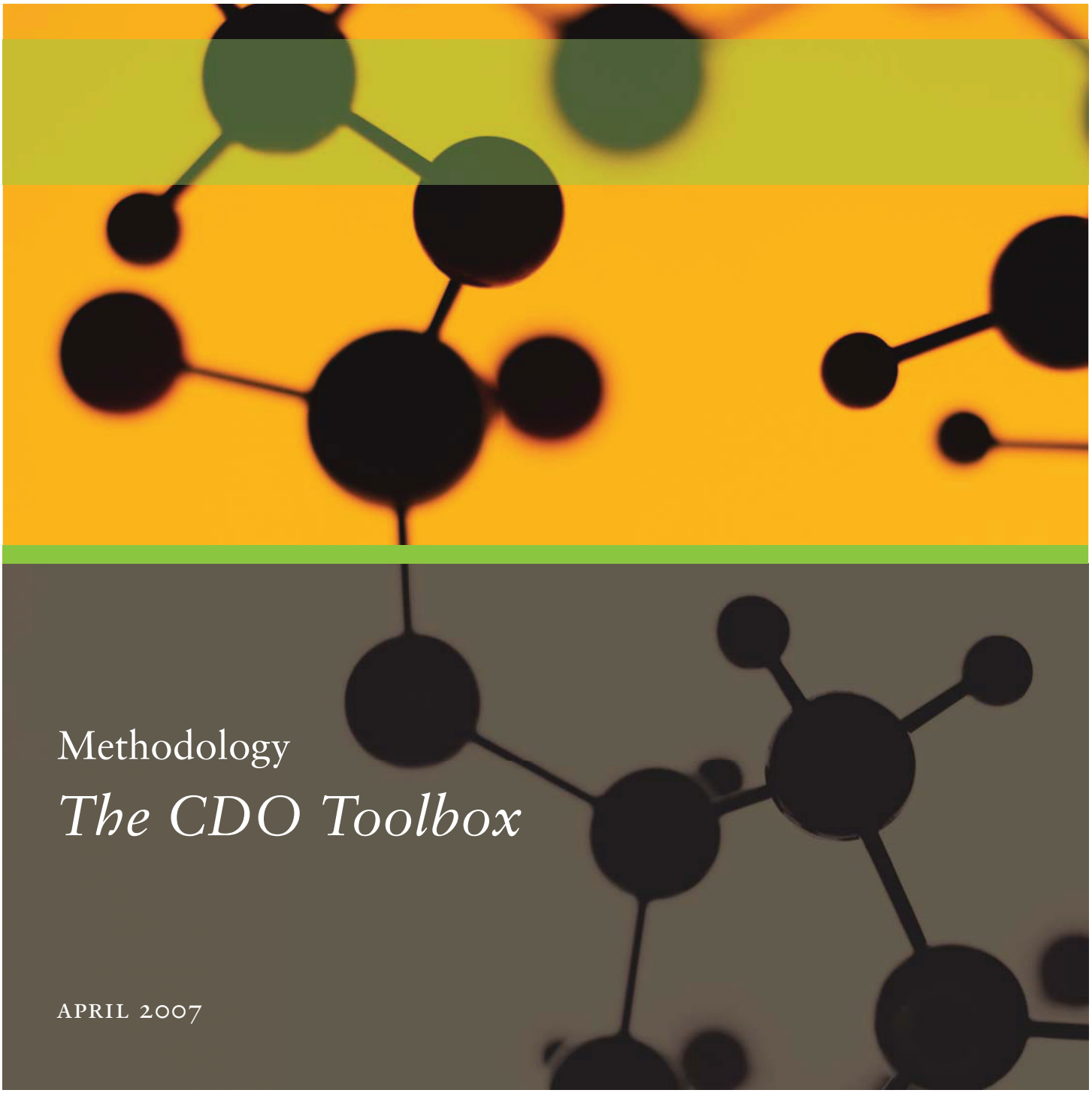

Methodology

The CDO Toolbox

APRIL 2007

DBRS

Insight beyond the rating.

CONTACT INFORMATION

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The CDO Toolbox

TABLE OF CONTENTS

DBRS has recently undertaken a review of the global criteria used to determine credit enhancement levels for collateralized debt obligations (CDOs)[1] in order to ensure that quantitative modelling assumptions are both globally consistent and grounded on empirical data analysis. In this article, we address the methodology and assumptions within the CDO Toolbox, DBRS's credit portfolio model for global CDO transactions, and discuss the default probabilities, correlations and recoveries that are used to create a distribution of portfolio losses for CDO transactions.[2] We will also look at the impact of these assumptions on hypothetical CDO portfolios and discuss future work to be undertaken by DBRS in this area.

CDO Methodology

IT'S ALL MONTE CARLO

The main objective of CDO analysis is to determine a level of portfolio loss that can be equated with a certain credit rating; that is, a loss that we expect, in the long run, to be exceeded with a probability that is less than or equal to the probability of default (PD) of an equivalently rated benchmark bond.[3] Over the past five to seven years, rating agencies have moved from relatively simple models (e.g., Moody's Binomial Expansion model) to more complex Monte Carlo models, which make use of the market standard Gaussian copula method.[4] This is partly a response to the rapid increase in the diversity and complexity of risks and structures in the CDO market, which were a daunting challenge for simpler models.

As inputs to the Monte Carlo models, each agency has its own set of rating-based default probabilities and asset-specific recoveries, along with correlation assumptions that vary according to whether assets are in the same industry sector, asset class or geographic region. This convergence of agency methodologies has meant that differentiating factors tend to be the degree to which the various assumptions in each model can be defended based on historical data and the ability of each agency's model to cope with new or complex risks or transaction structures.

STRUCTURED CREDIT – MORE AND MORE COMPLEXITY

In an environment of low credit spreads, many innovations have been introduced into the structured credit market that have led to an increase in the structural complexity of these products. In addition, the convergence of different asset classes has increased, as the synthetic CDO market continues to reference new assets and "borrow" technology from other areas. To some extent, agency models have struggled to keep pace with this innovation, as multiple interdependent risks often need to be captured within relatively simple modelling frameworks.

