

Integrating Market and Credit Risk Measures using SAS® Risk Dimensions™ software

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Abstract

Measures of market risk project the possible loss in value of a portfolio due to movements in financial markets. Credit risk measures project the possible losses in a portfolio due to poor performance by a counterparty such as a downgrading in credit rating or an actual default on an obligation. In the past, financial institutions have measured market and credit risk separately. As global markets have matured, financial institutions have recognized that market and credit risks are intertwined and should be measured in an integrated manner. The challenge facing risk managers attempting to achieve this integrated measurement include a continuum of issues from fundamental data management to implementing complex analytical techniques robustly, to producing effective reports in a timely fashion. Risk Dimensions provides risk managers with an integrated environment in which the obstacles to integrating market and credit risk management can be overcome.

Risk

One common point of confusion is that the term risk management and credit risk can have multiple meanings in the financial services industry, all of which are correct. For Risk Dimensions, risk management refers to financial risk (loss in value of a security or portfolio). Risk Dimensions is a firm-wide risk management solution. Specifically, Risk Dimensions is designed for;

- aggregating market risk measures
- loss in value due to normal fluctuations in financial markets, and credit risk measures
- loss in value from a change in credit rating or failure of a counter party to a transaction.

Figure 1 illustrates how Risk Dimensions graphically presents a classic Value at Risk (VaR) measure.

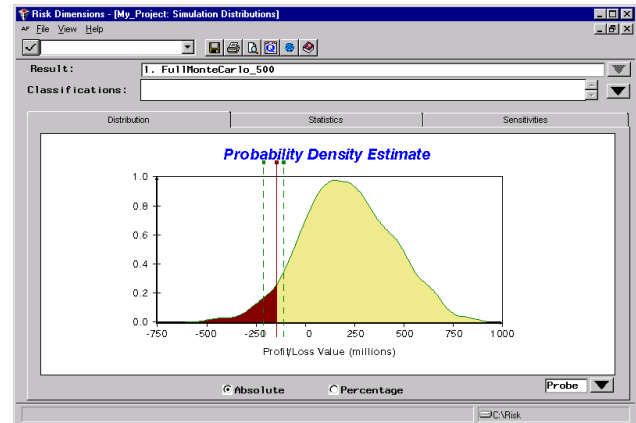


Figure 1. Probability Density Estimate Plot for Value at Risk.

Introduction

To solve the firm-wide risk management puzzle, institutions need to pull together many diverse kinds of information and collateral resources. Risk Dimensions provides an environment where this can be accomplished. Once you understand the pieces of the risk management puzzle you can systematically register each piece so that the Risk Analysis Engine can bring them together to analyze the risk positions.

An open, flexible, and extensible approach is required to integrate market and credit risk measures.

An open system enables the user to understand and explain the entire risk analysis process from the collection of data to the production of risk reports.

Extensibility enables the user to easily register new data, instrument types, market models, and pricing models.

Flexibility enables the user to mix and match the information and collateral resources necessary to produce credit and market risk measures for a given portfolio.

The Building Blocks

To solve the challenges of integrating market and credit risk measures, the problem should be broken down into manageable components. These components are then reassembled to produce the desired measures.

Valuation

Valuing an instrument is the fundamental building block. To effectively produce risk measures the instruments must be valued correctly at any given state of the world (market rates, credit ratings, spreads, etc.).

Full re-pricing provides the most complete information for producing risk measures. When efficiency is at a premium, approximations that do not use full re-pricing can be used.

Models

A pricing function is required in order to value an instrument at a given state of the world. Descriptive information about the instrument and the current state of the world are passed to the pricing function. The value of the instrument is returned. These pricing functions are commonly referred to as pricing models.

Risk measures can be based on Monte Carlo simulations that use statistical models. Monte Carlo simulation is made of three steps; simulation of the future state of the world, state variable transformations, and pricing the portfolio. Because the future state of the world is unknown, models of the state variables are used to forecast the future values of the state variables.

Data

Credit, market, and position data acquired from disparate sources must be extracted, validated, and possibly transformed. The credit and market data may include market rates, credit spreads and credit migration information. These data elements must be made available to the risk analytical engine at the proper form and at the proper time.

Measuring integrated market and credit risk involves modeling changes in the state of the world where the state variables are market rates, spreads, and credit ratings. The measurements also must allow for the interrelationships between all the state variables.

