

# SAS® Risk Analysis Environment

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## Abstract

Derivative securities offer hedging or insurance opportunities for businesses as ways to mitigate financial risks. These instruments also offer investment opportunities for the risk taker. The uses of derivatives for both hedging and trading on one's own account provide institutions the opportunity to control the volatility of their financial results. This paper discusses the financial risks associated with the use of derivatives and how these risks can be measured using SAS® software so that investors can make informed decisions.

## Introduction

The SAS Risk Analysis Environment is the latest business solution offering from SAS Institute. This solution enables users to perform firm-wide risk management and provides them with an open, flexible, and extensible environment for measuring and managing market and credit risk in a manner that is the most appropriate for an institution's unique needs.

The SAS Risk Analysis Environment delivers a full suite of modern market risk analysis techniques including: mark to market, scenario and sensitivity analysis, and Value-at-Risk using different methods including Monte Carlo simulation. In addition to market risk analysis, the SAS Risk Analysis Environment also supports credit risk techniques including Current Exposure and Potential Exposure. The solution provides tools for robust exploration of risk analysis results and subsequent publishing of customized risk analysis reports.

The SAS Risk Analysis Environment incorporates many features of SAS System software to provide an end-to-end risk management solution, from transaction, and market data through sophisticated analyses and data exploration, to presentation quality of reports.

## Risk

For purposes of this discussion, risk refers to financial risk and is defined as an adverse change in the market value of financial assets such as, fixed income, equity, foreign exchange, and various types of derivative securities.

## Derivatives

A derivative is a security where its market value is based on the value of an underlying financial asset, interest rate, foreign exchange rate, or index. Derivative securities include forwards, futures, and options.

### Forwards

A forward contract is an agreement to acquire or deliver a quantity of an asset at a particular date, price and location. The particular date is known as the maturity date and the price is known as the delivery price. Gains or losses are realized on forwards when they are sold prior to maturity or exercised on the maturity date.

### Futures

A futures contract is also an agreement to acquire or deliver a quantity of an asset at a particular date, price, and location. Gains or losses on futures are realized daily through a regulatory mechanism managed by the exchange through which they are traded.

Forwards and futures require an exchange of the specified asset on the maturity date unless the contract is sold or rolled over into a new contract.

### Options

An option is a contract where the owner – referred to as the holder of the option – is entitled to buy (call) or sell (put) a specified amount of an asset to the seller (writer) of the option at a specified (strike) price on a given expiration date. The owner of an option has the right to exercise it but is not obligated to do so. European options may be exercised on the expiration date. American options may be exercised anytime between when it is written and the expiration date.

Derivatives were first traded in the early 1960's. Now the notional value of contracts traded is now estimated to be greater than 50 Trillion. The real interest of risk management though is not the notional value of these derivative contracts but rather the market value of their impact on the value of portfolios while taking into consideration the changes in risk factors such as, interest rates, foreign exchange rates, indices, and the underlying value of the assets represented by the derivatives.

## Use of Derivatives

Derivatives serve two functions in the economy; hedging exposure to financial risk and investing. In fact these two functions are symbiotic in nature. You can only intermediate or hedge your risk with a derivative if there is an investor who is willing to absorb the risk and act as counter party to the transaction.

Derivatives are used in every imaginable business and industry for hedging financial risks that are otherwise beyond the control of the company. For example,

- Agricultural businesses use derivatives to ensure a known minimum price for their product when the crops or livestock are ready to go to market.
- Manufacturers hedge the cost of raw materials for use in future production runs to protect their gross margins.
- Businesses that borrow hedge future interest rate expenses against undesirable movement in the rates in order to protect their cash flows.
- Organizations that require foreign exchange to conduct their global sales use derivatives to protect the profitability of contracts negotiated today from becoming less profitable in the future when the payments are made and exchange rates may have moved adversely.
- Investors use derivatives to hedge exposures created by the positions that they hold in their portfolios. Financial engineers use derivatives to construct portfolios that produce a desired return on investment at a given level of risk.