For example, many risks not directly related to credit risk have recently been introduced into structured credit products, such as equities, commodities, foreign exchange (FX) and credit spreads. The last of these was first seen in the leveraged super-senior (LSS) product, followed by constant proportion portfolio insurance (CPPI) and constant proportion debt obligations (CPDOs). The challenge this presents to rating agencies is twofold:

(1) Historical credit default swap (CDS) data is severely limited (at the time of writing, the main CDS indices cover less than four years), leading to

[1] These criteria are also used in other simulation-based portfolio approaches to portfolios of rated securities, such as those used to assess program-wide credit enhancement in asset-backed commercial paper conduits.
[2] For cash flow CDOs, DBRS is developing additional criteria that take into account the revolving nature of these transactions and the treatment of excess spread within the transactions' priority of payments.
[3] The long run normally means a period comparable with a full economic cycle; benchmark bond normally refers to a corporate bond.
[4] The Gaussian copula essentially links individual asset default probabilities to create a joint default distribution via a (multivariate) normal distribution with a specified pairwise asset correlation matrix.

modelled spreads that may not exhibit a wide-enough range of potential outcomes.

(2) Market conditions (e.g., an abundance of liquidity) that have existed in the recent past may change in the future. As rating agencies are not directly involved in the market, they lack some of the information and skills necessary to analyse potential market developments.

At DBRS, there is a strong commitment to research that promotes a deeper understanding of the different risks inherent in these innovative products (see *CPDOs Laid Bare: Structure, Risk and Ratings Sensitivity,* a DBRS methodology report available at www.dbrs.com). The models that result from this research will benefit from increased data, more realistic dynamics of market variables and an improved understanding of the dynamics of the market itself.

CDO Modelling Assumptions

CORPORATE DEFAULT PROBABILITIES

Estimating long-run historical default probabilities is now relatively straightforward, given the large amount of data and research on this subject. Table 1, below, is a blended default table based on research undertaken by the DBRS quantitative group, on academic research and on published historical ratings performance (the full table can be found in Appendix 1). The table represents the expected long-term default behaviour of a diversified pool of corporate ratings, regardless of the rating agency.[5] It can also be used to model the default behaviour of sovereign bonds, CDO tranches and certain structured finance (SF) transactions.

CORPORATE CORRELATION

There are now several methods in the market for estimating the historical correlation of the asset values of large corporates.[6] Some of these make use of indirect proxies for asset correlation, such as the co-movement of equity prices or ratings transitions. Others attempt to link observed default correlation to the level of asset correlation required within the Gaussian copula framework. DBRS prefers the latter approach, as this ensures a stronger link between the data and the effects that are being modeled; namely, joint default events. The DBRS corporate correlation assumptions are shown in Table 2 below.

Table 2: Corporate Correlation Assumptions

	Within Sector	Between Sectors
Same region	0.15	0.06
Different regions	0.11	0.02

As can be seen from Table 2, two corporates in the same sector and geographical region will be assumed to have the highest asset correlation (0.15), whereas two corporates in different sectors and regions will be assumed to have the lowest asset correlation (0.02). DBRS uses the regional classifications shown in Table 3 on the following page.

Table 1: Corporate Cumulative Default Probabilities

Maturity (Years)	AAA	AA	A	BBB	BB	B	CCC
1	0.017%	0.047%	0.073%	0.304%	2.206%	5.299%	46.789%
2	0.043%	0.113%	0.172%	0.695%	4.386%	10.554%	60.798%
3	0.078%	0.190%	0.294%	1.145%	6.438%	15.186%	66.091%
4	0.123%	0.277%	0.439%	1.635%	8.341%	19.155%	68.785%
5	0.177%	0.373%	0.607%	2.154%	10.096%	22.540%	70.541%
6	0.241%	0.480%	0.796%	2.693%	11.712%	25.435%	71.861%
7	0.315%	0.597%	1.008%	3.246%	13.198%	27.925%	72.924%
8	0.399%	0.727%	1.240%	3.807%	14.567%	30.080%	73.809%
9	0.493%	0.868%	1.492%	4.374%	15.828%	31.959%	74.561%
10	0.597%	1.022%	1.762%	4.943%	16.994%	33.608%	75.209%

[5] In practice, this means that differences in rating opinion among agencies are assumed to be small and unsystematic and, therefore, largely cancel each other out in pools that are sufficiently diversified (e.g., more than 50 assets).
[6] This correlation is very different from the "base" correlation used by market participants, which reflects the current market price of tranched corporate credit risk

Table 3: DBRS Regional Classifications

Code	Region
1	Africa
2	Asia
3	Australia & New Zealand
4	North America
5	Other Europe
6	South America
7	Western Europe

CORPORATE RECOVERIES

Recoveries are probably the hardest assumption to pin down because historical data often have wide standard deviations and depend strongly on the level of security and post-default workout time. However, a reasonable assumption for senior unsecured bonds is an average recovery in the range 30% to 40%. Recoveries are generally observed to vary significantly with seniority, with a less pronounced dependence on other factors, such as the insolvency regimes of different countries and business-cycle effects. Given the lack of extensive recovery data, DBRS recovery assumptions are based purely on seniority, with adjustments that may be made if portfolios contain significant concentrations of assets with higher or lower expected recoveries.

Table 4: Corporate Recovery Assumptions

Asset Type	Recovery
Senior secured loans	50%–70%
Senior secured bonds	40%
Senior unsecured	33%
Subordinated	20%

STRUCTURED FINANCE DEFAULT PROBABILITIES

Estimating default probabilities for SF securities is difficult because performance data for different asset classes is limited, both in terms of the period covered and the initial ratings (e.g., the data are dominated by AAA securities). Most defaults have occurred in certain sectors of asset-backed securities (ABS), such as manufactured housing, and CDOs, such as high-yield collateralized bond obligations (CBOs). Classes of residential mortgage-backed securities (RMBS) and commercial mortgage-backed securities (CMBS) have generally experienced lower levels of default, mainly as a result of the strong performance of the underlying assets.

