Credit Risk Management
Challenges and opportunities in turbulent times
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Credit Risk Management in Times of Financial Crisis

No sooner had the banking sector adopted the Basel II regulations and begun to feel at ease with its credit risk management systems than the US subprime crisis popped up during the summer of 2007 and subsequently spilled over to become the most severe financial crisis since the Great Depression. In times of market turmoil, several weaknesses of risk management systems that had been developed in relatively benign market environments became apparent. In the area of credit risk, the shortcomings were most evident in relation to the assessment of structured and complex products, like mortgage backed securities (MBSs) and collateralized debt obligations (CDOs). Not all banks, however, performed equally poorly. A March 2008 survey of the Senior Supervisors Group 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.” (SSG 2008, p. 4)

As a consequence, the challenge today consists in refining and enlarging the traditional credit risk management repertoire on the one hand and in being more creative in the modeling and management of innovative credit products on the other hand. Furthermore, a successful risk management system will allow for the interdependencies between credit risk, liquidity risk and market risk and will contrast various quantitative analyses with qualitative considerations. Only an integrated approach has the chance of giving a reliable picture of the upside and downside of the overall bank portfolio. With this in mind, the focus in the following is on the credit risk management part of an integrated enterprise risk management system.

Internal Rating Systems

Banks have been using internal ratings to assess customers’ creditworthiness for a long time. Different banks developed different rating schemes, with rating results that were neither comparable nor consistent. 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 Basel II framework, for the first time in the area of credit risk, banks are allowed to use their own estimates of certain risk parameters to determine the required regulatory capital for an exposure. In the Internal Ratings-Based (IRB) approach, a bank may base the regulatory capital calculations on its internal rating systems, provided the internal rating systems fulfill a number of minimum requirements. The use of internal credit portfolios models for the determination of the necessary regulatory capital, though, 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.” (BCBS 2006, § 394)

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 the probability of default (PD) of a borrower and – in the advanced IRB approach – also for the loss given default (LGD) and the exposure at default (EAD) of a transaction.

### Regulatory Minimum Requirements

The aim of the minimum requirements is to make sure that an internal rating system is implemented in a consistent way and that it is sufficiently accurate in order to evaluate the credit risk in a transaction. These requirements with all their details laid out in the Basel II document (see BCBS 2006, Part 2, III.H) set the bar very high for the data management and reporting systems on the one hand and for the model development, monitoring and validation capabilities on the other hand.

Just to give an example, the 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.” (BCBS 2006, § 440) Similarly, among the responsibilities of the credit risk control unit(s) are: “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.” (BCBS 2006, § 441)

Furthermore, the minimum requirements provide a set of rules concerning the structure and the documentation of rating systems, the rating processes, the use test and senior management involvement.

### Disclosure Requirements

In addition to the minimum conditions disclosure requirements of pillar 3 have to be met. They, too, are substantial and detailed, especially for IRB banks, and call for an integrated and comprehensive database system with sufficient analyzing and reporting power on top.

### Effects of Basel II

The Basel II requirements have led to a standardization of certain aspects of internal rating systems. Notably, internal rating systems:

- Tend to be more objective and retraceable, less expert- and more model-based, and offer a greater number of distinct grades.
• Have to 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.

Nowadays, the development, implementation and maintenance of an internal ratings system is as much an art as it is a science.

**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 divided into credit scorings and credit ratings. In addition, ratings from market-driven rating models as well as external ratings are widely employed.

**Credit Scoring**

Credit scoring is extensively used in the retail customer segment. Typically, this segment comprises a large number of customers with similar characteristics or product requirements. The construction of a scorecard relies heavily on statistical analysis and employs techniques from data mining. Several statistical methods may be used with logistic regression being among the most popular ones. Often, a credit scoring model is developed for a certain customer segment or a certain product, e.g., a credit card. Depending on whether or not there is prior knowledge about the customer or his use of a product, one distinguishes:

• Application scoring for new customers or customers requesting a certain product for the first time.

• Behavioral scoring for customers who already have a credit history with the institution.

