on the respective notes are higher. The equity tranche receives the remaining cash flows, if any.

In a synthetic CDO, the risk in the asset pool is transferred by means of credit derivatives without selling the assets, and the picture has to be modified accordingly. For example, in a structure with an SPV, the proceeds of the issued notes are typically invested in very highly rated bonds. The SPV takes the interest payments of these bonds, together with the credit spread payments received from the protection buyer, in order to make payments under the notes.
Important Considerations for the Modeling of Securitizations

From a modeling point of view, securitizations are rather intricate. They require a consistent modeling of the underlying portfolio and the structure with all its details.

In a cash CDO, this involves the consideration of all waterfalls, triggers, options, credit enhancements and repayment provisions. The modeling has to be over the term of the deal, which often has a multiyear horizon. Furthermore, it is important to acknowledge that there are a number of risks in securitizations that do not lend themselves to being quantified, such as legal risks or risks coupled with the substitution of a servicer.

In contrast to the originating bank, which should have all necessary information about the assets in its portfolio, an investor in a tranche does not usually get all the details. Thus, in the investor’s risk assessment, plausible assumptions have to fill the gap, and scenario analysis becomes very important.

In a dynamically managed market-value CDO, the collateral portfolio will change during the course of a transaction, assets will be actively traded and sold or bought at market value, and the success of the transaction depends very much on the capability and experience of the asset manager.

The situation gets even more opaque when the underlying portfolio also includes structured products. For example, in a CDO-squared, the asset pool contains tranches of different CDOs. In a simple approach, the only information taken for the risk analysis could be the ratings of the CDOs with plausible assumptions on rating migrations, default probabilities, recovery values and the correlation level. A more appropriate approach would consider the composition of all the portfolios underlying the CDOs in the asset pool. The latter procedure could reveal important risk concentrations.

During the financial crisis, it became evident that many market participants did not even approximately capture the risks inherent in securitizations. This led the Basel Committee to release a revision of the Basel II securitization framework in the document *Enhancements to the Basel II framework* in July 2009 (BCBS 2009 a). In particular, the above-mentioned problems with repeated securitizations are addressed with resecuritization risk weights, which for the better ratings are roughly three times higher than the usual securitization risk weights in the IRB approach.
Challenges

Risk management practices in the area of securitization have to measure up to the complexity of the products. Among the challenges are:

- Achieving a broader and deeper understanding of the mechanics and risks in securitizations throughout the whole organization, and making sure that senior management has the knowledge to make a balanced risk assessment.
- Getting precise and detailed information on all relevant portfolio data and transaction parameters and making them available to all parties involved in a securitization. Based on this data, originators and investors can conduct their own risk analysis.
- Enhancing the quantitative models so that they describe the main risk drivers in a securitization transaction as faithfully as possible. The accuracy of parameter estimations, the sensitivity of model outputs and aspects that have been deliberately left out of the modeling should also be considered.
- Including the second-layer portfolios of ABS collateral in the modeling of resecuritizations. Hidden concentrations must become apparent.
- Complementing standard modeling techniques with stress tests and scenario analyses. These supplementary techniques should also cover situations that are not easily quantified, like management actions to avoid reputational damage or the unexpected drying up of relevant markets.

Counterparty Exposure

In the wake of the recent credit crisis, with counterparty risk being widely thought of as the center of the credit crisis, it is not surprising that regulators are demanding a significantly higher market discipline of counterparty exposure in risk management under the heading of Basel III.

While the July 2005 Basel regulation for CCR allowed banks to use more sophisticated and risk-sensitive approaches to exposure measurement, the credit crisis and the resulting losses experienced due to counterparty risk called for a significantly extended regulation. In the recent Basel III regulation, Basel 2011, one of the key focal points is the strengthening of the regulation for CCR due to the regulators’ observance of insufficient bank practices in validating and stress testing counterparty exposure models. Indeed, the failure of a few global financial institutions that brought down the notion of “too big to fail” suggests that the Basel II framework was either not sufficient in dealing with management of CCR or that banks were not capitalizing potential losses due to CCR.

The new regulation for counterparty losses that are not due to default requires banks to calculate a new CVA capital add-on based on a one-year horizon and a 99 percent VaR level of confidence. The exposure level in the CVA calculation is the total EAD of the counterparty, and the maturity is the longest dated netting set with the counterparty, yielding a representation of counterparty exposure as a zero coupon bond.