This begs the question of whether a global set of default assumptions should be determined for all SF assets or a separate set should be estimated for each asset class. DBRS's view is that the historical data is not yet at a level that supports the reliable estimation of default tables for each asset class. With the exception of highly rated CMBS and RMBS transactions, it is difficult to argue that average SF default performance has been significantly better than corporate default performance. In view of this, we feel that the best approach is to use the corporate default assumptions as a conservative proxy for the long-term default rates of SF securities. However, in order to reflect the more stable transition behaviour of RMBS and CMBS classes, we have introduced adjustments to the corporate transition matrix that better reflect the expected ratings stability. This adjusted default table is shown in Table 5 below, with the full table shown in Appendix 2.[7]

Table 5: Adjusted Cumulative Default Probabilities

Maturity (years)	AAA	AA	A	BBB	BB	B	CCC
1	0.007%	0.025%	0.051%	0.294%	2.296%	5.295%	46.211%
2	0.017%	0.055%	0.112%	0.603%	4.442%	10.591%	60.393%
3	0.028%	0.089%	0.181%	0.919%	6.402%	15.291%	65.925%
4	0.042%	0.126%	0.258%	1.237%	8.177%	19.319%	68.781%
5	0.058%	0.165%	0.343%	1.554%	9.777%	22.736%	70.631%
6	0.075%	0.206%	0.433%	1.869%	11.214%	25.628%	71.998%
7	0.095%	0.250%	0.529%	2.179%	12.503%	28.083%	73.080%
8	0.117%	0.295%	0.631%	2.485%	13.658%	30.173%	73.965%
9	0.140%	0.343%	0.738%	2.786%	14.693%	31.961%	74.703%
10	0.166%	0.392%	0.849%	3.081%	15.620%	33.498%	75.326%

[7] Note that default probabilities do not increase for maturities greater than ten years because we believe that the marginal default risk of SF securities is negligible beyond this point.

For investment-grade ratings, Figure 1 below compares the adjusted default table above with the corporate table for seven-year maturities.

For the reasons mentioned above, the adjusted default table in Table 5 is not used for all SF asset classes. Table 6 below shows how the PD is assigned depending on the asset class of each obligor within the portfolio.

Table 6: Default Tables Used for Different SF Asset Classes

SF Asset Class	Default Table
Mortgage-backed security (MBS) – prime	Adjusted
MBS – sub-prime	Adjusted*
MBS – other	Corporate*
Consumer ABS	Adjusted*
Commercial ABS	Corporate*
CDO/Collateralised loan obligation (CLO)	Corporate
CMBS	Adjusted
REIT	Corporate

* These assignments may be adjusted on a case-by-case basis, depending on vintage, collateral quality, etc.

STRUCTURED FINANCE CORRELATIONS

Given the relative paucity of historical default data, correlation between different SF securities is very difficult to quantify. Intuitively, the greater degree of systematic (macroeconomic) risk in SF asset pools would suggest that the average correlation of SF securities should be higher than corporate bonds. DBRS has decided to adopt the SF correlation assumptions shown in Table 7.[8]

Table 7: Structured Finance Correlation Assumptions

	Within Sector	Between Sectors
Same region	0.30	0.18
Different regions	0.12	0.03

DBRS also assumes a small positive correlation between SF and corporate obligors, which is 2% within a region and 1% between regions.

STRUCTURED FINANCE RECOVERIES

Recoveries for SF securities are very difficult to estimate. There are several reasons for this:

(1) Defaults of SF securities are relatively rare, especially for highly rated securities.

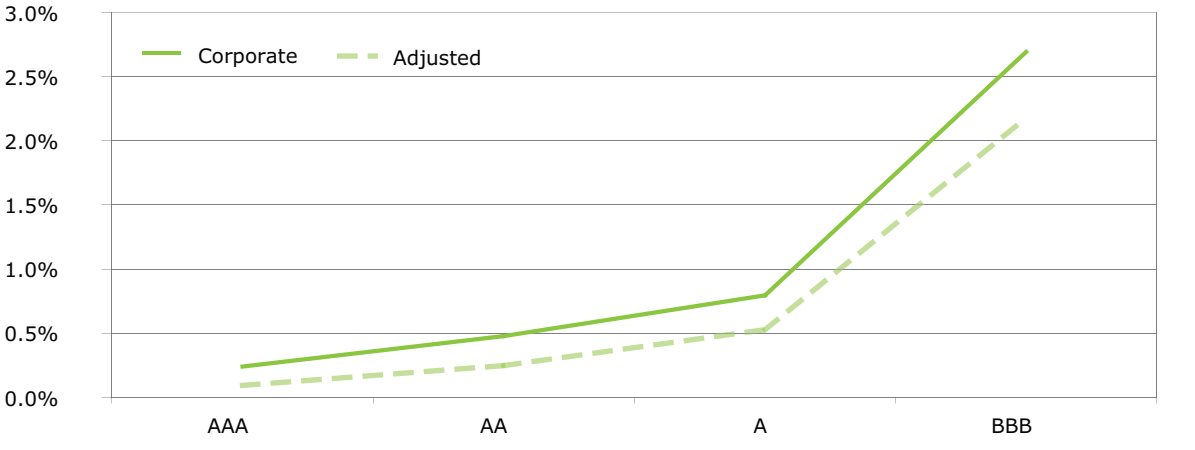
(2) In cases of default, ultimate principal recovery has not been reached in the majority of cases.

(3) Recoveries strongly depend on the level of seniority and thickness of each SF security.

Given the lack of sufficient historical data to estimate SF recoveries in a "bond-equivalent" fashion[9] and the analytical/modelling experience that rating agencies possess through rating these securities, the effectiveness of a bottom-up approach can be investigated. Put another way, the likely distribution of recoveries that a given tranche would experience can be estimated *directly* from the distribution of the underlying pool defaults and losses in different scenarios.

In the case of U.K. RMBS, we have performed some preliminary research on typical prime and sub-prime RMBS transactions using the recently

Figure 1: Seven-Year Corporate and SF Default Probabilities



[8] DBRS may adjust these assumptions, depending on the characteristics of a given CDO portfolio.
[9] In other words, ignoring the cash flows of the underlying assets and the capital structure of the transaction.

developed U.K. Residential Mortgage Credit Model.[10] The findings suggest that recoveries can vary significantly across the capital structure, with mezzanine tranche recoveries strongly dependent on subordination and thickness. Initial tests show that this is even more pronounced in more heterogeneous CMBS pools, with collateral quality and concentration of underlying loans playing a significant role.

For this reason, DBRS will not be including a fixed table of SF recoveries within the CDO Toolbox. The recovery assumptions used in the CDO analytical process will depend on the diversity and composition of each CDO portfolio.

CDO TRANCHES

In addition to using assumptions appropriate to the asset portfolio, a benchmark CDO default probability needs to be determined, based on the desired rating and target maturity of the CDO tranche. For all ratings and maturities, the corporate table (Appendix 1) will be used as the CDO benchmark.

Now that we have all of the modelling assumptions we need, we can use them within our Monte Carlo algorithm to determine the loss distribution for a variety of CDO portfolios. For a synthetic CDO, the simulation essentially involves three stages:

Putting It All Together

(1) Over a sufficiently large number of simulations,[11] generate a default time for each asset in the portfolio (see Appendix 3) and apply a recovery assumption to determine the associated loss.

