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Risks & Rewards

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INVESTMENT SECTION

Beware of Stochastic Model Risk!

By Stephen J. Strommen

Stochastic models have become a staple of actuarial work. In the life insurance and annuity business, they are often used for hedging of long-term guarantees and are needed for financial reporting where "market-consistent" valuations are required and where regulatory reserving mandates their use.

It wasn't always this way. Previous generations of actuaries put values on long-term guarantees by using conservative assumptions. Since there was no large and open market for long-term insurance guarantees, such values were largely a matter of professional judgment.

Around the beginning of the 20th century, Louis Bachelier was the first to apply the mathematics of stochastic processes to the valuation of stock options. His work implied that one might assign a probability to prices in the future based on assumptions made today. Later in the 20th century, Black and Scholes refined these ideas and incorporated the market price of risk to develop the Black-Scholes formula for stock option prices. Since then, similar techniques have been applied to fixed-income instruments and interest rate derivatives. These techniques have been widely adopted by actuaries and others for valuation of all sorts of out-of-the money options and guarantees. These techniques improve upon previous methods that were less quantitative and based largely on judgment.

Stochastic techniques have been successful at least partly due to their ability to explain market prices. One can choose an applicable stochastic model and fit the

CONTINUED ON PAGE 4

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Chairperson's Corner

By Bryan Boudreau

Time flies, and it is already time for my second (and final) Chairperson's Corner. As I write this, markets continue to confound, digesting mixed economic and political signals. We've gone from expected Fed rate hikes to expected rate cuts in the span of months. The only thing that is ever certain in the markets is uncertainty, and that is why the left-hand side of the balance sheet is so fascinating to me as an actuary.

It's already been a busy year for the Investment Section Council. In April, the council met face-to-face at the SOA offices. Increasing the value of section membership remains our prime directive. Everything we do is designed with this goal in mind, and to do this we need to engage effectively with our members. We discussed the area of actuarial and investment research and are actively exploring potential areas where the Investment Section can sponsor relevant and impactful research efforts. We're also looking into ways in which our new electronic newsletter format and LinkedIn page could be used interactively to better understand section member interests and preferences.

Our vice chairperson, Hal Pedersen, and I also participated in the SOA's April Council of Section Chairs. A recurring theme at this meeting was the rapidly changing SOA and section demographics and, in particular, the emergence of millennials as the (currently or soon to be) most populous generation in the SOA. As the father of two millennials, I can see firsthand that this generation interacts with information and experiences the world in far different ways from prior generations. To stay relevant, the SOA and Investment Section know they need to adapt. While this remains a continuing dialogue for the Section Council, I'd be happy to get emails, LinkedIn invites and other contacts with suggestions. (Millennials, you can email me at *bboudreau@metlife.com*, but you won't find me on Instagram!)

Our asset allocation contest is in full swing, with about 60 section members competing to deliver the best portfolio returns through September 30. We've also just closed the entry period for the Redington prize, which recognizes the best investment paper written by an actuary. We expect to announce the winners of these contests by early in the fall and will recognize the winners at the section breakfast at the SOA Annual Meeting & Exhibit.

Thanks to our continuing education subcommittee, our robust 2019 slate of section webcasts and podcasts continues. Several of the new "How I Became an Investment Actuary" podcasts are on the section webpage. There's also a new podcast from Andy Rallis, our SOA president-elect, where Andy provides insights on asset/liability management. We've also completed our highly successful 4/3/2 webcasts, which included a series on Investment Boot Camp as well as a series on Economic Scenarios and Cash Balance Plans. These webcasts can still be purchased in the SOA online store (and webcasts older than one year are free to members).

We're also in the process of planning our Investment Seminar, which will be held in Toronto on October 27, the Sunday before the annual meeting program begins. We're planning a networking event with the CFA Institute for the evening of the seminar. Be on the lookout for details.

It's truly been an honor to be an Investment Section Council member for the past three years and chairperson for the last year. Sincerest thanks to my fellow council members, the "friends" of our council, the SOA staff (especially David Schraub and Dee Berger) and, most importantly, our section members for providing me with the opportunity. ■

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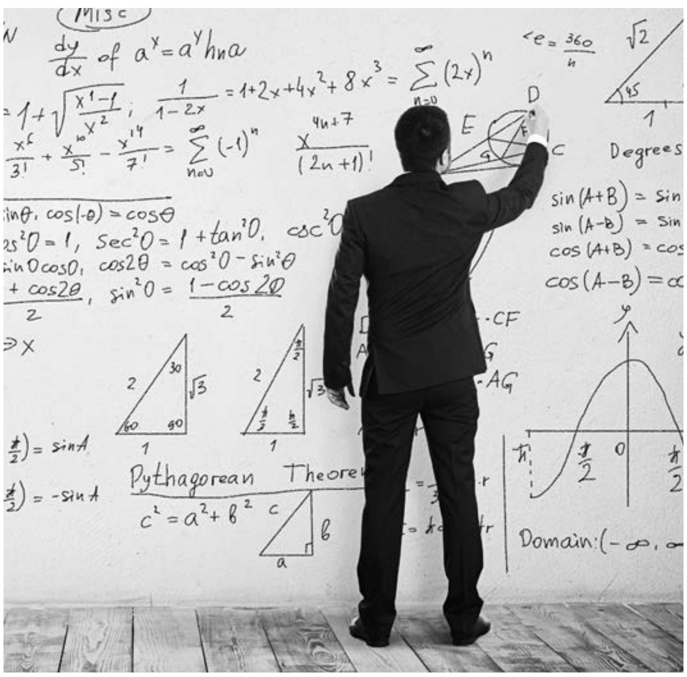
parameters of the model to some market prices. Then those same fitted parameters can be used in the stochastic model to determine a market-consistent price of something that is not actively traded, such as a life insurance or annuity contract with long-term guarantees. This idea has been extended to imply that such models can be used to determine the probability of failure of an insurance company or block of business. The 99.9 percent probability threshold in Solvency II is based on this extension of the technique, as are the probability levels specified by the NAIC for certain reserve and capital requirements.

Unfortunately, blind reliance on such models can be disastrous. Recall the fate of Long-Term Capital Management (LTCM), a hedge fund management firm that applied these models in a big way. The firm's strategy was basically to use market-consistent valuation to identify securities whose actual market price deviated from the market-consistent price, on the theory that the price would converge to become more market-consistent over time. The firm's results in the first few years were stellar. Then in 1998, the firm lost $4.6 billion in a few months and required a $3.6 billion bailout funded by 16 big banks under the supervision of the Federal Reserve. Actual market prices did not behave in the manner their models anticipated, and financial disaster ensued.

I am concerned that many actuaries do not understand the degree of model risk that is present any time stochastic models are used. Just like the founders of LTCM, some actuaries give undue deference to results from a stochastic model. Different stochastic models of the same business produce different results, and the differences can have big consequences.



With that in mind, the remainder of this article highlights several areas where model risk arises due to the choice of a stochastic model and its calibration. We focus here on models for future interest rates and equity market returns. Consider the model risk arising from each of the following.

USE OF THE NORMAL DISTRIBUTION

The familiar bell-shaped curve of the Normal or Gaussian distribution is widely used as a mathematical model for uncertainty. It is mathematically straightforward and facilitates derivation of closed-form formulas for many commonly used measures of risk and value.

Unfortunately, the Normal distribution is just a first-order approximate model for risks in the real world. It is well documented that the actual variability of most economic variables is better characterized by a distribution with both fatter tails and a stronger central peak than the Normal bell-shaped curve.

The Black-Scholes formula for stock option prices is one of the most common tools built on the Normal distribution. The "volatility" parameter of the formula is analogous to the standard deviation of the Normal distribution. If the model fit well, then a single value for volatility would approximately fit all market prices. But it does not. The fitting of actual market prices using the Normal distribution results in an "implied volatility surface," which is an array of different values depending on strike price and tenor. The knowledgeable actuary will understand this as evidence that the underlying model does not fit very well. In particular, it is not ideal for use in generating future scenarios for stochastic simulations because a generator can use only a single value for volatility at a point in time, not an array of fitted values.