The score as the result of a scoring can be used in various contexts in credit risk management, e.g., in defining a cut-off point in a credit approval situation, in determining the credit limit at the outset or in suggesting a later change of the limit. The credit score is linked to a probability of default, which can then be taken for portfolio modeling, pricing and capital allocation purposes.

Generally, the scoring process itself is fully automated and as such inexpensive. Scorecards are for the most part easy to understand, resulting in a good interpretability of the scoring outputs.
Credit Risk Management

Credit 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 is usually not available. In return, one often disposes of more information on an individual customer or a particular transaction, and expert judgment is used to complement the picture. Sometimes, additional information from external providers can be obtained.

An additional challenge is low default portfolios. This is a major issue with most banks when trying to comply with Advanced and Foundation IRB. Approaches for overcoming low default portfolios include changing default definition, using roll rates, expanding performance/sample windows, Pluto-Tasche, proxies, etc.

A typical example would be an internal rating model for large corporate customers consisting of different elements with certain weights such as balance sheet and cash flow ratios, peer and industry analysis, and the evaluation of the management capabilities and of the company’s strategic orientation. Such a rating system has a lot of adjusting levers, the significance of some of the employed criteria is not always evident, the weights applied to the individual criteria may be arbitrary or expert-based, and the historical default database at hand often does not provide sufficient ground for a statistical analysis with clear-cut results.

All elements of such an internal rating that are not deducted automatically from reliable hard-fact numbers imply the judgment of a credit expert. In addition, there is often the possibility of overrides if certain criteria are satisfied. As a rule, a rating is reviewed when material new information comes in, at least once a year.

As a result, a rating system gives a grade on the bank’s internal rating scale. The internal rating scale is calibrated to probabilities of default.

Market-Driven Rating Models

In order to track changes in credit quality more closely, models have been developed that build upon the market perception of the credit risk of a certain company or a specific transaction. 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, for many segments like small enterprises or private customers, this kind of market information does not exist. Nevertheless, relationships deduced for large, international companies may to some extent also be valid for smaller firms with no presence in the capital markets. For instance, they might give a good indication of the market’s current risk appetite and contain valuable information about industry correlations.
A class of models using share price data is based on an idea that traces back to the seminal papers of Fischer Black and Myron Scholes (Black & Scholes, 1973) and Robert C. Merton (Merton 1974). In the Black-Scholes-Merton model, the option pricing mechanism is used in order to derive a market value for the assets of a company from observed values of equity prices and equity volatility. Combined with balance sheet information on the liabilities of the firm, a probability of default can be calculated. 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.

\[ \text{Asset value today} \rightarrow \text{in one year} \]

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

Figure 1 shows one possible path of an asset value starting at 100 today. The depicted path doesn’t lead to a default, since the asset value stays above the threshold. The default probability is given by the shaded area under the curve of the density of the asset value distribution. An obvious generalization of the Black-Scholes-Merton model is to also 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. Updates of the default probabilities are possible with the frequency of available share price data. Practical implementations of asset value models range from early-warning indicators of a deterioration in credit quality to utilization as a benchmark or input parameter for an internal rating system and building blocks of portfolio models.
Validation of Internal Rating Systems

Considering the importance of the outputs of internal rating systems for regulatory capital adequacy assessment as well as for internal risk, capital and pricing calculations, it is essential to scrutinize the performance of the employed rating models. Validation of internal ratings systems has two different aspects: the verification of the design and discriminatory power of the rating model, and the examination of the parameter calibrations.

For the first aspect, it is important to check that the rating model takes account of all material factors 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 (see Thomas et al. 2002).

For the second aspect, the PDs assigned to the rating grades have to 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 sparsity of defaults in many business segments and the fact that defaults generally do not occur independently, the problem of validating the PD calibrations appears quite complex. In a Basel II working paper, the Validation Group of the Basel II Research Task Force states: “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.” (BCBS 2005 c, p. 3) It concludes that “[…] statistical tests alone will be insufficient to adequately validate an internal rating system” (BCBS 2005 c, p. 3) and proposes benchmarking with external sources as a complementary technique.

