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Risk Surface: Chart Your Risk Profiles[1]

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A KEY CHALLENGE in Enterprise Risk Management (ERM) is how to effectively increase risk transparency and improve risk communication within an insurance organization. Risks in the insurance industry are often managed by various cohorts of people with distinct backgrounds. Risk management in insurance organizations has become more sophisticated and quantitative, because risks in the real world have become more complex than before. Therefore, a consistent view and clear communication of a corporation's risk profiles are more in demand than ever before. Executives should be given a clear picture of the risks on the balance sheet when judging the external environment and forming their strategies.

Stress testing is certainly a powerful tool for an organization to understand its risk profiles under various scenarios. However, this can be like seeing the most astonishing previews of a horror movie without understanding the full context. In this article, we propose a new term called the "risk surface" to enhance risk communications.

IDEA OF RISK SURFACE

The risk surface is a surface of insurance liabilities or surplus values under nearly continuous changes of factors such as equity performance, equity volatility, interest rate curves, and credit spreads. We demonstrate an insurance company's surplus under alternative scenarios and provide three dimensional charts that assist in visualizing this surface.

It is difficult to show the full picture of a company's risk profile with a limited number of scenario or sensitivity tests, which usually demonstrates just optimistic, moderate, pessimistic, or extremely bad scenarios. It is particularly helpful to management if the overall liabilities or surplus values are displayed within three dimensions by various equity performance and interest rate (or spread) levels. This allows the executives to have live views of both the tail events and the risk factors' correlations within the tails. For instance, an insurance carrier with extensive variable annuity GMxBs, the executives appreciate a simple chart showing the capital positions with respect to the S&P 500 and interest rate levels.

Depending on the asset and liability mix, many insurance companies' performance and financial strength are largely driven by the following list of external risk factors:

- Interest rate curve
- Credit spread curve and credit events
- Equity performance and volatility

At the corporate level, assets, liabilities, and their relationship to external risk factors frequently are not straightforward when assets/liabilities are consolidated. This additional complication makes it difficult for management to understand the impact on the balance sheet from various economic shocks. As a tool for risk communication, a risk surface can help visualize the tails and the relationship of surplus/liability to key risk factors made evident from the shapes of the surface. Below is a simplified example of a risk surface.

RISK SURFACE OF A HYPOTHETICAL INSURER

We assume that a mono-line insurer writes a simple variable annuity (VA) product for our illustration example. It is assumed that the VA product has rich embedded GMxB guarantees that are not hedged. Suppose that there are $108 billion assets invested in zero coupon bonds and the liability totals $98 billion which are proxied by a replicating portfolio to facilitate extensive liability valuations. In our example, the replicating portfolio consists of only zero coupon bonds and vanilla put options (assuming the VA only has GMDB or GMAB types of living benefits). Though it provides only a rough approximation to the behavior of the VA liability, this simplified replicating portfolio works well to demonstrate the risk surface concept.

We consider three market risks: interest rate curve shifts, equity level changes, and equity volatility movements.

FOOTNOTES:

[1] The views in this article only represent the authors' personal opinions. This article does not represent any statements from the organizations where the authors are employed.

- The yield curve starts from 5.5 percent at the short end (1-year maturity) to 7.25 percent at the long end (30-year maturity). Parallel shifts of the yield curve from the base case range from -5 percent (i=0.5 percent for the short end and 2.25 percent for the long end) to 9 percent (i=14.5 percent for the short end and 16.25 percent for the long end).
- The Equity (S&P 500) level starts at 1100 in the base case. The percentage changes of the level of the S&P 500 range from -60 percent (S&P 500 = 440) to 55 percent (S&P 500 =1705).
- The base case of equity volatility (S&P 500 vol) is 20 percent and the variations range from 8 percent to 95 percent.

The specified full range of each risk factor is discretized to 30 points. Therefore, there are 27,000 scenarios in our simulation.