(2) Aggregate the above losses to determine the probability distribution of cumulative portfolio loss at a given maturity.

(3) Determine the level of portfolio loss (also known as the minimum attachment point) for which the probability of exceeding this level is less than or equal to the required CDO benchmark probability.

Tables 8 and 9 below show the variation in the AAA and BBB minimum attachment points (AP) for different hypothetical corporate portfolios, with A, BBB and BB average ratings. For corporate portfolios, an average recovery rate of 33% was assumed.

We repeated the exercise for 100-name SF portfolios, and Tables 10 and 11 on the following page show the results using 0% recovery rate.

Table 8: Five-Year Maturity Corporate Pool

		Diversified Pool*		Poorly Diversified Pool**
A	AAA AP	3.5%	AAA AP	4.0%
	BBB AP	2.4%	BBB AP	2.5%
BBB	AAA AP	6.9%	AAA AP	8.3%
	BBB AP	4.8%	BBB AP	5.4%
BB	AAA AP	18.4%	AAA AP	21.9%
	BBB AP	14.2%	BBB AP	16.1%

Table 9: Ten-Year Maturity Corporate Pool

		Diversified Pool*		Poorly Diversified Pool**
A	AAA AP	5.2%	AAA AP	6.0%
	BBB AP	3.5%	BBB AP	3.9%
BBB	AAA AP	10.0%	AAA AP	11.8%
	BBB AP	7.3%	BBB AP	8.1%
BB	AAA AP	23.5%	AAA AP	27.1%
	BBB AP	19.0%	BBB AP	20.9%

* There are 39 industries across three regions in well-diversified pools, with an average correlation of 1.7%.
** There are 21 industries in one region in poorly diversified pools, with an average correlation of 5.38%.

[8] DBRS may adjust these assumptions, depending on the characteristics of a given CDO portfolio.
[9] In other words, ignoring the cash flows of the underlying assets and the capital structure of the transaction.

Table 10: Seven-Year Maturity SF Pool

		Three Asset Classes		One Asset Class
A	AAA AP	9%	AAA AP	12%
	BBB AP	4%	BBB AP	4%
BBB	AAA AP	22%	AAA AP	28%
	BBB AP	11%	BBB AP	13%
BB	AAA AP	58%	AAA AP	68%
	BBB AP	39%	BBB AP	45%

Table 11: Ten-Year Maturity SF Pool

		Three Asset Classes		One Asset Class
A	AAA AP	10%	AAA AP	13%
	BBB AP	5%	BBB AP	5%
BBB	AAA AP	23%	AAA AP	30%
	BBB AP	12%	BBB AP	14%
BB	AAA AP	59%	AAA AP	69%
	BBB AP	41%	BBB AP	46%

Summary

The DBRS CDO Toolbox is a quantitative model that creates a distribution of portfolio losses for CDO transactions by analysing default probabilities, correlations and recoveries. Market participants will find that the criteria used for determining credit enhancement levels for CDO transactions are both globally consistent and grounded on empirical data analysis.

The model is available free of charge and allows complete control over all modelling assumptions, letting users conduct their own sensitivity and stress tests.

In addition to our standard CDO portfolio model, DBRS is currently developing a number of tools that allow the analysis of other important risks within structured credit transactions, such as recovery risk, ratings volatility and market risk. It is expected that these tools will be integrated with the CDO Toolbox to provide the market with a deeper insight into the risks inherent in the latest innovations in the structured credit market.

DBRS welcomes comments from market participants on the approach and assumptions outlined in this article. Please send your feedback to cdotoolbox@dbrs.com or fax +44 (0)20 7562 5634.

Application of Methodology

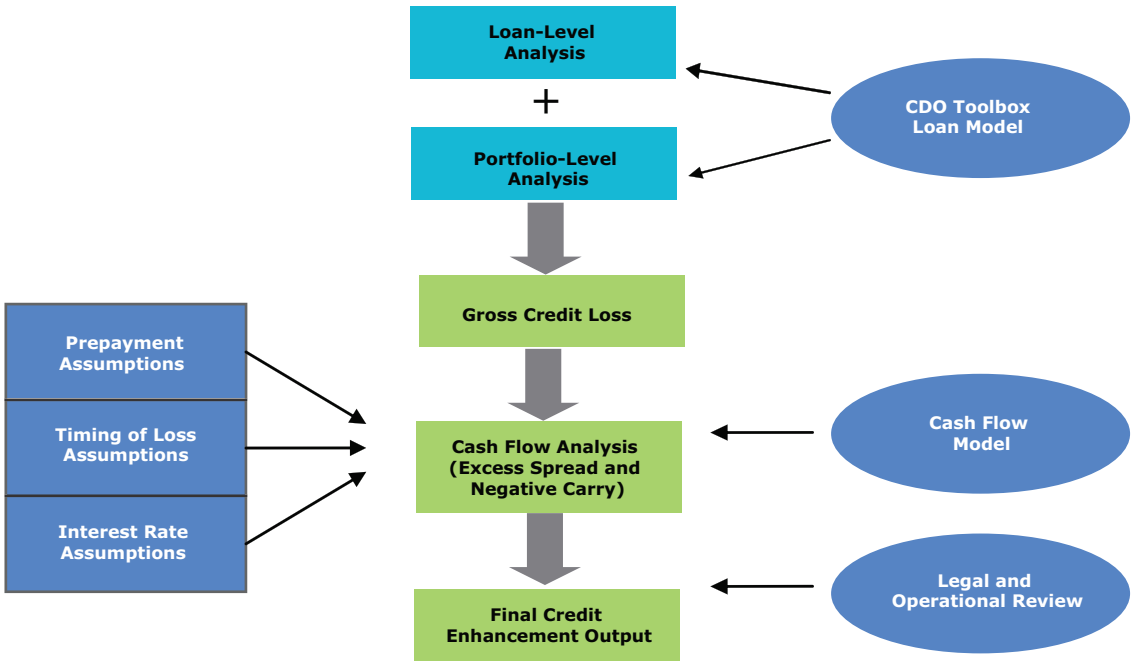
The following diagram describes the overall process used by DBRS to analyze a CDO transaction.

(1) DBRS conducts loan-level and portfolio-level analysis using the CDO Toolbox model. The resulting output of the model is the expected gross credit loss.

(2) DBRS performs a cash flow analysis based on the output from the CDO Toolbox model by incorporating assumptions regarding prepayment, timing of loss and interest rates in order to estimate the excess spread available over the life of the transaction and the required credit support for each rating level.