There are several ways to address this issue when choosing a stochastic model for use in a scenario generator. The three most common are:

- **Stochastic volatility.** The Normal distribution is still used, but the volatility parameter is made to follow its own mean-reverting stochastic process over time. When the volatility is lower than average in the scenario, values clump toward the center of the distribution. When the volatility is higher than average, relatively more tail values are generated. Overall, the ultimate distribution has longer tails and a stronger central peak.

- **Regime switching.** The Normal distribution is still used but the model switches between two regimes, which are characterized by different sets of parameter values for both the volatility and the mean. There is a high-volatility regime and a low-volatility regime, typically with different mean values. Switching between regimes results in an ultimate blended distribution that can have longer tails and a stronger central peak.

- **Different underlying distribution.** The Normal distribution is abandoned as a model of variability within each time step. A different distribution that has longer tails is used instead. There are many choices for such a distribution.

DEALING WITH THE ZERO LOWER BOUND

Interest rates may generally follow a random walk, but the ability to simply hoard cash makes it economically difficult for interest rates to fall much below zero. Slightly below zero is possible due to the expense and risk associated with hoarding cash, but far below zero is arguably not possible while markets continue to function. One would think that any interest rate model in common use would need to reflect this near-zero lower bound on interest rates.

Not so. For example, the Ho-Lee lattice model is commonly used for valuation of callable bonds and other fixed-income instruments with options. The underlying model is a recombining lattice for paths of future interest rates, with equally spaced up and down jumps. When carried far enough into the future, some paths through such a lattice involve negative interest rates. Yet this model is in common use because of its speed and efficiency and mathematical tractability.

Several approaches for dealing with the zero lower bound are in circulation. Among them are these:

- **Make the volatility of interest rates proportional to the current interest rate.** When interest rates are low, volatility becomes low so that it becomes unlikely that a random shock will push interest rates below zero. When interest rates are high, volatility is high, as happened in the early 1980s in the U.S. This approach has an effect on the implied future distribution of interest rates, making it skewed with a longer tail on the high side. Two versions of this are in common use.
  - The Cox-Ingersoll-Ross method makes the volatility proportional to the square root of the interest rate. The ultimate distribution of future interest rates tends toward a noncentral Chi-Square distribution.
  - The Black-Karasinsky method uses a constant volatility for the log of the interest rate rather than for the interest rate itself. The ultimate distribution of future interest rates tends toward a lognormal distribution.
- **Impose a zero floor at each time step.** If the stochastic process produces an interest rate below zero at any time step, set it to zero before proceeding to the next time step.
- **Track the theoretical path of the interest rate separately from the lower bound.** Under this method, the stochastic process is allowed to take its course and produce negative interest rates, but the interest rates actually output from the generator are floored at zero. This can lead to scenarios with extended periods of very low interest rates.

PERSISTENCY

For the sake of discussion, let's accept the proposition that interest rates are mean-reverting. In the U.S. the Federal Reserve largely controls interest rates. The Fed has a target level and moves interest rates up or down relative to that target depending on whether economic stimulus or inflation control is more important at the moment. A mean-reverting random walk seems to be a reasonable stochastic model for interest rates in these circumstances.

> Different stochastic models of the same business produce different results, and the differences can have big consequences.

In recent years, there has been concern that a simple mean-reverting random walk may not be particularly realistic. While interest rates may revert to the mean in the long run, they have tended to be very persistent and stay within a narrow range in the short run. This suggests a stochastic process with persistence, whereby scenarios can remain far from the ultimate mean for long periods of time. A simple mean-reverting model is anti-persistent because any diversion from the ultimate mean is immediately countered with a stochastic tendency to revert back to the ultimate mean.

Persistence can be increased by modifying the stochastic process. In a simple mean-reverting model, the mean is constant. In more complex models, the mean itself can be made to vary over time.

- In a double-mean-reverting model, there is a current mean and a long-run mean. The long-run mean is constant, but the current mean follows a simple mean-reverting process. In the short run, scenarios revert to the current mean, not to the long-run mean.
- In a regime-switching model, there are two different values for the mean. Only one is active for each time step. There is a probability of switching from one to the other at each time step, but that probability is typically low.

I have measured the proportion of 30-year scenarios containing periods where short-term interest rates remain below 2 percent for 10 years or more. Similarly calibrated generators (based on the distribution of interest rates 30 years in the future) using different stochastic processes yielded proportions that varied from less than 3 percent to more than 10 percent. Such differences could easily affect modeled capital requirements in connection with long-term minimum interest guarantees.

CHOICE OF CALIBRATION PERIOD

Calibration of an economic scenario generator for stochastic simulations is typically done using historical data over an extended period of time. Unfortunately, the historical record does not include enough time steps to provide stable calibration. The choice of time period to use for calibration can affect the results significantly, making calibration unstable. It can be instructive to compare the results of stochastic simulations using alternate calibration periods for the parameters of the scenario generator.

This should be kept in mind any time market-consistent or "risk-neutral" scenarios are used. Such scenarios are typically calibrated to market conditions on a single day. When used for stochastic simulations that extend over decades, the results can be notoriously unstable unless there is some sort of mean reversion built into the parameters of the stochastic process over time.

CALIBRATION FOR REGULATORY PURPOSES

Sometimes the parameters of a generator may need adjustment in order to meet regulatory calibration targets. This should be viewed as substituting the regulator's judgment for one's own. The regulatory calibration targets may be based on a different calibration period, a different stochastic model or both. When employing stochastic modeling, one should not blindly accept the regulator's judgment as embedded in regulatory calibration criteria. Valuable insight can be gained by running a stochastic model using your own generator and your own calibration before determining the effect of any adjustment needed to meet regulatory calibration requirements.

CONNECTIONS BETWEEN INTEREST RATES AND EQUITY RETURNS

When stochastic economic scenarios were first proposed for actuarial risk management, the theoretical work on scenario generators accepted certain long-term economic relationships as axiomatic. Interest rates and inflation were related. Stock returns and inflation were related. Stock returns were volatile but had an expected mean higher than interest rates due to a risk premium. The Wilkie model, an early stochastic scenario model, reflected these axiomatic relationships.

Recently, a more statistical approach has taken hold, and relationships that cannot be proven as statistically significant based on historical data are often abandoned. In particular, the relation between interest rates and equity returns is often treated as nonexistent because it cannot be proven beyond statistical doubt. The idea that the limited time span of the modern historical record provides insufficient data to either prove or disprove such conjecture tends not to be considered. An example of this is the generator currently mandated by the NAIC for regulatory use, which treats interest rates and equity returns as independent.

If you believe in a relationship between risk and expected return, then you may accept it as an axiom that in a real-world model, the expected return on equities should exceed the risk-free rate by an expected risk premium at every time step in every scenario. In a risk-neutral model, the expected return on equities should equal the risk-free rate and the risk premium should be zero. Such relationships between risk and return are violated when the stochastic processes for interest rates and equity returns are independent.

Just because something cannot be proven does not mean it isn't true. This is true in statistics, it's been proven true by Gödel in mathematics, and I believe it is true in the context of stochastic economic scenario models. As a matter of professional judgment, one should be careful when using models that do not reflect relationships that one believes to be true.

SUMMARY

The point of this article is not to discredit stochastic models. Such models can be very useful tools for analysis of risk. The point here is that results from a stochastic model should not be given any more deference or be considered more exact than any other kind of actuarial estimate. Instead, they should be viewed as approximate guidance that can best be used to inform professional judgment. The choice of model and its calibration should be treated with just as much care and review as the underlying actuarial assumptions in a deterministic calculation.

