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Effective Risk Aggregation and Reporting Using SAS

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ABSTRACT

Both recent banking and insurance risk regulations require effective aggregation of risks. To determine the total enterprise risk for a financial institution, all risks must be aggregated and analyzed. Typically, there are two approaches: bottom-up and top-down in risk aggregation. In either approach, financial institutions face challenges due to various levels of risks with differences in metrics, data source, and availability. First, it is especially complex to aggregate risk. A common view of the dependence between all individual risks can be hard to achieve. Second, the underlying data sources can be updated at different times and can have different horizons. This in turn requires an incremental update of the overall risk view. Third, the risk needs to be analyzed across on-demand hierarchies. This paper presents SAS® solutions to these challenges. To address the first challenge, we consider a mixed approach to specify copula dependence between individual risks and allow step-by-step specification with a minimal amount of information. Next, the solution leverages an event-driven architecture to update results on a continuous basis. Finally, the platform provides a self-service reporting and visualization environment for designing and deploying reports across any hierarchy and granularity on the fly. These capabilities enable institutions to create an accurate, timely, comprehensive, and adaptive risk-aggregation and reporting system.

INTRODUCTION

Risk management for financial institutions involves risk measurement, monitoring, and management at individual risk levels such as market risk for trading book, credit risk for trading and banking book across business lines and legal entities as well as the enterprise level. To determine the total enterprise risk for a financial institution, all risks must be aggregated and analyzed. The global financial turbulences in the last decade have exposed risk aggregation as one of the weakest links in institution's technology and risk architecture. This weakness hinders the efficient and effective risk-based decision making that could help institutions improve their responses to internal and external crises.

Risk aggregation, as defined by the recent Basel Committee (2013a) paper "Principles for effective risk data aggregation and risk reporting", is about defining, gathering and processing risk data according to the institution's risk reporting requirement. This knowledge enables the institution to measure its performance against its risk tolerance and appetite. The process includes data collection, management, risk analysis on top of the aggregated data and consistent reporting. In the same paper, fourteen principles were laid out by the committee to warrant sound "overarching governance and infrastructure", "risk data aggregation capacity", "risk reporting practices", and "supervisory review, tools, and cooperation". In a follow-up paper Basel Committee (2013b) reported compliance difficulties in especially in data architecture, data accuracy, completeness, timeliness and adaptability based on the self-assessments from the global systematically important banks.

In this paper we discuss building an effective risk-aggregation and reporting system using the latest SAS analytical and reporting technology.

RISK AGGREGATION INFRASTRUCTURE

For both regulatory and internal management purpose, accurate and comprehensive risk aggregation provides an enterprise or portfolio view of the total risks and exposures. It allows the decision makers and analysts to look for trends, risk concentrations, and risk contributions. In practice risk aggregation is complex. Organizational silos, disparate data sources, varying data formats, data quality, frequencies, analytics, and reporting hierarchies are just some of the sources of the complexity.

The situation is further complicated by the need to aggregate massive volumes of data volume from the most granular level. Another complexity is the different risk horizons when aggregating different risks. Market risk on the trading book typically has the shortest risk horizon and thus more frequent and regular data while credit risk on the banking book has the longest risk horizon and a very large number of exposures. Non-financial risks such as operational, reputational and other material non-financial risks can be assessed using a different quantitative approach. Another financial risk, liquidity risk adds additional complexity because it is a consequential risk.

Rolling all risks up across business lines, legal entities, and other reporting dimensions is a daunting task. Even simple changes such as altering a reporting hierarchy can require a significant effort for many institutions.

From a data point of view, building a consolidated risk data warehouse is a critical first step. As a second step an adaptive, scalable risk aggregation system mitigates difficulties and increase the efficiency.

SAS provides risk data warehouse and risk reporting models to help institutions collect source data in a consistent and comprehensive manner. SAS data management tools also help improve data quality and integrity. Although a consistent risk platform is ideal, in reality, institutions are most likely to have functioning risk management systems for the individual risks. The infrastructure of the SAS risk aggregation and analysis platform does not require replacing these existing functioning systems, but instead, works with the systems to source the pre-calculated results for aggregation and post-aggregation risk analysis for example Value-at-Risk, Expected Shortfall and incremental/marginal risk impact analysis.