(3) The legal and operational aspects of the transaction are also reviewed with the understanding that the credit enhancement is subject to adjustment if necessary.

DBRS Rating Process for CDO Transactions



Appendix 1: Corporate Transition Matrix and Default Table

Corporate One-Year Transition Matrix

	AAA	AA (high)	AA	AA (low)	A (high)	A	A (low)	BBB (high)	BBB	BBB (low)	BB (high)	BB	BB (low)	B (high)	B	B (low)	CCC (high)	CCC	CCC (low)	D
AAA	81.625%	9.820%	5.724%	1.110%	0.583%	0.279%	0.413%	0.095%	0.187%	0.017%	0.059%	0.057%	0.005%	0.003%	0.002%	0.001%	0.000%	0.001%	0.000%	0.017%
AA (high)	0.106%	81.008%	12.026%	4.336%	0.970%	0.773%	0.232%	0.130%	0.186%	0.090%	0.080%	0.011%	0.006%	0.003%	0.003%	0.002%	0.000%	0.002%	0.000%	0.038%
AA	1.162%	1.128%	80.415%	10.375%	3.372%	2.120%	0.542%	0.429%	0.244%	0.026%	0.011%	0.035%	0.031%	0.007%	0.008%	0.025%	0.002%	0.021%	0.001%	0.047%
AA (low)	0.086%	0.198%	1.155%	79.822%	11.086%	5.542%	1.070%	0.361%	0.214%	0.123%	0.075%	0.049%	0.013%	0.043%	0.094%	0.006%	0.004%	0.002%	0.001%	0.055%
A (high)	0.048%	0.199%	1.138%	4.912%	79.229%	9.199%	3.342%	0.882%	0.490%	0.138%	0.048%	0.102%	0.056%	0.057%	0.083%	0.006%	0.004%	0.002%	0.001%	0.064%
A	0.132%	0.181%	0.981%	1.744%	4.266%	78.637%	9.599%	2.588%	0.981%	0.285%	0.157%	0.162%	0.103%	0.068%	0.029%	0.005%	0.002%	0.002%	0.006%	0.073%
A (low)	0.145%	0.055%	0.213%	0.394%	1.193%	2.863%	78.044%	12.725%	3.022%	0.704%	0.191%	0.144%	0.055%	0.104%	0.030%	0.030%	0.003%	0.004%	0.001%	0.081%
BBB (high)	0.076%	0.068%	0.097%	0.210%	0.830%	2.772%	2.170%	77.451%	13.748%	1.525%	0.354%	0.274%	0.076%	0.082%	0.051%	0.016%	0.004%	0.010%	0.001%	0.185%
BBB	0.030%	0.025%	0.140%	0.158%	0.445%	1.083%	2.105%	6.385%	76.858%	10.306%	0.974%	0.649%	0.195%	0.155%	0.136%	0.025%	0.008%	0.016%	0.002%	0.304%
BBB (low)	0.177%	0.013%	0.184%	0.430%	0.581%	1.538%	1.974%	5.892%	19.518%	62.659%	2.042%	2.380%	0.949%	0.482%	0.187%	0.155%	0.038%	0.019%	0.007%	0.776%
BB (high)	0.192%	0.009%	0.020%	0.201%	0.171%	0.479%	1.013%	1.170%	4.891%	11.943%	62.067%	12.713%	1.914%	0.993%	0.414%	0.201%	0.047%	0.047%	0.011%	1.504%
BB	0.011%	0.051%	0.106%	0.072%	0.035%	0.393%	0.303%	0.635%	1.756%	4.928%	16.612%	61.474%	8.202%	2.023%	0.646%	0.281%	0.124%	0.114%	0.028%	2.206%
BB (low)	0.006%	0.009%	0.015%	0.088%	0.157%	0.276%	0.483%	0.666%	1.379%	2.175%	6.603%	16.858%	60.881%	5.597%	0.853%	0.299%	0.123%	0.081%	0.034%	3.417%
B (high)	0.006%	0.091%	0.021%	0.188%	0.084%	0.159%	0.426%	0.576%	0.327%	0.585%	1.302%	4.739%	20.090%	60.288%	5.318%	0.868%	0.330%	0.226%	0.097%	4.280%
B	0.012%	0.006%	0.174%	0.021%	0.084%	0.471%	0.484%	0.389%	0.358%	0.210%	0.926%	1.933%	4.652%	21.315%	57.977%	3.770%	1.069%	0.584%	0.268%	5.299%
B (low)	0.029%	0.002%	0.008%	0.009%	0.230%	0.220%	0.225%	0.437%	0.258%	0.210%	0.477%	0.706%	1.578%	8.163%	18.076%	57.163%	2.250%	0.979%	0.351%	8.628%
CCC (high)	0.030%	0.002%	0.009%	0.029%	1.174%	0.122%	0.103%	0.849%	0.483%	0.065%	0.236%	0.254%	1.648%	4.977%	9.583%	21.323%	33.480%	0.420%	0.170%	25.042%
CCC	0.330%	0.009%	0.010%	0.006%	0.040%	0.344%	0.359%	0.669%	0.391%	0.106%	0.965%	0.992%	0.625%	1.909%	7.382%	6.279%	11.491%	20.911%	0.393%	46.789%
CCC (low)	0.011%	0.010%	0.001%	0.001%	0.002%	0.009%	0.015%	0.019%	0.034%	0.033%	0.054%	0.649%	0.180%	1.905%	2.161%	1.634%	2.479%	1.571%	20.318%	68.913%
D	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	100.0%