The possibilities for the healthy use of derivatives are perhaps endless. All institutions that use derivatives for hedging have an aversion to volatility in their financial results, whether they are measuring cash flow, profitability, or some other measure of return on investment. Derivatives are used to minimize the volatility in these financial results.

Using derivatives for hedging would not be possible without counterparties who have an opposing view of the future for the asset values to be hedged or investors who are willing to absorb risk in hopes of profiting from a leveraged investment strategy.

Derivatives are equivalent to a zero sum game. When one party to a derivative contract wins financially the counterparty loses. This exchange occurs when the value of the derivative transaction changes in value. The next section discusses how derivatives change in value and how these changes can be measured and managed.

## Dependency of Instruments on Variables

All financial instruments depend on market variables to determine their value. Equities depend on the investors' perception of the future earnings potential of the company. A fixed income instrument's value is dependent on the contracted payments and prevailing interest rates. A derivative instrument's value is dependent on the present value of the underlying asset, related risk factors such as interest rates, and the cost of exercising the contract.

The relationship between an asset's price and the variable on which it depends, can be expressed as a mathematical function. The price (value) of a non-callable bond can be described as:

$$P = \sum_{t=1}^T \frac{C_t}{(1+y)^t},$$

The required inputs are: coupon payment, principal payment, periods to each payment, periods to maturity, and yield to maturity.<sup>1</sup>

Figure 1

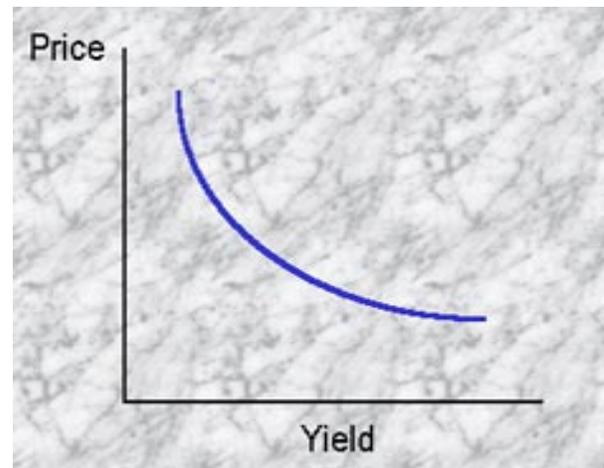


Figure 1 illustrates the inverse relationship between the value of fixed income securities and interest rates. As interest rates increase, the value of the bond decreases. Likewise, as interest rates decrease, the value of the bond increases.

<sup>1</sup> Where:

$C_t$  = the coupon or principal payment or both in period  $t$ ,  
 $t$  = the number of periods to each payment,  
 $T$  = the number of periods to final maturity,  
 $y$  = the yield to maturity for this particular bond.

Interest rates are a type of primitive risk factor. The influence of interest rates on a portfolio can be assessed as follows:

You can specify and fit data to a model for the evolution of interest rates and subsequently simulate a distribution of future interest rates. The fixed income security is then priced at each rate in the distribution to create a distribution of future prices for the asset.

The same concept can be expanded to create a distribution of simulated values for a portfolio of fixed income securities by simulating and summing the individual values of each security at the given interest rate.

### Instrument Complexity Continuum

Derivative securities are valued in a similar, but more complex, manner. We have defined a derivative as an asset where the value is dependent on an underlying financial asset, rate, or index. To value a derivative security we need a way to represent or simulate a future value for the underlying asset. (Jarrow and Turnbull, 1996, p. 108) The value of the underlying asset and any other variables on which it depends is then used as input in a pricing function. The derivative security value can then be determined.