Assembling the building blocks

All of the registrations for the building blocks and the metadata of the risk management problem must be stored. That is, in order to pull the pieces together, Risk Dimensions creates an environment in which to organize them and manage their relationships.

To store metadata and other data, Risk Dimensions uses the concept of a risk analysis environment. Logically, a Risk Dimensions environment is just a set or collection of information and files that are created to implement a particular risk management solution.

Physically, an environment consists of a SAS catalog, which stores the various registrations as different entries, and an associated directory, which stores various files produced by the analysis process.

You can derive various benefits depending on how you configure the Risk Dimensions environment. For example;

- Risk Dimensions can store the environment in any directory that you prefer.
- You can create any number of environments. Multiple environments provide users the ability to compartmentalize the risk management solution along organizational or other logical lines.
- You can specify that analysis environments inherit information from another. Inheritance can be useful when individuals in a risk management department are working on different projects and all are based on the common corporate risk management system.
- You can perform analysis on individual portfolios while firm-wide risk measures are being produced concurrently. For example an analyst investigating the risk impact of a proposed new financial product might create an individual analysis environment to serve a specific project. The analyst's individual environment would be based on the corporate analysis environment, inheriting all the information about the current portfolio, and the analyst would add new registrations and hypothetical holdings.

This inheritance feature for linking environments together also is convenient for plugging in registrations of pricing function libraries, libraries of simulation models, and other resources into the configuration.

After you define a physical and logical location where Risk Dimensions registers the parts of the risk management problem, you collect these elements in an environment.

Describing the Risk Dimensions Environment

The key in creating a Risk Dimensions solution is to register the data structures and preferred valuation algorithms. The following items need to be registered.

The Variables Used by the System

Before instrument types can be defined, the variables that comprise the data fields of those instruments must be declared. Before a user can model market risk factors, the user must declare these market variables. Before a user can write pricing method programs, the instrument variables, risk factors, and other variables that the pricing program uses must be declared.

Risk Dimensions supports five kinds of variable definitions:

- **System-defined Variables** are automatically created to serve various roles in the process. Their definitions cannot be changed.
- **Instrument Variables** are the columns contained in an instrument record.
- **Risk Factor Variables** are market-derived values upon which the valuation of an instrument depends. The risk analysis process consists of modeling how these risk factor variables might change and analyzing the resulting change in the value of the instruments in a portfolio.
- **Risk Factor Curves** are aggregations of related risk factor variables. Essentially, a risk factor "curve" in Risk Dimensions is contained in an array. Risk factor curves are used for representing various forms of yield curves for different currencies, for representing currency exchange forward rate curves, and for other similar purposes.
- **Reference Variables** are special variables used to link instrument variables to the risk factors variables needed to value the instrument.

Reference variables enable pricing method programs to be written in a generic way that avoids the need for much special-case programming.

The Instrument Types

There are a variety of financial instruments a user might hold in their portfolio. Risk Dimensions can process any type of financial instrument, but the definitions of those instruments must be registered in the environment. Instrument type definition consists of at least the following:

- the list of variables or fields that define the instrument
- the name of a pricing method program used to value instruments of that type.

Optionally, an instrument definition also can include:

- a list of default values for an identified field
- the name of an input method program to compute derived fields as instrument data is read
- specification of supplemental records for an instrument that provide lists of cash flow values or risk factor sensitivities.

An instrument variable list has an inheritance structure and can inherit a variable list for a more general specification. Thus, fields that are common to all instruments or to a group of instruments can be specified once and included in subsequent definitions through inheritance.

Pricing Method Programs

Risk Dimensions is a "full re-pricing" risk analysis system. Full re-pricing means that any possible change in the market state will be considered as part of a risk analysis. For each instrument in the portfolio, Risk Dimensions computes an estimate of the instrument's value under those market conditions. Therefore, Risk Dimensions must be able to price every type of instrument that may be included in any portfolio to be analyzed.

Each instrument type must include the name of a program, known as a pricing method, which Risk Dimensions calls to value instruments of that type.

Risk Dimensions enables a user to compute the value of instruments in any way that is needed. The full power of the SAS programming language is available to implement pricing algorithms.

In most cases, however, a user need not write code to price instruments. Instead, the pricing method programs would call functions in a library of pricing functions.

Pricing Functions

Pricing functions that value different kinds of financial instruments using algorithms derived from financial theory. Libraries of pricing functions are available from third-party vendors. In most cases, as part of implementing a Risk Dimensions solution, a user will choose and license pricing libraries from one or more third-party vendors. Given the availability of a pricing library, the pricing method programs will in most cases, consist of calls to the pricing functions library.