After the valuation of assets and liabilities, the risk surface of the VA writer is easily produced. The graphical representation is in terms of surplus (capital) positions with regard to the evolution of the underlying risk factors. **Figure 1** shows the risk surface with respect to interest rate curve shifts and the percentage change in the level of the S&P 500 with the S&P 500 volatility fixed at 20 percent. It is presented in both a three dimensional plot and a two dimensional contour plot. The color surface in the left plot represents the surplus values under all possible combinations of interest rate curve shifts and the percentage changes in the level of the S&P 500. From this surface, observe how the two risk factors affect the insurer's surplus position, where upward (downward) shifts in both the interest rate curve and the S&P 500 profits (harms) the insurer. The tail of the surplus is located at the left front corner marked by blue where the interest rate shifts down by 5.5 percent and the S&P 500 drops by 60 percent. The contour plot also reveals how the surplus changes relative to interest rate and S&P 500 changes. The color of the graph shows the surplus level for various combinations of these two risk factors. For example, a shift of -5 percent from the base interest rate curve and no change in the S&P 500 base level of 1100 represents the current market condition at the time of writing, with a surplus level

Figure 1: S&P 500 volatility = 20 percent

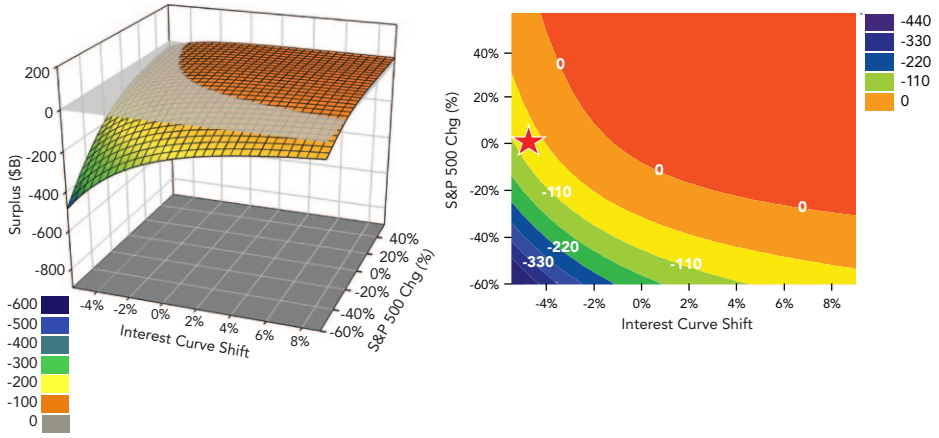
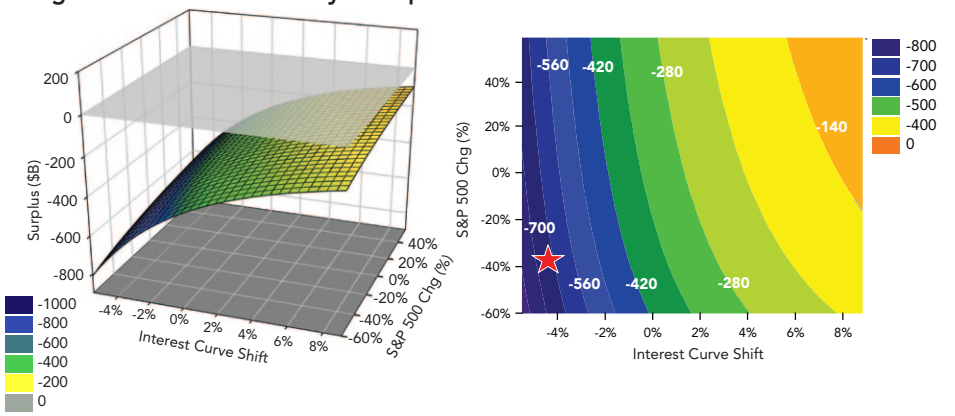


Figure 2: S&P 500 volatility = 95 percent



of -$110 billion denoted by the red star. Considering the initial asset position of $108 billion, we conclude that this business is extremely risky, due mainly to the fact that this business has very rich unhedged GMxBs.