The Black-Sholes formula for pricing a European call option is shown below:

$$c[S(0), T; K] = S(0)N(d_1) - KB(0, T)N(d_2),$$

Simply stated the required inputs are the asset price, the strike price, the time to maturity, the risk free rate of interest, and the volatility.<sup>2</sup>

<sup>2</sup> Where;

c = Payoff for a European call option

K = The strike price

T = The maturity date

S = The asset price

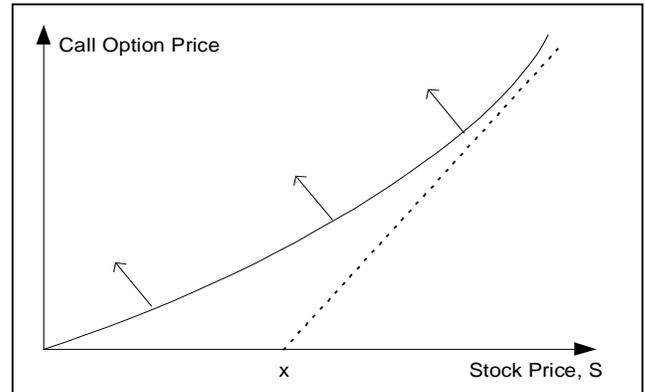
B = The value of a zero coupon

N = The cumulative normal distribution function

$$d_1 \equiv \left\{ \ln[S(0) / KB(0, T0)] + \sigma^2 T / 2 \right\} / (\sigma \sqrt{T}),$$

$$d_2 \equiv d_1 - \sigma \sqrt{T},$$

Figure 2



The value of a European call option is equal to the value of a synthetic portfolio comprised of the asset (stock) and a risk free asset (bond). (Jarrow and Turnbull, 1996, p. 117)

Although a more detailed discussion of the Black-Sholes option pricing model is possible, Figure 2 does illustrate that as the financial instruments under consideration become more complex, so do the formulas and computational power required for pricing the instruments.

The value of a financial asset is dependent on some variable such as an asset price, interest rate, foreign exchange rate, or an index. These variables are known as primitive risk factors. However, the relevant risk factors for a portfolio may have correlations. For example, stock prices and interest rates are commonly understood to be correlated. As the combination and number of assets in a portfolio is increased the number of risk factors and financial markets that need to be monitored increases as well.

### Aggregating Risk Measures

Institutions that trade financial instruments as their primary line of business need to measure the value and risk associated with the portfolios they hold for regulatory, strategic, and tactical reasons. These financial institutions group individual portfolios by asset type or structured to meet a particular business need. Tools exist for calculating the appropriate risk measures for each type of traded financial instrument. However, not all these measures are additive. You can not simply add such risk measures for each portfolio because correlations between the respective risk factors for the portfolios may not be taken into account. When two portfolios are combined, the risk measures can be increased or decreased due to the structure (positive or negative) of correlation of the risk factors on which each depends. Although these risk measures are not all additive, the risk measures need to be aggregated along the same lines of the organization's management and control structures. These structures may follow a plan where individual portfolios of similar

instruments are at the foundation and an aggregated firm-wide or enterprise-wide measure is at the top.

### Risk Management Failures

Figure 3 outlines examples of where the management of financial risk failed in a most spectacular fashion. (Jorion, 1997, pp. 23 - 40)

**Figure 3**

Institution	Estimated Loss
Barings	\$1.30 Billion
Daiwa	\$1.10 Billion
Orange County	\$1.64 Billion
Metallgesellschaft	\$1.30 Billion

These failures all have one thing in common – They could all have been avoided if proper risk management and administrative controls had been in place. Preventing such losses is an objective of risk management.

### Objective of Risk Management

The objective of risk management is to control the volatility of financial results so that the results conform to the investors’ expectations and goals. This control is achieved by identifying, analyzing, communicating, and responding to risk measures that can be derived from your portfolio of financial instruments.