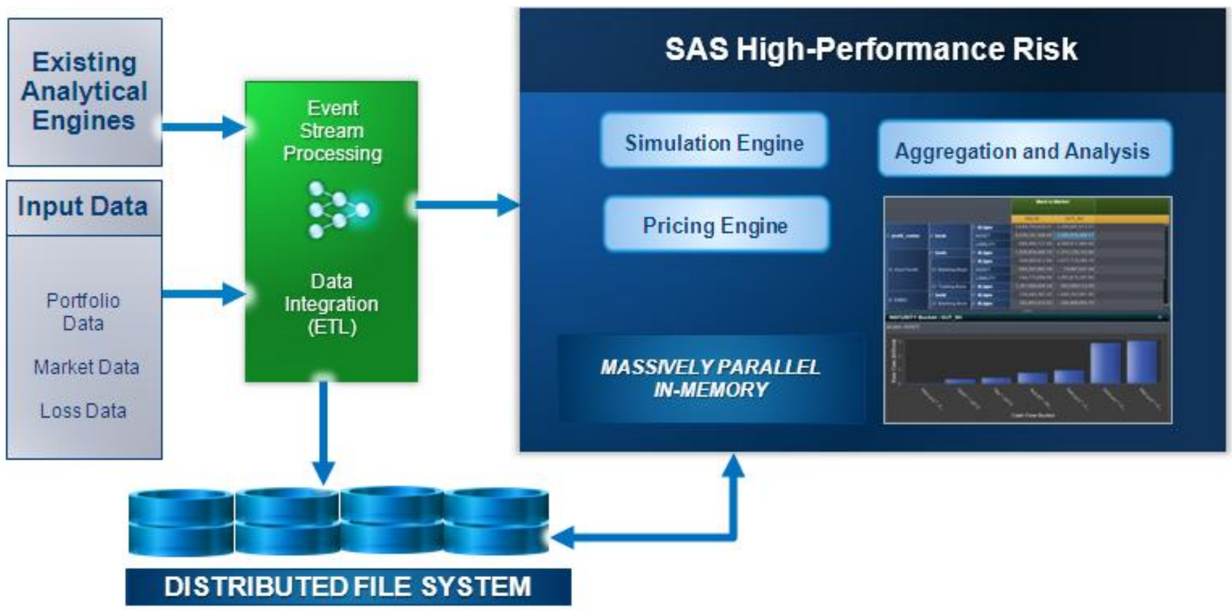


Figure 1. SAS risk aggregation infrastructure

Figure 1 represents a high-level risk aggregation process with automation and data orchestration supported by SAS. The core of the SAS Risk Aggregation platform is SAS High-Performance Risk, which is the new generation of SAS risk engine using the in-memory grid computing technology. SAS High-Performance Risk itself is a simulation and pricing engine. It can incorporate simulation and pricing models in SAS and C/C++ libraries. It is also an aggregation and risk analysis engine that can quickly execute tasks on an on-demand hierarchy.

At the most granular level, the system sources computed results from the institution's existing analytical systems, together with the portfolio results computed within the SAS High-Performance Risk engine. The granularity in the system allows adaptive slice-dice of the entire portfolio using the fast in-memory technology. The system also provides a rich set of out-of-box risk measures ranging from the classical Value-at-Risk to contribution and incremental risk analysis. Unlike the traditional OLAP type of reporting mechanism, the aggregation and risk aggregation are all done on-the-fly per user's requests. It dramatically shortens and simplifies the delivery process when a new analysis hierarchy or a new risk measure is to be introduced. For example, when the Greek crisis hit the market in 2011-2012 many institutions had a hard time reporting their exposures to Greek counterparties because this subset of the portfolio was not on the reporting hierarchy by itself.

Also included in the SAS risk aggregation platform is the data integration and quality control capability. Depending on the use case, the system offers two data extraction, transformation and loading (ETL) options. The first option is based on low latency event driven data streaming technology to move data from various source systems to the risk analysis and aggregation engine without much of the data I/O. This option is particularly useful for near real-time end-to-end risk aggregation and analysis. For example, pre-deal incremental risk analysis or continuous risk limit monitoring at portfolio level.