As was demonstrated by the case of LTCM, blind reliance on stochastic models can pose a significant risk. Careful review and appropriate use of such models can lead to rewards. So this fits squarely within the risk manager's purview of risks and rewards! ■

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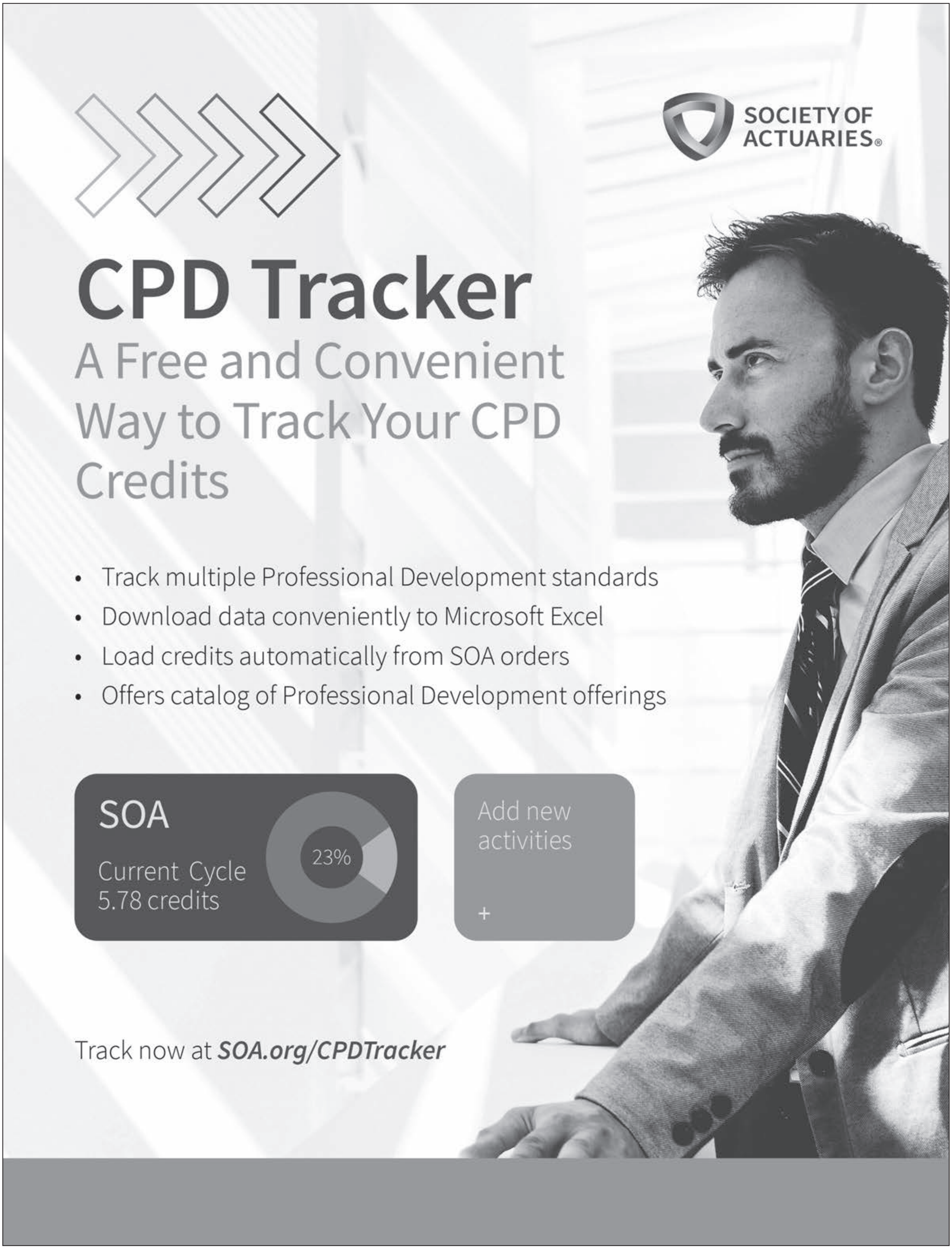
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Research Summary: Updating Wilkie's Economic Scenario Generator for US Applications

By Saisai Zhang, Mary Hardy, David Saunders
Edited by Gwen Weng

Editor intro: *This article is a condensed version of a paper the authors published in the December 2018* North American Actuarial Journal 22, no. 4. *That paper discusses the Wilkie economic scenario generator (ESG) in a U.S. context and provides practitioners with valuable insights on model robustness and performance. Practitioners working in ALM for pension plans and insurers may find this to be a useful point of reference, as the Wilkie ESG is a relatively simple multivariate model based on macroeconomic variables, suitable for investigating long-term ALM strategies. All are encouraged to read the original article to better understand the context, impact and limitations of the model. Any errors in summarizing their view are my own.*

The Wilkie model is an open-access ESG that was introduced by Wilkie (1986).[1] It was the first comprehensive ESG to be formally presented to the actuarial profession. The model distinguishes itself from other ESGs in that it has been subjected to a high level of public scrutiny, to a degree that no proprietary model has experienced. Our research presents the model in a U.S. context with U.S. data, analyzes the performance of the model historically, and considers the relevance of the model for North American applications now and going forward.

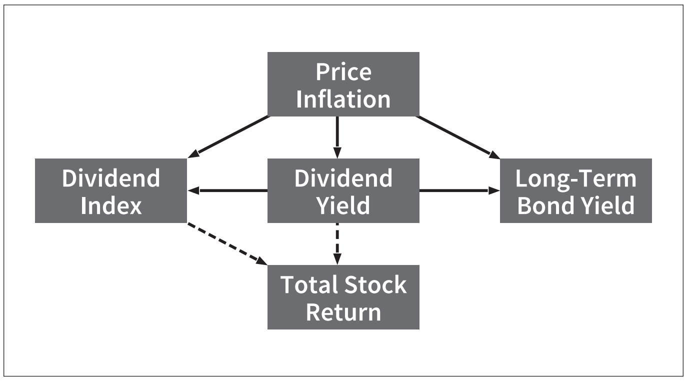
For investigating asset-liability management strategies for pension plans, the Wilkie model is quite suitable, because the assessment is long term and the pension assets are relatively passively invested, so the annual time step suffices.[2] Additionally, the relationship between the assets and liabilities of a defined benefit pension plan is critically connected to future inflation, real rates of interest and real rates of return on stocks, so the multivariate approach is a good fit to the problem.

Our main findings indicate that there exist challenges in modeling long-term economic series due to the presence of multiple structural shifts in the historical time series. Consequently, certain assumptions of stationarity are violated, and parameters are sensitive to the calibration period. These challenges can be mitigated by performing a change-point analysis and selecting an appropriate sample period for the parameter estimations. It is critical that these tasks be facilitated by a qualitative understanding of the true data-generating process (i.e., historical economic events and economic theories). A back-test based on 30-year out-of-sample data indicated that over that period, the model had tended to overestimate inflation (due to a structural shift in an implicit inflation targeting decision by the Federal Reserve in the 1980s), underestimate total return on stocks (due to the unprecedented dot-com bubble in the 1990s), and performed relatively well for long-term interest rates.

MODEL DESCRIPTION

The Wilkie model is a *P* (real-world) measure model with an annual frequency. It adopts a *cascade* structure, with inflation being the driver of other economic variables. It can be expressed diagrammatically as shown in Figure 1. Note that total stock returns are modeled by combining dividend yield and index, hence the dotted lines. We use subscripts to distinguish the series: q for inflation, y for dividend yield, d for dividend index and c for long-term bond yield.

Figure 1
Wilkie's ESG: Model Structure



The dividend index references the dollar amount of dividends generated annually by the economy. The price of the equity index is implicitly the present value of a perpetuity that pays the dividend index, discounted at the dividend yield.

Setting initial conditions (time $t=0$ parameters) for the model requires the user to judge the extent to which recently observed market data represents the relevant values for economic scenario generation and how much it represents random noise. In practice, users will set initial conditions based on average observed values in a recent sample period.