The pricing method programs map the instrument variables and risk factor variables, (configured in the user's risk analysis environment), to the pricing function arguments (defined by the third-party pricing algorithm vendor).

A user also can create their own pricing function libraries using functions and subroutines written either in the SAS language or in the C programming language. Figure 2 illustrates pricing functions in both the SAS language and C that have been registered in a sample environment.

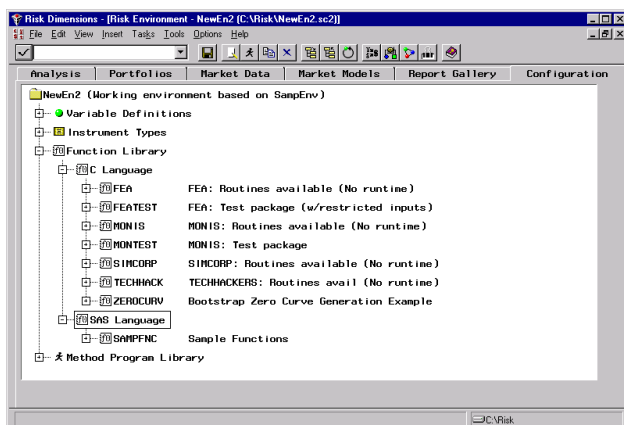


Figure 2. Risk Dimensions' Function Library Tree

Input Method Programs

Some of the instrument variables needed by the pricing method programs might not be available in

the instrument data. Instead, those needed attributes can be derived from the available instrument data.

A user could compute these variables in the pricing method program. However, it may be more efficient to pre-compute the missing instrument variables as the instrument is read in and store them with the given instrument variables. In this way, the derived instrument variables need to be computed only once rather than every time the instrument is re-valued.

You can create SAS programs, called Input Method Programs, to perform these calculations, and you can specify the names of these input method programs as part of the instrument type definition.

Registering the Portfolio Data Sources

Once the structure of the user's data is known and the pricing algorithms are available, the actual portfolio data to be analyzed are defined to the risk analysis environment. Setting up access to the portfolio data involves the following elements:

Portfolio Data Sources

The user may have multiple sources of portfolio data residing in various databases corresponding to different lines of business or subsidiary operating units. Risk Dimensions can read portfolio data represented in virtually any format. To supply this data to Risk Dimensions, the portfolio data sets or data views must be registered in the analysis environment.

Portfolio Input Lists

Because the portfolio to be analyzed often will be stored in different databases, the names of the portfolio data source registrations providing access to this data must be created.

If there is a need to analyze different portfolios for different purposes, Risk Dimensions enables users to create and use any number of Portfolio Input Lists.

Portfolio Filters

In some instances, users may want to analyze only part of a portfolio. Risk Dimensions enables the user to create Portfolio Filters that supply WHERE clauses to select instruments and to create subset portfolios. The user can create any number of filters and combine them in different ways for different analysis runs.

Portfolio Files

A portfolio input list and, optionally, a list of portfolio filters, is used to create a binary extract file. The extract file contains the instruments of the portfolio to analyze and are in a form that Risk Dimensions can process efficiently. A user can create an unlimited number of these portfolio files in an analysis environment. Figure 3. illustrates a sample portfolio file.

INSTTYPE	INSTID	INSTSOURCE	CURRENCY	HOLDING
Government_Bond	gbond002	Fixed Income	DEM	1
Government_Bond	gbond003	Fixed Income	DEM	1
Government_Bond	gbond006	Fixed Income	USD	100
Money_Market_Deposit	mdep002	Fixed Income	JPY	1
Interest_Rate_Swap	irsup001	Derivatives	DEM	1
Interest_Rate_Swap	irsup004	Derivatives	USD	1
FX_Forward	fxfed001	Derivatives	DEM	10

BUNIT:	Fixed Income	MAT_DATE:	15MAR2002	PAR_USD:	52036350
REGION:	London	COUPON:	0.065	COUPFREQ:	12
ISS_TYPE:	Bob1	PAR_ILC:	75000000		

Figure 3. Sample Portfolio file in Risk Dimensions

Registering and Modeling Market Data

Market data may need to be transformed or modeled. The market data registration includes the following:

Market Data Sources

The following types of market data can be registered:

- **Current Market Data** are used to compute the base case market-state for the initial portfolio mark-to-market.
- **Time Series Data** at varying frequencies can be used to drive historical simulation analysis, to initialize lagged processing for model-based simulations, and to estimate the parameters of simulation models.
- **Volatility Data** are used to supply estimates of the standard deviations of market risk factors.
- **Co-variance Matrix Data** supplies estimates of the variances and co-variances of market risk factors, and it is used for co-variance-based simulation analysis.
- **Scenario Data** enables the user to drive market simulations using risk factor perturbations generated externally to Risk Dimensions.

