Regulatory Stress Testing—A Manageable Process with SAS®

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ABSTRACT

As a consequence of the financial crisis, banks are required to stress test their balance sheet and earnings based on prescribed macroeconomic scenarios. For example, in the US, this exercise is known as the Comprehensive Capital Analysis and Review (CCAR) or Dodd-Frank Act Stress Testing (DFAST). In order to assess capital adequacy under these stress scenarios, banks need a unified view of their projected balance sheet, incomes, and losses. In addition, the bar for these regulatory stress tests is very high regarding governance and overall infrastructure. Regulators and auditors want to ensure that the granularity and quality of data, model methodology, and assumptions reflect the complexity of the banks. This calls for close internal collaboration and information sharing across business lines, risk management, and finance. Currently, this process is managed in an ad hoc, manual fashion. Results are aggregated from various lines of business using spreadsheets and Microsoft SharePoint. Although the spreadsheet option provides flexibility, it brings ambiguity into the process and makes the process error prone and inefficient. This paper introduces a new SAS® Stress Testing solution suite that can help banks define, orchestrate, and streamline the stress-testing process for easier traceability, auditability, and reproducibility. The integrated platform provides greater control, efficiency, and transparency to the regulatory stress testing process. This will enable banks to focus on more value-added analysis such as scenario exploration, sensitivity analysis, capital planning and management, and model dependencies. Lastly, the solution was designed to leverage existing in-house platforms that banks might already have in place.

INTRODUCTION

The 2007 financial crisis saw a lack of preparation for the liquidity crunch and capital drains in many financial institutions. Inadequate preparation for crises can lead to systemic risk and severe economic and political turmoil. With the lessons learned from the 2007 financial crisis, regulators are now requiring both quantitative and qualitative methodologies for robust, forward-looking capital-planning processes that account for each bank's unique risks under common regulatory scenarios.

In the wake of the 2007 financial crisis, the SCAP exercise began in the U.S. in 2009. Now its successor, CCAR (Comprehensive Capital Analysis and Review), has become a major focus of the top banks in the U.S. Thirty one banks including a few global bank holding companies in the U.S. are required to submit annual capital plans to the Federal Reserve for review in the 2015 submission. However, smaller banks are also joining the group. The DFAST (Dodd-Frank Act Stress Testing) regulation requires U.S. banking organizations with consolidated assets of $10 billion or more to conduct stress tests. The same evolution of the firm-wide stress testing has been followed by other regulators around the world, for example, in Europe with the EBA/ECB stress testing. In Europe, banks may also face country-specific firm-wide stress test regulations. An example is the Prudential Regulation Authority in the UK where the prescribed macroeconomic scenarios are also to some extent overlapping with the EBA prescribed macroeconomic scenarios. The outcome of the regulatory stress testing can have significant impact on the banking system as well as the individual banks. It is true for the SCAP era to the annual CCAR in the U.S. and the most recent EBA stress testing (24 out of 123 participating banks failed the stress check, according to The European Banking Authority 2014).

Initially, regulators emphasized credit losses and revenue by stressing a few macroeconomic risk factors - as was the focus of SCAP in the U.S. in 2009-10. Today, regulators are interested in not only the effect of stress scenarios on credit performance and revenue, but also the stressed results on a broader array of measures that include liquidity and full balance sheet projections. In other words, stress testing must now be an integral part of the bank's capital plan. The requirement to assess the influence of stress scenarios across these different measures has created many challenges for financial institutions. Stress testing has become a systematic way to examine and identify an institution's financial vulnerability.

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MANAGING A HOLISTIC STRESS TESTING PROCESS

Building a solid firm-wide stress testing process is done through several iterations that need constant improvement and investment. The firm-wide stress testing process not only allows a bank to gauge its capacity to meet regulatory capital requirements such as CCAR and DFAST, but also significantly improves an institution's ability to identify and prevent potential issues that may affect its revenue, liquidity, market growth, and earnings. In a typical stress testing ecosystem as shown in Figure 1, various parties including risk, treasury, finance, and lines of business employ a number of systems to accomplish the necessary processes ranging from data management, modeling, and scenario management to the calculations, planning, and adjustment needed for the final capital stress testing. The entire process must be well governed with properly documented policies and assumptions.

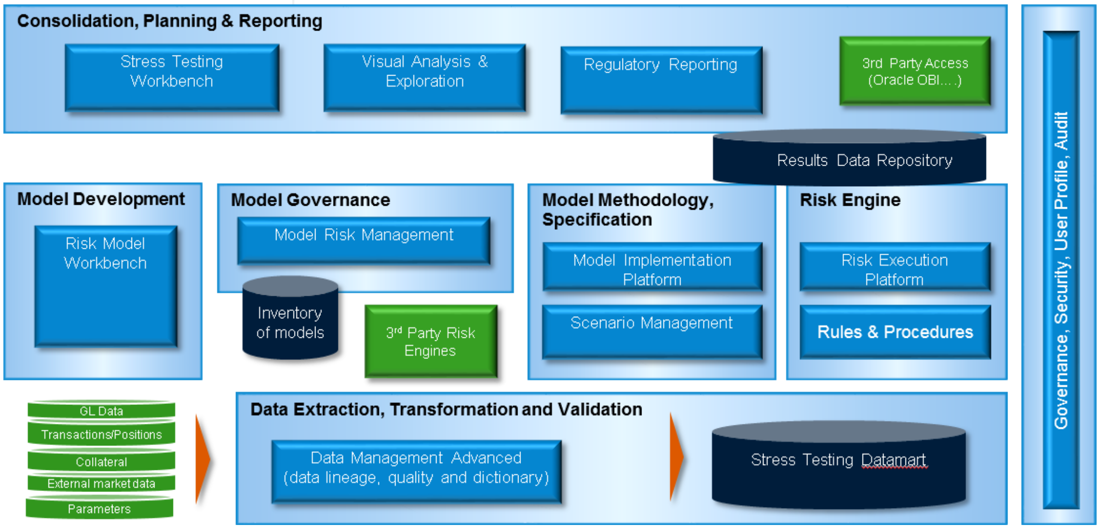


Figure 1: Illustration of a Stress Testing Ecosystem

The total balance sheet-based firm-wide stress testing exercise certainly calls for adherence to sound data management principles. The need to integrate both risk and financial measures into stress scenarios when creating the capital plan is the other challenge in the firm-wide stress testing. These common requirements appear in most regulatory stress testing regimes and require banks to quantitatively project assets, liabilities, income, losses, and capital across a range of macroeconomic scenarios. Since these functions are traditionally operated in independent silos, the regulatory firm-wide stress testing constitutes a change in practice for many financial institutions and has an impact on how banks manage risk beyond the stress testing itself. Such collaboration requires a coordinated systematic support that maintains a good degree of efficiency and accountability. Project governance thus becomes important.

The first process in the entire stress testing ecosystem is obviously on the data-related issues. Comprehensive stress testing poses higher demands on the data provisioning, data consolidation, and data aggregation. Different parties in the stress testing project must operate on a reconciled data source, with a consistent data definition and they must map to a common data hierarchy so that the input and the output of every party's operation can be brought to a common ground.