Inflation

Inflation is measured by the continuously compounded rate of change of the Consumer Price Index (CPI). The deviation from the long-run mean is modeled by a stationary AR(1) process:

$$\delta_q(t) = \log\frac{Q(t)}{Q(t-1)}$$

$$\delta_q(t) - \mu_q = a_q\left\{\delta_q(t-1) - \mu_q\right\} + z_q(t)$$

$$|a_q| < 1, \quad z_q(t) \sim i.i.d.\ N\left(0, \sigma_q^2\right)$$

where $\delta_q(t)$ is the force of inflation in the year $[t-1, t)$, $Q(t)$ is the CPI at time t, μ_q is the long-run unconditional mean, a_q is the parameter governing the strength of autoregression to the long-run average, and σ_q is the standard deviation of the innovation term.

The June series of non-seasonally adjusted U.S. City Average All Items CPI for All Urban Consumers from January 1926 to December 2014 (monthly), obtained from Bloomberg, is used. We have 89 observations of CPI and 88 inflation observations due to log differencing. The fitted parameters are reported in Table 1.

Table 1
Parameter Estimates of the US Inflation Model: 1926–2014 (Standard Errors Are in Parentheses)

	Estimated Parameter (SE)	
	1926–2014	
μ_q	0.0307	(0.0084)
a_q	0.5731	(0.0862)
σ_q	0.0337	(0.0026)

The original article compares this calibration to Wilkie's original model and illustrates the range of parameters using different calibration periods.

Dividend Yield

The log-transformed dividend yield, after subtracting its long-run mean, is described by a transfer function model with *input* inflation and an AR(1) noise:

$$\log y(t) - \log\mu_y = w_y\delta_q(t) + yn(t)$$

$$yn(t) = a_y yn(t-1) + z_y(t)$$

$$|a_y| < 1, \quad z_y(t) \sim i.i.d.\ N\left(0, \sigma_y^2\right)$$

where $y(t)$ is the dividend yield in the year $[t-1, t)$, μ_y is the long-run mean of the dividend yield, a_y is the autoregressive factor of the noise process, and σ_y is the standard deviation of the innovation term of the noise process.

The June series of price index and total return index of the S&P 500 from January 1926 to December 2014 (monthly) are used. Data up to December 2009 are obtained from Morningstar, Inc., with later values obtained from Bloomberg. We have 88 observations for fitting the dividend yield model. The fitted parameters are reported in Table 2. The reduced model omitted the insignificant parameters (at 5 percent level), including the parameter w_y which makes the dividend yield dependent on the force of inflation.

Table 2
Parameter Estimates of the US Dividend Yield Model: 1926–2014 (Standard Errors Are in Parentheses)

	Estimated Parameter (SE)	
	1926–2014 Reduced	
w_y	–	
μ_y	0.0309	(0.0097)
a_y	0.9368	(0.0387)
σ_y	0.1632	(0.0124)

Dividend Index

The dividend index process is modeled through the exponential rate of dividend growth. It is described by a transfer function model with multiple inputs from inflation, from the random shocks to previous dividend yields, and an independent invertible MA(1) process:

$$\delta_d(t) = \log\frac{D(t)}{D(t-1)}$$

$$\delta_d(t) - \mu_d = w_d dm(t) + (1-w_d)\delta_q(t) + y_d z_y(t-1) + b_d z_d(t-1) + z\_d(t)$$

$$dm(t) = (1-d_d)dm(t-1) + d_d\delta_q(t)$$

$$0 \le d_d \le 1, \quad |b_d| < 1, \quad z_d(t) \sim i.i.d.\ N\left(0, \sigma_d^2\right)$$

where $\delta_d(t)$ is the dividend growth in the period $[t-1,t)$, $D(t)$ is the dividend index at time t, μ_d is the long-run mean of dividend growth in excess of inflation, $dm(t)$ is the exponentially weighted average of inflation up to time t, d_d governs the *smoothness* of $dm(t)$ (the smaller the value, the more responsive it is to current inflation), y_d measures the effect of the previous shocks to the dividend yield, and σ_d is the standard deviation of the innovation. Consistent with Wilkie (1995),[3] w_d is set to 1 and d_d to 0.38.

The total return index assumes reinvestment of gross dividends. The dividend index, $D(t)$, is related to the price index, $P(t)$, and the total return index $TR(t)$, as:

$D(t)=\frac{TR(t)}{TR(t-1)}P(t-1)-P(t)$. The implied annual dividend yield is calculated by $y(t)=\frac{D(t)}{P(t)}$. We have 88 observations for dividend index and 87 dividend growth observations due to log differencing. The fitted parameters are reported in Table 3.

Table 3
Parameter Estimates of the US Dividend Growth Model: 1926–2014 (Standard Errors Are in Parentheses)

	Estimated Parameter (SE)	
	1926–2014 Reduced	
d_d	0.38	–
μ_d	0.0129	(0.0069)
y_d	–	–
b_d	−0.6004	(0.1062)
σ_d	0.1581	(0.0121)

The inflation effect on the dividend growth rate is captured in the first two terms, with the total weight assigned to current inflation being $1-w_d+w_d d_d$ and the weight assigned to inflation going back t years being $w_d(1-d_d)d_d^{\tau}$. It is immediate that past inflation has a diminishing effect on the current rate of dividend growth.

The dividend yield effect is modeled through the inclusion of $y_d z_y(t-1)$. Note that $z_y(t-1)$ is lagged by 1. This reflects the assumption that "investors can take into account the unexpected change in dividend yield in the previous period, in order to forecast changes in dividends in the coming year, as dividends are declared early" (Wilkie, 1986).[4] Note this term is set to zero in the reduced model. The inclusion of $b_d z_d(t-1)$ assumes that "companies pay out only part of any additional earnings in dividends in one year, with a further part in the following year" (Wilkie, 1986).[5] This implicitly assumes that the sign of b_d is positive. Mathematically, this means that a shock in dividend growth in the previous year will carry forward the same effect to the current period. However, our estimated b_d is uniformly below zero. This indicates a dividend smoothing effect. Previous shocks are carried forward as having opposing effects in the next period.

The dividend yield and index are combined to give the total return on stocks:

$py(t)=\log\left\{\frac{\frac{D(t)}{y(t)}+D(t)}{\frac{D(t-1)}{y(t-1)}}\right\}$ where $py(t)$ is the annual total log return on stocks for the period $[t-1,t)$.

Long-Term Interest Rate

The long-term interest rate is modeled as a combination of *inflationary* and *real* components through a transfer function model with a single input:

$$c(t)=w_c cm(t)+cr(t)$$

$$cm(t)=(1-d_c)cm(t-1)+d_c\delta_q(t)$$

$$\log cr(t)-\log\mu_c=a_c\{\log cr(t-1)-\log\mu_c\}+y_c z_y(t)+z_c(t)$$

$$0\le d_c\le 1,\quad |a_c|<1,\quad z_c(t)\sim i.i.d.\ N(0,\sigma_c^2)$$

where $c(t)$ is the long-term interest rate at time t, w_c is a factor moderating the impact of current and past inflation, $cm(t)$ is the exponential weighted moving average of inflation up to time t, $cr(t)$ is the real interest rate component at time t, μ_c is the long-run average of the real interest rate, a_c is the autoregressive parameter, and y_c measures the sensitivity of the real interest rate to the current shocks to the dividend yield (and is set to zero in the reduced form of the model shown here). Evidently the model is nonlinear.

Huber (1997)[6] pointed out that the parameters w_c and d_c cannot be determined using the method of maximum likelihood or least squares; thus, they are set to plausible values and are set such that the inferred real interest rate is above zero.

The June series of Moody's Seasoned AAA Corporate Bond Yield from January 1927 to December 2014 (monthly), obtained from *federalreserve.gov*, is used. We have 88 observations. The fitted parameters are reported in Table 4.