Challenges

The development, refinement, calibration and validation of an internal credit scoring or credit rating model is an ongoing issue at banks. Among the challenges are to:

• Obtain a clean and consistent database as a basis for model development and validation.

• Come up with creative and plausible solutions in the case of business segments with a scarce default history.

• Conceive intelligent ways to deal with the problem of reject inference in scoring models.

• Integrate forward-looking indicators into the rating models.
• Find the right balance between mechanically derived rating components and expert judgment and define clear rules for judgmental overrides.

• Objectify soft factors and arbitrary settings in the rating systems as much as possible.

• Devise feasible techniques for the validation of the accuracy of PD estimates.

• Come up with more accurate models after an analysis of the models’ performance in the past. Consider also alternative techniques like 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 is 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 non-comprehensive list of drivers that should be considered in the context of a LGD estimation (see CEBS 2006 § 273).

An important observation is that in times of an economic downturn, not only are higher-than-average PDs realized, but also the LGDs increase for many products. 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 in July 2005 that there is not yet a common standard of how to make allowance 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.” (BCBS 2005 a, p. 1) In the Basel II provisions concerning the LGD estimation, it is therefore required that the LGD be gauged to a downturn scenario.

One possibility for achieving a downturn bias could consist in 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 are predictive of actual recovery rates and are in part also predictive of actual defaults. The factors should also be able to reflect current and projected economic conditions.
Challenges

Determining the average historically realized LGDs has a number of intricacies (see CEBS 2006, Chapter 3.3.3.2). Nonetheless, it is still more demanding to come up with a stochastic LGD model as sketched above. Exacting tasks are to:

- Obtain quantitative and qualitative improvements regarding the institution’s loss database.
- Identify the variables that have an impact on the LGD and serve as good predictors.
- Establish an estimation methodology that includes relevant historical data as well as pertinent market information.
- Formulate a clear procedure of how the downward adjustment is achieved.
- Set up a stochastic model for the LGD. Try to be better than just assuming a distribution with the same mean as the average observed LGDs.
- Consider correlations between PD and LGD in the portfolio model context.

Exposure Calculation

For many credit products, the future exposure is a known quantity. Examples are bullet loans and loans with a fixed installment scheme. Uncertainty concerning the height of the future credit exposure of a bank comes mainly in two guises: first, in the form of revolving credit facilities, and 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 the liquidity situation of a bank. 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 draw upon its lines. Thus, the uncertainty as to 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 in which the market value of the contract assumes a positive value from the perspective of the bank, and no or insufficient offsetting risk mitigants like collateral or netting agreements are in place. The implied counterparty credit risk has attained a particular focus through the Lehman bankruptcy in September 2008: Lehman was the derivatives counterparty for many banks, which all of a sudden saw themselves confronted with unexpected write-downs due to their Lehman exposure.
As pointed out in a recent Basel II paper on current 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, as it involves gathering data from multiple systems; measuring exposures from potentially millions of transactions (including an increasingly significant percentage that exhibit optionality) spanning variable time horizons ranging from overnight to thirty or more years; tracking collateral and netting arrangements; and categorizing exposures across thousands of counterparties.” (BCBS 2009 c, p. 4)

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 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 aspects have to be resolved:

- Establish a database with historical drawings of defaulted customers. Record the drawings at default and at different time horizons before default.
- Identify important drivers for drawings of committed lines.
- Implement a stochastic model for drawings under revolving credit lines. Such a model should, among others, reflect the higher probability of a drawing with deteriorating credit quality and allow for different time-to-default horizons.
- The correct calculation for the credit exposures arising from derivatives requires a database with all the contractual details, including the collateral provisions. Counterparty credit risk calls for a joint modeling of market and credit risks.
- In an integrated risk calculation, the interdependencies between market, liquidity and credit risk also have to be addressed for the exposure component.
Internal Credit Portfolio Models

Internal models for market risk have been in use for a long time in the banking industry. In 1995, the Basel Committee decided that they may also be the basis for the calculation of the regulatory minimum capital requirements for market risk (BCBS 1995). This document put forward important concepts such as quantitative and qualitative standards to be fulfilled, back-testing, stress testing and scenario analysis. In the area of credit risk, however, there is no comparable approach on the part of the supervisors up to now.