A recent real case study of a trading book risk aggregation for a global investment bank proved that the SAS Event Stream Processor was able to handle 4,000 simulated profit and loss vectors. The same processor was also able to join 3.5 million Profit and loss vectors with trade attributes in under a second. The SAS High-Performance Risk engine performed risk aggregation from the trade profit and loss vectors and allow user to request on-demand hierarchical risk measures within minutes.

The event driven process allows the institutions to pre-configure scenarios that trigger a new data and risk aggregation update. The system also enables a virtual "join" of the underlying source data that accommodates incremental update instead of full update of the underlying sources. Therefore, the aggregated risk analysis is always up-to-date while remain comprehensive and accurate.

The second option of the risk ETL is through a more traditional data integration process that accommodates more sophisticated data management for governance, quality, lineage, and integrity. This option is more suitable for enterprise risk aggregation and reporting that must include all risk types across all business lines. The grid enabled process together with SAS High-Performance Risk engine can still provide fast on-demand risk aggregated analysis.

Lastly, the SAS risk aggregation platform as revealed in Figure 1 also supports a wide range of data storages. The system provides and keeps improving a grid failover and data backup. To achieve the best performance of the overall system, a high-performance database is highly recommended.

RISK AGGREGATION METHODOLOGY

Ideally a consistent set of market and economic risk factors must be modeled and applied to the most granular level so that the modeling details can be exercised against the risk factors and the aggregated impact of the changes to the earnings and losses can be evaluated for the entire institution. Recently, regulators have also focused on stress tests and scenario analyses that focus on the joint behavior of risk factors across risk types that cover banks all material lines of businesses. Examples include the Comprehensive Capital Assessment Review (CCAR) mandated to banking holding companies by Federal Reserve, and the European Banking Authority's EU-wide stress tests. The regulatory stress tests not only help institutions to assess firm-wide risk but also help regulators to understand the overall impact of the banking system resilience within their jurisdiction by rolling the scenario-based outcomes up one more level. In order to achieve accuracy of the calculation in the scenarios, finest granularity must be retained in order to capture the exact response to the scenario. This imposes a large computational challenge to banks with large portfolios. This bottom-up approach can be extended to simulation-based analysis as well but introduces more computational burden to the system because of the additional dimension introduced by the simulation numbers and horizons. Simulated earnings and losses must be aggregated along the same scenario and horizon first.
Finally, risk measures are calculated on top of the aggregated simulated outcomes. Only in the recent years, thanks to the advances in technology can such massive computation be accomplished in a timely fashion. SAS High-Performance Risk engine builds risk intelligence on the in-memory grid based technology to speed up calculation and reduce I/O cost. It also adds special techniques such as virtual data join to effectively accommodate data append and delta changing.

The following excerpt is from a SAS log where an aggregated risk is created by virtually joining the five different books in a bank. In SAS High-Performance Risk a unit of data collection is called a risk cube which only contains the most granular data that can then be organized into hierarchical aggregated results per the end user's requests. Each risk cube has a descriptor file associated with it for the system to find relevant data on the grid. In this example, five descriptor files each correspondent to a data source are located on a net drive. A virtual join can then be created by the JOINCUBES task command, which creates a new descriptor file on the same drive (or a different location per user's specification) that links all the data sources together. It is therefore a very fast process.