- **Change Scenario Data** are similar to scenario data, but are in the form of changes that need to be applied to the base-case market-state instead of simulated risk factor values.
- **Linear Transformation Matrix** supplies a matrix used to compute a list of risk factor variables from the values of another list of risk factors.
- **Parameters Data Set** supplies values for parameter matrices that can be used in method programs.

Risk Factor Transformation Programs

Some risk factor variables or risk factor curves are not available directly from the market data but must be derived. For example a zero-coupon yield curve used to price instruments is a derived risk factor variable. The zero-coupon rates are not observable in the market but may be inferred from the market prices of bonds of different maturity dates.

Risk factor transformation method programs can be written to perform these calculations. These method programs are written in the SAS programming language and stored in the method program library of the analysis environment. These programs are similar to pricing method programs and can call third-party or proprietary C functions.

Parameter Matrices

Parameter matrices are matrix variables to be associated with a parameter type market data source and are used in risk factor transformation or pricing method programs.

Transformation Sets

A number of different risk factor transformation programs may need to be executed to compute the values of derived risk factor variables and curves. Users can create transformation sets that mix-and-match different transformation programs for use in different analyses.

Market Models

The most advanced kind of risk analysis provided by Risk Dimensions is a full model-based Monte Carlo simulation of probable market movements. For this kind of simulation, users need a set of models for the various risk factors, together with statistical estimates of the model parameters computed by fitting the models to historical market data.

Figure 4 illustrates model specifications and fitted models that have been registered in a sample environment.

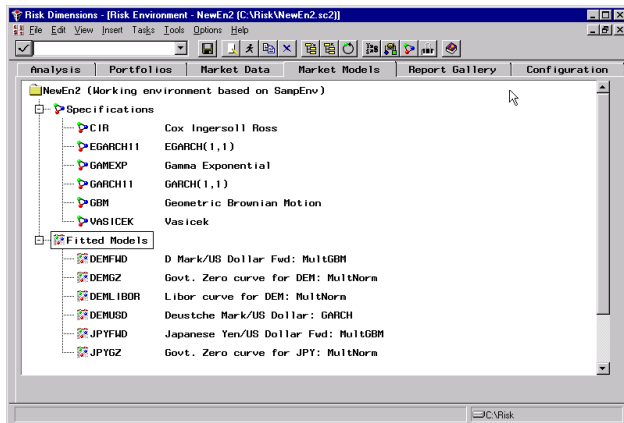


Figure 4. The Market Models Tree

Analysis Specifications

After the risk environment has been populated with information about the user's instruments, shown how to price those instruments, linked to the portfolio data, and pointed to market data, the next part of the process is to define how the risk of the portfolio is to be analyzed. Risk Dimensions can perform several different types of analysis. Each analysis type considers a different kind of possible change in the market state and investigates the impact of that change on the value of the portfolio, which presents the risk of the portfolio from different perspectives.

Each type of analysis can be done in different ways. Some analysis types are simple, while other types allow numerous options.

Risk Dimensions enables a user to create a library of analysis specifications. Each analysis specification has a name and indicates the type of analysis to be performed as well as the values of any options that control the analysis. Risk Dimensions supports the following analysis types:

- **Sensitivity Analysis** determines how much, a portfolio value changes as particular risk factors change given that other risk factors are constant.
- **Scenario Analysis**, which is commonly referred to as "what if" analysis, determines how much the portfolio value changes when the risk factors change according to a user-specified scenario.
- **Profit/Loss Curve Analysis** plots the change in the portfolio value as a function of changes in

one risk factor given that other risk factors are constant.

