



# Model Risk Management with SAS®



SAS Institute Inc.

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**Model Risk Management with SAS®**

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# About This Book

## What Does This Book Cover?

Model risk can occur when a model has inappropriate data, specifications, assumptions, calibration, or other errors. Proper model risk management can mitigate this risk through the development, validation, and governance of models across the entire organization. SAS Model Risk Management is a web-based solution that helps your organization capture and manage information that you can use for model inventory management, model validation, ongoing monitoring and maintenance, change management, and model usage documentation.

The training in this book prepares members of your organization's project team to be effective and informed participants in the requirements development and solution design phases of your implementation. The book includes hands-on demonstrations, and it teaches key concepts, terminology, and base functionality that are integral to SAS Model Risk Management.

The first chapter of this book provides an overview of the regulatory environment, and it introduces the SAS Model Risk Management platform. This chapter is based on videos narrated by David Asermely and Peter Plochan, which are available on the SAS video site at <https://video.sas.com/category/videos/sas-model-risk-management>. The remainder of the chapters are a step-by-step introduction to using SAS Model Risk Management based on the course *SAS® Model Risk Management: Workshop* from SAS Education.

In addition, this book includes an Appendix that provides an overview of SAS Model Implementation Platform (MIP). SAS MIP executes complex and computationally intensive modeling systems for bank stress tests and for other enterprise-level risk assessments. SAS MIP is a web-based solution that helps you streamline the model estimation-to-implementation process, dramatically reduce model run times, and improve auditability.

## Is This Book for You?

SAS is the largest and most successful model risk management software vendor in the world. Software like SAS Model Risk Management and SAS Model Implementation Platform enable organizations to use a data-driven approach to assess their model risks, identify gaps, review and update their policies and procedures, and reassess their risks. This iterative approach continually improves their model quality and efficiency. If you want to learn more about the model risk management life cycle, as well as fine tune your governance policy and approach, then this book is for you.

## What Are the Prerequisites for This Book?

Familiarity with SAS Model Risk Management is helpful to understand this book. Access to the software is necessary to follow along with the demonstrations.

## What Should You Know about the Examples?

This book includes tutorials for you to follow to gain hands-on experience with SAS.

## Software Used to Develop the Book's Content

SAS Model Risk Management 7.4, SAS Model Implementation Platform 3.2, and SAS Visual Analytics were used to develop the content and examples for this book.

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# Appendix A: SAS Model Implementation Platform

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## Overview

In this appendix, you will learn about the SAS Model Implementation Platform. This product is designed primarily for model developers, model implementation teams, and analysts tasked with generating loss forecasts for stress testing or financial reporting. It is also a central component of the SAS CECL, IFRS 9, and stress testing solutions.

The platform provides a controlled framework for testing and implementing statistical models. Through the automated handling of generalized procedural logic, the platform allows for complex models, such as state transition models, to be implemented quickly and easily. Models are automatically executed in parallel across a cluster of machines for faster performance. Developers can also analyze and compare the results of their models quickly and easily using built-in tools for backtesting, sensitivity analysis, and attribution analysis.

The task of implementing complex systems of credit risk models is something that many financial institutions struggle with. This process involves writing code to combine a portfolio of loans, economic forecasts, and estimated models to officially forecast expected losses, balances, and cash flows over time. There is often a skill mismatch because modelers are more often trained in econometrics or statistics rather than software development.

The SAS Model Implementation Platform streamlines this process for consistent implementations across an organization. SAS provides a built-in framework for rapidly implementing complex systems of models that can be executed efficiently. The results can be dynamically explored to assess each forecast.

## Business Use Cases

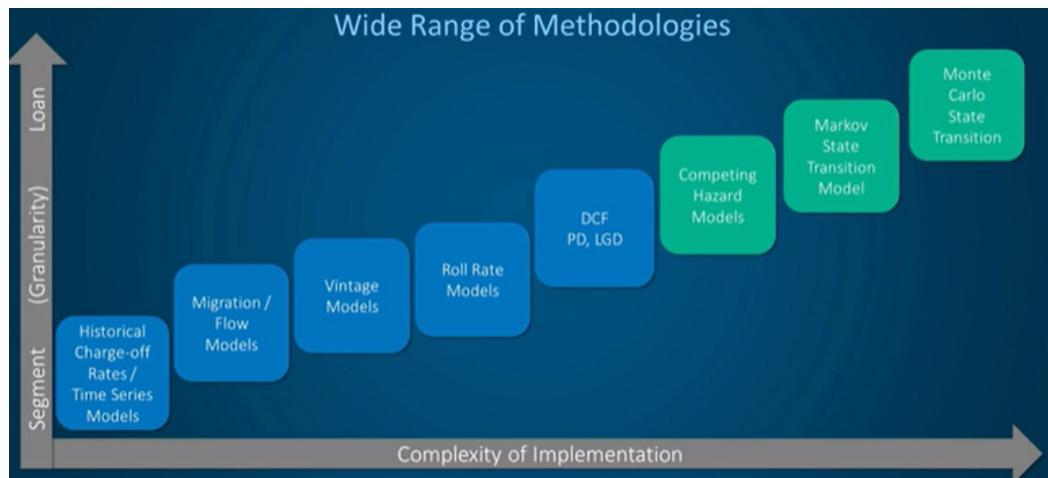
Some of the common use cases for SAS Model Implementation Platform (MIP) include the following:

- Life of loan forecasting
- IFRS 9
- CECL
- Enterprise stress testing
- Mortgage models

MIP is mostly geared toward any type of loan loss forecasting model. More complex models like mortgage models are especially strong use cases.

Different firms use a wide variety of modeling methodologies, as shown in Figure A.1.

**Figure A.1: MIP Methodologies**



MIP does an excellent job of handling models of many different types. However, it is in the more complex modeling structures, such as the Monte Carlo State Transition framework, where MIP really shines.

## Benefits

The real value of MIP lies in streamlining the pipeline between estimating models and implementing them into an integrated system. This is most important when you have many models that need to work together in concert, also known as atomic models. Oftentimes, institutions employ a team of econometricians to build the models and then have another team of developers who code in something like C++ to actually implement models. MIP makes this pipeline much smaller so that the people who estimate the models can actually implement the models during the estimation process. This allows them to get instant feedback on the results of their model during the development process so that they can make better models and get the results very quickly. Often it can take six to nine months between when sets of models are estimated to when they are implemented to see results. MIP makes that time much, much shorter.

Another thing that MIP does is promote broader model use within an organization. Usually, the people who are building the models own the code and are the ones who are able to actually run the model. So whenever an ad hoc request to get a model result comes from the organization or from regulators, the request has to go through the small set of people who own the code and know the code. With MIP, the models are in a platform where they can be accessed by many different people within the organization. Analysts who don't even know how to write code can access the models and get meaningful and valuable results from them. MIP helps to facilitate collaboration between analysts and model review teams.

MIP encourages the building of more complex architectures. Some of the more complex types of models are difficult to build, and they require a lot of programming. The platform handles a lot of the *process logic*. The benefit of separating out the modeling logic from the process logic is that some institutions start off with up to 10,000 lines of code. By handling the process logic, the platform drastically reduces the amount of code that institutions have to maintain – as much as a 90% code reduction in some instances. This makes it much easier to review and maintain the code over time.