The second challenge in this round of the regulatory stress testing lies in the quality of the quantitative results. Models are required to best describe the behavior of both asset and liability projections that can capture the loss, income, risk provisions, and capital in a scenario-sensitive manner and reflect the bank's true unique risk. The granularity and transparency of the models continue to be challenged by the regulators. The model development, calibration, and validation are therefore brought to center stage of the regulatory stress testing. Model governance and implementation therefore faces unprecedented challenges in that only models that go through rigorous validation process can be used in the stress-testing submission and these models are often applied to a very granular level of a bank's portfolio capturing all the key aspects of the consumer and business behavior.

Regulators provide stress scenarios that contain a number of key macroeconomic factors. However, many of these factors do not impact, or only indirectly impact, a bank's specific business. Banks are thus required to augment and enhance the scenarios to include the regional and bank's idiosyncratic risk factors that influence the regulatory scenario. Even if banks can purchase some enhanced scenario from vendors, banks are still responsible for managing and explaining the significance of the scenarios. In some jurisdictions reverse stress testing is required to support the stress testing scenarios. Sensitivity analysis and additional bank-specific scenario analyses are useful to support the bank's regulatory stress testing and present values beyond that.

The firm-wide stress testing is a process that requires many iterative calculations on credit loss, and in some cases market profit and loss, based on global shock on the international investment banks provisions and risk-weighted assets as well as the pre-provision net revenue from interest income and expenses and non-interest income. The forward looking projection also requires that all these calculations take into account the growth assumption as well as the bank's capital and business policies under the respective scenarios. There are inevitably back and forth communications of the results, adjustments, and management overrides in the entire process. Unfortunately because of the disparate systems operated by various teams the communication of the results are usually ad-hoc and hard to track. Many banks rely on spreadsheets and manual recording of the results for the collaboration. As a result, the process lacks efficiency, is hard to audit, and progress is difficult to monitor. During the months of a regulatory stress-testing season, the teams involved in the project constantly remain in fire drill mode but are often still unable to satisfy the regulations. The disconnection between the model development and production is another challenge especially for the large banks. For sophisticated granular level models, banks typically face challenges in model integrity, implementation efficiency, and execution speed.

These challenges are reflected by the regulatory stress testing outcomes. For example the Board of Governors of the Federal Reserve System (2014) in their retrospective themes from CCAR 2014 and are expected to be properly addressed in 2015 and onward. Banks (for examples, Hansis 2012, PWC 2014 and Faenza 2015) are also striving to address these challenges and call for an effective stress testing ecosystem that not only alleviates the burden of stress testing projects but also makes stress testing more relevant to the actual business planning and management. The SAS Stress Testing solutions address these challenges in a holistic manner by providing an end-to-end orchestration of a stress testing exercise ranging from data management, model life cycle management, model integration and implementation, scenario management, aggregation, and capital planning all the way to reporting. The solution also allows banks to apply modules in the solution to augment their existing stress testing system to address specific challenges. This paper will focus on three specific areas that SAS can help in making a regulatory stress testing process manageable.

ANALYSIS CONSOLIDATION, CAPITAL PLANNING AND REPORTING

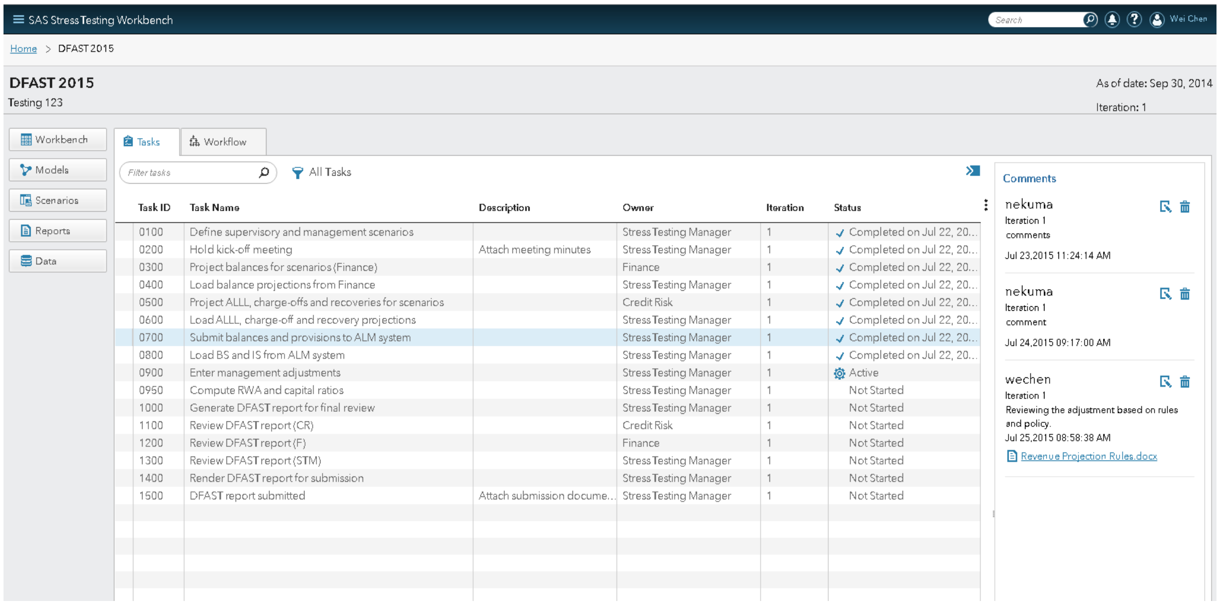
The SAS® Stress Testing Workbench provides an integrated environment for managing financial data collection, aggregation, allocation between multiple hierarchies, and forward projection to support capital planning and reporting. Even if not all the tasks in a stress test are in one system like SAS, the workbench serves as a hub for all the results to be consolidated across different working hierarchies, and can be used for final reporting. The workbench also provides out-of-the-box basic accounting capabilities such as balancing a balance sheet, rolling over line item values over projection horizons, and auditing all the adjustments and overrides.

Firstly, a bank can customize one or more stress testing workflows to standardize stress testing processes and improve the governance and documentation of the stress testing projects. The workflow capability also will assist stress testing users in tracking and completing the assigned action items. It allows stress testing managers in overseeing and auditing the end-to-end process.

Display 1 is an example of the workbench hub where a user can create or work on a user-defined regulatory stress testing project called "DFAST 2015". It provides a list of the open task(s) under the user.

If the task can be accomplished within SAS then the user can launch an action directly from the task list. Each task allows user to insert comments and attach supporting documents. In addition the user can also get an overview of the status and the task owner of the key tasks in the project so that the user may understand the context of his or her work. The workbench also shows a graphical view of the standardized workflow with status indicators for the stress testing process.