- **Profit/Loss Surface Analysis** plots the change in portfolio value as a function of changes in two risk factors given that other risk factors are constant.
- **Historical Simulation** determines the statistical distribution of changes in portfolio value that would result if, in the future, the market undergoes the same changes that were experienced over some period in the past. Historical simulation is driven by historical time series variables.
- **Monte Carlo Analysis** determines the statistical distribution of changes in portfolio value that would result if the statistical distribution of future market fluctuations correspond to the statistical models fit to past market movements.
- **Scenario Simulation** determines the statistical distribution of changes in portfolio value that would result if, in the future, the market undergoes changes given a user-specified distribution of market movements.
- **Delta-Normal** computes the VaR for the portfolio from the sensitivity of portfolio value to risk factor changes and from a co-variance matrix of risk factor changes. Delta-normal is based on the assumption that risk factor changes have a multivariate normal or log normal distribution.
- **Current Exposure Analysis** computes current credit risk exposure from a mark-to-market analysis.
- **Potential Exposure Analysis** computes potential future credit risk exposure using a model-based Monte Carlo simulation of probable market movements.

Portfolio Statistics Specifications

In addition to analyzing the risk of market changes to portfolio value, Risk Dimensions can compute descriptive statistics for any instrument variables in the portfolio. Users can create a library of portfolio statistics specifications with each specification indicating which statistics to compute for which instrument variables.

Using portfolio statistics specifications, users can compute descriptive statistics for the values of any numeric instrument variable over the instruments in the portfolio.

Cross-Classification Specifications

Typically, the risk manager will want to compute the results for various analysis specifications and portfolio statistics specifications for various sub-portfolios as well as for the portfolio as a whole. Often managers will want the results broken down by certain cross-classifying variables so that end-user can drill down into parts of the portfolio and "slice and dice" the output.

Risk Dimensions enables users to compute results across classifications by any set or sets of instrument variables. Users can create a library of cross-classification specifications and select different breakdowns for different analysis executions.

Report Specifications

The user can create custom reports using the power of SAS/EIS as well as PROC REPORT, and other SAS reporting tools.

Risk Dimensions enables users to register batch reporting programs, or EIS applications as report templates in the analysis environment. Registering reports in the environment enables users to have the result files created by the analyses to be automatically associated with the report templates. Figure 5 is an example of a multi-dimensional report with cross-classifications utilizing SAS/EIS.

Analysis Results			Value at Risk			
Total	Derivatives	London	2,864,784			
		<table border="1"> <tr> <td>DeltaGammaType</td> <td>1,065,223</td> </tr> <tr> <td>FX_Option</td> <td>1,864,107</td> </tr> </table>	DeltaGammaType	1,065,223	FX_Option	1,864,107
	DeltaGammaType	1,065,223				
	FX_Option	1,864,107				
	New York	Forward_Rate_Agreement	6,597,253			
		IR_Cap_Floor	13,251,117			
		Interest_Rate_Swap	1,117,718			
		Tokyo	48,566,403			
	FixedIncome		190,755,698			

Figure 5. Multi-dimensional VaR Report with Cross-classifications

Putting the Pieces Together

After all the pieces are registered they can be combined to produce the desired analyses. One of the strengths of Risk Dimensions is its flexibility—the way it enables users to "mix and match" different specifications to perform different analyses for

different purposes. In Risk dimensions the pieces are brought together in an analysis project.

An analysis project is a named object that serves as a script to drive the analyses. When a user executes an analysis project, the specifications contained in the analysis project tell Risk Dimensions:

- which portfolio file to process
- which market data sources to use
- what risk factor transformations to use
- which analyses to perform
- how the results should be cross-classified.

The analysis project supplies this information by naming the selected specifications and registrations from the analysis environment that have been described in the preceding sections. Figure 6 is an example of a completed project specification.

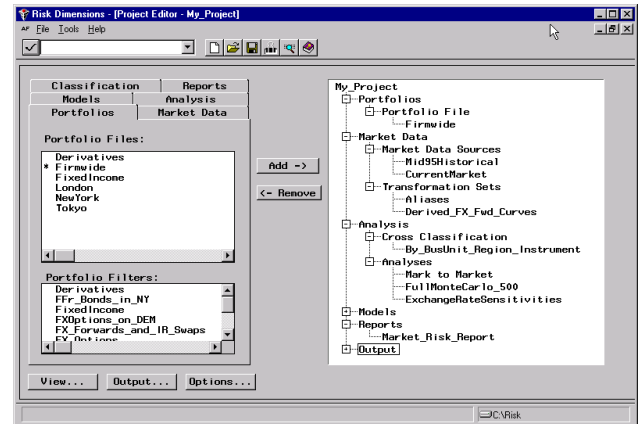


Figure 6. Risk Dimensions Project Editor

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