The next benefit of MIP is that it can significantly increase the productivity of the modeling team. When modelers have to do things like backtesting, sensitivity analysis, attribution analysis, and other ad hoc tasks related to model building, the platform allows those things to be done much more efficiently and in a much more structural way with out-of-the box capabilities. This allows the modelers to more closely focus on building better models and makes ancillary things easier for them.

Related to the much-reduced codebase is the reduction of “key person” risk. When you have 10,000 lines of code that only a few people in the organization can understand, and one of those people leaves the organization, then the institution is in a lot of trouble because it doesn’t have people who can maintain the code going forward. Because the amount of code that has to be maintained in MIP is much smaller in a much more controlled environment, there is much less risk of an institution being in trouble when a key person leaves.

Finally, the most important benefit of MIP for many banks is that, whether you are doing simple or complex models, there is a desire to have a transparent, controlled, and auditable process.

## Core Components

Now we will cover the following core components of the Model Implementation Platform:

- **User Interface:** quickly load estimated models
- **Atomic Model Inventory:** an inventory of individual atomic models
- **Model Groups:** combine individual atomic models that execute together and generate desired outputs
- **High-performance Risk Explorer:** explore model results across any number of scenarios and cross-classifications in real time via an in-memory interface
- **Backtesting:** easily assess model accuracy by comparing model results to actuals
- **Model Sensitivity Analysis:** enables users to shock economic risk factors through an intuitive user interface
- **Out-of-the-box Attribution Analysis:** compare the results between two runs via iterative swapping of risk factors

### User Interface

The user interface allows many different people within the organization to have access to the models, see them, and be able to understand what's going on in the model. There are two different types of key users who use this interface. One group of users is the model developers or model implementation team who set up the models and get them into the platform along with details about the models. The second set of users are the people who want to be able to execute or run the models. Once the models are in the platform, some users load the portfolio, load the economic data, and execute those models to get the results. Once the results are in the platform, then those results can be explored.

### Atomic Model Inventory and Model Groups

Within the setting up of the models there is the Atomic Model Inventory. This is where you load the estimated model or single result of an estimation procedure. These single models are loaded into the platform. Then they are collected in model groups. Model groups are one or more atomic models that are put together in a meaningful way to give a specific desired result – for example, lifetime losses, monthly losses over time, or default dollars. This is where the implementation process really occurs.

### High-performance Risk Explorer

Once a model has been executed through the user interface, you can dynamically explore your results in the high-performance risk explorer. These results are dynamically explored in-memory. You can drill up or drill down. You can see results across many different dimensions, also known as cross-class variables. This is very useful if you are trying to drill down to find potential problems in a model run across your portfolio. Or, if your model is not performing on a particular

segment, you can really drill down as far as you want to go, even all the way down to the low level to find potential problems in your models.

As mentioned earlier, modelers are not the only ones who can do this. Any analyst who has access to the platform can do this sort of work. It extends the number of people who can be involved in the interpretation of your model results and driving that value throughout the organization.

## Backtesting

Backtesting can really help you in getting additional results around the modeling process.

Backtesting often has to be done on a monthly or quarterly basis to make sure that your models are performing as intended. MIP makes it very easy to run a model at some point in the past, for example, one, two, or three years back in time. You run it forward and overlay the actual results of the output variables that the model is creating; that is, you can overlay your actuals with your predicted values. Similar to the way you can dynamically explore the results of a forecast, you can also dynamically explore the results of your backtesting. This is very important for being able to work with regulators and validation teams.

## Model Sensitivity Analysis

It is very important to get instant feedback, particularly if you have a big system of models. Let's say you have 30 atomic models that are working together within the system of models. You need to know that the output of this model group is sensitive in appropriate ways to important factors. What you get out of the box with MIP is the ability to choose various shocks – for example, up and down 10% or 20% of these economic factors. With a few clicks, you can set up and execute these shocks. Then you are able to explore the results of the shocks just like you can explore the results of any of your model runs. This enables you to quickly respond to questions from anyone who asks how sensitive your models are to important factors.

## Out-of-the-box Attribution Analysis

Attribution analysis enables you to take a run from a past quarter or year ago and compare it to results run today. The first question anyone will want to know is: what changed between those two runs? A host of things could have changed, but you want to identify which factors have changed. For example, there could be new loans at a deep portfolio, some loans might no longer be in your portfolio, or economic factors may have changed. Loans might also have aged, so even if the same loans are still in the portfolio, they are different from what they were at some point in the past. The models themselves may also have been re-estimated or changed. Maybe tuning factors have been changed in the model. So how do you determine which of these many things might have changed? MIP enables you to set up the analysis very conveniently and get the result in a waterfall graph that shows all changes.

In this section, you have been introduced to a summary of some of the key things that you are able to do within the Model Implementation Platform. Next, we will walk through a demo of the platform.

## Demo

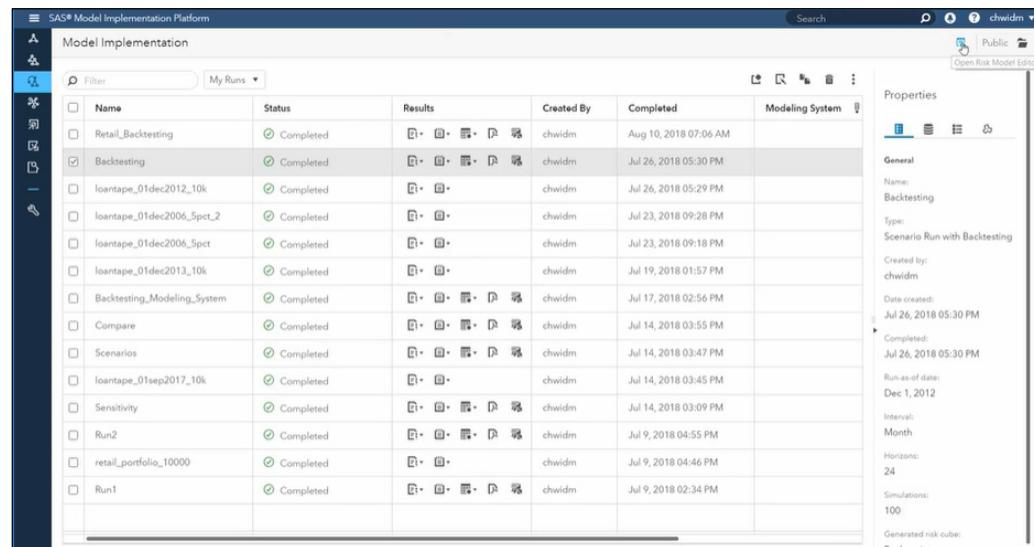
In this demonstration, we will do two things. First, we will walk through the process of how you would implement a model into the SAS Model Implementation Platform. Once that model is implemented, the second demonstration shows how to create forecasts and learn about the different types of analysis you can conduct.

### Implement a Model

The SAS Model Implementation Platform (MIP) is an implementation product. The basic setup of actually creating a model can be broken down into two phases. The first phase is *estimation*, where there is a set of historical data and some set of models is estimated depending on the framework to create the basic model equations. The MIP picks up from this point. Once the models are already estimated, the models need to be combined to produce a forecast given a new portfolio.