The SAS Stress Testing workbench provides a user all the key functionalities that are critical to a stress testing project. The user can configure how calculations are done through models, define hierarchies of the data sources, and reconcile different hierarchies through many-to-one or one-to-many mappings with user selected aggregation and allocation rules (Display 2). It enables transparency of the data lineage in the system and automates data loading. The workbench also allows a user to manage models, define scenarios, and carry out other analyses such as a loan loss analysis. In the rest of this section we will focus on data collaborations and reporting. The other parts of the workbench include summary information on the project workflow indicators of the status of the various tasks in the project and the tasks that the login user is scheduled to complete as well as high level financial information.



DFAST 2015
Testing 123

As of date: Sep 30, 2014
Iteration: 1

Task ID	Task Name	Description	Owner	Iteration	Status
0100	Define supervisory and management scenarios		Stress Testing Manager	1	✓ Completed on Jul 22, 20...
0200	Hold kick-off meeting	Attach meeting minutes	Stress Testing Manager	1	✓ Completed on Jul 22, 20...
0300	Project balances for scenarios (Finance)		Finance	1	✓ Completed on Jul 22, 20...
0400	Load balance projections from Finance		Stress Testing Manager	1	✓ Completed on Jul 22, 20...
0500	Project ALLL, charge-offs and recoveries for scenarios		Credit Risk	1	✓ Completed on Jul 22, 20...
0600	Load ALLL, charge-off and recovery projections		Stress Testing Manager	1	✓ Completed on Jul 22, 20...
0700	Submit balances and provisions to ALM system		Stress Testing Manager	1	✓ Completed on Jul 22, 20...
0800	Load BS and IS from ALM system		Stress Testing Manager	1	✓ Completed on Jul 22, 20...
0900	Enter management adjustments		Stress Testing Manager	1	Active
0950	Compute RWA and capital ratios		Stress Testing Manager	1	Not Started
1000	Generate DFAST report for final review		Stress Testing Manager	1	Not Started
1100	Review DFAST report (CR)		Credit Risk	1	Not Started
1200	Review DFAST report (F)		Finance	1	Not Started
1300	Review DFAST report (STM)		Stress Testing Manager	1	Not Started
1400	Render DFAST report for submission		Stress Testing Manager	1	Not Started
1500	DFAST report submitted	Attach submission docume...	Stress Testing Manager	1	Not Started

Comments

nekuma
Iteration 1
comments
Jul 23,2015 11:24:14 AM

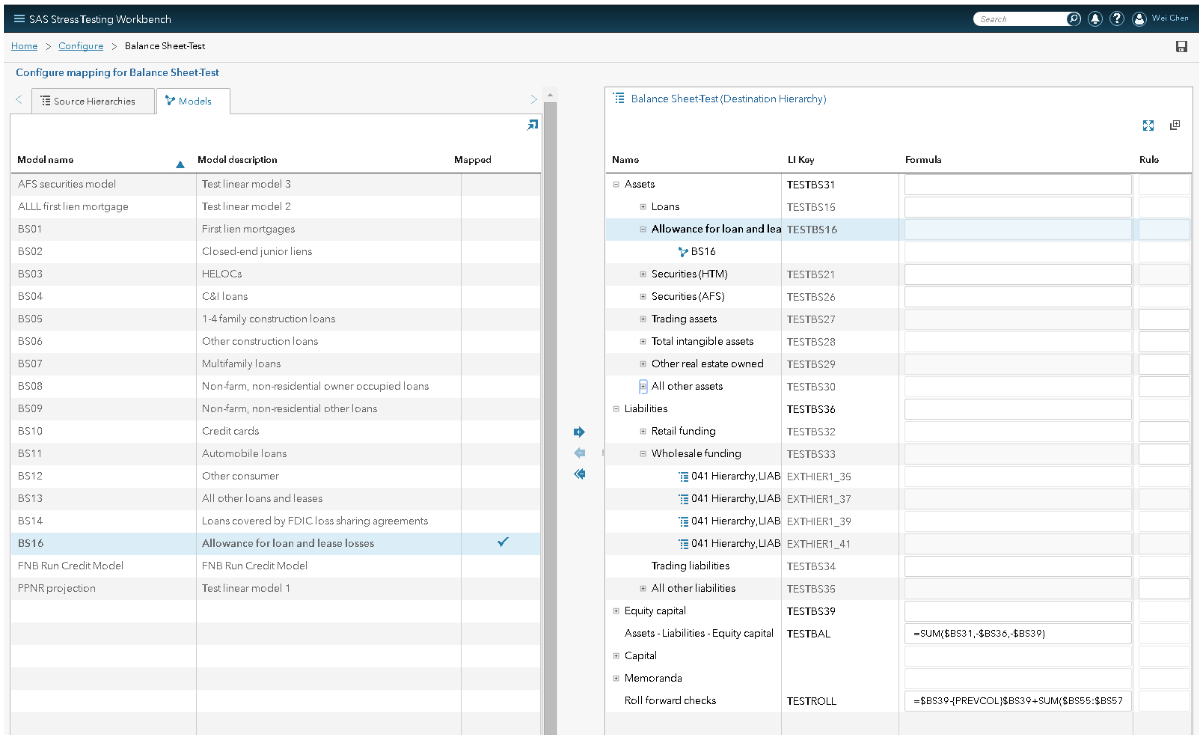
nekuma
Iteration 1
comment
Jul 24,2015 09:17:00 AM

wechen
Iteration 1
Reviewing the adjustment based on rules and policy.
Jul 25,2015 08:58:38 AM
Revenue Projection Rules.docx

Display 1: SAS Stress Testing Workbench Project Overview

The workbench comes with an editable spreadsheet-like view of the historical and projected balance sheet (see Display 2), income statement and any other user-defined sheets for multiple scenarios. Finer grained financial projections from SAS models and external systems can be loaded and aggregated to the stress testing line items via the hierarchy configurations. Multiple users with proper roles can collaborate simultaneously to review, enter, and adjust amounts and formulas, enter comments, and compare scenarios. Read and write security controls which sheets, scenarios, and cells each user has permission to view or modify. The data-driven data loading and web-based workbench reduces manual data manipulations through one-off spreadsheet work and increases the collaborations and planning activities among all the relevant parties in a stress testing process.

In addition, all changes and comments entered into the workbench sheets are tracked in a history log as illustrated in Display 4. Changes can be tracked either from the cell level or the system level, which makes it convenient for auditing purposes.