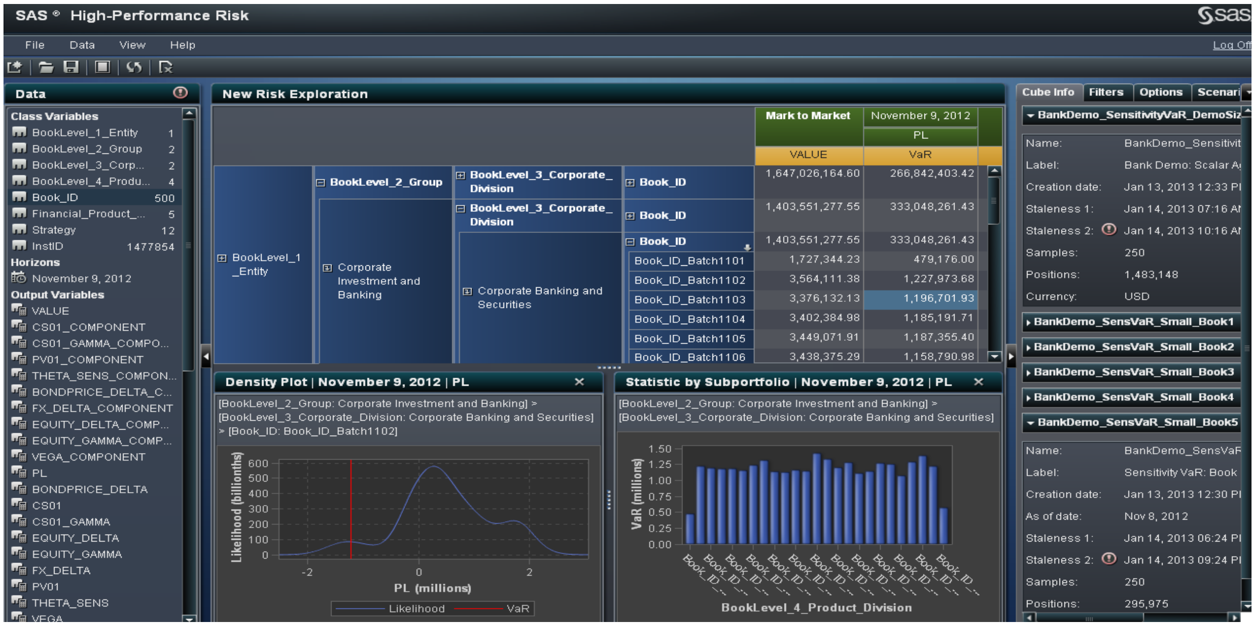
```
%let cubeloc=\\netdrive\risk\hprisk_cube_descriptors\hprisk\;

proc hprisk
     task = JOINCUBES
     cube = "%trim(%left(&cubeloc))BankDemo_SensitivityVaR_Aggregated"
     subcubes=("%trim(%left(&cubeloc))BankDemo_SensVaR_small_Book1"
               "%trim(%left(&cubeloc))BankDemo_SensVaR_small_Book2"
               "%trim(%left(&cubeloc))BankDemo_SensVaR_small_Book3"
               "%trim(%left(&cubeloc))BankDemo_SensVaR_small_Book4"
               "%trim(%left(&cubeloc))BankDemo_SensVaR_small_Book5"
              );
run; quit;
```

```
NOTE: The JOINCUBES task wrote the combined cube descriptor
```

```
      \\netdrive\risk\hprisk_cube_descriptors\hprisk\
BankDemo_SensitivityVaR_Aggregated.rskcdesc.
NOTE: PROCEDURE HPRISK used (Total process time):
      real time           00:01.20
      cpu time            00:01.19
```

Display 1 shows a risk exploration with virtual data join. The right panel shows the information of the individual data sources. The aggregated risk cube in this risk exploration consists of five banking and trading books in a demo bank. The total number of positions in all the five books is 1,483,148 positions. There are 250 simulated scenarios applicable to all the five books. Because individual data sources can be updated independently, the system allows each data source to specify its data validity. A data staleness indicator at level of green (valid), yellow (slightly overdue) or red (overdue) is applied to each source based on the validity. The overall aggregated data validity is based on all its sources. It provides clear timeliness of the aggregated data. In this example, the aggregated data is overdue because at least one data source is overdue (Book5).



Display 1: Risk exploration with virtual risk cube join

Despite careful data management and advanced computational power, complete bottom-up aggregation from every risk type, across every line of business, using joint models might still be impractical. This includes, for example, the difficulty of specifying granular risk factor-level dependence. Hence, in practice, enterprise risk measures will be a combination of bottom-up risk aggregation and a top-down risk aggregation approach. The risk types and lines of business that can be aggregated bottom-up becomes a marginal input source to the top-down risk aggregation approach. Aggregate enterprise risk can then be obtained at a second level - applying the top-down risk aggregation approach. It is in principle also possible to include non-financial risks in a risk aggregation approach to enterprise risk. For example, quantification of strategic and reputational risk is often modeled in a similar way to operational risk processes. That is, it is event and severity based. The events and their severity are usually assessed by expert views. The outcome is however still a marginal loss distribution. The assignment of event probabilities and correlations allow non-financial risks to be aggregated with other financial risks. Mixing the top-down with the bottom-up approach can improve the efficiency of the aggregation modeling. The top-down approach is frequently used in the financial industry. The delta-normal Value-at-Risk for market risk has been in practice for about two decades. The insurance solvency regulation enacted by the European Parliament (2009) also known as Solvency II applies the correlated aggregation to many levels of aggregation. More advanced copula-based aggregation is gaining popularity in both banking and insurance industry because of the nice mathematical property of copulas.