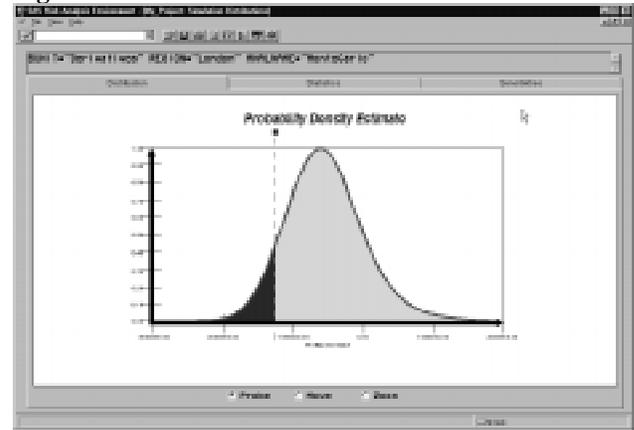
The first step is to identify sensitivities of the instruments within the portfolio to risk factors or variables that impact the value of the instruments.

Given the sensitivities to risk factors, you then model how these risk factors may evolve over time and create a new market state for each predicted value of the risk factor.

At each market state you price the instrument or portfolio at the level of aggregation needed. With the output from this analysis, you then quantify the worst possible financial results at a given confidence level.

With a measurement of exposures in hand, you then communicate the quantification of risk exposures. For an analysis that computes Value-at-Risk (VaR), you could articulate a statement in the form “Tomorrow, under normal market conditions, the maximum amount we could lose in our portfolio is \$X million at a Y% confidence level.” Figure 4 graphically illustrates such a VaR statement.

**Figure 4**



After the risk measures have been communicated, the firm can respond to the identified risk exposures. Typical responses would be to rebalance the portfolio or to add instruments that reduce the risk exposures and thus provide a hedge against undesirable financial results.

### SAS Risk Analysis Environment

Extensibility, flexibility and openness are key requirements of a modern risk management system. The SAS Risk Analysis Environment offers extensibility with robust tools for adding new transaction data, market data and functions written by end users or third party vendors. The SAS Risk Analysis Environment approach to risk management tasks offers a flexible environment for risk analysis resource management. The openness of the SAS Risk Analysis Environment enables the user to completely understand and control the methodology, work flow and processes employed for measuring risk.

To ensure that the SAS Risk Analysis Environment meets the requirements outlined above and the expectations of risk managers around the world, SAS Institute Inc. has entered into a collaborative design effort with McKinsey & Company, Inc.

### SAS Institute Inc.

Risk management is essentially a decision support and information delivery challenge. The SAS Risk Analysis Environment adapts the world-renowned analytical capabilities of SAS software into advanced methodologies that enable firms to interpret and communicate evaluations of different risk measures.

### McKinsey & Company, Inc.

McKinsey & Company is an international management consulting firm with distinct expertise in the area of market, credit and insurance risk management. This expertise is provided by the Financial Institutions Practice, which serves major financial institutions and

commodity trading companies around the globe in the areas of risk management.

### ***SAS and McKinsey for Risk Management***

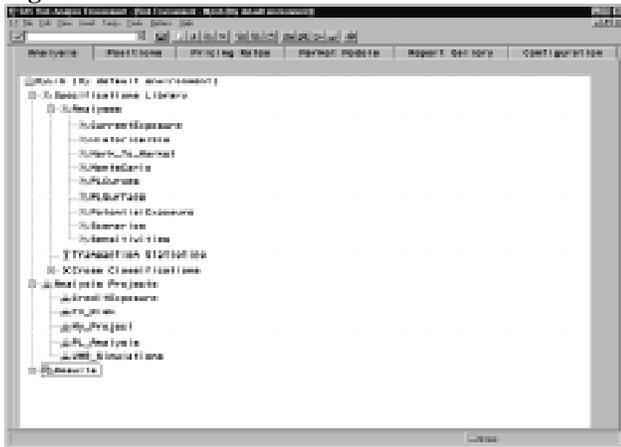
Both SAS Institute and McKinsey & Company are actively solving the complex problems found in the risk management area within trading organizations around the world. SAS Institute and McKinsey & Company have decided to bring their complementary skills together to develop jointly a risk management solution that will address both the business and IT issues found in the area of global risk management.