SAS Stress Testing Workbench
Search
Wei Chen
Home > Configure > Balance Sheet-Test
Source Hierarchies
Models

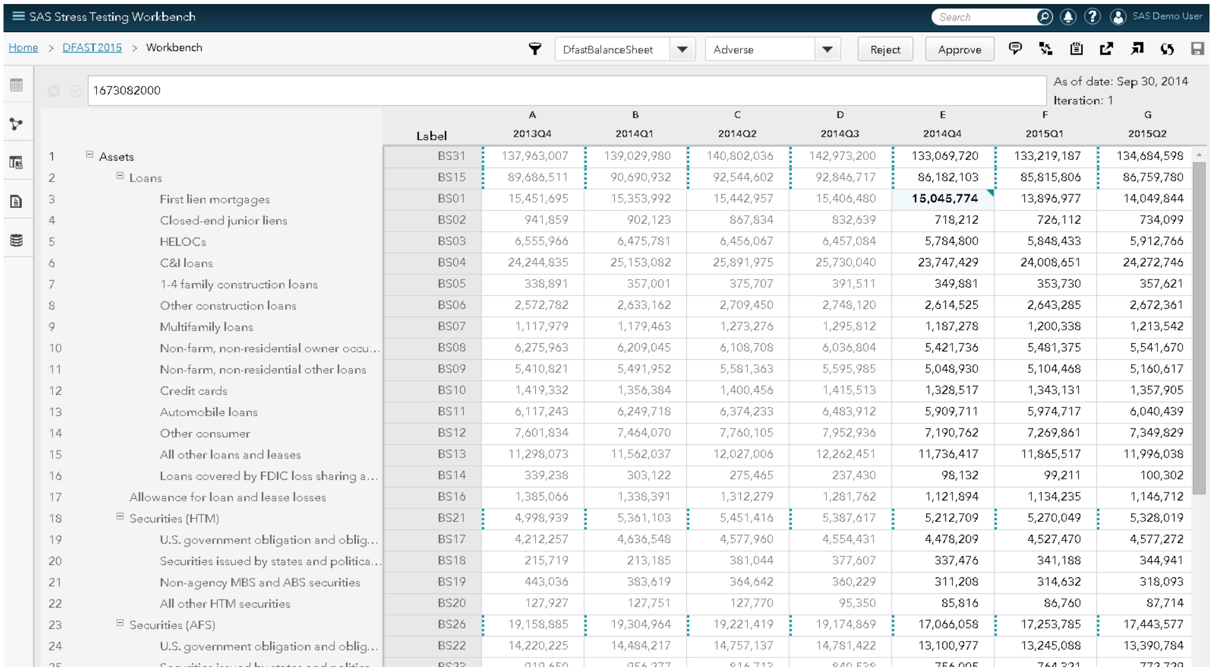
Configure mapping for Balance Sheet-Test

Model name	Model description	Mapped
AFS securities model	Test linear model 3	
ALLL first lien mortgage	Test linear model 2	
BS01	First lien mortgages	
BS02	Closed-end junior liens	
BS03	HELOCs	
BS04	C&I loans	
BS05	1-4 family construction loans	
BS06	Other construction loans	
BS07	Multifamily loans	
BS08	Non-farm, non-residential owner occupied loans	
BS09	Non-farm, non-residential other loans	
BS10	Credit cards	
BS11	Automobile loans	
BS12	Other consumer	
BS13	All other loans and leases	
BS14	Loans covered by FDIC loss sharing agreements	
BS16	Allowance for loan and lease losses	✓
FNB Run Credit Model	FNB Run Credit Model	
PPNR projection	Test linear model 1	

Balance Sheet-Test (Destination Hierarchy)

Name	LI Key	Formula	Rule
⊟ Assets	TESTBS31		
⊞ Loans	TESTBS15		
⊟ Allowance for loan and lea	TESTBS16		
BS16			
⊞ Securities (HTM)	TESTBS21		
⊞ Securities (AFS)	TESTBS26		
⊞ Trading assets	TESTBS27		
⊞ Total intangible assets	TESTBS28		
⊞ Other real estate owned	TESTBS29		
⊞ All other assets	TESTBS30		
⊟ Liabilities	TESTBS36		
⊞ Retail funding	TESTBS32		
⊟ Wholesale funding	TESTBS33		
041 Hierarchy,LIAB	EXTHIER1_35		
041 Hierarchy,LIAB	EXTHIER1_37		
041 Hierarchy,LIAB	EXTHIER1_39		
041 Hierarchy,LIAB	EXTHIER1_41		
Trading liabilities	TESTBS34		
⊞ All other liabilities	TESTBS35		
⊞ Equity capital	TESTBS39		
Assets - Liabilities - Equity capital	TESTBAL	=SUM($BS31,-$BS36,-$BS39)	
⊞ Capital			
⊞ Memoranda			
Roll forward checks	TESTROLL	=$BS39-{PREVCOL}$BS39+SUM($BS55:$BS57	

Display 2: SAS Stress Testing Workbench Sheet Hierarchy Configuration and Mapping