In **Figure 2**, to demonstrate the impact of volatility, we assume that the S&P 500 volatility jumps to 95 percent. Observe how the insurer is insolvent in all scenarios. Recall how during the recent market turmoil, the S&P 500 dropped to 680 (-40 percent down from the base level of 1100), and interest rates were historically low (-5 percent shift from the base level). The red star in the contour plot below identifies the state of this company under similarly stressed situation (though the equity volatility is even higher here).

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Figure 3: S&P 500 volatility = 8 percent

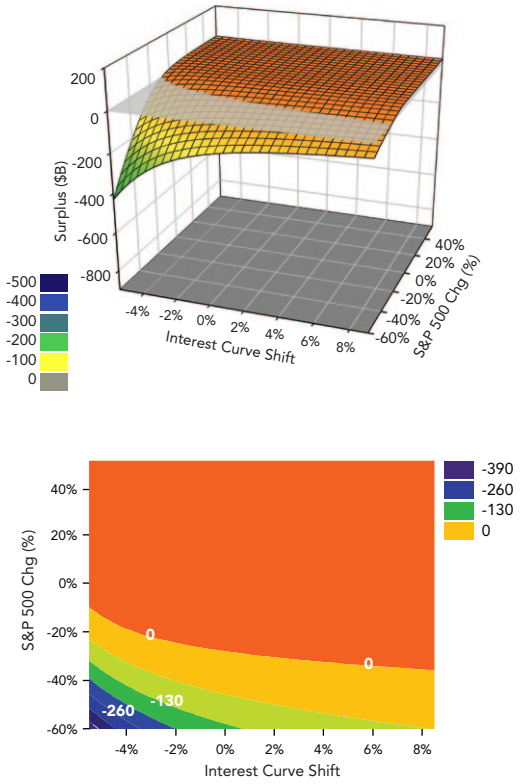

Figure 4: S&P 500 index jumps 50 percent / drops 60 percent

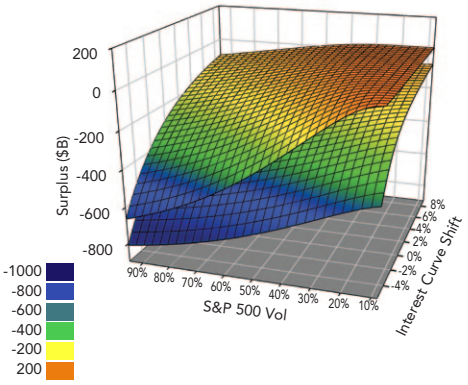

Figure 3 shows the risk surface when a favorable S&P 500 volatility of 8 percent occurs. Observe in the 3-d plot that most of the surface is above the zero-surplus plane (the gray transparent plane). Note this as well in the contour plot where the majority of the plot consists of red and orange. However, tail risk does not disappear as shown in blue.

We have illustrated the risk surface with respect to interest rate curve shifts and the percentage changes in the level of the S&P 500 for only three volatilities. By discretizing the range of volatility by 30 points, we obtain 30 risk surfaces. Separately, we have plotted the three surfaces, however, all of the risk surfaces could be plotted in the same plot, which a risk manager can use to visualize surplus movement with all three risk factor changes occurring simultaneously. See how **Figure 4** displays two risk surfaces plotted in one graph with respect to volatility level and interest rate shift. The upper surface is for the 55 percent jump of S&P 500 index (=1705) and the lower one shows a 60 percent drop (=440).