24 BCBS 2005 d
25 BCBS 2011
The spread of the zero coupon bond is the credit default swap (CDS) premium of the counterparty, and the CVA VaR is calculated using a model for the CDS premium (spread). The new CVA capital add-on is essentially a new market risk charge for counterparty exposure – where both general interest rate risks and spread risks (CDS premium) must be taken into account. The regulatory CVA VaR model is seen to be similar to the banks’ VaR model for bond issuer risk (spread risk). In particular, the market risk charge for specific spread risk of bond issuers is calculated using a model for market credit spreads for instruments, while the CVA VaR model explicitly makes use of CDS premiums of the counterparty as spreads.

Since, by no arbitrage, the CDS premium is equivalent to the market credit spread of the instrument, the two models are in principal the same. It is therefore not surprising that banks use their market-risk-specific spread risk bond VaR model to calculate CVA VaR. However, while the market risk model has a preset horizon of 10 days (usually the model is calculated on a one-day horizon with scaling to 10 days), banks can use a multiplier on the 10-day market risk charge for idiosyncratic spread risk to scale to one year. The CVA capital charge allows hedges such as CDS to be recognized. The portion of the counterparty exposure covered by the CDS may benefit from the CDS counterparty CDS premiums. For contingent CDS, the covered notional should be treated as fixed and equal to its current value.

Exposures with specific wrong-way risk were not treated separately before, but in the new Basel III regulation, the capital charge for exposures with specific wrong-way risk have a separate regulatory treatment, including a new Pillar 1 capital charge. This new Pillar 1 capital charge stipulates:

1) That the value of an equity derivative with a counterparty, under the assumption of default of an underlying equity that is legally tied to the counterparty, should be the EAD of the counterparty.
2) That the notional of a CDS with a legal connection between the counterparty and the underlying equity should be the EAD of the counterparty.

Deals that are identified by the bank as belonging to the specific wrong-way risk category are hence not using exposure times the alpha factor as the measure of exposure. For deals with general wrong-way risk, there will be no specific capital charge, and the capital charge will be calculated as the exposure times the alpha factor, as in the July 2005 Basel regulation. However, the new Basel III regulation introduces a change in the requirement for how exposure models are calibrated. In particular, exposure models should be calculated on a stressed period of data, which is supposed to capture general wrong-way risk. The stressed exposure is calibrated on a three-year period that includes one year of stress, with the year of stress being consistent with the stressed market VaR period for the new Basel III requirements on stressed VaR for market risk.
In addition to the new capital charges for CVA and specific wrong-way risk, the Basel III framework for counterparty credit risk (CCR) exposure measurement includes a more conservative regulatory specification for collateral haircuts, increased margin periods of risk for collateral agreements, as well as an increase in the correlation between financial firms in the risk-weighted asset (RWA) calculation.

All these new regulations – together with the Basel III requirement for calibration of CCR exposure models on a period of stress – are expected to increase banks’ current Basel II capital for CCR with bilateral netting. The Basel committee has stated clearly that it wants to motivate a move to central counterparty (CCP) clearing or multilateral netting by using a zero risk weight should the CCP be eligible. This creates strong motivations for banks to establish CCPs going forward. Interested readers may wish to check out the SAS white paper *Counterparty Exposure Management in the Basel III Era* by Jimmy Skoglund and Sumit Mathur.

**SAS® Solutions for Credit Risk Management**

The foregoing discussion shows that the open questions and challenges in credit risk management relate to a multitude of quantitative, statistical and business intelligence techniques. They are called for in various contexts, ranging from: the standalone modeling of specific aspects of credit risk; to the performance of statistical analysis, data management and reporting tasks; to the implementation of an integrated, firmwide approach to risk management.

Implementing a system for credit risk management should not only enable a bank to meet regulatory and departmental requirements, but also provide the analytical and reporting capability for enterprise risk management and advanced performance management. It is increasingly important to integrate credit risk environments into the wider risk management infrastructure and meet the mission-critical requirements around risk management.

SAS offers solutions and technologies that tackle these problems on different levels. In the following section, we will highlight several important SAS products and technologies. You can find a more complete discussion on these topics on the SAS website at [sas.com/software](http://sas.com/software) or via a SAS sales representative.
SAS® Enterprise Miner™

SAS Enterprise Miner is a powerful data mining solution capable of performing data analysis, knowledge discovery and model building tasks on vast amounts of business data via an intuitive, flexible and easy-to-use interface. Due to its graphical capabilities, the whole process – from raw data to the final model – is highly transparent. Different preconfigured building blocks guarantee swift model creation and modification.

SAS Enterprise Miner provides various tools for each step in the data analysis and model building process, which is structured in five different phases:

1) Sampling.
2) Exploration.
3) Modification for data preparation.
4) Transformation.
5) Modeling and assessment for model creation and evaluation.