Let's look at an example of how to implement estimated models in the system. We will use a current to d30 model that has already been created. Open the SAS Model Implementation Platform. Open the **Risk Model Editor** by clicking on the icon in the upper right corner as shown in Figure A.2.

**Figure A.2: Open Model Risk Editor**



The screenshot shows the SAS Model Implementation Platform interface. On the left is a sidebar with icons for Model Implementation, Model Catalog, Model Store, and Help. The main area is titled 'Model Implementation' and contains a table with the following data:

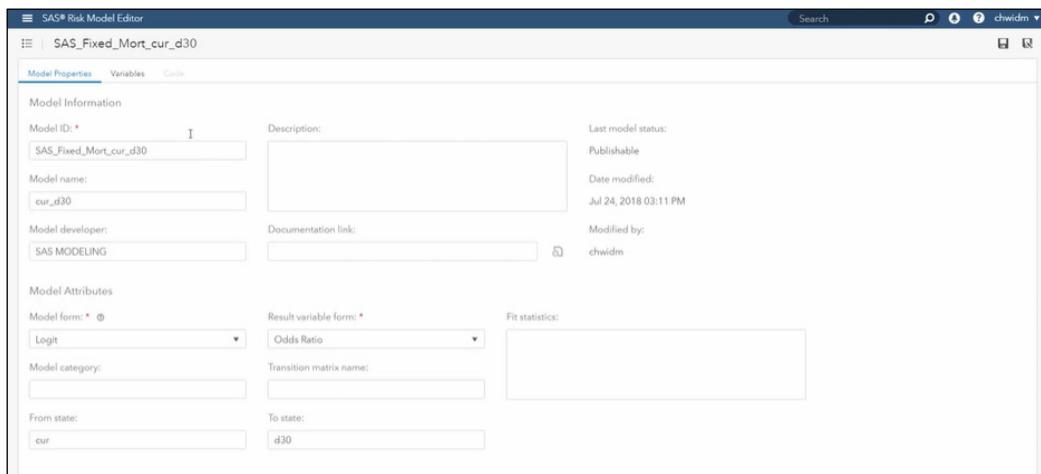
Name	Status	Results	Created By	Completed	Modeling System
Retail_Backtesting	Completed	...	chwidm	Aug 10, 2018 07:06 AM	
Backtesting	Completed	...	chwidm	Jul 26, 2018 05:30 PM	
Ioantape_01dec2012_10k	Completed	...	chwidm	Jul 26, 2018 05:29 PM	
Ioantape_01dec2004_5pct_2	Completed	...	chwidm	Jul 23, 2018 09:28 PM	
Ioantape_01dec2004_5pct	Completed	...	chwidm	Jul 23, 2018 09:18 PM	
Ioantape_01dec2013_10k	Completed	...	chwidm	Jul 19, 2018 01:57 PM	
Backtesting_Modeling_System	Completed	...	chwidm	Jul 17, 2018 02:56 PM	
Compare	Completed	...	chwidm	Jul 14, 2018 03:55 PM	
Scenarios	Completed	...	chwidm	Jul 14, 2018 03:47 PM	
Ioantape_01sep2017_10k	Completed	...	chwidm	Jul 14, 2018 03:45 PM	
Sensitivity	Completed	...	chwidm	Jul 14, 2018 03:09 PM	
Run2	Completed	...	chwidm	Jul 9, 2018 04:55 PM	
retail_portfolio_10000	Completed	...	chwidm	Jul 9, 2018 04:46 PM	
Run1	Completed	...	chwidm	Jul 9, 2018 02:34 PM	

On the right, a 'Properties' panel is open for the 'Backtesting' model. It shows the following details:

- General**
  - Name: Backtesting
  - Type: Scenario Run with Backtesting
  - Created by: chwidm
  - Date created: Jul 26, 2018 05:30 PM
  - Completed: Jul 26, 2018 05:30 PM
  - Run-as-of date: Dec 1, 2012
  - Interval: Month
  - Horizon: 24
  - Simulations: 100
  - Generated risk cube: Backtesting

After the Model Risk Editor opens, double-click the model that you want to implement from the list of models shown. In the **Model Properties** tab, enter some metadata about the model including giving it a Model ID, a Model name, saying who developed it, entering a model description, and adding a documentation link.

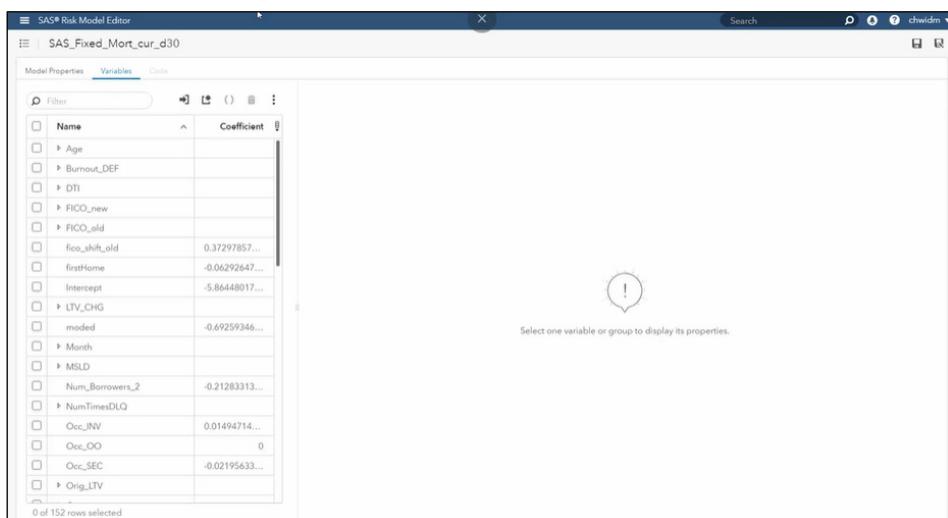
Figure A.3: SAS Risk Model Editor



You can choose a **Model form** from the drop-down menu, which are the prebuilt forms that MIP supports. If none of the options fit what you want, you can select **Custom** or choose **Code** and write the code yourself. Use the **Results variable form** drop-down menu to tell the system what type of form the result will produce. If the model is a transition model like the one shown in Figure A.3, you would enter the **From state** and the **To state**. Once we get to the model group, we will see how that will be used.

If the model form contains variables – most of them do, but the constant model does not have variables, for example – then you will see the **Variables** tab. Click on the tab. To create the variables, click the icon to go to load a coefficient file. This allows you to select locally a coefficient data set that can either be a SAS data set or a CSV file. Once you load the file, you will get an entire listing of variables with the variable name and coefficients, as shown in Figure A.4.

Figure A.4: Variables Tab



You can see in Figure A.4 that some of the variables are grouped together with no coefficients. That's because these are spline variables that the system has automatically grouped together. Underneath each group, you can see the individual knots of the spline. Click on any of the variables in the left pane to look at the associated metadata.

When you are building a new variable, you need to enter in the group name, calculation type, and a little bit of metadata about each one to tell the system what this variable is and explain to it how it will work. With the spline variable in Figure A.5, you can see the individual knots in the group. Click on the **Show graph** icon to see its effect.