Table 4
Parameter Estimates of the US Long-Term Interest Rate Model: 1926–2014 (Standard Errors Are in Parentheses)

Estimated Parameter (SE)		
1926–2014 Reduced		
d_c	0.058	–
a_c	0.9175	(0.0439)
μ_c	0.0238	(0.0097)
y_c	–	–
σ_c	0.2832	(0.0213)
c_{min}	0.005	–

The Fisher Relation (Fisher, 1930)[7] is explicitly assumed here through $w_c \; cm(t)$. Wilkie, in his 1986 paper, remarked that "as inflationary expectations have risen, so have interest rates … [we] assume that the market's expectations are influenced by the past history of inflation." The dividend yield contribution is captured in the term $y_c z_y(t)$. It suggests that an unexpected change in dividend yield has an effect on the real long-term interest rate (although the sign of y_c is not stated, and this term was not significant at the 5 percent level). The log-transformed real component can be alternatively seen as an AR(1) process. This implicitly gives rise to the assumption that $cr(t)$ is strictly positive.

MODEL ROBUSTNESS

In general, model robustness refers to the insensitivity of the model specifications to slight changes in the input data. We assess the robustness of Wilkie's ESG with particular attention paid to the assumption of stationarity, structural breaks in the empirical processes and parameter stability.

Stationarity and Structural Breaks

Stationarity is a key assumption in real-world ESGs. It implies that the economic series has a constant mean and an auto-covariance function independent of time. This is important when projecting in the long term, since time trends in both the mean and variance may result in explosions, yielding a significant number of implausible scenarios. Inflation and dividend growth fail our stationarity test at the 5 percent significance level. Inflation appears to fluctuate around a constant mean, but prior to the 1950s, during the world wars and postwar recessions, it is highly volatile. At this stage, one may question the relevance of data prior to the late 1950s, as there appears to be a shift in the dynamics among series around this time. We use Auto-PARM to detect structural breaks in the inflation, dividend yield and long-term bond yield models. Results are reported in Table 5.

Table 5
Auto-PARM Output: 1926–2014

	Segmentation	AR Order
Inflation	1926–1951	1
	1952–1991	1
	1992–2014	0
Log Dividend Yield	1926–2014	4
Log Real Interest Rate	1926–2002	1
	2003–2014	0

The 1952 inflation breakpoint marks the end of large-scale, post-world-war recessions. The 1992 break in inflation signifies the beginning of the "modern experience of U.S. inflation" (Reed, 2014).[8] Since 1992, we have seen very modest volatility in inflation. The deflation in 2009 is caused by the global financial crisis. We also see no significant serial correlations, which suggests an AR model may have become inappropriate. It is argued that after the inflation experience in the 1970s and early 1980s, the Federal Reserve system has focused more strongly on maintaining price stability through implicit and explicit (post-2012) inflation-targeting procedures. Price inflation since then has been dramatically more tame than any other time in the past 90 years.

Due to multiple structural shifts in the historical time series, inflation most strongly violates the assumption of stationarity,

and parameters are sensitive to the calibration period. We also studied the dependency among the simulated observations and conclude that the model outputs total share returns that appear independent of inflation and long-term interest rates and bond yields that are positively driven by inflation.

Parameter Stability

In practice, it would be undesirable to have a model with parameters that are highly sensitive to changes in the input data. This implies high model uncertainty, which leads to unreliable interpretation of the model's output. We study parameter stability for the U.S. model using a moving-window approach, and the results are summarized in Table 6.

Table 6
Parameter Stability

Parameters	Observations
Inflation	The estimates are not smooth over time, due to small numbers of observations and nonstationarity.
Dividend Yield	The [1974, 2003] to [1976, 2005] models have μ_y highly inflated, due to a_y being near its boundary. The parameter w_y rises as late 1970s observations enter the window, indicating a strengthened inflationary effect. This mirrors the conclusion of Huber (1997), which argues that w_y is sensitive to outliers and tends to capture co-movements between inflation and the dividend yield in extreme conditions.
Dividend Growth	Considerable uncertainty surrounding the dividend growth model, especially b_d and y_d.
Long-Term Bond Yield	Large uncertainty is seen for the high inflation period, in particular for a_c and σ_c. Parameters are relatively stable for the remaining sample periods.

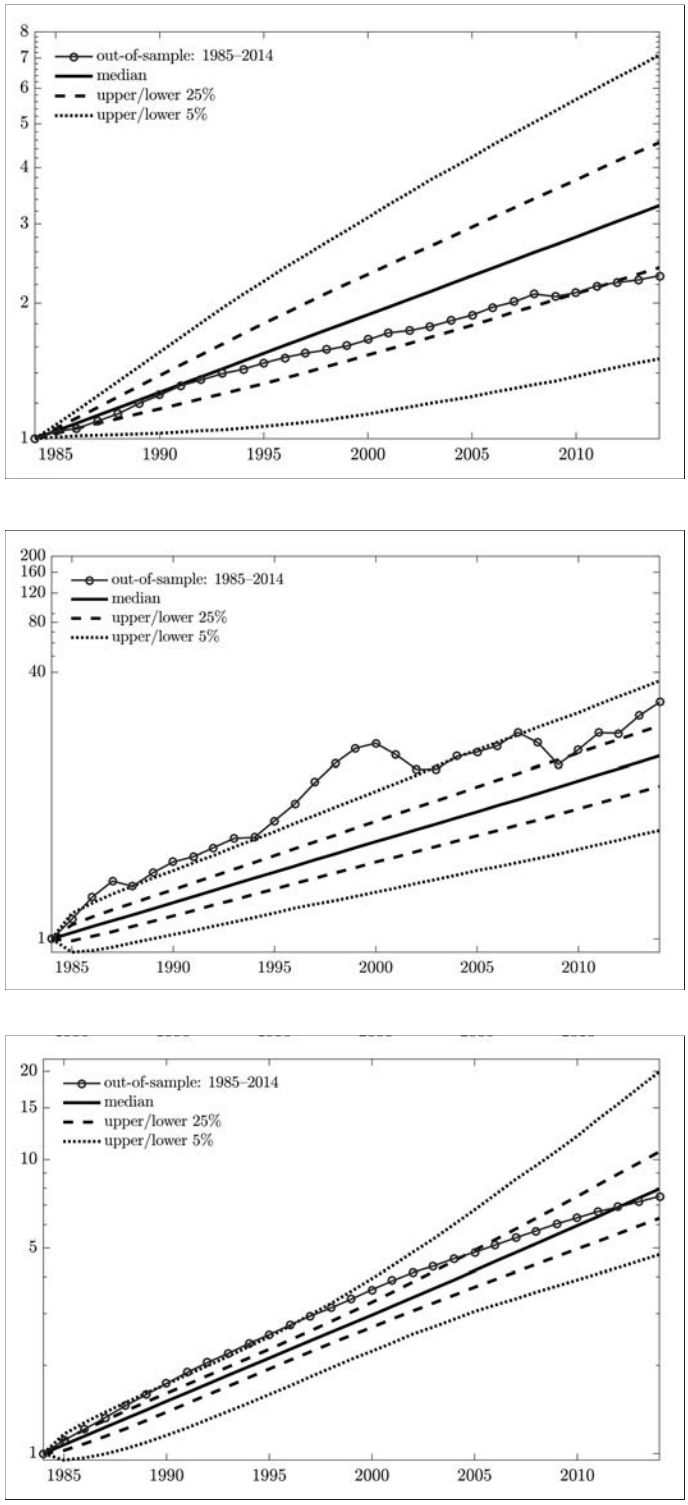
Back-Testing

A back-test based on 30-year out-of-sample data indicated that over that period the model had tended to overestimate inflation (due to a structural shift in inflation-targeting policy in the early 1990s), tended to underestimate total return on stocks (due to the unprecedented dot-com bubble in the 1990s), and performed relatively well for long-term interest rates. These findings are apparent in Figure 2.