The SAS risk engine includes a special procedure to allow a flexible specification of copula hierarchy and structure. We refer readers who are interested in more technical details of this mixed copula aggregation algorithm to Skoglund *et al* (2013).

The following code is an example of the aggregation procedure syntax. The user can specify the source of the marginals, copula specifications and can apply copulas to different levels in a hierarchy. The marginal input to the aggregation can be either the fully simulated results from the source data or in an analytical distribution form.

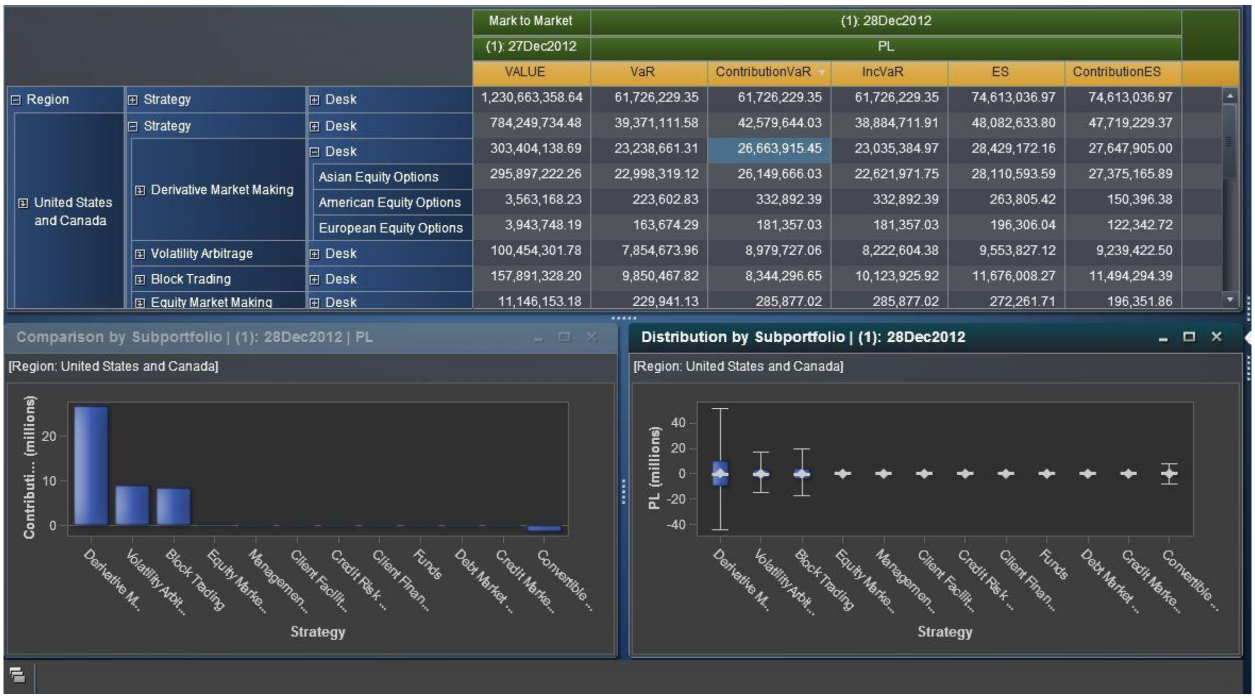
```
proc aggregation env = mylib.aggrenv name=sampleaggr
  vars =( pl comptype=pl)
  ccv =(bunit region)
  config_data = mylib.config
  copula_spec=mylib.copula_01
  marginal_spec=mylib.marginal_01
  ndraws = 5000
  tolerance = 1.e-8
  out_simdata = mylib.simmarg_01
  out_statdata = mylib.statmarg_01
  ;
runaggr;
run;
```

Because of the granularity involved in these aggregation methodologies, risk can be decomposed, attributed, and allocated to both risk factors and portfolio sources. The risk information measures resulted from the aggregated risk analysis area nonparametric statistics that attribute the risk of each slice of the portfolio to a specific set of risk factors. This is useful for the risk analyst and decision makers to understand the source of risk to each part of the portfolio. The measures can also assist the construct of the reverse stress testing to identify the impact of risks.