The characteristics of the risk surface are uniquely determined by an insurer's business and risk management strategies. In this example, we show the surplus surface when the embedded derivatives are unhedged. In the case of liability options being hedged, the hedging asset surface, liability surface, and the net hedging surface (asset surface minus liability surface) is a great aid to the risk manager. The hedging effectiveness in the tails can be easily visualized and examined. Furthermore, by plotting surplus surfaces of both hedged and unhedged positions, we are in a good position to assess the value added from hedging.

Ideally, the insurer should maintain risk surfaces that are above the zero-plane for most of the cases and whose tails below the zero-plane are narrow and short. In our simplified case, only interest rate curve shift, S&P 500 level and volatility are considered. Nevertheless, other risk factors affecting the business can be included too.

Companies can plot their insurance liabilities in the same manner. Liability surfaces would be a valuable tool for pricing actuaries, ALM practitioners and insurance asset managers to understand the underlying dynamics of insurance liabilities.

PROS AND CONS OF RISK SURFACE

The risk surface has clear advantages as a risk communication tool:

- Develops a common language to demonstrate alternative scenarios
- Increases risk transparency by visualizing tail events
- Facilitates risk communications to understand risk correlations
- Adds value allowing asset managers to gain deeper understanding of insurance liabilities when developing investment strategies and establishing investment constraints
- Visualizes the business' sensitivities to risk factors evident from the shape of the liability or surplus surface

"As a tool for risk communication, a risk surface can help visualize the tails and the relationship of surplus/liability to key risk factors made evident from the shapes of the surface."

There are also challenges in constructing the risk surface. Under current liability valuation systems, it is extremely time-consuming to develop a liability or surplus surface illustrated in this article, as actuaries from every business line need to re-process their liability models possibly hundreds of times to consider all of the combinations of risk factors. It is especially true for complex liabilities such as UL with secondary guarantees and variable annuities with GMxBs. Therefore, it makes this nearly impossible as a frequent reporting process. However, this challenge can be overcome by using replicating portfolio techniques (although some basis risks cannot be captured by the tool).

The idea of a risk surface is to demonstrate how an insurance company's surplus or liabilities react to external market factors such as equity performance and volatility or interest rates. This concept can be expanded to include other actuarial risks such as mortality, lapse, morbidity or other actuarial risk factors; however, it may be difficult to include these additional risk factors using portfolio replication.

POSSIBLE IMPLEMENTATION

Even though the implementation of the risk surface may not be an easy exercise, companies may want to integrate this into existing processes such as capital forecasting or stress testing. We propose the following key implementation steps:

- Select the key risk factors. An insurance company has to first understand the key underlying drivers of their business values / risks. This could be challenging for multiline companies that write business with distinctive product economics / risk profiles.
- Define the granularity of the shocks to each risk factor and the tails (e.g., 20 percent interest rate level is in the extreme tail). History can be a source to determine how tails should be modeled. Care should be taken in selecting the range of risk factor movements for modeling runtime considerations.
- Implement a portfolio replicating tool and use it to construct a replicating portfolio used as a liability benchmark.
- Once the replicating portfolio is constructed, set the selected risk factors according to the specified granularity assumptions and then value both the asset portfolio and the liability benchmark.
- Import these series of market values into any standard plotting software which allows the generation of the risk surface.
- Assess the reasonableness (magnitude and shape) of the surface (e.g., by comparing with capital forecasting results).

CONCLUSIONS

Strategists who steer the ship may not always have a clear picture of the depth of the water underneath. But by using a risk surface, which facilitates risk communication and risk transparency within insurance organizations and other financial institutions, they will have the knowledge that will prevent them from running aground.

Actuaries should make their models match reality as closely as possible. Our models are complex because the world is even more complex. But as financial modelers who handle extensive levels of complexities, we often struggle to find simple rules of thumb to explain our findings to the people who steer the ship. However, graphics have always served as a common language throughout history of mankind. When executives are provided with risk surface charts that convey this complexity and if they are properly educated on the use of the charts, they will have a much greater understanding of the company's risk profile. ■