## **Solving Risk Management Issues with the SAS Risk Analysis Environment**

### ***The Environment***

The SAS Risk Analysis Environment solves the complex issues of measuring market and credit risk by providing an environment or collection of the tools that are required for the task. For example, the solution includes tools for managing position and market data, modeling market variables, pricing and transformation functions, analysis specifications, and reporting all presented in an integrated, interactive graphical user interface (GUI). Figure 5 shows part of the GUI.

**Figure 5**



### ***Collecting Position Information***

The first task of risk management is to identify the position or transaction information that you want to analyze. The complexity of this task easily can be compounded when financial institutions merge or when you need to build a global transaction data warehouse. Issues that compound the complexity include combining data from legacy systems at each location, and scheduling data extractions in multiple time zones.

Traditionally, risk management for derivatives has been managed locally so that managers can have close oversight of the derivative trading activities. However, trading has evolved into a 24-hour, global activity. Rapid communications technology has provided us with the ability for traders to move capital around the world with astonishing speed. This creates new types and magnitudes of exposures for global trading organizations. Therefore, a need for global risk management has evolved in order to manage these newly created exposures.

A generic organizational structure may have trading operations in New York, London, and Tokyo. In each location, the organization may have different systems for each of its various trading activities such as fixed income, foreign exchange, and derivatives.

The challenge of the global risk manager is to identify each of the systems, schedule an extraction of data, transform the data from the source to a common structure, and make it available in a single instance for risk analysis. This task is commonly thought of as building a data warehouse for risk management.

The SAS Risk Analysis Environment can be integrated with the award winning SAS/Warehouse Administrator™ software.

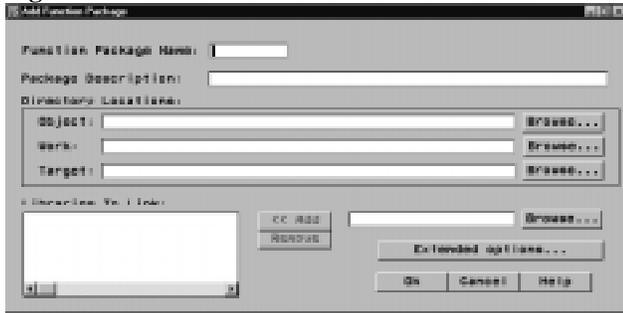
### ***Pricing Functions***

Risk management requires the ability to price a given financial instrument when the variables on which the value depends are provided for a given market state. For consistency, firms should use the same pricing functions in their front office trading activities as they use in the middle office risk management activities.

Proprietary pricing functions provide firms an opportunity to gain a competitive advantage by leveraging their intellectual capital. As new instruments are traded, new pricing functions are required to analyze their risk measures.

To solve these issues related to pricing functions, the SAS Risk Analysis Environment includes an add function package tool for managing the registration of user defined and third party pricing functions written in C or SAS. Figure 6 shows a sample add function package page.

Figure 6

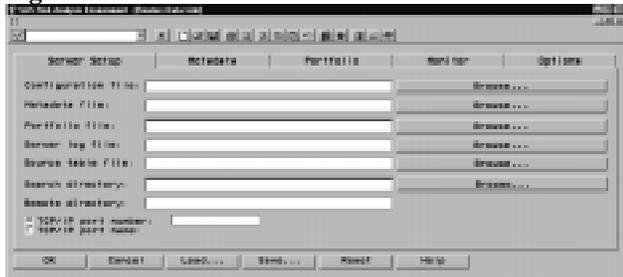


## Accessing Market Data

Access to current and historical market data is required to measure market and credit risk. One well-known provider of this data is Reuters. The risk management challenge is to make the market data available for analysis.

As Figure 7 illustrates, the SAS Risk Analysis Environment includes an interface to Reuters data available over the Triarch Network.