**Figure A.5: Show Graph**

The screenshot shows the SAS Risk Model Editor interface. The 'Variables' tab is selected. A group named 'SATO\_PMMMS' is defined as 'Piecewise-Linear 1D' with 'Simulation' as the calculation type and 'Number' as the data type. The 'SATO\_PMMMS' group is selected in the left pane. The 'Piecewise-Linear Variables' table lists four knots:

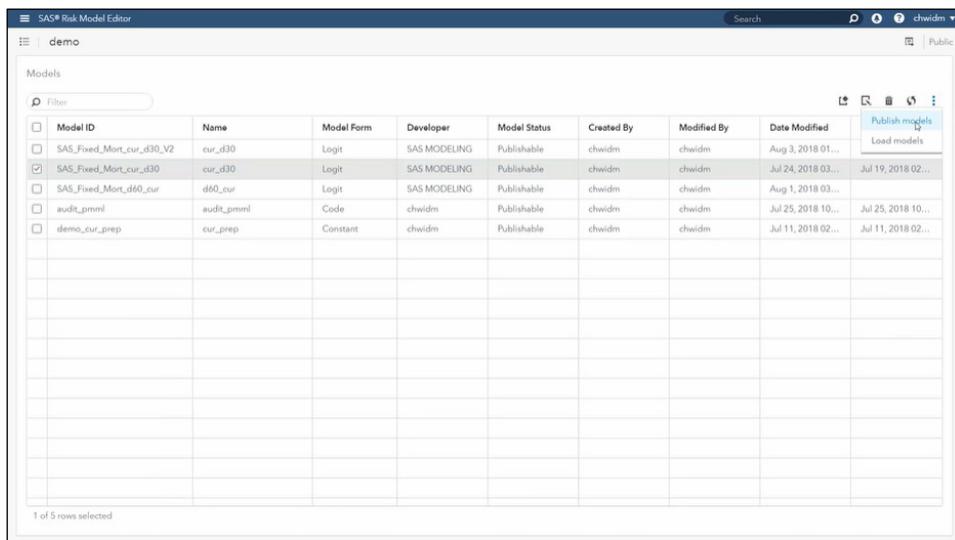
Name	Knot Value	Coefficient
SATO_PMMMS_m1	-1	-0.160186499299519
SATO_PMMMS_0	0	0
SATO_PMMMS_0p5	0.5	0.128530135075028
SATO_PMMMS_1	1	0.219899471007771

Click on the icon in the upper right corner to return to the list of models. For every model that you want to use, you need to enter in some metadata about the model and each of the variables. For example, in a simple hazard framework, you might have a default model, a prepay model, and a severity model. After you build all three models, you would enter them into the system, load the variables, and define the variables. It will take a few minutes for each of them.

## Publish a Model

Once you have defined all variables for model, in the SAS® Risk Model Editor window, select the model that you have finished defining by clicking the check box to the left of the Model ID. In the upper right corner, click the **More options** icon, and then choose **Publish Models** from the drop-down menu, as shown in Figure A.6.

Figure A.6: Publish Models



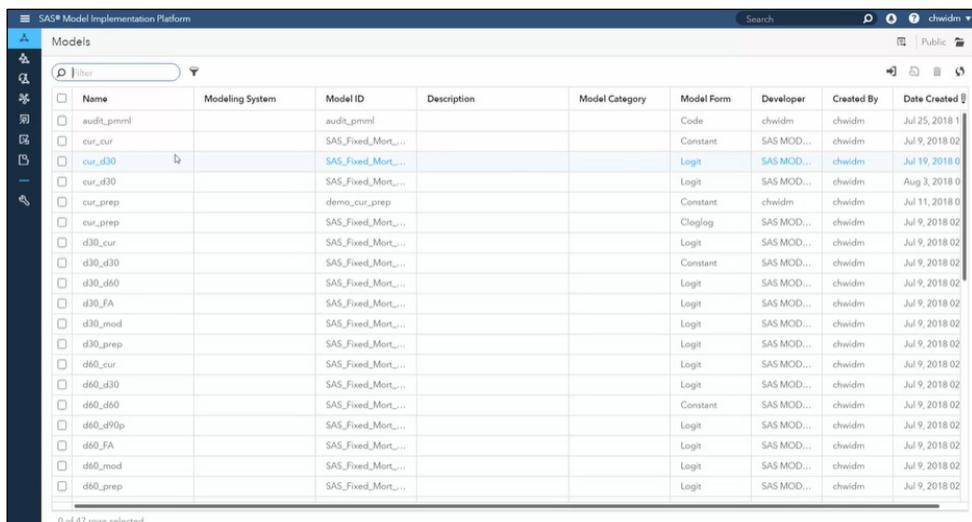
The screenshot shows the SAS Risk Model Editor interface. The left sidebar shows a project structure with 'demo' selected. The main area is titled 'Models' and contains a table with the following data:

Model ID	Name	Model Form	Developer	Model Status	Created By	Modified By	Date Modified
SAS_Fixed_Mort_cur_d30_V2	cur_d30	Logit	SAS MODELING	Publishable	chwidm	chwidm	Aug 3, 2018 01...
SAS_Fixed_Mort_cur_d30	cur_d30	Logit	SAS MODELING	Publishable	chwidm	chwidm	Jul 24, 2018 03...
SAS_Fixed_Mort_d60_cur	d60_cur	Logit	SAS MODELING	Publishable	chwidm	chwidm	Aug 1, 2018 03...
audit_pmmrl	audit_pmmrl	Code	chwidm	Publishable	chwidm	chwidm	Jul 25, 2018 10...
demo_cur_prep	cur_prep	Constant	chwidm	Publishable	chwidm	chwidm	Jul 11, 2018 02...

At the bottom left, it says '1 of 5 rows selected'. In the top right corner of the table header, there are two buttons: 'Publish models' (highlighted in blue) and 'Load models'.

Clicking **Publish Models** sends the model into the Model Inventory. Let's take a look now at the Model Inventory. From the main screen of the Model Implementation Platform, click on the single triangle icon at the top of the left sidebar. You will see that the Model Inventory has a listing of all the models that have been published and are available. (See Figure A.7.)

Figure A.7: Model Inventory



The screenshot shows the SAS Model Implementation Platform interface. The left sidebar has a 'Models' icon selected. The main area is titled 'Models' and contains a table with the following data:

Name	Modeling System	Model ID	Description	Model Category	Model Form	Developer	Created By	Date Created
audit_pmmrl		audit_pmmrl			Code	chwidm	chwidm	Jul 25, 2018 11:59:59 AM
cur_d30		SAS_Fixed_Mort...			Constant	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
cur_d30		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 19, 2018 02:00:00 PM
cur_prep		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Aug 3, 2018 01:59:59 PM
d30_d30		SAS_Fixed_Mort...			Constant	SAS MOD...	chwidm	Jul 11, 2018 02:00:00 PM
d30_d60		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d30_FA		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d30_mod		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d30_prep		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d60_cur		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d60_d30		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d60_d60		SAS_Fixed_Mort...			Constant	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d60_d90p		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d60_FA		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d60_mod		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM
d60_prep		SAS_Fixed_Mort...			Logit	SAS MOD...	chwidm	Jul 9, 2018 02:00:00 PM