CONCLUSIONS

The uncertainties around the long-term stability of the processes and parameters are relevant; however, there are benefits to a relatively simple static model, and Wilkie's ESG could offer some insight into the risk and volatility of pension plans, taking

Figure 2
Wilkie's ESG (Fitted to 1951–1984): Funnel-of-Doubt Plots (Log Scale) of Simulated Accumulation Factors, with Out-of-Sample (1985–2014) Observations



Top to bottom: inflation, total stock returns, long-term bond portfolio returns.

into consideration the known limitations, such as potentially thin left tails for equity returns. Parameter uncertainty may be addressed using sensitivity analysis, and model risk can also be explored, for example, by comparing results using the Wilkie model with other models. ■

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ENDNOTES

1 Wilkie, A.D. 1986. A stochastic investment model for actuarial use. *Transactions of the Faculty of Actuaries*, 39, 341–403.

2 In general, it is not valid to "adapt" the model by changing the parameters, since the model was fitted to annual data and, hence, describes an annual multivariate time series. The original paper discussed the use of Brownian bridge for more frequent time steps in footnote 5.

3 Wilkie, A.D. 1995. More on a stochastic asset model for actuarial use. *British Actuarial Journal*, 1(05), 777–964.

4 Ibid 1

5 Ibid 1

6 Huber, P. 1997. A review of Wilkie's stochastic asset model. *British Actuarial Journal*, 3(01), 181–210.

7 Fisher, I. 1930. The theory of interest, New York.

8 Reed, S.B. 2014. One hundred years of price change: the Consumer Price Index and the American inflation experience. *http://www.bls.gov/opub/mlr/2014/article/one-hundred-years-of-price-change-the-consumer-price-index-and-the-american-inflation-experience.htm#edn30* (2015-05-12).

LIBOR Might Cease in 2021, are Insurers Ready?

By Xavier A. Madrid and Chad Runchey

The London Interbank Offered Rate (LIBOR) will possibly cease to exist at the end of 2021, as regulators will no longer compel banks to provide quotes. This will create the largest challenge in the financial markets today. LIBOR is embedded in $350 trillion of contracts, including OTC and exchange-traded derivatives, structured products, floating rate notes, syndicated and business loans, mortgages and other instruments.

Globally, the Financial Stability Board noticed the decline of liquidity on the interbank short-term funding and the structural risk of relying on a benchmark based on limited transactions. That led to the creation of a working group in each jurisdiction composed of regulators and market participants. Each jurisdiction identified alternative reference rates (ARRs) that are compliant with the International Organization of Securities Commission's (IOSCO's) standards for each currency.

In the U.S., the secured overnight financing rate (SOFR) was identified as the replacement of USD LIBOR and was launched in April 2018; the volume has been increasing since its launch. As of April month-end, there were 130+ participants in the futures market, with a total outstanding open interest of $431 billion, more than $64 billion in outstanding notional in cleared swaps and more than $86 billion in outstanding cash issuances. (See Table 1)

Table 1
Overview of Replacement Rates in UK, US, Eurozone: Replacement in the US Market Is SOFR

Working groups in each jurisdiction have recommended robust, alternative ARRs to transition away from existing IBORs. The RFR benchmarks are overnight whereas current use of IBORs is largely in term rates.

Jurisdiction					
IBORs	GBP LIBOR	USD LIBOR	EURIBOR, Euro LIBOR	CHF LIBOR	JPY LIBOR, JPY TIBOR, EUROYENTIBOR
Working Group	Working Group on Sterling Risk-Free Reference Rates	Alternative Reference Rates Committee	Working Group on Euro Risk-Free Rates	The National Working Group on Swiss Franc Reference Rate	Study Group on Risk-Free Reference Rates
Alternative RFR	Reformed Sterling overnight index average (SONIA)	Secured overnight financing rate (SOFR)	Euro short-term rate (ESTER)	Swiss average rate overnight (SARON)	Tokyo overnight average rate (TONA)
Description	• Unsecured • Fully transaction-based • Encompasses a robust underlying market • Overnight, nearly risk-free reference rate • Includes a volume-weighted trimmed mean • Sub-groups on term rates, SONIA futures, pension funds	• Secured • Fully transaction-based • Robust underlying market • Overnight, nearly risk-free reference rate that correlates closely with other money market rates • Sub-groups on cash products (loans, CLOs, FRNs, mtgs, other) and outreach	• Unsecured • Fully-transaction based • Based on daily money market rates from 52 largest euro area banks • Will start publishing by October 2019 • Sub-groups on term rates, contract robustness, cash and derivatives products, risk management and communications	• Secured • Became the reference interbank overnight repo on Aug. 25, 2009 • Secured rate that reflects interest paid on interbank overnight repo • Sub-groups on loan and deposit markets and capital markets and derivatives	• Unsecured, transaction-based benchmark for the robust uncollateralized overnight call rate market • The Bank of Japan calculates and publishes the rate on a daily basis using information provided by money market brokers known as Tanshi • As an average, weighted by the volume of transactions corresponding to the rate
Rate administrator	Bank of England	Federal Reserve Bank of New York	European Central Bank	SIX Swiss Exchange	Bank of Japan
Transition plan published	No[1]	Yes	No	No	No

[1] The Working Group's preference for a potential plan has been indicated, but a plan has not been published (Source: Bank of England Official Website).

SELECTED ACRONYMS

ARRC—Alternative Reference Rates Committee. U.S. national working committee.

ARR—Alternative reference rate. Rate that has been proposed by the ARRC to substitute for LIBOR.

LIBOR—London Interbank Offered Rate.

SOFR—Secured overnight financing rate. The ARR proposed by the ARRC.

IOSCO—International Organization of Securities Commission. The IOSCO set up the standards for acceptable financial markets benchmarks. New ARRs must meet those standards. (*https://www.iosco.org/library/pubdocs/pdf/IOSCOPD415.pdf*).

DIFFERENCES BETWEEN USD LIBOR AND SOFR

The ARRs do not contain the same credit premium as LIBOR, which had embedded the credit spread of banks in unsecured lending. It is a primary focus of the industry groups to drive consensus on the credit spread for each ARR and how it should be calculated.

SOFR is a secured overnight rate. As an overnight rate, when compared with term rates like LIBOR three months, it has a higher volatility. (See Figure 1.) SOFR is correlated to Treasury issuance and money market flows (month/quarter/year-end activity). However, the SOFR three-month term rate would be considerably less volatile than the overnight rate.

Term Rates

The ARRs are overnight rates and do not have term rates like LIBOR has. Some market participants, especially in the cash market, would prefer that term rates exist to facilitate a transition for cash products. There are several approaches on how to calculate terms rates, and it is possible that term rates might differ from cash instruments and derivatives, giving rise to some basis risk between the cash and derivatives term rates.

The preliminary results of the International Swaps and Derivatives Association's (ISDA's) consultation on Fallbacks for Derivatives Contracts indicate "compounded setting in arrears rate" to be the preferred choice of calculating term reference rates using historical ARR data.