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

Approaches to Modeling Credit Portfolios

In the 1990s, many banks developed and implemented a number of different portfolio models. Among the most prominent are the Portfolio Manager of Moody’s KMV, CreditMetrics of RiskMetrics Group (originally JPMorgan), CreditRisk+ of Credit Suisse and CreditPortfolioView of McKinsey.

Although implemented credit portfolio models are in general quite complex, a basic setup with idealized assumptions allows the derivation of a loss distribution that captures the most important characteristics of real-life loss distributions of credit portfolios. 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 consists of (infinitely) 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). 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 loss distributions for credit portfolios.
Figure 2: Density of the loss distribution for a homogeneous portfolio.

In Figure 2, the density of the loss distribution is shown for a probability of default of 2 percent, a loss given default of 100 percent and two values of the asset correlation, 16 percent and 8 percent. Also indicated by the vertical lines are the 99.9 percent quantiles for the two cases. Especially the density for \( p = 16\% \) 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 (see BCBS 2005 b, BCBS 2006) the model is able to 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

In addition to regulatory requirements and reporting according to Basel II, 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, a risk-adjusted pricing can be established. For most of the internal credit models, the economic portfolio capital can no longer be determined in an analytic way. Instead, Monte Carlo simulations are used.

In general, there are two ways to look at credit risk. The traditional and simpler one 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 approach 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 has to be simulated.

A common measure for the risk quantification of a portfolio is the portfolio’s value-at-risk (VaR). It 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 enterprise-wide 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. With respect to approaches currently applied by many banks, the March 2009 Basel II economic capital paper states: “Practices and techniques in risk aggregation are generally less sophisticated than the methodologies that are used in measuring individual risk components. They rely heavily on ad-hoc solutions and judgment without always being theoretically consistent with the measurement of the components.” (BCBS 2009 c, p. 2).

In 1997, JP Morgan published the CreditMetrics model (Gupton, et al. 1997), 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 again Figure 2). One of the main differences between various models lies in 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 where significant development is ongoing. Among the challenges are:

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

**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 (Guill 2009), 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 would be:

\[
RAROC = \frac{\text{Revenues} - \text{EL} - \text{Costs}}{\text{Economic Capital}}.
\]
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 sub-portfolio, all income, cost and economic capital components have to 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 consists in the allocation of the total economic capital to individual transactions.

RAROC can be used to identify in which business segments, business units and individual deals value is created. To this end, it has to 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, otherwise not – at least not on a standalone basis. Thus, during the deal negotiation, the RAROC can be an incentive for obtaining higher margins, additional collateral, or 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 the minimum margin for a transaction. For the calculation of the minimum margin, it is important to take into account the possibility of rating migrations during the time, in which 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. Such a 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 in the whole organization may be intricate. Important steps in this demanding task are:

- Implementing an allocation procedure of the 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 of how to use this benchmark in day-to-day business situations.
• Defining the interplay between available capital, bound regulatory capital and required economic capital.

• Deducing a fair price for credit risk and implementing this price in pricing tools. Solve possible conflicts arising from divergences between model prices and observed market prices. 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

In view of the immense write-downs in the banking sector and the financial distress suffered by many banks during the current financial crises, considerable skepticism regarding the merits of sophisticated risk management models has arisen. One of the lessons learned is that a risk model can only make loss predictions based on the risk factors that are implemented and based on 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 have to be complemented by stress testing and model-independent risk analysis. In particular the use of stress tests will become much more important in the future. In a current document (BCBS 2009 b), the Basel Committee states that the stress testing practices before the crisis were insufficient in several respects. For example, stress tests tended to:

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

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

• Be based too much on historically observed relationships.

• Fail to take account of specific risks connected with structured products and leveraged lending.

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

• Lack senior management involvement.