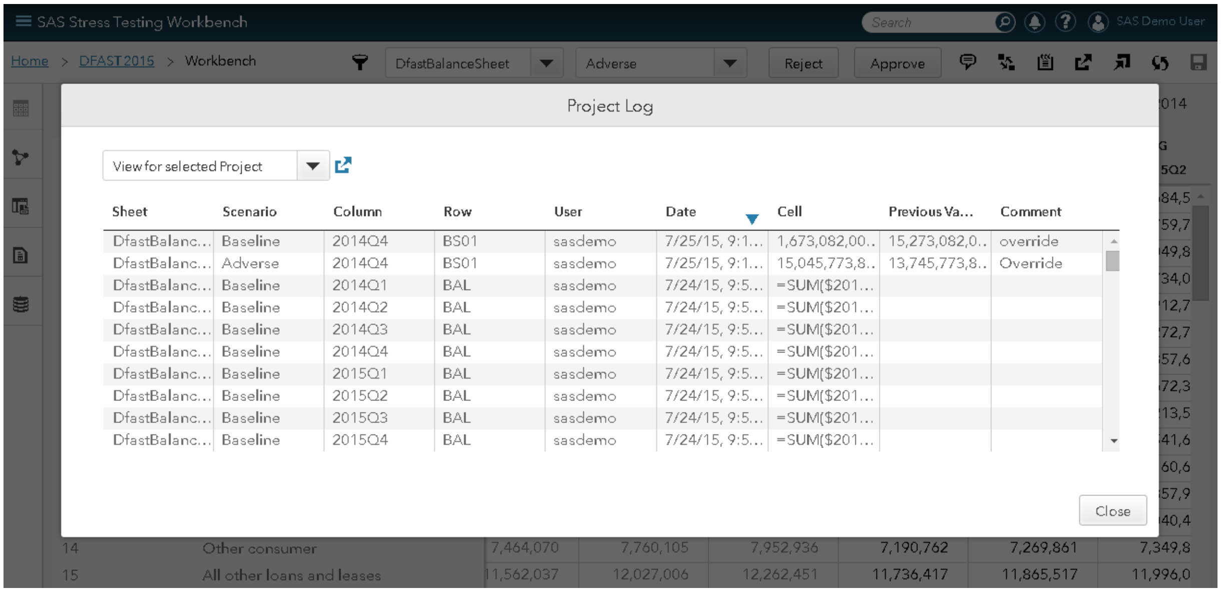


1673082000

As of date: Sep 30, 2014
Iteration: 1

			A	B	C	D	E	F	G
		Label	2013Q4	2014Q1	2014Q2	2014Q3	2014Q4	2015Q1	2015Q2
1	⊟ Assets	BS31	137,963,007	139,029,980	140,802,036	142,973,200	133,069,720	133,219,187	134,684,598
2	⊟ Loans	BS15	89,686,511	90,690,932	92,544,602	92,846,717	86,182,103	85,815,806	86,759,780
3	First lien mortgages	BS01	15,451,695	15,353,992	15,442,957	15,406,480	**15,045,774**	13,896,977	14,049,844
4	Closed-end junior liens	BS02	941,859	902,123	867,834	832,639	718,212	726,112	734,099
5	HELOCs	BS03	6,555,966	6,475,781	6,456,067	6,457,084	5,784,800	5,848,433	5,912,766
6	C&I loans	BS04	24,244,835	25,153,082	25,891,975	25,730,040	23,747,429	24,008,651	24,272,746
7	1-4 family construction loans	BS05	338,891	357,001	375,707	391,511	349,881	353,730	357,621
8	Other construction loans	BS06	2,572,782	2,633,162	2,709,450	2,748,120	2,614,525	2,643,285	2,672,361
9	Multifamily loans	BS07	1,117,979	1,179,463	1,273,276	1,295,812	1,187,278	1,200,338	1,213,542
10	Non-farm, non-residential owner occu…	BS08	6,275,963	6,209,045	6,108,708	6,036,804	5,421,736	5,481,375	5,541,670
11	Non-farm, non-residential other loans	BS09	5,410,821	5,491,952	5,581,363	5,595,985	5,048,930	5,104,468	5,160,617
12	Credit cards	BS10	1,419,332	1,356,384	1,400,456	1,415,513	1,328,517	1,343,131	1,357,905
13	Automobile loans	BS11	6,117,243	6,249,718	6,374,233	6,483,912	5,909,711	5,974,717	6,040,439
14	Other consumer	BS12	7,601,834	7,464,070	7,760,105	7,952,936	7,190,762	7,269,861	7,349,829
15	All other loans and leases	BS13	11,298,073	11,562,037	12,027,006	12,262,451	11,736,417	11,865,517	11,996,038
16	Loans covered by FDIC loss sharing a…	BS14	339,238	303,122	275,465	237,430	98,132	99,211	100,302
17	Allowance for loan and lease losses	BS16	1,385,066	1,338,391	1,312,279	1,281,762	1,121,894	1,134,235	1,146,712
18	⊟ Securities (HTM)	BS21	4,998,939	5,361,103	5,451,416	5,387,617	5,212,709	5,270,049	5,328,019
19	U.S. government obligation and oblig…	BS17	4,212,257	4,636,548	4,577,960	4,554,431	4,478,209	4,527,470	4,577,272
20	Securities issued by states and politica…	BS18	215,719	213,185	381,044	377,607	337,476	341,188	344,941
21	Non-agency MBS and ABS securities	BS19	443,036	383,619	364,642	360,229	311,208	314,632	318,093
22	All other HTM securities	BS20	127,927	127,751	127,770	95,350	85,816	86,760	87,714
23	⊟ Securities (AFS)	BS26	19,158,885	19,304,964	19,221,419	19,174,869	17,066,058	17,253,785	17,443,577
24	U.S. government obligation and oblig…	BS22	14,220,225	14,484,217	14,757,137	14,781,422	13,100,977	13,245,088	13,390,784

Display 3: SAS Stress Testing Workbench Balance Sheet View with User Override and Comments


SAS Stress Testing Workbench
Search
SAS Demo User
Home > DFAST 2015 > Workbench
DfastBalanceSheet
Adverse
Reject
Approve
Project Log
View for selected Project
Close

Sheet	Scenario	Column	Row	User	Date	Cell	Previous Va...	Comment
DfastBalanc...	Baseline	2014Q4	BS01	sasdemo	7/25/15, 9:1...	1,673,082,00..	15,273,082,0..	override
DfastBalanc...	Adverse	2014Q4	BS01	sasdemo	7/25/15, 9:1...	15,045,773,8..	13,745,773,8..	Override
DfastBalanc...	Baseline	2014Q1	BAL	sasdemo	7/24/15, 9:5...	=SUM($201...		
DfastBalanc...	Baseline	2014Q2	BAL	sasdemo	7/24/15, 9:5...	=SUM($201...		
DfastBalanc...	Baseline	2014Q3	BAL	sasdemo	7/24/15, 9:5...	=SUM($201...		
DfastBalanc...	Baseline	2014Q4	BAL	sasdemo	7/24/15, 9:5...	=SUM($201...		
DfastBalanc...	Baseline	2015Q1	BAL	sasdemo	7/24/15, 9:5...	=SUM($201...		
DfastBalanc...	Baseline	2015Q2	BAL	sasdemo	7/24/15, 9:5...	=SUM($201...		
DfastBalanc...	Baseline	2015Q3	BAL	sasdemo	7/24/15, 9:5...	=SUM($201...		
DfastBalanc...	Baseline	2015Q4	BAL	sasdemo	7/24/15, 9:5...	=SUM($201...		

14	Other consumer	7,464,070	7,760,105	7,952,936	7,190,762	7,269,861	7,349,8
15	All other loans and leases	11,562,037	12,027,006	12,262,451	11,736,417	11,865,517	11,996,0

Display 4: SAS Stress Testing Workbench Auditing Log View

The workbench produces reports using standard report templates (such as the annual DFAST template by Office of the Comptroller of the Currency 2014) or customer-specific templates. Users can render reports at any time in a stress testing process if the user wishes to check the progress or generate an interim report for internal approval. Reports can be rendered in Excel or other formats such as plus-delimited (for direct submission to the Fed's Reporting Central) or CSV.

```
H1039502+FRY16+02-17-2015
LCSTX8901+John Doe
LCSTX8902+(212) 720-1234
LCSTX9116+415-292-0000
LCSTX4086+johndoe@gmail.com
LCSTX4769+Cover page remarks
SCSPTP006+4
LCSPTN193++5,660,050+5,704,226+5,715,270+5,764,968+5,825,710+5,853,320+5,88
0,930+5,908,540+5,925,106
LCSPTN194++4,258,875+4,292,115+4,300,425+4,337,820+4,383,525+4,404,300+4,42
5,075+4,445,850+4,458,315
LCSPTN195++17,348,125+17,483,525+17,517,375+17,669,700+17,855,875+17,940,50
0+18,025,125+18,109,750+18,160,525
LCSPTN196++16,751,575+16,882,319+16,915,005+17,062,092+17,241,865+17,323,58
0+17,405,295+17,487,010+17,536,039
LCSPTN197++110,700+111,564+111,780+112,752+113,940+114,480+115,020+115,560+
115,884
LCSPTN198++627,300+632,196+633,420+638,928+645,660+648,720+651,780+654,840+
656,676
```

Output 1: A Plus-delimited DFAST Report File Output

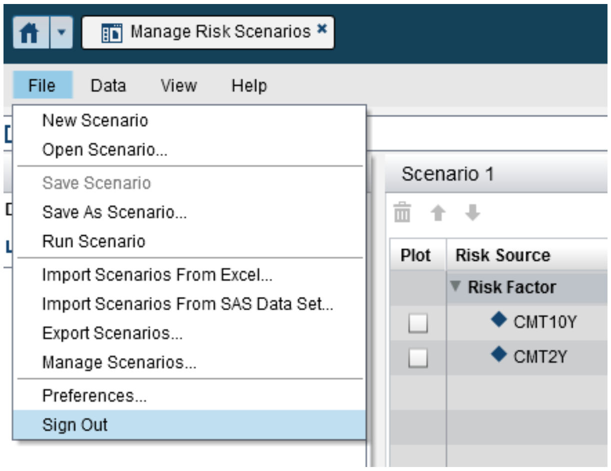
Finally, the reporting capability of the system maintains the history of every report rendered and a snapshot of the source data used for each report, supporting audit, and reproduction of historical reports.