Corporate Cumulative Default Probabilities

Maturity (Years)	AAA	AA (high)	AA	AA (low)	A (high)	A	A (low)	BBB (high)	BBB	BBB (low)	BB (high)	BB	BB (low)	B (high)	B	B (low)	CCC (high)	CCC	CCC (low)
1	0.017%	0.038%	0.047%	0.055%	0.064%	0.073%	0.081%	0.185%	0.304%	0.776%	1.504%	2.206%	3.417%	4.280%	5.299%	8.628%	25.042%	46.789%	68.913%
2	0.043%	0.083%	0.113%	0.127%	0.147%	0.172%	0.206%	0.415%	0.695%	1.518%	3.017%	4.386%	6.394%	8.290%	10.554%	16.211%	36.370%	60.798%	84.629%
3	0.078%	0.136%	0.190%	0.215%	0.248%	0.294%	0.371%	0.686%	1.145%	2.239%	4.493%	6.438%	9.021%	11.867%	15.186%	22.344%	42.632%	66.091%	88.658%
4	0.123%	0.199%	0.277%	0.318%	0.366%	0.439%	0.573%	0.998%	1.635%	2.943%	5.907%	8.341%	11.360%	15.011%	19.155%	27.254%	46.746%	68.785%	90.003%
5	0.177%	0.270%	0.373%	0.435%	0.502%	0.607%	0.808%	1.345%	2.154%	3.634%	7.248%	10.096%	13.456%	17.769%	22.540%	31.221%	49.775%	70.541%	90.664%
6	0.241%	0.352%	0.480%	0.567%	0.655%	0.796%	1.076%	1.722%	2.693%	4.315%	8.510%	11.712%	15.344%	20.193%	25.435%	34.471%	52.155%	71.861%	91.108%
7	0.315%	0.444%	0.597%	0.714%	0.825%	1.008%	1.372%	2.127%	3.246%	4.984%	9.696%	13.198%	17.050%	22.329%	27.925%	37.171%	54.096%	72.924%	91.455%
8	0.399%	0.547%	0.727%	0.875%	1.012%	1.240%	1.695%	2.554%	3.807%	5.642%	10.809%	14.567%	18.597%	24.221%	30.080%	39.443%	55.715%	73.809%	91.743%
9	0.493%	0.661%	0.868%	1.051%	1.214%	1.492%	2.040%	2.999%	4.374%	6.288%	11.853%	15.828%	20.005%	25.904%	31.959%	41.378%	57.088%	74.561%	91.988%
10	0.597%	0.786%	1.022%	1.241%	1.433%	1.762%	2.407%	3.460%	4.943%	6.923%	12.833%	16.994%	21.289%	27.408%	33.608%	43.043%	58.267%	75.209%	92.200%
11	0.712%	0.922%	1.188%	1.445%	1.667%	2.050%	2.792%	3.933%	5.512%	7.547%	13.756%	18.074%	22.466%	28.760%	35.064%	44.489%	59.289%	75.774%	92.385%
12	0.838%	1.071%	1.367%	1.664%	1.917%	2.355%	3.193%	4.415%	6.080%	8.159%	14.625%	19.077%	23.547%	29.981%	36.359%	45.756%	60.184%	76.270%	92.548%
13	0.974%	1.231%	1.559%	1.897%	2.181%	2.675%	3.607%	4.905%	6.645%	8.760%	15.447%	20.011%	24.544%	31.088%	37.517%	46.875%	60.975%	76.710%	92.692%
14	1.122%	1.403%	1.764%	2.144%	2.459%	3.009%	4.034%	5.399%	7.206%	9.350%	16.226%	20.884%	25.467%	32.097%	38.560%	47.870%	61.679%	77.103%	92.822%
15	1.281%	1.587%	1.981%	2.404%	2.750%	3.356%	4.470%	5.898%	7.763%	9.929%	16.966%	21.702%	26.325%	33.021%	39.504%	48.762%	62.309%	77.457%	92.938%
16	1.451%	1.784%	2.211%	2.676%	3.054%	3.715%	4.915%	6.399%	8.315%	10.498%	17.670%	22.472%	27.125%	33.871%	40.363%	49.566%	62.878%	77.777%	93.043%
17	1.633%	1.992%	2.454%	2.962%	3.370%	4.084%	5.367%	6.901%	8.861%	11.058%	18.343%	23.198%	27.874%	34.657%	41.149%	50.295%	63.395%	78.069%	93.139%
18	1.826%	2.213%	2.708%	3.259%	3.697%	4.463%	5.824%	7.404%	9.402%	11.608%	18.988%	23.886%	28.577%	35.387%	41.872%	50.961%	63.867%	78.337%	93.227%
19	2.030%	2.445%	2.974%	3.567%	4.035%	4.851%	6.286%	7.906%	9.937%	12.149%	19.607%	24.539%	29.241%	36.067%	42.541%	51.572%	64.301%	78.584%	93.308%
20	2.246%	2.689%	3.252%	3.887%	4.383%	5.246%	6.751%	8.407%	10.466%	12.681%	20.203%	25.161%	29.869%	36.704%	43.162%	52.135%	64.702%	78.813%	93.382%
21	2.473%	2.944%	3.540%	4.216%	4.740%	5.649%	7.219%	8.907%	10.989%	13.205%	20.778%	25.756%	30.465%	37.302%	43.741%	52.658%	65.075%	79.026%	93.452%
22	2.711%	3.211%	3.840%	4.555%	5.105%	6.057%	7.688%	9.404%	11.507%	13.722%	21.334%	26.326%	31.033%	37.867%	44.284%	53.145%	65.422%	79.226%	93.517%
23	2.959%	3.488%	4.149%	4.904%	5.478%	6.471%	8.159%	9.899%	12.018%	14.231%	21.873%	26.874%	31.576%	38.403%	44.796%	53.600%	65.748%	79.414%	93.578%
24	3.219%	3.775%	4.468%	5.260%	5.858%	6.890%	8.630%	10.391%	12.525%	14.733%	22.396%	27.402%	32.097%	38.912%	45.279%	54.029%	66.055%	79.592%	93.636%
25	3.488%	4.073%	4.796%	5.625%	6.244%	7.313%	9.101%	10.881%	13.025%	15.228%	22.905%	27.913%	32.598%	39.397%	45.738%	54.434%	66.346%	79.761%	93.690%
26	3.768%	4.380%	5.132%	5.996%	6.637%	7.739%	9.572%	11.367%	13.521%	15.717%	23.402%	28.407%	33.080%	39.862%	46.175%	54.817%	66.622%	79.921%	93.742%
27	4.057%	4.697%	5.477%	6.375%	7.034%	8.168%	10.042%	11.850%	14.011%	16.200%	23.887%	28.886%	33.547%	40.309%	46.592%	55.183%	66.885%	80.075%	93.791%
28	4.356%	5.022%	5.830%	6.759%	7.437%	8.600%	10.511%	12.330%	14.496%	16.677%	24.361%	29.353%	33.999%	40.738%	46.993%	55.531%	67.137%	80.222%	93.839%
29	4.663%	5.356%	6.189%	7.149%	7.844%	9.034%	10.979%	12.807%	14.976%	17.148%	24.825%	29.807%	34.438%	41.153%	47.377%	55.866%	67.378%	80.363%	93.884%
30	4.980%	5.697%	6.556%	7.544%	8.254%	9.469%	11.445%	13.281%	15.451%	17.614%	25.280%	30.251%	34.865%	41.555%	47.749%	56.187%	67.611%	80.500%	93.928%