However, the benchmark administrator, an affiliate of Intercontinental Exchange (ICE) has launched the ICE term risk-free rates portal that provides forward-looking term rates based on the futures and swaps markets. Forward-looking term rates appear to be the preference for cash products. (See Table 2, pg 16)

Figure 1
Historical Data of Overnight SOFR Versus Three-Month LIBOR

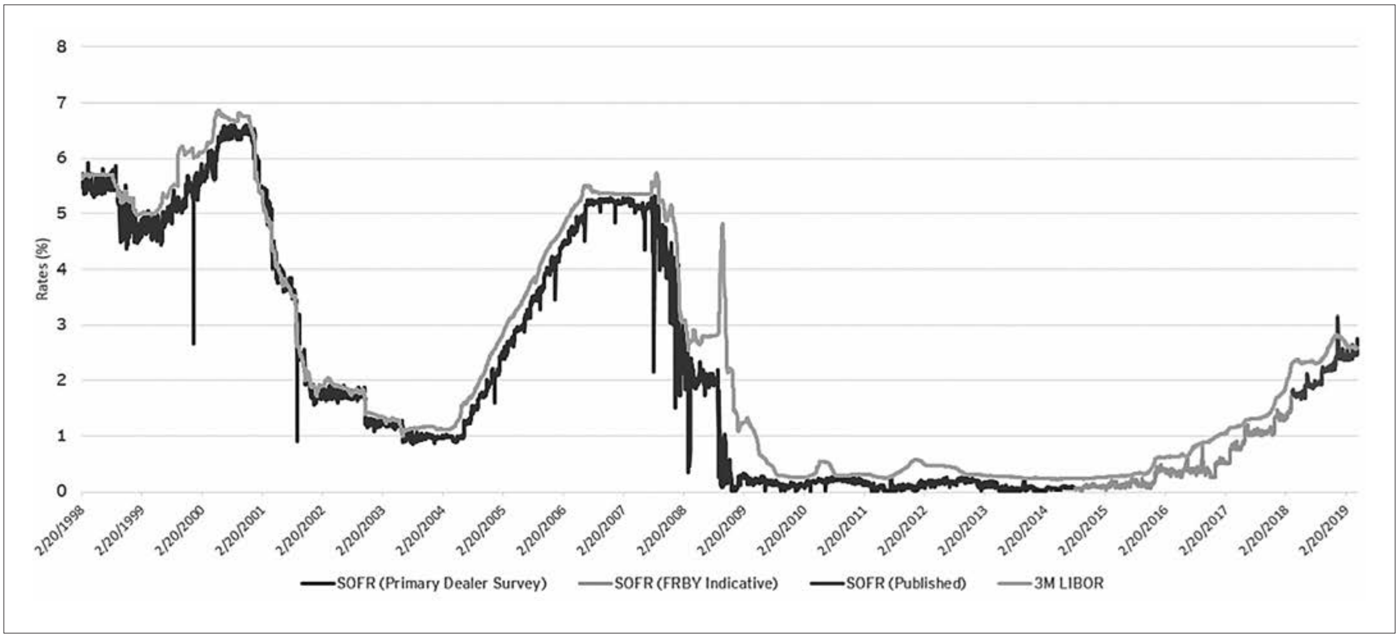


Table 2
Overview of Potential Term Rate Calculations for ARRs

Term Reference Rate Calculation Method	Backward Looking	Forward Looking
ISDA—Compounded setting in arrears rate	✓	
IBA—Simple Average	✓	
IBA—Compounded in Arrears	✓	
IBA—Futures Method		✓
IBA—Swaps Method		✓

LIBOR TRANSITION SCENARIOS AND TIMELINES

The Alternative Reference Rates Committee (ARRC) has worked on developing a transition timeline from USD LIBOR to SOFR. Figure 2 shows the major transition milestones.

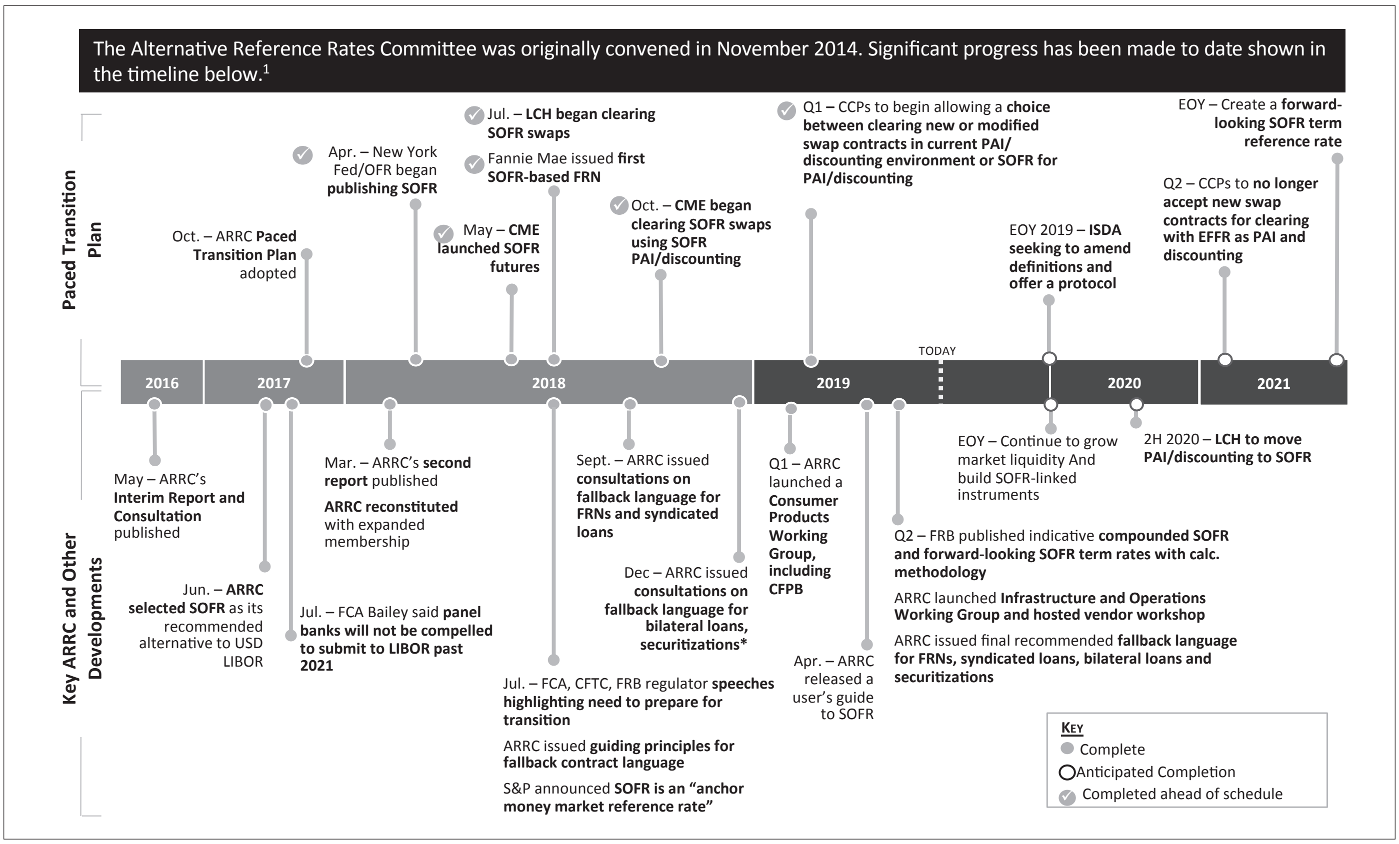
However, we have observed several institutions considering different scenarios of how transition might occur to develop appropriate plans. Following are three potential scenarios we have developed and used to understand the potential LIBOR transition implications.

1. Smooth and timely transition. The majority of legacy contracts maturing post-2021 have been transitioned to ARRs; all new transactions are based on ARRs. Liquidity has migrated from LIBOR to ARR for all products. A full suite of derivatives instruments are available across the entire term structure to hedge.

2. Partial transition. Some legacy contracts have been transitioned to ARRs. All new transactions are based on ARRs. LIBORs continue to be published and are pretimed for use with legacy transactions. Liquidity is bifurcated across LIBOR and ARR products; liquid basis markets are available to hedge LIBOR-ARR basis risk.

3. Disruptive transition. A significant volume of legacy transactions with weak fallback language remain at the point of discontinuation. A permanent cessation of LIBOR occurs post-2021. Market liquidity and adoption of ARRs is weak; term rates are not available for all ARRs. There is significant disruption and litigation risk in financial markets.

Figure 2
Timeline of US Transition From LIBOR to SOFR



[1] As published by the ARRC on Jan. 31, 2019: *https://www.newyorkfed.org/arrc/sofr-transition#pacedtransition*.