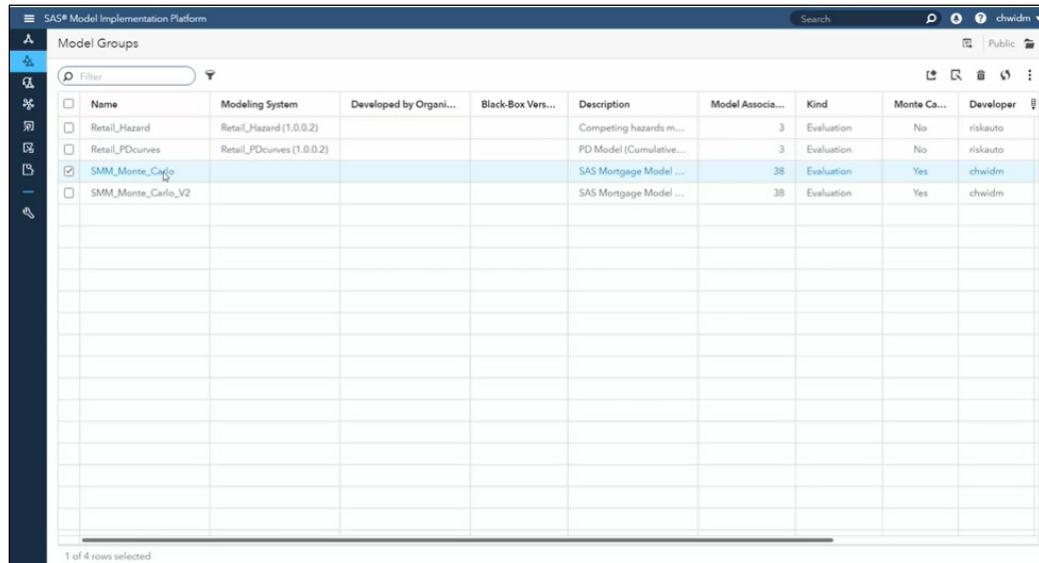
At the bottom left, it says '0 of 47 rows selected'.

Click on a model **Name** to see the metadata information stored in the database. You can also see the variables along with their individual information. A model in the Model Inventory is ready to use.

## Create a Model Group

Now that you have entered individual models, we want to put them together and use them in a system called a *model group*. Click on the second icon on the left-hand sidebar that shows two interlocking triangles. This shows a listing of your model groups. (See Figure A.8.)

**Figure A.8: Model Groups**



Name	Modeling System	Developed by Organi...	Black-Box Vers...	Description	Model Associa...	Kind	Monte Ca...	Developer
Retail_Hazard	Retail_Hazard (1.0.0.2)			Competing hazards m...	3	Evaluation	No	riskauto
Retail_PDcurves	Retail_PDcurves (1.0.0.2)			PD Model (Cumulative...	3	Evaluation	No	riskauto
<input checked="" type="checkbox"/> SMM_Monte_Carlo				SAS Mortgage Model ...	38	Evaluation	Yes	chwidm
SMM_Monte_Carlo_V2				SAS Mortgage Model ...	38	Evaluation	Yes	chwidm

Double-click on a model Name to see a preexisting model group. You can give the model group a name and a description. The system keeps track of who created the model group and when it was last modified. The models in the model group show up in the **Model Associations** table on the left. To add a model, click the **plus** (+) button in the **Model Associations** panel. This opens the **Associate Models** window that is the same as the Model Inventory. Select whichever models you want to add, then click **OK**.

To use these models together to produce a forecast, look at the **User-Defined Logic** pane. (See Figure A.9.) The user-defined logic follows a very simple pattern: derive some variables, score some models, and produce some outputs.

**Figure A.9: Model Group**

SAS® Model Implementation Platform

# SMM\_Monte\_Carlo

Name:  Modeling system: Kind: Modified by:

Description: SAS Mortgage Model - Monte Carlo Created by: chwidm Date modified: Aug 3, 2018 02:06 PM

Model Associations

Name	Override
cur_cur	
cur_d30	
cur_prep	
d30_cur	
d30_d30	
d30_d60	
d30_FA	
d30_mod	
d30_prep	
d60_cur	
d60_d30	

User-Defined Logic \*

```
1 /*  
2 000  
3 STATES:  
4 1. Cur  
5 2. D30  
6 3. D60  
7 4. D60P  
8 5. Mod  
9 6. REO  
10 .....(Below are not From states)  
11 7. OON  
12 8. PHT  
13 9. Prep  
14 10. REOSold  
15 11. Foreclosure Alternative  
16 */  
17 beginblock L0M_INIT;  
18 array TransVec(1) / nosymbol;  
19 array TransFroms(4) / nosymbol;  
20 array FromStates(7) Cur_D30_UPB D30_D60_UPB Modification_UPB REO_UPB PHT_UPB;  
21 array Transitions(*) Cur_D30_UPB Cur_D60_UPB D30_D60_UPB Mod_UPB REO_UPB Prep_UPB;  
22 D30_Cur_UPB D30_D30_UPB D30_D60_UPB D30_Mod_UPB D30_OON_UPB D30_FA_UPB  
23 D30P_D30_UPB D30P_D60_UPB D30P_Mod_UPB D30P_OON_UPB D30P_FA_UPB  
24 D30P_PHT_UPB D30P_Mod_UPB D30P_OON_UPB D30P_PHT_UPB D30P_Prep_UPB D30P_FA_UPB  
25 PHT_Cur_UPB PHT_D30_UPB Mod_D30_UPB PHT_D60_UPB PHT_D60P_UPB  
26 Mod_Mod_UPB Mod_OON_UPB  
27 Mod_Mod_UPB Mod_OON_UPB  
28 REO_UPB REO_SOLD_UPB  
29 REO_UPB REO_Mod_UPB  
30 */  
call streaminit(10);  
31
```

We won't be diving further into the code in this brief demonstration, but if we did, you would notice that it's a relatively small amount of code compared to the complexity of the system that it is building. The reason for that is a lot of the infrastructure tasks such as looping over horizons, looping over simulations, looping over scenarios, parallelizing the logic, handling the output variables, and merging of economic data are automatically handled by the system. The only thing developers need to do is tell the system how the specific model works, what variables the model needs, when to score the models, and what outputs to produce.

Once you have imported your models, written the code that says what to produce, and tell the system what output variables to keep track of, then you are finished. You are now ready to produce a forecast.

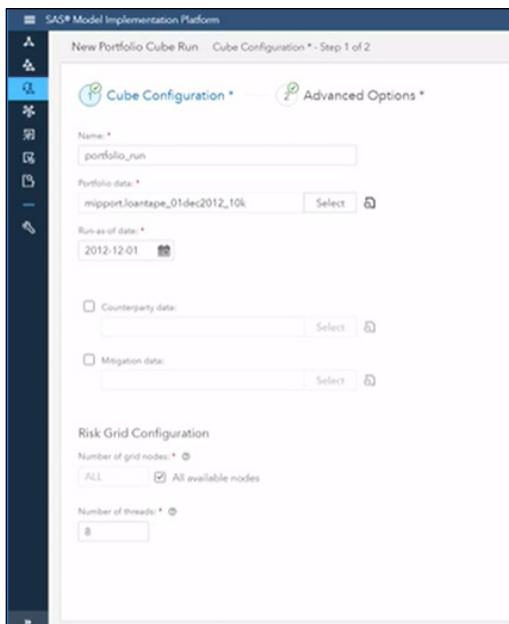
## Create a Model Group Map

However, there is one final concept to cover before creating a run – creating a model group map. A *model group map* is a traffic cop that picks up loans off of the portfolio and reads a field and tells it which model group to execute. Click the wrench icon in the left-hand sidebar to view the **Configuration** window. Select **Model Group Maps** to create a view model group maps.