Figure 7



## Types of Analysis

Risk measures need to be aggregated on a firm wide level for today's global trading organizations. Risk managers also need to be able to aggregate risk measures at other levels that follow organizational management and control structures.

The SAS Risk Analysis Environment meets this requirement by enabling users to specify cross classification variables from which results are then aggregated. Summable numbers such as sensitivities are simply summed and non-summable numbers such as VaR are recomputed at each level.

Within the SAS Risk Analysis Environment, all analysis features are based on full pricing on each transaction in the portfolio being analyzed.

## Sensitivities

Deltas and gammas – first and second derivatives with respect to any specified risk factor – can be computed numerically. Even though the results are in terms of deltas, the computed and reported deltas can be equivalent

to rhos or vegas. The deltas are equivalent to rhos if the specified risk factor is an appropriate interest rate. Deltas are equivalent to vegas if the specified risk factor is one that is actually a volatility of another risk factor. Calculations are by numerical derivatives and not analytical derivatives since arbitrary pricing functions need to be accommodated.

## Scenarios

Risk managers need to analyze sensitivities to risk factors and measure how the exposure to these factors can change the value of the portfolio under normal market conditions. In addition to measuring risk under normal market conditions, risk managers may want to analyze the impact of risk factors at specified market states. For example, you may want to measure the value of a portfolio with stock prices or interest rates changing by a fixed amount or a percent change of increase or decrease in the risk factor value. The portfolio can be stress tested by using extreme shocks to the risk factor values.

The SAS Risk Analysis Environment enables the user to compute profit or loss to the portfolio in these scenarios by perturbing risk factors according to user specifications. Choices available to the user include absolute and relative perturbations of the risk factors.

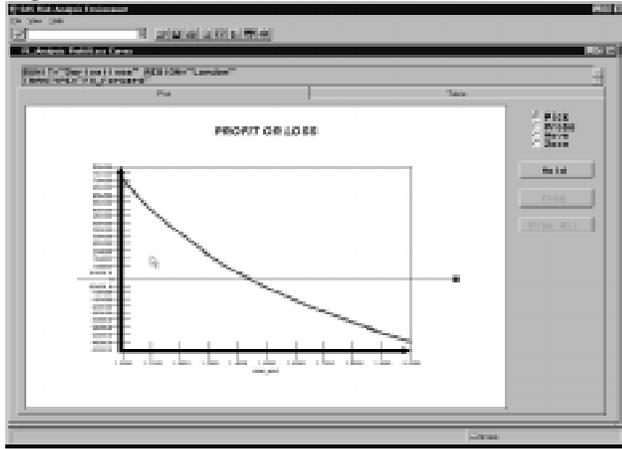
## Profit / Loss Curves and Surfaces

In addition to scenario analysis where the portfolio is revalued for a specified shock to the risk factors, you need to be able to measure the change in value to a portfolio for a range of values for a risk factor. This measurement is represented by a curve when the portfolio is exposed to one risk factor and a surface when the portfolio is exposed to multiple risk factors.

In the SAS Risk Analysis Environment, a P/L curve is produced by computing P/L for one specified risk factor over a user-specified linear grid. A P/L surface is produced by computing P/L for a specified pair of risk factors over a user-specified rectangular grid.

A sample P/L curve is shown in Figure 8 for a portfolio of FX Forwards where it is exposed to a range of values for the risk factor; foreign exchange rates.

Figure 8



## Current Exposure

Risk managers also need to measure risk exposures due to the failure of a counterparty to meet their obligations.

The SAS Risk Analysis Environment provides a means to associate transactions with the appropriate counterparty and the appropriate netting set. Current exposure for a group of transactions in a counterparty netting set is computed as the maximum of zero and the aggregated mark to market value of the transactions in the netting set.

## VaR by Delta Normal

Measuring the impact of many risk factors on a portfolio consisting of many complex instruments is more difficult than the simple task of measuring VaR on an individual instrument or a portfolio of the same type of instruments.