Display 2 is an example of the risk information chart for the emerging market subportfolio of an institution's trading portfolio. In this example, among all the top ten risk factors, the Asia Pacific and China indices are clearly the most influential to the subportfolio's profit and loss risk. For more details about this topic see Skoglund and Chen (2009).

Display 2. Risk factor information measure for an emerging market subportfolio

The portfolio risk contribution and allocation is key to modern risk-based pricing and performance analysis. The SAS risk engine calculates these measures following the industry standard Euler decomposition algorithm (see Tasche (2007)). Display 3 shows risk contribution and incremental risk analysis for a trading portfolio, which is aggregated across region, strategy, and desk. The portfolio Value-at-Risk close to $62 million can be attributed to each region, strategy, and desk through the several risk decomposition measure. The Value-at-Risk contribution, *ContributionVaR* provides information on how each slice of the portfolio contributes to the overall risk. Therefore, it can be used to allocate the overall risk or total requirement capital into each subportfolio for performance adjusted performance analysis. Users can also sort the result or plot by *ContributionVaR* to examine top contributors. Incremental Value-at-Risk, *IncVaR* carries a different economic meaning than Contribution Value-at-Risk. It means how much excessive risk is introduced into the portfolio when a subportfolio is added. A closely related measure Value-at-Risk without, *VaRWO* is also available in the application. These risk attributions are not for risk allocation but useful for risk acquisition analysis. If Expected Shortfall is used together with or instead of Value-at-Risk, the same results can be calculated.



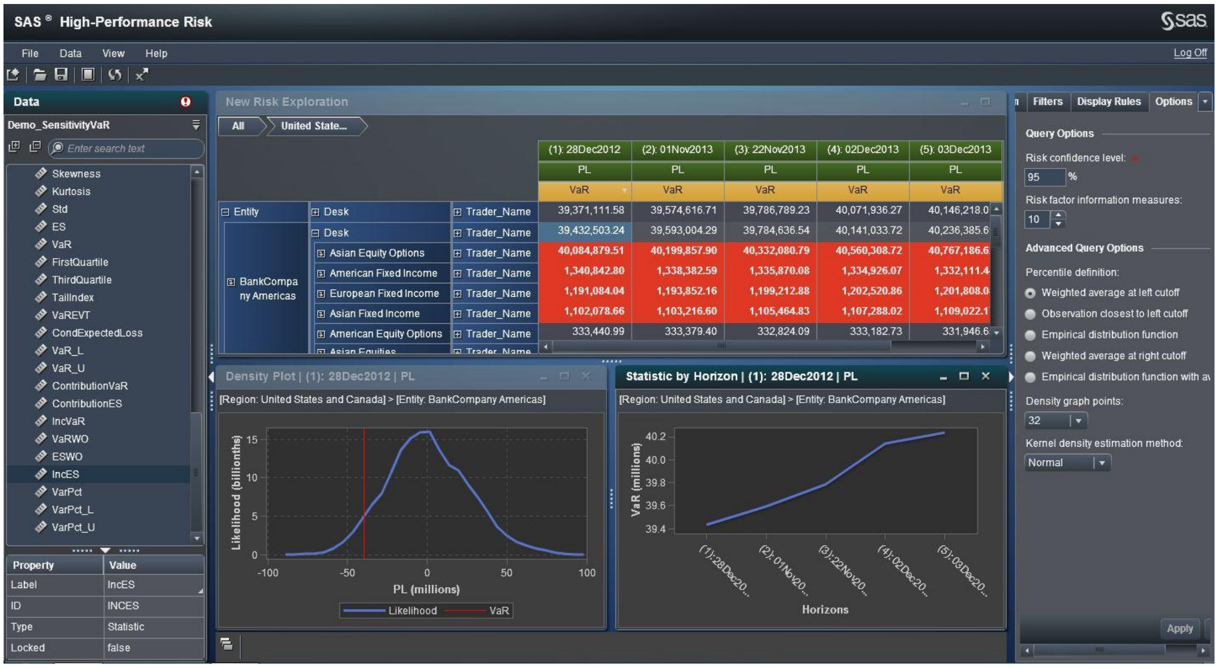
			Mark to Market	(1): 28Dec2012				
			(1): 27Dec2012	PL				
			VALUE	VaR	ContributionVaR	IncVaR	ES	ContributionES
Region	Strategy	Desk	1,230,663,358.64	61,726,229.35	61,726,229.35	61,726,229.35	74,613,036.97	74,613,036.97
United States and Canada	Strategy	Desk	784,249,734.48	39,371,111.58	42,579,644.03	38,884,711.91	48,082,633.80	47,719,229.37
	Derivative Market Making	Desk	303,404,138.69	23,238,661.31	26,663,915.45	23,035,384.97	28,429,172.16	27,647,905.00
		Asian Equity Options	295,897,222.26	22,998,319.12	26,149,666.03	22,621,971.75	28,110,593.59	27,375,165.89
		American Equity Options	3,563,168.23	223,602.83	332,892.39	332,892.39	263,805.42	150,396.38
		European Equity Options	3,943,748.19	163,674.29	181,357.03	181,357.03	196,306.04	122,342.72
	Volatility Arbitrage	Desk	100,454,301.78	7,854,673.96	8,979,727.06	8,222,604.38	9,553,827.12	9,239,422.50
	Block Trading	Desk	157,891,328.20	9,850,467.82	8,344,296.65	10,123,925.92	11,676,008.27	11,494,294.39
	Equity Market Making	Desk	11,146,153.18	229,941.13	285,877.02	285,877.02	272,261.71	196,351.86