We have walked through the basic steps of how a developer might implement a model in the SAS Model Implementation Platform. Once the individual models have been added, the model group has been created, and a model group map has been defined that points to the model groups, we are ready to use them. Click on the **Model Implementation** icon in the left-hand sidebar. This opens the Model Implementation window. Before you can create any forecasts, you need to send the portfolio to the grid.

Click the  icon in the upper right corner. Select **New portfolio cube run** from the drop-down menu. This opens the **Cube configuration** window. (See Figure A.10.) Give it a name. In the **Portfolio data** field, click the **Select** button. Select the data set of the portfolio that you want to use. Next, tell the system which date is the **Run as-of date**. In the **Risk Grid Configuration** section, tell the system how many nodes and how many threads to run on. By default, you can use the entire grid, or you can use some smaller subset. Click **Submit Run** in the upper right-hand corner.

**Figure A.10: Cube Configuration**



This picks up the portfolio, distributes it out to the grid, and makes the data available for use. The running of the model is separate from the distribution of the data. You can push the portfolio out to the grid once and use it as many times as you would like.

## Run a Scenario

Now let's examine a run. Return to the Model Implementation window. The first thing we want to do is create a basic scenario run using a portfolio that has been pushed to the grid, uses the model group map defined earlier, and uses some economic scenarios to create a forecast. Click the  icon in the upper right-hand corner. From the drop-down menu, select **New scenario run**. This opens the **Edit Scenario Run** window. The first thing you do in this window is select one of the portfolio cubes that have been pushed out to the grid or a previous scenario run.

Next, click on **Scenario Data** at the top of the screen. This is where you will select your economic data. Under **Scenario economic data**, click **Select** and choose the economic data in the file system. If you would like, you can quickly graph the economic data by clicking the graph icon.

Click **Maps and Methods** in the Edit Scenario Run window. Here you choose the model group map to run through. Remember, the model group map points to the model groups that it will use. Under **Evaluation model group map**, click **Select** and choose your model group map. If it is a Monte Carlo model, you will tell it the number of **Simulations** to run through.

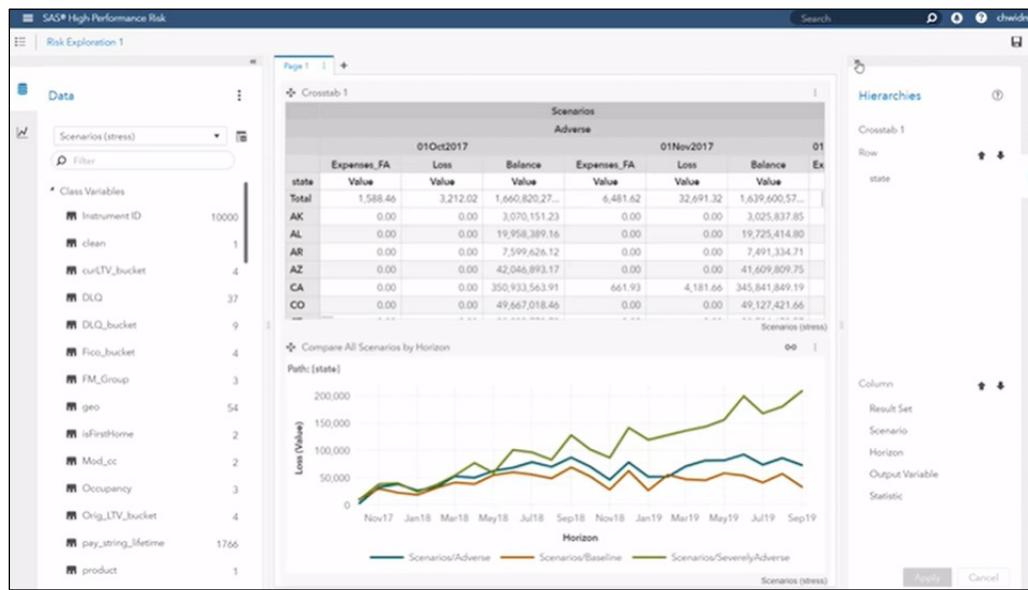
There are a few other options that can be selected in this step, and you can use **Advanced Options** and **Execution Options** to customize other aspects of the data and execution. At this point, however, the scenario is ready to be run. Click **Submit Run** in the upper right-hand corner. This goes out to the grid, takes the portfolio cube that you had distributed, runs these scenarios using the model group that you created, and produces the forecast according to the given parameters.

The results are stored in two different places. The individual results are stored on the grid and can be looked at using the risk explorer. Also, depending on the query you look at, the query level determines what results are brought back locally. To launch the risk explorer, click the **Explore results** icon  in the **Results** column of the Model Implementation window. This opens a **Risk Exploration** window. Here you can interactively evaluate the forecast and compare the results.

In the **Data** panel of the risk explorer, click on **Scenarios** to expand it. You can see all of the scenarios that you ran. Right-click the Scenarios folder and select **Add “Scenarios” to “Crosstab 1”** to add the scenarios to the cross-tab. Next, click **Output Variables** to expand it. Right-click on a variable to add it to the cross-tab. Add a cross-class variable to drill down. Click **Class Variables** and follow the same process to add any class variables to the cross-tab.

Now you can look at the individual results. Right-click inside the cross-tab and choose the first option in the drop-down menu to compare variables. Results can be compared by **Subportfolio**, **Horizon**, or **All Scenarios by Horizon**. Choose **All Scenarios by Horizon** to compare variables by all horizons and all scenarios. (See Figure A.11 for an example that shows a total portfolio forecast for all losses for every scenario.)

Figure A.11: Compare All Scenarios by Horizon



You can adjust the graph by double-clicking on any cell within the cross-tab. With just a few clicks, you can see any of the cross-class variables that you have made available to the system. You can drill down on your output variables by any of the cross-class variables. You can also drill down as finely as you would like to evaluate your results.

## Run Other Analyses

Using the model that you have implemented with your model group map to produce a scenario forecast is the most basic type of run and the most common. The goal of the SAS Model Implementation Platform is to make it as quick and easy as possible to run a whole host of different types of analyses. Let's examine a few of the others.