These make the internal auditing control and regulatory examination of the stress testing more manageable.

SCENARIO MANAGEMENT

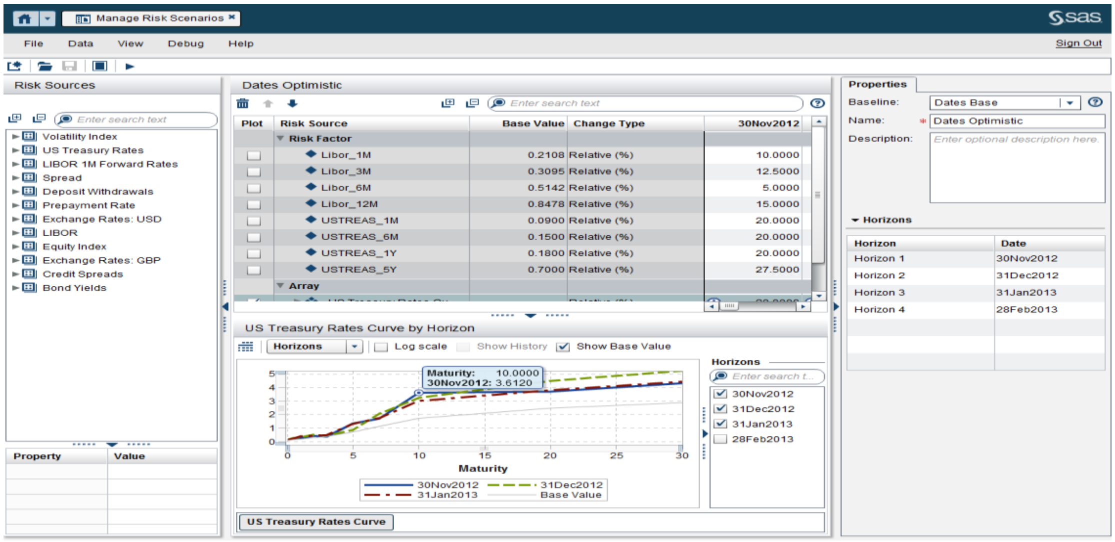
In a regulatory stress test like CCAR or DFAST scenarios contain a set of macroeconomic factors that are often given by the regulators. Banks are supposed to augment and enhance the regulatory scenarios by including the economic factors that are pertinent to their business. For example, when a bank has concentrated mortgage exposures in Florida, California, and North Carolina, the bank is expected to shock the housing price index, unemployment rate, and other risk factors at the level local in these geographic entities. When a bank has significant exposure to the commercial loans in the fracking sector that can be hit by low oil prices, the bank must include the crude oil price in the scenario for its stress testing. Although many banks tend to purchase scenarios from third-party vendors it remains the banks' responsibility to manage and justify the scenarios. As a stress testing best practice a bank is supposed to incorporate stress testing into its management decisions with bank-specific scenarios. Sensitivity analysis and what-if analyses can even require additional scenarios.

The SAS stress testing scenario manager allows a user to import scenarios from spreadsheets, SAS data sets, create new scenarios, modify, augment, and enhance existing scenarios. Display 5 shows the scenario actions a user can take through the SAS Stress Testing Scenario Manager.



Display 5: SAS Risk Scenario Manager

The user can also explore the scenarios graphically to compare the projected scenario values with the historical values for the same risk factor. When a user is going to create or modify a scenario, the user can choose or assign a baseline scenario and then define scenarios relative to that baseline. The user can define horizons either in relative interval increments or in absolute dates. Likewise, a user can shock risk factors relatively or by a certain value. For the risk factor curves like yield curves or forward curves, the user can either shock the entire curve or shock each individual member of the curve. Users can also define risk factor groups such as large cap stocks, interest rates, and credit spreads and shock the entire group homogeneously or move each subset individually. Display 6 shows a scenario that is being developed by a user where the user can choose all the defined risk factors in the system from the left panel and build the desired scenario, perturb them at the single risk factor, curve, or even driver level, associate scenarios to a baseline, define future horizons, compare risk factor values across scenarios, and explore risk factor history. All the scenarios are stored in a scenario library where the scenario management information such as creation and modification date and time, owner, and data source type are recorded. In a typical stress testing process, the stress testing manager can use the scenario manager to create and centrally manage the scenario and export the scenarios to various parties involved in the stress testing project so that all the parties use the same scenario for their part of the calculation and projection. This avoids the need for each party to individually manage the scenarios.



Plot	Risk Source	Base Value	Change Type	30Nov2012
	Risk Factor			
□	Libor_1M	0.2108	Relative (%)	10.0000
□	Libor_3M	0.3095	Relative (%)	12.5000
□	Libor_6M	0.5142	Relative (%)	5.0000
□	Libor_12M	0.8478	Relative (%)	15.0000
□	USTREAS_1M	0.0900	Relative (%)	20.0000
□	USTREAS_6M	0.1500	Relative (%)	20.0000
□	USTREAS_1Y	0.1800	Relative (%)	20.0000
□	USTREAS_5Y	0.7000	Relative (%)	27.5000
	Array			

Baseline: Dates Base

Name: Dates Optimistic

Description: Enter optional description here.

Horizons

Horizon	Date
Horizon 1	30Nov2012
Horizon 2	31Dec2012
Horizon 3	31Jan2013
Horizon 4	28Feb2013

Display 6: SAS Risk Scenario Manager: Scenario Development and Exploration

Using the scenario manager and the workbench together a bank can leverage the well-defined stress testing workflow to initiate or copy a stress testing project based on any ad-hoc scenarios for the bank's own scenario and sensitivity analysis to support their regulatory stress testing.

In the next section we are going to introduce the SAS risk engine as a model implementation platform that is connected with the scenario manager. That is, if the models are implemented with the SAS risk engine then a user can execute the scenario directly from the scenario manager. This connection will allow a quick smoke test run of a scenario or model implementation as well as an ad-hoc risk analysis.

MODEL INTEGRATON AND IMPLEMENTATION

A big challenge for many banks is bringing all stress testing models together in a controlled environment where models can be implemented efficiently. Pertaining to the stress testing life cycle illustrated in Figure 1, SAS technology helps make this possible by providing a way to store all models in a model inventory where models can be governed through SAS® Model Risk Management and can be executed in the SAS® Model Implementation Platform solution in the SAS Stress Testing Suite. It is very important for firms to have a controlled, integrated model inventory where all production models can be stored, and the modeling process can be streamlined. This ensures that only model parameters that have gone through appropriate model governance channels can be used in the stress testing process. Models can be appropriately versioned so that different model iterations can be tracked and documented.