A common solution to this problem is to use the Delta Normal method. Assuming a multivariate normal density for changes in risk factors with a zero mean and user provided covariance matrix, VaR is computed by multiplying numerically calculated deltas for the portfolio with the covariance matrix.

## Modeling Subsystem

The Modeling Subsystem of the SAS Risk Analysis System can be used to specify, estimate, and then save models for risk factor evolution. The saved models can be used later in Monte Carlo simulations by which market and credit risk measures can be computed.

## Specifying Models for Risk Factors

Specifying models for risk factors and subsequently making the fitted models available for risk analysis is an arduous task when one must specify the models in one application and use them in another. This problem of creating models in one environment for use in another environment can be the case with proprietary risk management systems that are created by combining several legacy systems and applications.

In the SAS Risk Analysis Environment, specifications essentially consist of (possibly nonlinear) equations that the user can set up to model the conditional mean and the conditional variance of the dynamics of the risk factor. The Modeling Subsystem can accommodate nonlinearity in the conditional variance equation making possible non-normal distributions for the risk factors. Various types of GARCH are an example of this. Specifications are not tied to a particular set of parameters and can be reused.

## Fitting and Saving Models

The parameters in a model specification can be estimated based on user-provided data. A variety of estimation methods including Maximum Likelihood and Generalized Method of Moments are available. Estimated models containing all the relevant information such as the mean and variance equations, the parameter values and the residual vector can be saved for use in Monte Carlo simulations.

## Simulations

Risk management can involve using a model to predict the path for the evolution of a risk factor value. Simulations offer risk managers a means to value a portfolio of nonlinear instruments, such as options, at a specified time point using a risk factor from a future state of the market.

The generated market states are for a single user-specified time point or for a full path on a user-specified time grid. For each state of the market at a point in time, each transaction is fully valued using the user-specified pricing function. For each state of the market, P/L and/or exposure is calculated for as many levels of aggregation as requested by the user through the cross-classification feature. The sample draws thus obtained for the P/L or exposure distributions at various levels of aggregation are then used to summarize the distributions using measures such as VaR, maximum exposure, quantiles, etc.

## Methods for Generating Risk Factor Values

In the SAS Risk Analysis Environment, risk factor values for different future states of the market are generated according to user specifications, which can be either Historical, Covariance, and Monte Carlo.

## Historical

User-provided historical data is used to compute a set of changes in risk factor values at a specified frequency such as daily. This set of changes is used to repeatedly perturb the current set of risk factor values.

## Covariance

The user provides a covariance matrix for the log of the relative change in risk factors, that is,  $\log[x(t)/x(t-1)]$ , assuming zero mean and multivariate normality. Monte Carlo simulation is performed with this multivariate normal distribution to generate risk factor values.

## Monte Carlo

The user provides different univariate and/or multivariate models for different risk factors (for example GARCH models for some FX rates, CIR type models for some interest rates, etc.) all saved earlier in the modeling subsystem. The separate univariate or multivariate models for the different risk factors are combined to form a unified multivariate model that is capable of simulating all the risk factors on which the portfolio value depends. The key step in combining the models is calculating a correlation matrix for the error terms in the different models using the residual vectors that have been saved with the models. The unified multivariate model is used to perform Monte Carlo simulation to generate risk factor values.

## Summary Measures for P/L and Exposure Distributions

In the SAS Risk Analysis Environment, summary risk measures are available including:

- Value-at-Risk at specified critical values
- Potential Exposure at specified critical values and at specified time points
- Quantiles, Mean, Variance, Skewness, Kurtosis, etc.
- A Shannon Information Measure of the sensitivity of the P/L distribution at different levels of aggregation to different risk factors

## Reporting Tools

After identifying exposures and calculating risk measures for a firm, the risk manager must communicate these measures in a clear, concise, and constant manner.

The SAS Risk Analysis Environment includes an enterprise information system that can be used to report risk measures at the specified cross classifications or levels of aggregation.