### Scenario Run with Backtesting

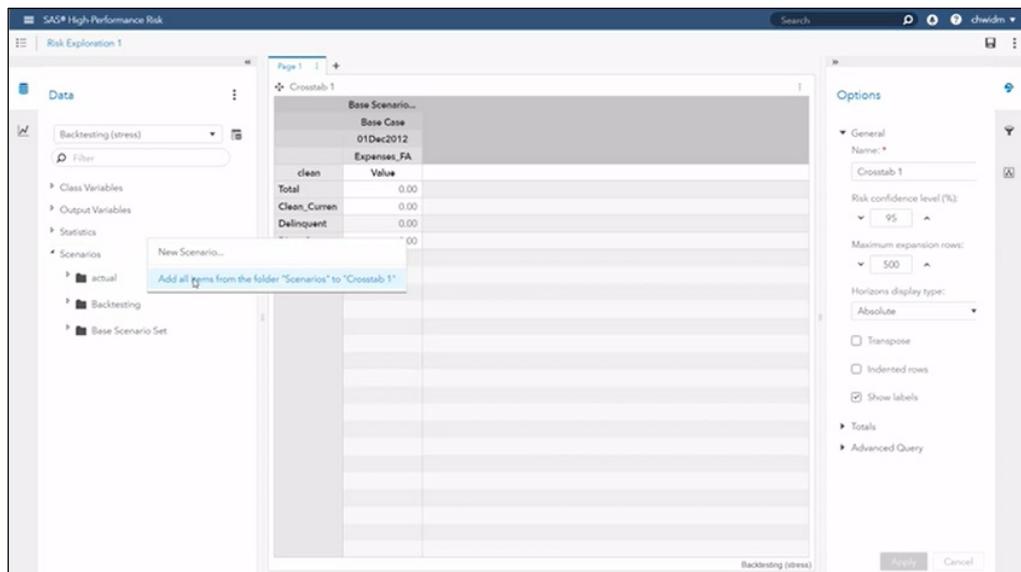
The first analysis we will look at is a scenario run with backtesting. With backtesting, you have a historical portfolio and you want to compare your model forecast against what happened. This is a common situation that a modeler or an analyst will have to do to demonstrate the accuracy of their model. The SAS MIP makes backtesting very quick and easy by providing it as a built-in run type.

Return to the **Model Implementation** window. Click the icon in the upper right corner to create a new run. From the drop-down menu, select **New scenario run with backtesting**. The setup for this scenario looks very similar to the setup of the normal scenario run. Select a **Source risk cube**, select some **Scenario data**, and select which model group map you want to backtest. Here you will get an extra step in the wizard for the backtesting setup. In the **Backtesting** step, you will select an external data set that contains information about what actually happened for

the output variables that you are concerned about. In the **Actuals data set for backtesting**, select the data set you want to use. Click the box next to **Calculate variables for backtesting metrics** to select any of the output variables contained in the run and get built-in metrics for those variables. The possible metrics are cumulate percentage error, mean absolute error, mean absolute percentage error, mean error, and root mean square. If you need an additional metric, you can also create your own.

Once you have gone through all of the steps in the wizard, you are ready to run. Click **Submit Run**. Once the run has finished, you can view the results in the Risk Explorer. Once you have launched the Risk Explorer, you will notice in the **Data** pane on the left side under **Scenarios** that you have two scenarios. The first is automatically labeled as **actual**. Those are the results from the actual data set that you loaded. The second scenario is the name of your run. Right-click **Scenarios** and choose **Add all items from the folder “Scenarios” to “Crosstab 1”** to add all scenarios to the cross-tab. (See Figure A.12.)

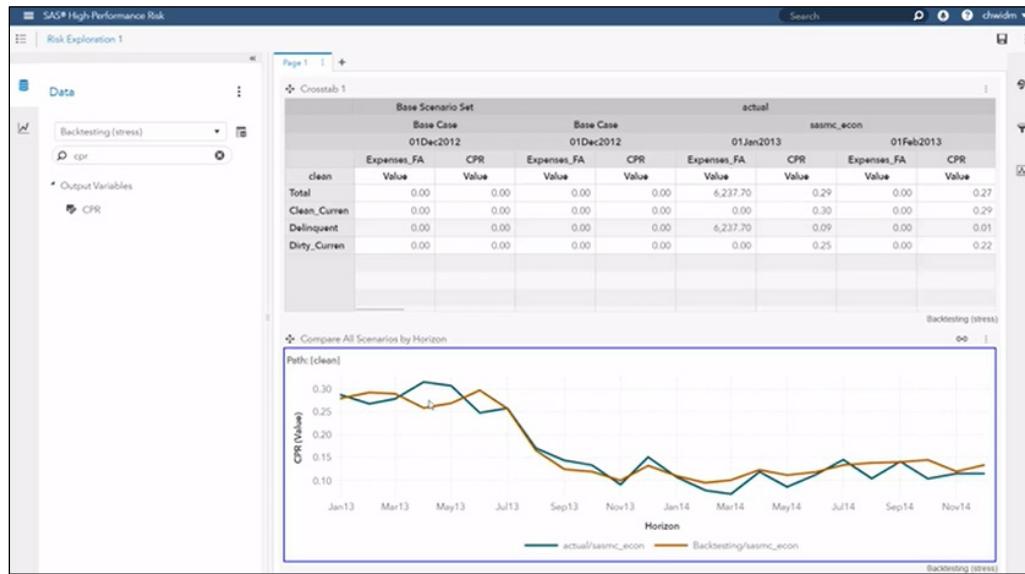
**Figure A.12: Add Scenarios to Cross-tab**



Next, choose the output variables that you are interested in. Click **Output Variables** in the left pane and use the filter search to find and select variables. Right-click on the variable name and add it to the cross-tab. Once you have added a variable to the cross-tab, right-click inside the

cross-tab and use the options in the drop-down menu to compare the variable by all scenarios and horizons. This enables you to very quickly plot the results of your forecast against what actually happened. (See Figure A.13.)

**Figure A.13: Compare All Scenarios by Horizon**



You can drill down and look at any lower cross-class segment. Double-click on any cell in the cross-tab to look at a lower segment.

### Sensitivity Analysis

The next type of run that we will walk through is a sensitivity analysis. This is a common type of analysis that a modeler or an analyst might need to perform to demonstrate the sensitivity of their model by shocking some economic factors or numerical portfolio factors. For example, you might want to demonstrate the sensitivity of your prepayment forecasts to interest rates or the sensitivity of your default forecast to unemployment rates.

From the Model Implementation window, click the icon in the upper right corner to create a new run. From the drop-down menu, select **New scenario run with model sensitivity analysis**. Again, the setup wizard is very similar to the previous runs that we have set up. You will select a source risk cube and select your scenario data. There is a new step here to create a Model Sensitivity Analysis page. In this step, you can create shocks.

Under **Risk source type**, select which type of factor you want to shock. Under **Variable**, you will select a risk factor group from your economic data. Next, select if you want to create absolute or relative shocks under **Shock type**. In the **Shock values** box, enter the values that you want in a list separated by returns. You can give it a **Floor** and a **Cap** to say that you don't want values to go above or below a certain number. You can also **Fade in** or **Fade out** the shock over a period of months. (See Figure A.14.) When you are happy with what you have entered, click **Apply**.