Referring to the situation prior to the crisis, the Basel Committee asserts: “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.” (BCBS 2009 b, p.3) Based on their observations, the Basel Committee formulates 15 recommendations for improving stress testing programs.
Stress testing should be applied to the firmwide portfolio in an integrated manner and take into consideration the specific risk characteristics of the portfolio. It includes techniques like 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, and reverse stress tests that identify events jeopardizing the survival of the bank. 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 of 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.

Challenges

Reflecting on the shortcomings of the pre-crisis stress testing, we can create a plan for improved stress testing. Among the key points are to:

- Extend stress tests to address the total firm risk and embrace all business units and risk types. Condition the data management and analytic systems to be apt for this task.
- Devise more creative and forward-looking stress scenarios. Make use of different stress testing techniques, including reverse stress testing. Enlarge the scope of existing stress tests and consider also risks in new products, warehousing, and basis risk in imperfect hedges.
- Anchor stress testing as a crucial element in the firm’s risk governance. The outcomes of stress testing must be taken seriously and should have an impact in risk management practices, in particular in the current hedging and the future investment and lending policy.
- Use stress tests as one element in the assessment of capital adequacy. Consider stress testing results in the context of determining the extent to which 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 loan or a bond of a third party. In the documentation of credit default swaps, and credit derivatives in general, it is laid down precisely what kind of deterioration in credit quality 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. In return for the risk taken the protection seller receives regular premium payments.

Thus, for a credit default swap, there are only the protection premiums flowing, if no credit event occurs. 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.

Figure 3: Single-name credit default swap with cash settlement.
Although in principle the credit risk of a counterparty 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 loan of a company, while the reference obligation is a bond of 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 $n$-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 $n$-to-default credit default swap depends crucially 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, a huge variety of credit derivatives products are common, e.g., credit spread options, credit linked notes or credit derivatives indices.

**Challenges**

Important issues to be resolved with credit derivatives are:

- 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 understanding in the organization of the products, risks and models is adequate and corresponds with the complexity of the used credit derivatives products.
Securitizations and Asset-Backed Securities

The reasons for an institution to carry out a securitization can be manifold – 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 concentrations in its credit portfolio due to a strong regional presence or because of a certain industry or customer focus may think securitization is an appropriate means of getting 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 to pass 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 in comparison 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 like 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 is typically made up of 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 large part 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 a bankruptcy of the bank. The SPV refinances 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:

![Diagram of a cash CDO](image)

**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.

Some important considerations concerning 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 multi-year horizon. Furthermore, it is important to acknowledge that there are a number of risks in securitizations that do not lend themselves to be 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 includes also 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 current financial crises, it has become 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 newly introduced 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 to:

- Achieve a broader and deeper understanding of the mechanics and the risks in securitizations throughout the whole organization. Make sure that the senior management has the knowledge in order to make a balanced risk assessment.

- Get precise and detailed information on all relevant portfolio data and transaction parameters, and make them available to all parties involved in a securitization. Based on these data, originators and investors can conduct their own risk analysis.

- Enhance the quantitative models so that they are able to 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 in the modeling should also be considered.

- Include the second-layer portfolios of ABS collateral in the modeling of resecuritizations. Hidden concentrations must become apparent.

- Complement standard modeling techniques by stress tests and scenario analysis. These supplementary techniques should also cover situations that are not easily quantified, like actions of the management to avoid reputational damage or the unexpected drying up of relevant markets.

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 systems for credit risk management should not only allow a bank to meet regulatory and siloed 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 technology on different levels in order to tackle these problems. In the following, a number of important SAS products and technologies are highlighted. A more complete description can be obtained on the SAS home page (under http://www.sas.com/software/) or via SAS sales contacts.
The fundamental statistics software includes a comprehensive state-of-the-art set of statistical tools, covering a huge variety of statistical and data analysis methods. The product bundle SAS Analytics Pro, for instance, provides an attractive combination of three of the most popular SAS software products meeting the data analysis, graphical visualization and reporting needs arising in many business contexts: Base SAS, SAS/STAT® and SAS/GRAPH®. They can be complemented by SAS/ETS® software with particular focus on time series modeling, forecasting techniques and econometric analysis. SAS/OR® offers another extension, with emphasis on optimization and operations research techniques. A particularly convenient access to much of the analytic power of SAS software is provided by SAS® Enterprise Guide®. It is a Microsoft Windows client application offering a comfortable graphical user interface with process flow diagrams, interactive dialog boxes, a variety of wizards and a wide range of data access, reporting, graphical and analytical capabilities.