Display 3. Risk contribution and incremental risk analysis for a trading portfolio

RISK AGGREGATION EXPLORATION AND REPORTING

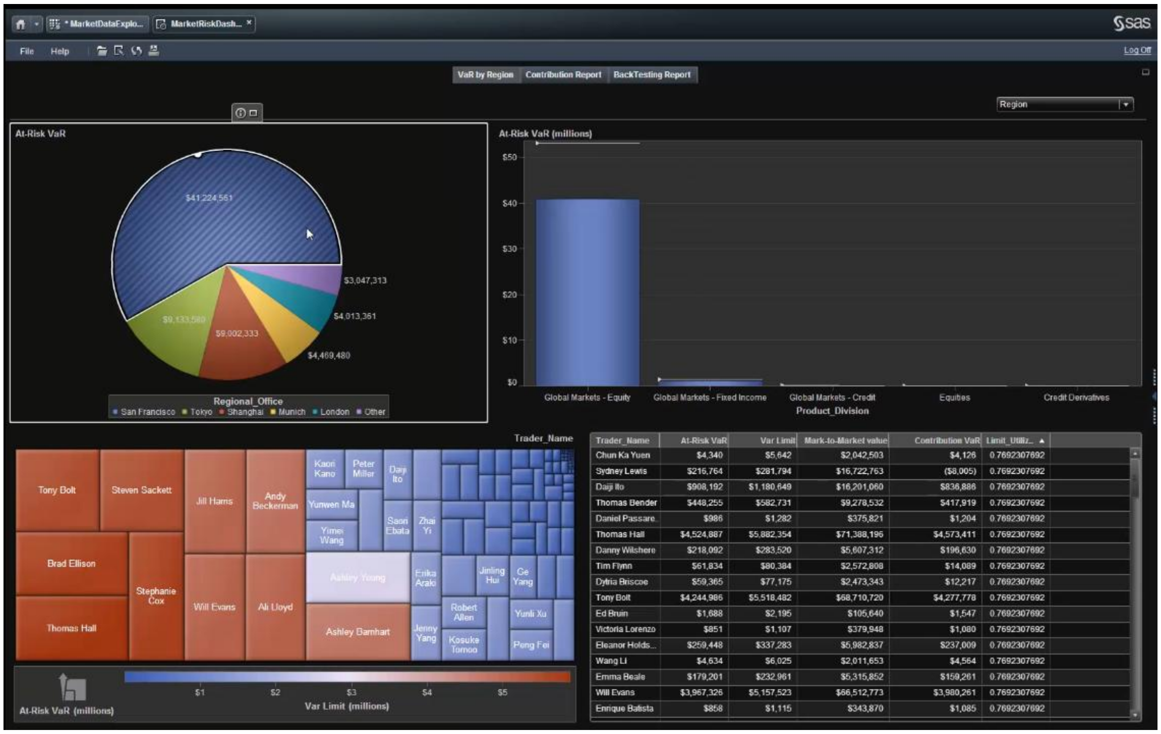
Besides the principles of accuracy, comprehensiveness, timeliness, and adaptability already exemplified by the SAS system above, a risk aggregation system must communicate information in a clear and concise manner. The system should provide comprehensive yet intuitive information with ample visual summarization. A risk exploration component should aid the decision makers to drill into lower level details for any area of interest. In addition, online ad hoc reports should be securely and conveniently accessible by the management. The content should also be customized for each reporting scenario that the management needs. SAS web based risk exploration and visual analytics tools provide exactly these capabilities.