Appendix 2: Structured Finance Transition Matrix and Default Table

Adjusted Transition Matrix

	AAA	AA (high)	AA	AA (low)	A (high)	A	A (low)	BBB (high)	BBB	BBB (low)	BB (high)	BB	BB (low)	B (high)	B	B (low)	CCC (high)	CCC	CCC (low)	D
AAA	94.087%	3.159%	1.842%	0.357%	0.188%	0.090%	0.133%	0.031%	0.060%	0.005%	0.019%	0.018%	0.002%	0.001%	0.001%	0.000%	0.000%	0.000%	0.000%	0.007%
AA (high)	0.106%	93.494%	4.074%	1.469%	0.328%	0.262%	0.079%	0.044%	0.063%	0.031%	0.027%	0.004%	0.002%	0.001%	0.001%	0.001%	0.000%	0.001%	0.000%	0.016%
AA	0.807%	0.783%	92.901%	3.299%	1.072%	0.674%	0.172%	0.136%	0.078%	0.008%	0.004%	0.011%	0.010%	0.002%	0.003%	0.008%	0.001%	0.007%	0.000%	0.025%
AA (low)	0.190%	0.437%	2.553%	92.308%	2.657%	1.328%	0.256%	0.087%	0.051%	0.029%	0.018%	0.012%	0.003%	0.010%	0.023%	0.001%	0.001%	0.001%	0.000%	0.033%
A (high)	0.018%	0.075%	0.427%	1.845%	91.715%	3.752%	1.363%	0.360%	0.200%	0.056%	0.019%	0.042%	0.023%	0.023%	0.034%	0.003%	0.001%	0.001%	0.001%	0.042%
A	0.062%	0.085%	0.461%	0.820%	2.006%	91.123%	3.700%	0.998%	0.378%	0.110%	0.061%	0.063%	0.040%	0.026%	0.011%	0.002%	0.001%	0.001%	0.002%	0.051%
A (low)	0.090%	0.034%	0.133%	0.246%	0.744%	1.784%	90.530%	4.773%	1.133%	0.264%	0.072%	0.054%	0.020%	0.039%	0.011%	0.011%	0.001%	0.001%	0.000%	0.059%
BBB (high)	0.062%	0.056%	0.079%	0.172%	0.679%	2.267%	1.775%	89.937%	4.071%	0.451%	0.105%	0.081%	0.022%	0.024%	0.015%	0.005%	0.001%	0.003%	0.000%	0.195%
BBB	0.021%	0.018%	0.098%	0.110%	0.312%	0.759%	1.476%	4.476%	89.344%	2.555%	0.241%	0.161%	0.048%	0.038%	0.034%	0.006%	0.002%	0.004%	0.001%	0.294%
BBB (low)	0.232%	0.016%	0.242%	0.564%	0.763%	2.019%	2.592%	7.736%	25.628%	57.909%	0.487%	0.567%	0.226%	0.115%	0.045%	0.037%	0.009%	0.005%	0.002%	0.806%
BB (high)	0.192%	0.009%	0.020%	0.200%	0.170%	0.478%	1.010%	1.166%	4.875%	11.904%	57.317%	16.475%	2.481%	1.286%	0.537%	0.261%	0.060%	0.060%	0.015%	1.484%
BB	0.013%	0.062%	0.130%	0.088%	0.043%	0.480%	0.370%	0.775%	2.144%	6.017%	20.283%	56.724%	7.597%	1.874%	0.599%	0.261%	0.115%	0.105%	0.026%	2.296%
BB (low)	0.008%	0.011%	0.019%	0.109%	0.196%	0.343%	0.601%	0.829%	1.718%	2.710%	8.227%	21.003%	56.131%	3.714%	0.566%	0.199%	0.082%	0.053%	0.022%	3.457%
B (high)	0.006%	0.092%	0.021%	0.190%	0.085%	0.161%	0.432%	0.584%	0.332%	0.593%	1.320%	4.802%	20.361%	55.538%	8.852%	1.444%	0.550%	0.376%	0.161%	4.100%
B	0.013%	0.006%	0.184%	0.022%	0.089%	0.499%	0.513%	0.412%	0.379%	0.223%	0.981%	2.049%	4.930%	22.588%	54.945%	4.553%	1.291%	0.705%	0.324%	5.295%
B (low)	0.030%	0.002%	0.008%	0.010%	0.241%	0.230%	0.236%	0.458%	0.271%	0.219%	0.499%	0.740%	1.652%	8.549%	18.929%	54.353%	3.416%	1.486%	0.533%	8.138%
CCC (high)	0.029%	0.002%	0.009%	0.028%	1.163%	0.121%	0.102%	0.841%	0.478%	0.065%	0.234%	0.252%	1.633%	4.930%	9.492%	21.122%	32.488%	2.440%	0.988%	23.582%
CCC	0.010%	0.009%	0.010%	0.006%	0.040%	0.347%	0.363%	0.676%	0.395%	0.107%	0.975%	1.002%	0.631%	1.928%	7.455%	6.341%	11.605%	20.672%	1.217%	46.211%
CCC (low)	0.011%	0.010%	0.001%	0.001%	0.002%	0.009%	0.016%	0.019%	0.034%	0.033%	0.055%	0.656%	0.182%	1.924%	2.182%	1.650%	2.504%	1.587%	20.079%	69.045%
D	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	100.000%