**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 the 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 of the steps in the data analysis and model building process, which is structured in five different phases: Sampling, Exploration and Modification for data preparation and transformation and Modeling and Assessment for model creation and evaluation. Algorithms include, among others: linear and logistic regression, decision trees, neural networks, and partial least squares. An additional strength of the product is that it allows the direct, side-by-side comparison of models constructed with different techniques. 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. The complementary product Credit Scoring for SAS Enterprise Miner is also available specifically for credit scoring.

**SAS® Credit Scoring for Banking**

As any credit manager in the banking industry knows, controlling 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 to manage 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, analytics and reporting tools incurs high integration costs, and adds to infrastructure implementation risks. “Best of breed” tools that don’t integrate with each other leaves banks with expensive, inefficient solutions.

SAS Credit Scoring for Banking enables lenders to rapidly develop, validate, deploy and monitor credit scorecards faster, cheaper and more flexibly in a low risk integrated environment than any outsourcing alternative.

SAS Credit Scoring for Banking provides for application and behavioral scoring for virtually all consumer lending products—including cards, installment loans and mortgages—to assess and control risk within existing consumer portfolios and to improve acquisition strategies. Through enterprise data access, collection and manipulation, and predictive analysis 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 providing a single, comprehensive risk management environment for credit risk management – 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 products highlighted above are very useful instruments for the solution of specific tasks and problems in credit risk management, SAS Risk Management for Banking aims at a complete, integrated and firmwide solution for risk management in the banking sector. It covers the whole process from data management, via business analytics and risk modeling to reporting.

Based on core SAS functionality, the solution includes, among other features, state-of-the-art risk analytics with a wide range of methods and models, simulation engines and pricing algorithms. It encompasses different risk types, such as market risk, credit risk and liquidity risk, allows for interdependencies between risk types, and consolidates the interrelated risks on a firmwide level.

Based on the valuation and exposure calculation of the constituent instruments, portfolio risk can be calculated with respect to different risk measures, such as value-at-risk, expected shortfall, earnings-at-risk or liquidity-at-risk. Economic capital is determined for the bank’s entire portfolio and allocated to individual transactions, from where 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 business architecture.

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 and consistency of architecture.
- Degree of integration.
- Scope and excellence of implemented methods, models and algorithms.
- Data management and reporting capabilities.
- Flexibility and adaptability.
- Computational efficiency and speed.

It is not difficult to predict that banks that are able to come up with a consistent database, build their risk systems upon 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 pay off the necessary investment many times.

The suite of the presented SAS products, with SAS Risk Management for Banking leading the way, provides a superb basis for transforming the current challenges in risk management into future business opportunities.
Appendix

In the following, some useful formulas relating to the loss distribution of a homogeneous portfolio are presented. The derivation of the formulas as well as technical details can, for example, be found in Bluhm et al., 2003.

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:

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

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:

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

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:

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

URLs accessed July 2009


[BCBS 2009 c] Basel Committee on Banking Supervision: Range of practices and issues in economic capital frameworks, March 2009


[CEBS 2006] Guidelines on the implementation, validation and assessment of Advanced Measurement (AMA) and Internal Ratings Based (IRB) Approaches, April 2006


Further Reading

The following resources are a non-comprehensive 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 www.defaultrisk.com.

General


Credit Risk Modeling


Credit Portfolio Models


Credit Scoring


Siddiqi, Naeem: Credit Risk Scorecards: Developing and Implementing Intelligent Credit Scoring; Wiley and SAS Business Series, 2005

Mays, Elizabeth: Credit Scoring For Risk Managers: The Handbook For Lenders; South-Western Educational Pub., 2003
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 focus (among other books) on the use of SAS software in order 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 [http://support.sas.com/publishing/](http://support.sas.com/publishing/). In particular, for the three above-mentioned books, tables of contents and sample chapters are provided.