The implementation of systems of models can be made more efficient by making direct calls to this inventory, removing the need to hard code parameters into the implementation code. This section provides more detail on the benefits of the SAS Model Implementation Platform for efficient model implementation.

In the risk engine, a system of models can be connected together to accomplish the desired analytics such as loss and income analysis. This engine can run on a single computer or a supplied grid of any size. The engine distributes complicated calculations to a grid for the user. Depending on the complexity of the models and the processing speeds required, this grid hardware can be scaled to meet the needs of each institution. Instead of taking many hours or even days to get the results of a suite of models, it is possible to get results in minutes by using the distributed computing power without the burden of manual control of the job distribution.

This system also provides modeling templates for the implementation of commonly used modeling methodologies to reduce significantly the effort required to set up implementation code. These implementation templates can call the production models directly from the model inventory, which provides a clear audit trail for all models that are run during a stress testing process. The user can also leverage existing code, which can be modified based on firm specific factors. It reduces the model risk during the implementation process and shortens the time to production of these models.

As the discipline of stress testing matures, regulators are increasingly requiring banks to adopt more advanced modeling techniques. For example, where pool level roll rate loss models may have been acceptable several years ago, regulators are now increasingly pushing for loan level models that can model the full life cycle of a loan and take into account important factors such as delinquencies, prepayments, modifications, and varying types of liquidations. To appropriately handle all of these factors well, increasingly complex modeling frameworks need to be put into place. However, this can place a high cost on an institution. While the resource burden of estimating a complex suite of models is daunting enough, the implementation of these models can add an additional layer of difficulty. This is especially the case when an implementation requires expertise in languages other than SAS, such as C++. With this risk engine, there is no need to have a separate C++ implementation team, as models can both be estimated and implemented within SAS. Moreover, the SAS code base is very manageable because it handles several important aspects of model implementation internally.

A real example of a complex system of models that would traditionally have been very difficult to implement would be the Monte Carlo state transition model. In this type of model, a loan can move through various states of delinquency during its life. It explicitly captures the movement through delinquency states prior to termination by default. In addition, it captures the risk that a loan can prepay in full in any given month.

Figure 2 illustrates an example of this type of model. In the transition matrix, there are models that dictate the movement of a loan through different delinquency states. A loan that is current can either stay current (make a payment), transition to D30 (miss a payment), pay off the loan in full, or directly move to default. Similarly, a model from any starting state has a finite number of potential states that it could migrate to. This type of model is very powerful because it is able to explicitly model the movement of loans through delinquency states and the resulting path dependency of these movements. For example, a loan that is current, but has been delinquent in the past bears a much higher risk than a loan that has always been current. This type of model can capture this dynamic both at the beginning of the model run and throughout all forecasted horizons. It also allows the output of specific cash flows that would result from each simulated path that a loan could take.

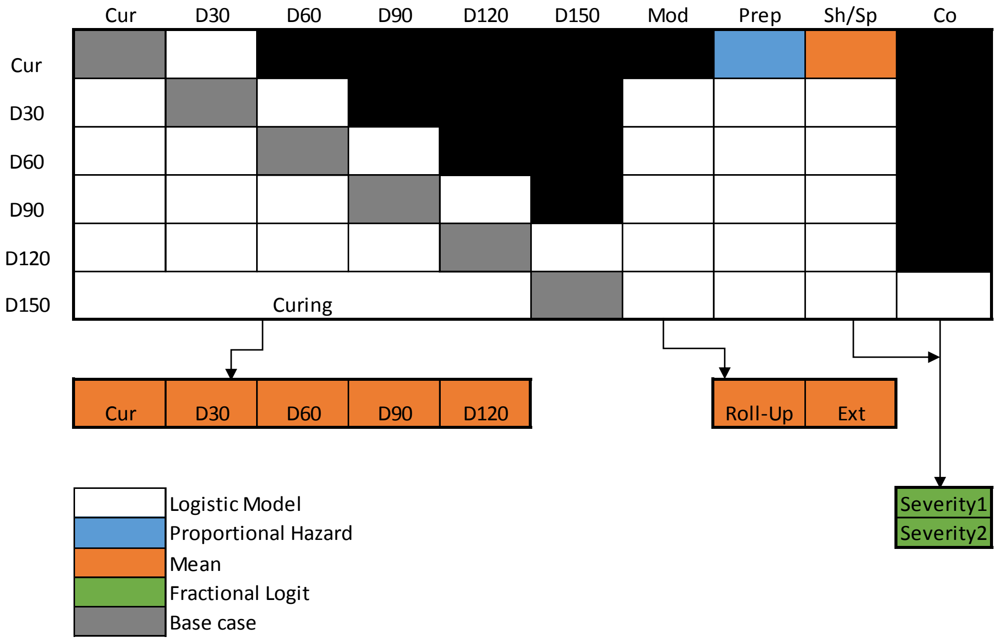
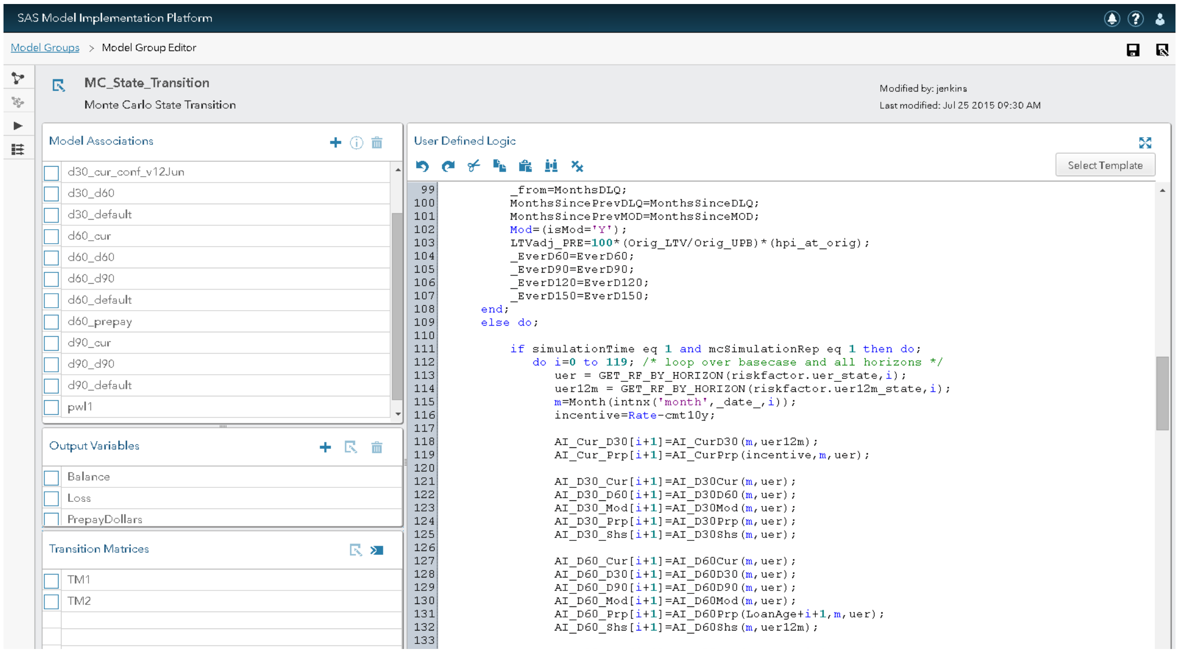