Algorithms include, among others: linear and logistic regression, decision trees, neural networks and partial least squares. In addition, SAS Enterprise Miner allows the direct, side-by-side comparison of models constructed with different techniques, thus allowing easy benchmarking. Models offering an optimal tradeoff between complexity and predictive power can be easily identified.

SAS Enterprise Miner is an extremely valuable solution for a wide array of business analyses. In the context of credit risk management, applications in the design, modification and validation of internal rating systems are most obvious. As a complementary product, Credit Scoring for SAS Enterprise Miner is also available specifically for the development of credit scorecards. In addition to building various models using SAS Enterprise Miner, Credit Scoring for SAS Enterprise Miner provides additional capabilities for building scorecards through various processes, such as interactive grouping using weight of evidence, scorecard scaling and production of related reports, and reject inference.

SAS® Credit Scoring for Banking

As any credit manager in the banking industry knows, managing risk is a delicate business. Too much credit exposure can lead to high default rates and charge-offs; not enough often means lost business and revenue. Assigning scores to new credit applications, as well as existing accounts, helps in designing better risk-adjusted strategies for managing this balancing act, but there are serious limitations to many current credit scoring strategies.

Outsourced strategies often lead to long development cycles or high annual expenditures. Makeshift, in-house scoring strategies often lack the ability to access the data needed to either enhance market segmentation or proliferate scorecard development, and credit managers have no effective way to identify how much potential income or loss rides on their decisions.
In addition, once credit scores are obtained from a third-party or legacy system, a lack of streamlined reporting can prevent managers from disseminating this vital information to employees in a timely way, keeping staff from making timely decisions on their own. Using disparate data management, analytic and reporting tools incurs high integration costs and adds to infrastructure implementation risks. “Best of breed” tools that don’t integrate with each other leave banks with expensive, inefficient solutions.

SAS Credit Scoring for Banking enables lenders to rapidly develop, validate, deploy and monitor credit scorecards in a low-risk, integrated environment faster, cheaper and more flexibly than any outsourcing alternative. The solution enables application and behavioral scoring for virtually all consumer lending products – including cards, installment loans and mortgages – to assess and manage risk within existing consumer portfolios, and to improve acquisition strategies. By accessing, collecting and manipulating enterprise data, and applying predictive analytics, you’ll get a better understanding of the specific risk characteristics and subsequent attributes that lead to delinquency, default and, ultimately, bad debt.

**SAS® Credit Risk Management for Banking**

For regulatory credit risk requirements, SAS Credit Risk Management for Banking provides a complete, end-to-end application that integrates data aggregation, analytics and reporting in a transparent framework to provide a single, comprehensive credit risk management environment. The solution offers an open, flexible and extensible means of measuring and managing an ever-changing business environment.

SAS Credit Risk Management for Banking enables financial institutions to quickly and accurately calculate critical risk measures – e.g., credit migration, risk-weighted assets and regulatory capital – from an authoritative and comprehensive data environment for risk. After the analyses are complete, customizable templates enable reports to be published to the Web, stored as PDFs or integrated within desktop applications. Flexible reporting capabilities enable managers to quickly identify problems and meet regulatory requirements related to credit risk.

**SAS® Risk Management for Banking**

While the solutions highlighted enable you to tackle specific tasks and problems in credit risk management, SAS Risk Management for Banking aims at a complete, integrated and firmwide solution for risk management. It covers the whole process – from data management, to business analytics, to risk modeling, to reporting. Based on core SAS functionality, the solution includes state-of-the-art risk analytics with a wide range of methods and models, simulation engines and pricing algorithms. It encompasses different risk types (e.g., market risk, credit risk and liquidity risk), it allows for interdependencies among risk types, and it consolidates interrelated risks on a firmwide level.
Based on the valuation and exposure calculation of the constituent instruments, the solution can calculate portfolio risk with respect to different risk measures, such as value at risk, expected shortfall, earnings at risk or liquidity at risk. The solution calculates economic capital for the bank’s entire portfolio and allocates it to individual transactions, from which risk-adjusted performance can be derived. A portfolio optimization algorithm lays the foundation for the identification of strategies in order to attain portfolios with better risk-return characteristics. The solution also provides for stress testing routines.

Figure 5: SAS Risk Management for Banking overview of capabilities.

In SAS Risk Management for Banking, credit risk management appears as one module in the context of an interconnected enterprise risk management system. Isolated solutions for risk types or business lines are no longer necessary.