Adjusted Cumulative Default Probabilities

Maturity (Years)	AAA	AA (high)	AA	AA (low)	A (high)	A	A (low)	BBB (high)	BBB	BBB (low)	BB (high)	BB	BB (low)	B (high)	B	B (low)	CCC (high)	CCC	CCC (low)
1	0.007%	0.016%	0.025%	0.033%	0.042%	0.051%	0.059%	0.195%	0.294%	0.806%	1.484%	2.296%	3.457%	4.100%	5.295%	8.138%	23.582%	46.211%	69.045%
2	0.017%	0.034%	0.055%	0.070%	0.092%	0.112%	0.136%	0.397%	0.603%	1.410%	3.066%	4.442%	6.289%	8.220%	10.591%	15.860%	35.546%	60.393%	84.583%
3	0.028%	0.055%	0.089%	0.111%	0.148%	0.181%	0.229%	0.604%	0.919%	1.896%	4.607%	6.402%	8.703%	11.939%	15.291%	22.188%	42.329%	65.925%	88.571%
4	0.042%	0.077%	0.126%	0.154%	0.211%	0.258%	0.335%	0.815%	1.237%	2.313%	6.048%	8.177%	10.804%	15.188%	19.319%	27.236%	46.726%	68.781%	89.926%
5	0.058%	0.102%	0.165%	0.201%	0.280%	0.343%	0.452%	1.028%	1.554%	2.687%	7.369%	9.777%	12.654%	17.997%	22.736%	31.278%	49.893%	70.631%	90.604%
6	0.075%	0.129%	0.206%	0.251%	0.353%	0.433%	0.579%	1.244%	1.869%	3.034%	8.568%	11.214%	14.291%	20.419%	25.628%	34.554%	52.332%	71.998%	91.059%
7	0.095%	0.159%	0.250%	0.303%	0.431%	0.529%	0.716%	1.462%	2.179%	3.361%	9.651%	12.503%	15.744%	22.510%	28.083%	37.242%	54.286%	73.080%	91.410%
8	0.117%	0.190%	0.295%	0.358%	0.514%	0.631%	0.859%	1.681%	2.485%	3.674%	10.628%	13.658%	17.035%	24.321%	30.173%	39.473%	55.888%	73.965%	91.697%
9	0.140%	0.223%	0.343%	0.415%	0.600%	0.738%	1.010%	1.900%	2.786%	3.976%	11.509%	14.693%	18.186%	25.892%	31.961%	41.344%	57.224%	74.703%	91.936%
10	0.166%	0.259%	0.392%	0.475%	0.690%	0.849%	1.166%	2.119%	3.081%	4.268%	12.305%	15.620%	19.212%	27.262%	33.498%	42.925%	58.348%	75.326%	92.140%

Appendix 3: Simulating Correlated Default Times

The creditworthiness of an obligor *(i)* is often described by a single normally distributed latent variable (V_i), frequently referred to as the obligor's asset value. Dependence between different obligors is then introduced through their dependence on common factors. For example, in the simplest case of a single factor *(F)*, $V_i = \sqrt{\rho}\,F + \sqrt{1-\rho}\,\varepsilon_i$, where ρ denotes the correlation between two obligors and *F* and ε_i are standard normal variables, representing global and idiosyncratic (obligor-specific) risk factors, respectively.

In practice a single correlation factor is often too restrictive for risk management purposes and generalisations to a multifactor framework are preferred.

For corporate obligors, DBRS employs the following multifactor model: $V_i = \sqrt{\rho}\,F + \sqrt{\rho^S - \rho}\,F_{S(i)} + \sqrt{\rho^R}F_{R(i)} + \sqrt{\rho^{SR} - \rho^R}F_{SR(i)} + \sqrt{1-\rho^{SR}-\rho^S}\varepsilon_i$, where *F* denotes a global, $F_{R(i)}$ a regional, $F_{S(i)}$ a sector specific and $F_{SR(i)}$ a region-sector factor. We use $\rho = 2\%$, $\rho^S = 15\%$, $\rho^R = \rho^{SR} = 4\%$, which produces the sector and regional correlations shown in Table 2 on page 6.

For SF securities, we use the same factor model as above, but distinguish it from the model for corporates by rewriting it as $\overline{V}_i = \sqrt{\overline{\rho}}\,F^A + \sqrt{\overline{\rho}^S - \overline{\rho}}\,F_{S(i)} + \sqrt{\overline{\rho}^R}F^A_{R(i)} + \sqrt{\overline{\rho}^{SR} - \overline{\rho}^R}F_{SR(i)} + \sqrt{1-\overline{\rho}^{SR}-\overline{\rho}^S}\varepsilon_i$. We use $\overline{\rho}$ =3%, $\overline{\rho}^S$ = 12%, $\overline{\rho}^R$ = 15% and $\overline{\rho}^{SR}$ = 18%, which reproduces the correlations shown in Table 7 on page 8.

In both cases, given *N* different sectors in *M* different regions, *(N+M+NM+1)* different factors would need to be simulated.

Default occurs prior to maturity *(T)* if the asset value V_i falls below the default barrier – $d_i = N^{-1}(PD_T^i)$ – of the obligor, where PD_T^i denotes the obligor's cumulative *T*-year default probability.

Rather than computing default events prior to maturity, a default time (τ_i) can be computed for each obligor as follows:

(1) Calculate $u_i = \Phi(V_i)$.
(2) Calculate a default time $\tau_i = S^{-1}(u_i)$ for each asset.[12]

If τ_i is less than the maturity of the transaction, the loss (L_i) is determined as $L_i = N_i \times (1-\delta_i)$, where N_i and δ_i are the exposure-at-default and recovery,[13] respectively, for the *i*th asset. We can therefore write the portfolio loss up to time *t*, *L(t)*, as $L(t) = \sum_i N_i \times (1-\delta_i) \times 1_{\{\tau_i \le t\}}$, where $1_{\{\tau_i \le t\}}$ is the default indicator for the *i*th asset.[14]

[12] S^{-1} is used to denote the quasi-inverse of the survival function derived from the default curves PD_t^i.
[13] The recovery can either be assumed to be constant or drawn from a distribution.
[14] The default indicator equals 1 if the expression within parentheses is true and 0 if it is false.

CORRELATION BETWEEN CORPORATE OBLIGORS AND SF SECURITIES

By correlating both the global factors (F and F^A) and the regional factors ($F^A_{R(\bullet)}$ and $F_{R(\bullet)}$), dependence can be introduced between corporate obligors and SF securities within and between regions. We introduce two new, independent standard normal variables, F^{ABS} and $F^{ABS}_{R(\bullet)}$, and write F^A and $F^A_{R(\bullet)}$ as $F^A = \sqrt{g}F + \sqrt{1-g}F^{ABS}$, with $Corr(F^A, F) = g$ and $F^A_{R(j)} = \sqrt{r}F_{R(j)} + \sqrt{1-r}F^{ABS}_{R(j)}$, with $Corr(F^A_{R(j)}, F_{R(j)}) = r$.

As a result, the correlation between corporates and SF is $Corr(V_i, \overline{V}_j) = \sqrt{\rho}\ \sqrt{g}\sqrt{\overline{\rho}} + \sqrt{\rho^R}\sqrt{r}\sqrt{\overline{\rho}^R}$ within a region and $Corr(V_i, \overline{V}_j) = \sqrt{\overline{\rho}}\sqrt{g}\sqrt{\overline{\rho}}$ between regions.

Using g = 16.67% and r = 1.67%, results in a 1% correlation between a corporate obligor and SF security in different regions and a 2% correlation if they are in the same region.

Insight beyond the rating.

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