Figure A.14: Model Sensitivity Analysis Setup

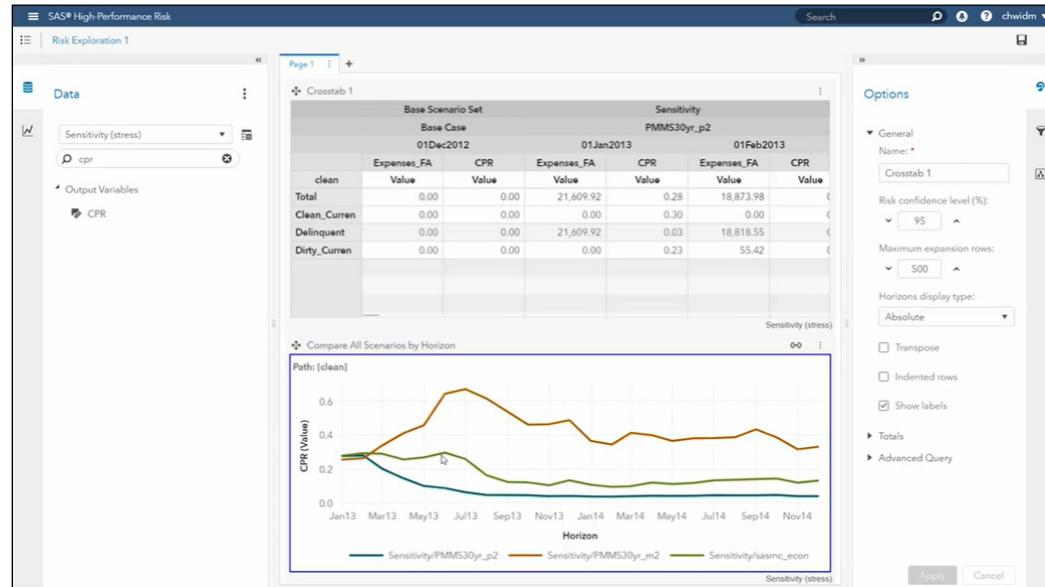
Name	Risk Source Type	Variable	Shock Type	Shock Value	Floor	Cap	Fade-in
PMMS30yr_m2	Risk Factor	PMMS30yr	Absolute	-2			6
PMMS30yr_p2	Risk Factor	PMMS30yr	Absolute	2			6
hpi_m0.2P	Risk Factor Group	hpi	Relative	-0.2			6
hpi_p0.2P	Risk Factor Group	hpi	Relative	0.2			6

Now you will have created new scenarios that correspond to the shock values you entered. The rest of the setup in the wizard is the same as shown previously. When you have finished configuring your options, select **Submit Run**. The system will run all the scenarios that were created in the sensitivity analysis step.

Go the Risk Explorer to evaluate the results. In the **Data** pane, click **Scenarios ▶ Sensitivity**. You can see the shocks that you created. To evaluate a shock, right-click the shock that you want to see and add it to the cross-tab. You can add as many shocks as you would like. Next, add any output variables that you want to assess by clicking **Output Variables** and then right-clicking the name of the variable to add it to the cross-tab.

Now you can plot the forecast. Right-click inside the cross-tab on the variable that you want to compare. Select **Compare (Variable) by ▶ All Scenarios by Horizon**. Hopefully, the plot will quickly show that your model is very sensitive to shocks. (For example, see Figure A.15.)

Figure A.15: Compare All Scenarios by Horizon



### Attribution Analysis

The last type of analysis that will we run is an attribution analysis. A common situation in any sort of regular reporting, for example, stress testing or reserving, is that you will produce a number at one time and then the next quarter you will forecast a new number. And, of course, the questions from senior management are. "Why is there a change? What happened? Can you explain to me why the two numbers are different?" Typically, the process for attributing the differences involves starting at the first run, then iteratively swapping in the factors from the second run to walk forward from the first run to the second run, and explaining why the two numbers differed.

In the most recent release of SAS Model Implementation Platform, the attribution analysis process is built-in for you. In the sidebar on the left side of the Model Implementation screen, there is an icon for Attribution Analysis. Click on the icon of the page with a magnifying glass. This takes you to the **Attribution Analysis** window where you can create a new attribution analysis.

Click the  icon in the upper right corner. This opens the **New Attribution Analysis** screen. First, give the analysis a name. Then, in the **Run 1** box, select the first run you want to compare. In the **Run 2** box, select the second run. Click **Apply**. The system now brings in the economic factors, risk data objects, and computed variables. It lists them all in the attribution factors table, as shown in Figure A.16.

Figure A.16: New Attribution Analysis

Name	Type	Label
portfolio	Portfolio	portfolio
hpi	Risk factor	hpi
pmms15yr	Risk factor	pmms15yr
pmms30yr	Risk factor	pmms30yr
uer	Risk factor	uer
logic	Logic	logic

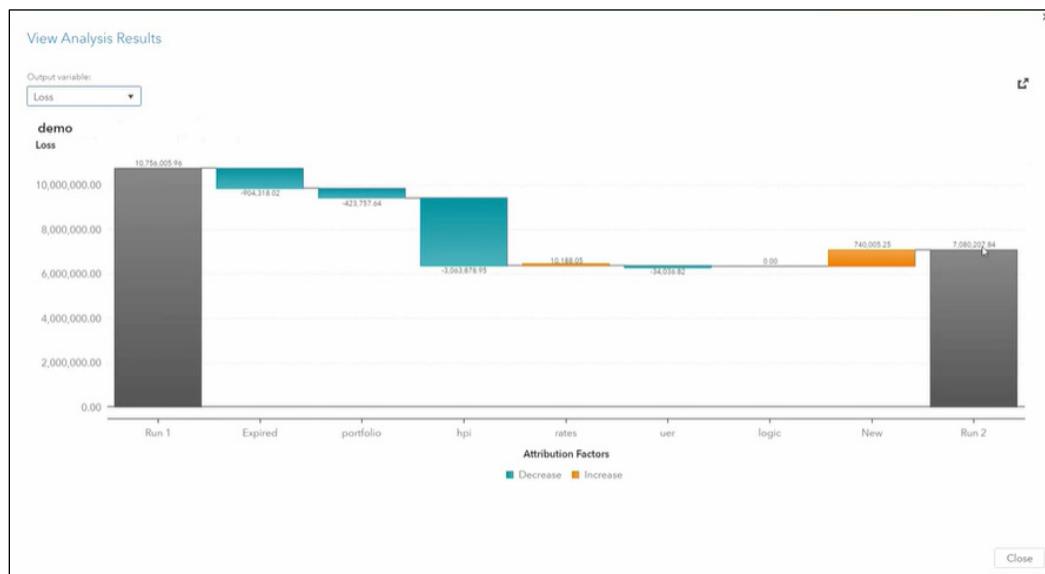
The attribution factors listed in the table are acting as the sequence of updates that the system will go through. It starts at Run 1 and swap in the factors from Run 2 in the order specified in the table. You can change the order in the table by clicking a factor and using the up and down arrows in the upper right to move the factor up or down in the list. However, the portfolio must be first and the logic must be last. You can also group factors. Select any factors that you want to see a grouped impact, rather than the individual impact. Click the **New Group** icon in the upper right corner. A new row appears titled **Group 1**. You can rename the group if you want.

Next, select any output variables that you are interested in. Click **Select** under **Common output variables** to add variables. For example, if you stress testing, the loss variable would be an important one. You can select any two scenarios with a different. So you could compare, for example, base versus adverse from Run 1 to Run 2. Or you can compare all scenarios that have the same name, for example, base versus base, adverse vs. adverse, severely adverse vs. severely adverse, and so on.

Click **Advanced Options** to customize the advanced options. You can set the number of nodes and threads. By default, the generated risk cube is discarded, but if you want to query them later, you can uncheck that option to keep those cubes.

Now you are ready to click **Analyze**. With just a few small steps to set up, you are ready to create and launch this potentially large analysis. Once the attribution analysis is complete, you can view the results. The results are a chart that walk you from Run 1 and ends at Run 2. (See Figure A.17.) For each of the factors in the table that you had set up, you can see which part of the difference between Run 1 and Run 2 is attributed to each of these factors.

**Figure A.17: Attribution Analysis Results**



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