SAS Risk Management for Banking has a number of outstanding features:

- Unified approach to risk management using a consistent architecture.
- High degree of integration.
- Scope and excellence of implemented methods, models and algorithms.
- Superior data management and reporting capabilities.
- Flexibility and adaptability.
- Computational efficiency and speed.

It is not difficult to predict that banks that can come up with a consistent database, build their risk systems on an integrated and efficient architecture, and employ cutting-edge risk management techniques will have strong competitive advantages. Abandoning outdated systems, patchwork solutions and standalone workarounds by making a major move toward a modern, integrated risk management system can free up resources and generate a fast return on investment many times over.

The SAS solutions we have presented, with SAS Risk Management for Banking leading the way, provide a superb basis for transforming current challenges in risk management into future business opportunities.
Conclusion

In the wake of the financial crisis, banks established a variety of credit risk methodologies and metrics across many areas. However, the continuing evolution of effective credit risk management still represents a significant challenge for banks as they seek to enhance their current approaches to measuring and managing credit risk.

While these challenges initially may put a significant burden on banks as they upgrade existing credit risk systems and processes, there is a significant payoff – a transparent, auditable and efficient credit risk management process that enables fast, decisive action in response to market changes, as well as an improved ability to steer the risk profile of a bank’s credit risk exposures.

“The SAS gives us the power to analyze a variety of concentration risks from many different perspectives, enabling us to take decisions to bring the portfolio into balance.”

Boaz Galinson
Head of Credit Risk Modeling and Measurement Group, Bank Leumi
Appendix

In this appendix, we will present some useful formulas relating to the loss distribution of a homogeneous portfolio.\(^{26}\)

Loss Distribution of a Homogeneous Portfolio

In a one-factor asset value model, the loss distribution for a homogeneous portfolio can be derived in the limit of infinitely many obligors. The relevant random variable is the percentage portfolio loss \(L\%\), i.e., the portfolio loss \(L\) divided by the product of total portfolio exposure, denoted by \(\text{EXP}\), and the LGD, which is assumed to be the same for all credits:

\[
L\% = \frac{L}{\text{EXP} \times \text{LGD}}.
\]

The loss distribution \(F(x)\) is given by:

\[
F(x) = P[L\% \leq x] = N \left[ \sqrt{1 - \rho} \frac{N^{-1}[x] - N^{-1}[p]}{\sqrt{\rho}} \right].
\]

Here, \(N[x]\) denotes the cumulative distribution function of the standard normal distribution and \(N^{-1}[x]\) its inverse. The two parameters of the loss distribution are the probability of default \(p\) and the asset correlation \(\rho\).

The density \(f(x)\) of the loss distribution is obtained by differentiation:

\[
f(x) = \frac{1 - \rho}{\sqrt{\rho}} \exp \left[ \frac{(N^{-1}[x])^2}{2} \right] \exp \left[ -\frac{(\sqrt{1 - \rho} N^{-1}[x] - N^{-1}[p])^2}{2\rho} \right].
\]

Here, \(\exp[x]\) stands for the exponential function. In Figure 2 of the main text, the density is shown for \(p = 2\%\) and two different values for the correlation, \(\rho = 8\%\) and \(\rho = 16\%\).

The \(\alpha\)-quantile \(Q^\alpha\) is given by:

\[
Q^\alpha = N \left[ \frac{N^{-1}[p] + \sqrt{\rho} N^{-1}[\alpha]}{\sqrt{1 - \rho}} \right].
\]

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\(^{26}\) The derivation of the formulas, as well as technical details, can be found in Bluhm et al., 2003.
Further Reading

The following resources are a noncomprehensive selection of publications, in addition to the cited references, that might be useful for further reading. Moreover, a large number of interesting papers on credit risk modeling and measurement are available at defaultrisk.com.

General


Credit Risk Modeling


Credit Portfolio Models


Credit Scoring


Credit Derivatives and Securitization


Linear and Logistic Regression with SAS®

Linear regression and logistic regression belong to the most popular statistical techniques for modeling relationships between variables.
The following books (among others) focus on the use of SAS software to perform various types of regression and statistical data analysis tasks:


In addition, a multitude of publications relating to SAS software products are listed under support.sas.com/publishing. In particular, for the three above-mentioned books, tables of contents and sample chapters are provided.

References


Best Practices in Credit Risk Management


About SAS

SAS is the leader in business analytics software and services, and the largest independent vendor in the business intelligence market. Through innovative solutions, SAS helps customers at more than 55,000 sites improve performance and deliver value by making better decisions faster. Since 1976, SAS has been giving customers around the world THE POWER TO KNOW®. For more information on SAS® Business Analytics software and services, visit sas.com.