Figure 2: Example of a Monte Carlo State Transition Model



MC_State_Transition

Monte Carlo State Transition

Modified by: jenkins

Last modified: Jul 25 2015 09:30 AM

Model Associations

- □ d30_cur_conf_v12Jun
- □ d30_d60
- □ d30_default
- □ d60_cur
- □ d60_d60
- □ d60_d90
- □ d60_default
- □ d60_prepay
- □ d90_cur
- □ d90_d90
- □ d90_default
- □ pwl1

Output Variables

- □ Balance
- □ Loss
- □ PrepayDollars

Transition Matrices

- □ TM1
- □ TM2

```
        _from=MonthsDLQ;
        MonthsSincePrevDLQ=MonthsSinceDLQ;
        MonthsSincePrevMOD=MonthsSinceMOD;
        Mod=(isMod='Y');
        LTVadj_PRE=100*(Orig_LTV/Orig_UPB)*(hpi_at_orig);
        _EverD60=EverD60;
        _EverD90=EverD90;
        _EverD120=EverD120;
        _EverD150=EverD150;
    end;
    else do;

        if simulationTime eq 1 and mcSimulationRep eq 1 then do;
           do i=0 to 119; /* loop over basecase and all horizons */
              uer = GET_RF_BY_HORIZON(riskfactor.uer_state,i);
              uer12m = GET_RF_BY_HORIZON(riskfactor.uer12m_state,i);
              m=Month(intnx('month',_date_,i));
              incentive=Rate-cmt10y;

              AI_Cur_D30[i+1]=AI_CurD30(m,uer12m);
              AI_Cur_Prp[i+1]=AI_CurPrp(incentive,m,uer);

              AI_D30_Cur[i+1]=AI_D30Cur(m,uer);
              AI_D30_D60[i+1]=AI_D30D60(m,uer);
              AI_D30_Mod[i+1]=AI_D30Mod(m,uer);
              AI_D30_Prp[i+1]=AI_D30Prp(m,uer);
              AI_D30_Shs[i+1]=AI_D30Shs(m,uer);

              AI_D60_Cur[i+1]=AI_D60Cur(m,uer);
              AI_D60_D30[i+1]=AI_D60D30(m,uer);
              AI_D60_D90[i+1]=AI_D60D90(m,uer);
              AI_D60_Mod[i+1]=AI_D60Mod(m,uer);
              AI_D60_Prp[i+1]=AI_D60Prp(LoanAge+i+1,m,uer);
              AI_D60_Shs[i+1]=AI_D60Shs(m,uer12m);

```

Display 7: A Monte Carlo State Transition Model Framework Implementation with SAS Model Implementation Platform

Although this model framework has many benefits, it has traditionally been very difficult to implement. It requires many interconnected models, the movement through forecasted time horizons, and the ability to simulate a loan (potentially several thousand times) across many different states. The SAS Model Implementation Platform powered by SAS High Performance Risk engine makes implementing this complex model framework easy with a prebuilt implementation template that can be modified by the user. More importantly user can select models from the model inventory for each state transition into this template with recoding. For this type of model framework, a transition matrix object is also provided to help visualize the transition definition. Display 7 shows an illustration of how this model framework can be assembled using the SAS Model Implementation Platform. This implementation approach greatly increases the range of modeling options from which an institution can choose in their stress testing processes.

Below is a summary of some of the key benefits of the SAS Implementation Platform:

- One system can quickly implement many kinds of structures (hazards, Monte Carlo, Markov chain)
- Thread-safe parallelization is automatically handled
- Built-in movement through forecasted time horizons
- No need to join economic variables to loan data at each time horizon
- Ability to handle complex transition (for example, many models over a single time step)
- Simplification of post-processing calculations such as averaging across many simulations
- Smart distributed processing allows for quick model output aggregation
- Direct interface with a model inventory where model governance can also be placed

Furthermore, templates for commonly used modeling methods are provided, which can be customized for a specific firm's needs. In other words, almost any model type can be run on the same platform. Also, the software internally handles thread-safe parallelization that allows for a large grid of servers to be utilized. There is no need for a user to write code to send data to each of the nodes or to make sure that processes on each node are handled efficiently. This allows model developers to focus on building models instead of having to worry about how to set up a distributed computing environment. In the Monte Carlo simulation model outlined above, this is critical since many thousands of loan simulations are required. Without significant processing power, this would be nearly impossible.

Incorporating economic forecasts within a suite of models typically involves first expanding the loan level data out into the future for the desired forecast horizon (potentially extending out to the life of the loan). Then all economic factors need to be merged into the expanded table so that the models can be applied at each forecasted horizon. Depending on the size of the portfolio, this expansion of the loan data and merging of the economic variables can create a significant bottleneck in the implementation process. However, the SAS High-Performance Risk engine eliminates the need to do both of these time consuming processes. All that is required is that the user point to the loan level data and the economic forecasts and the relevant information is retrieved by the system as needed by the underlying models.

Additionally, the risk engine provides sophisticated built-in features for simulation and calculates risk measures such as the expectation of standard Monte-Carlo methods. One merely needs to specify a Monte Carlo framework and the engine will handle simulation flows, re-setting variables, tracking paths, and the necessary calculations after the simulation is finished to provide the user with the desired output. For example, when running a Monte Carlo simulation model, the post-processing calculations of averaging across many simulations are taken care of within the engine. In addition, the engine can easily handle sub-models within a single time step. If a time step is a single month, it is possible to capture the possibility of a loan going through several different states within that single month.

Finally, after a model is run, there is significant work required related to aggregation and analysis of the data. Since the SAS High-Performance Risk engine uses the advanced in-memory grid computing technology, the loan level results can easily be aggregated through any desired hierarchy almost instantly. This allows users to slice and dice their portfolios in many different ways when analyzing results. Besides the batch programming interface, a graphical user interface is available to make the aggregation intuitive to model implementation teams as well as to business analysts. This user interface is also connected to the scenario manager introduced in the last section. Once a scenario is defined, the system can streamline the scenario input, model execution from the model inventory, risk aggregation, and exploration all the way to the data collaboration and planning.

CONCLUSION

This paper introduces new SAS Stress Testing solutions that provide a holistic stress testing platform for managing the regulatory stress testing ecosystem for banks. The solution can also be applied modularly for banks to pragmatically augment a bank's stress testing process leveraging existing systems and models. The paper covers in some details a few key components in the solution that can be used for stress testing collaboration, capital planning, governance, reporting, scenario management as well as model implementation. Together with other solution capabilities and series such as model risk management, benchmark modeling, and loan data consortium services, the SAS Stress Testing solutions aim to support the best practices for and beyond the regulatory stress testing.

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