Figure 9 illustrates risk measures reported at the Business Unit, Geographic, and individual portfolio levels. The user can navigate among the cross classification levels.

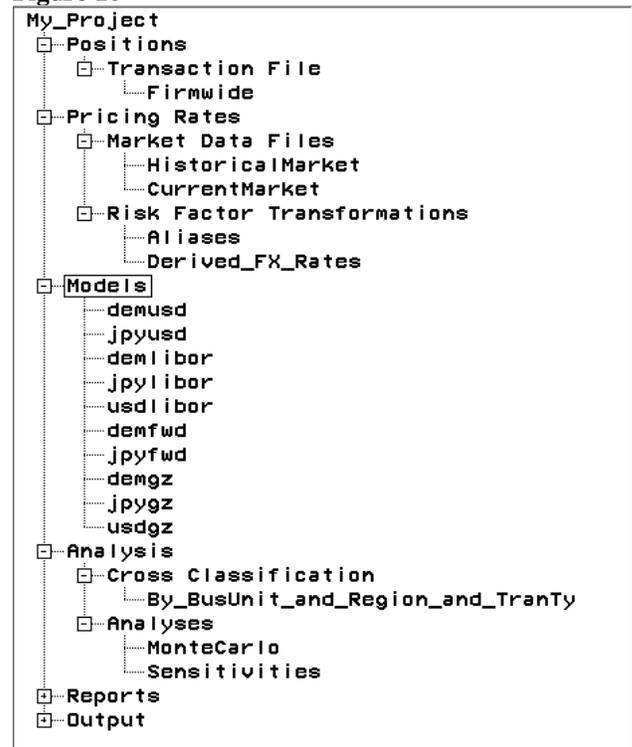
Figure 9

Business Unit			Value at Risk	
BU1			26923	
BU2	Asia	Equity	646	
		FX	1196	
		Interest Rate	314	
	BU2.1	Eastern Europe		2950
		North America		2468
		South America		2552
		Western Europe		3461
BU2.2			12296	

## Managing the Assets Required for Risk Measurements

Risk managers have to coordinate numerous assets in order to calculate firm-wide risk measures. The SAS Risk Analysis Environment uses the concept of a project and a project editor to manage these assets. Within a project, the risk manager specifies the position data, market data, models, cross classifications, analyses, and reports for the desired risk measures. Figure 10 shows the Project Editor Tree.

Figure 10



## Project Workflow

When a project is executed, the SAS Risk Engine selects the transaction file that has been specified in the project editor. In Figure 10, the transaction file “Firmwide” provides the snapshot of the portfolio that will be analyzed.

The market data required for the analysis that has been chosen is specified within the project editor. For My\_Project, both historical and current market data are required. The user has chosen to use a full Monte Carlo simulation and sensitivities analyses for My\_Project. You specify report templates and batch reports in the project editor.

When the user is satisfied that all the appropriate risk management assets have been selected for the project the project can then be run. The output of the project will be written to the specified path for distribution or subsequent analysis. With the project output results, the user is able to publish reports of the firm’s risk measures.

## Conclusion

Risk is not to be avoided but rather measured and managed. Risk is desirable when you know how much of it you actually have.

The volume and complexity of financial instruments has exploded over the past twenty years. In the past, risk could be managed satisfactorily by controlling an individual portfolio’s exposure to the relevant risk factors or hedging against the risk factors at a portfolio level. Today firms need to measure risk at an enterprise level in order to avert unanticipated financial results or failure.

Risk managers need to command and control vast amounts of data, models, analyses, and publishing tools to effectively identify sources of risk, measure the amount of risk, and communicate these measures throughout the firm.

The SAS Risk Analysis Environment provides risk managers with a system to command and control position and market data, model specifications, fitted models, various types of analyses, and risk measure reporting.

## References

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Jorion, Philippe, *Value at Risk: The New Benchmark for Controlling Market Risk*, Illinois, Irwin Professional Publishing, 1997.

## Acknowledgements

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