Display 4 is a screen shot of a sample risk exploration. The risk object navigation panel in the left organizes the data into dimensions and measures. Measurements are further divided into system computed, ad hoc computed and risk statistics. Users can build the exploration content by selecting dimensions to build an on-demand hierarchy, computed measures, and statistics into the middle exploration canvas. Also available to the selection are time horizons and scenarios for stress tests. The middle panel allows users to create exploration to any slice-dice specification, drilling down to a specific portion (for example, all trades by certain traders in the desks of certain legal entities in certain regions). Users can position data table and graphs into this exploration canvas. In this particular exploration, the user is examining a trading portfolio across business entities, desks and traders. The risk analysis starts from Value-at-Risk on the profit and loss for five horizons. The application offers several graphical and analytical tools for data exploration and visualization. Also displayed in this example are the profit and loss distribution for the Americas business entity (*BankCompany Americas)* and a line plot of the trend of the Value-at-Risk trend. The subportfolios where Value-at-Risk exceeds 5% of the mark-to-market value today are highlighted. The conditional highlight rules can be specified by a user based on an absolute target such as 5% in this example, relative to other horizons or benchmarks such as limits set to the subportfolio. Users can also apply several risk calculation rules including the Value-at-Risk confidence level on the fly in this application. The left and right panels can be collapsed to give more space to the exploration. A user can also save a specific exploration and apply it to any updated data or share it with colleagues. The right panel contains information about the aggregated data and source data, allowing users to create filters, specify risk analysis options and define display rules for conditional highlight and so on.



Display 4: Sample risk exploration

The application allows users to drill into more analytical details, for example, risk factors, demographics, and historical trends and risk heat maps. Standard report templates can then be built on the fly based on regulatory and management requirements or ad hoc needs. Display 5 is a sample dashboard risk report that provides Value-at-Risk breakdown view across region, product, and trader. As a report to the management the report view contains more visualization content but less exploration details than is delivered in Display 3. It is done to make sure the information is conveyed to the audience in an appropriate fashion, which is a reporting principle prescribed by Basel (2013). The report template can be saved and applied to any updated data incidences. The on-demand reporting capability not only enables timely and adaptive reporting but also improves the productivity of the information technology personnel in financial institutions. Reports can also be made available on mobile devices for convenient access.



Display 5: Sample dashboard report showing VaR breakdown across Region, Product, and Trader

CONCLUSION

Effective risk aggregation and reporting are critical for financial institutions to meet regulatory requirements and stay competitive in business. SAS risk aggregation and reporting platform provides a powerful yet flexible infrastructure that is equipped with the latest risk analytical mythologies, exploration, and reporting capabilities to enable financial institutions to achieve accurate, comprehensive, timely, clear, and adaptive risk aggregation and reporting.

REFERENCES

Basel Committee on Banking Supervision. 2013a. *Principles for effective risk data aggregation and risk reporting*. Basel, Switzerland: Bank for International Settlements Communications.

Basel Committee on Banking Supervision. 2013b. *Progress in adopting the principles for effective risk data aggregation and risk reporting*. Basel, Switzerland: Bank for International Settlements Communications.

European Union and Parliament. 2009. “Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the Taking-Up and Pursuit of the Business of Insurance and Reinsurance (Solvency II).” Official Journal of the European Union.

Skoglund, J, and W. Chen. 2009. "Risk Contributions, Information and Reverse Stress Testing." *Journal of Risk Model Validation* 3(2).

Skoglund, J, D. Erdman and W. Chen. 2013. "A mixed approach to risk aggregation using hierarchical copula." *Journal of Risk management in Financial Institutions* 6(2).

Tasche, D. 2007.Euler Allocation: Theory and Practice, available at: http://arxiv.org/abs/0708.2542.

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