IMPLICATIONS FOR INSURERS

Insurers have the most exposure on their investments portfolio. Based on our experience, more than 95 percent of the exposure on insurers is in the investment portfolio and hedging program. A large part of the hedging is associated with the hedging of variable annuities and fixed index annuities, but other financial products with intensive hedging activity include guaranteed investment certificates (GICs) and medium-term notes.

However, the insurance products could experience a secondary impact. While the volume of insurance liabilities indexed to LIBOR is limited, the main impact could be on its fair value due to changes in the discount curve. This might not materialize in the short term but might have an impact when ARRs, including SOFR, become the market-preferred rate. A new discount curve build using ARR data points could be lower than a LIBOR-based curve and result in an increase of the liabilities value. An increase in the value of the liabilities could impact insurers' capital and reserves. This is a mainly an issue for insurers based or operating in Europe that follow Solvency II, where the discount curve is a function of LIBOR provided by the European Insurance and Occupational Pensions Authority.

In the United States, where some insurers use economic capital measures, the value of certain liabilities may be assessed through replicating portfolios. For many of these economic frameworks, LIBOR may be an input. The use of LIBOR could result in a valuation impact during transition as well as potential changes in sensitivities to interest rate movements.

Liquidity in Long-Dated Financial Products

Development of liquidity for long-dated ARR-linked products in both the cash and derivatives is critical for insurers. Insurers tend to invest in long-dated instruments—like, for example, liability-driven investing—where pension funds hold long-dated swaps, many of which are based on LIBOR, to hedge long-dated interest rate risk. So far, the SOFR-linked products are occurring on the short end of the curve, with cash instruments going out up to 24 months. This liquidity will take time, but participation of insurers in the market will be essential to the development of long-dated products.

Value Transfer

There is a risk of an adverse profit and loss impact due to lack of explicit bank credit premium in ARRs. The spread and behavior differences between LIBOR and SOFR can result in value transfer during transition and, in turn, impact value of investments, funds net asset value and performance fees. The potential value transfer is contingent on the transition scenarios discussed in the previous section; one of the primary objectives of the fallback consultations is to develop a consensus among market participants on how to calculate an appropriate spread that reduces value transfer.

Fiduciary Duties

Fiduciary risk is a top priority for money managers; transition poses a high potential for reputational and litigation risk if the transition negatively impacts clients. Organizations should make sure they have necessary representation from legal as part of their LIBOR transition program to manage the risk.

Hedging

The differences in the behavior between LIBOR and SOFR and potential differences in term rate calculations between cash and derivatives can cause some basis between the hedges and the instruments hedge. That basis might have an economic impact.

From a hedge accounting perspective, the FASB is considering providing relief for hedge accounting. Key potential impacts include:

1. The modification of a derivative to include an ARR may be considered a change in critical terms requiring de-designation.
2. The modification of a hedged cash product to include an ARR may be deemed an extinguishment from an accounting perspective requiring de-designation.
3. Difficulty in asserting that forecast cash flows are still probable when LIBOR may not exist post-2021.
4. Limited availability of historical data for ARRs, including discount curves, when assessing hedge effectiveness.
5. The need to update the modeling of hedged items given the change in hedged risk and associated impacts to hedge effectiveness.
6. Mismatches in timing of the hedging instrument and hedged item's transition to an ARR.
7. The ability to continue to assert hedge effectiveness qualitatively when either the hedging instrument or hedged item transitions.

Inconsistent Fallback Terms for Contracts Tied to LIBOR

Currently the fallback language across asset classes or even within the same asset class is varied. Generally, the most important terms are related to triggers that would require the move to another benchmark, replacement benchmarks and the spread that would have to be added. New fallbacks proposed by the ARRC and industry associations like ISDA try to bring consistency of fallback for contracts moving forward. (See Table 3, pg 18)

Table 3
Fallback Language Consultation Summary

Consultations by industry working groups have outlined enhanced fallback provisions that address challenges related to triggers, successor rates and spread adjustments for new, and in some cases legacy, products which are summarized in this table.

Products		Triggers	Benchmark Replacement Waterfall	Benchmark Replacement Adjustment	Consultation Stage	Industry Working Group
OTC Derivatives[1]		• Benchmark discontinuance event	1. Compounded setting in arrears rate	• Historical mean/median approach	Finalized	ISDA
Floating Rate Notes		• Permanent cessation trigger • Pre-cessation trigger	1. Forward-looking term SOFR + adjustment 2. Compounded OR simple average SOFR + adjustment 3. Relevant governmental body (e.g., ARRC) selected rate + adjustment 4. ISDA fallback rate + adjustment 5. Issuer (or designee) selected rate + adjustment	• ARRC selected adjustment • ISDA fallback adjustment • Issuer (or designee) selected adjustment	Finalized	ARRC Floating Rate Notes Working Group
Syndicated Loans	Amendment Approach	• Permanent cessation trigger • Pre-cessation trigger • Early "opt-in" trigger	1. Agreed between borrower and administrative agent	• Agreed between borrower and administrative agent	Finalized	ARRC Business Loans & CLOs Working Group
Syndicated Loans	Hardwired Approach	• Permanent cessation trigger • Pre-cessation trigger • Early "opt-in" trigger	1. Forward-looking **OR** next available term SOFR + adjustment 2. Compounded OR simple average SOFR + adjustment 3. Borrower and administrative agent selected rate + adjustment	• ARRC selected adjustment • ISDA fallback adjustment • Borrower and administrative agent selected adjustment	Finalized	ARRC Business Loans & CLOs Working Group
Bilateral Loans	Amendment Approach	• Benchmark discontinuance event • Determination by agent or required lenders	1. Agreed between borrower and lender	• Agreed between borrower and lender	Finalized	ARRC Business Loans Working Group
Bilateral Loans	Hardwired Approach	• Benchmark discontinuance event • At least two syndicated loans are priced over term SOFR plus benchmark spread	1. Forward-looking **OR** next available term SOFR + adjustment 2. Compounded OR Simple average SOFR + adjustment 3. Lender selected rate + adjustment	• ARRC selected adjustment • ISDA fallback adjustment • Lender selected adjustment	Finalized	ARRC Business Loans Working Group
Securitizations		• Benchmark discontinuance event • Pre-cessation trigger events	1. Forward-looking term SOFR + adjustment 2. Compounded or simple average SOFR + adjustment 3. Relevant governmental body (e.g., ARRC) selected rate + adjustment 4. ISDA fallback rate + adjustment 5. Transaction-specific fallback rate + adjustment	• ARRC selected adjustment • ISDA fallback adjustment • Designated transaction representative selected adjustment	Finalized	ARRC Securitizations Working Group

Considerations
- ISDA's supplement of enhanced fallback provisions for OTC derivatives will be applicable to all new trades once issued.
- ARRC's guiding principles indicate that it is completely voluntary for market participants to implement or adopt any suggested contract language.

[1] LCH will update rulebooks consistent with the updated ISDA definitions to mirror the triggers, waterfalls, and spread adjustments defined.

WHAT TO DO TO PREPARE FOR TRANSITION

Moving from LIBOR to the ARRs is a massive undertaking that requires coordination in both the market and each organization. Development of liquidity in the SOFR-linked products will be important, but there are many activities that insurers can undertake today.

Governance

The key to an effective transition will be a robust governance structure that oversees the design and implementation of LIBOR transition efforts. Governance should be under the auspices of the board and is typically led by Treasury, risk, markets/investments or special projects groups. The objectives are:

- Establish a robust program governance to oversee the successful transition, including regular reporting to senior management.
- Allocate budget and confirm staffing needs to execute impact assessment and implementation.
- Implement a workstream structure, including reporting to monitor exposure to LIBOR throughout the transition period.

Conduct Impact Assessment

Exposure to LIBOR

Assess a product inventory of LIBOR-linked products based on exposureand maturity profile. Validate assessment with the core business lines.

Contracts

Determine the need for fallback language amendments, repapering and client outreach.

Models

Assess the volume of models that use LIBOR as an input and new models needed to price and risk SOFR-linked products. Assess both quantitative and qualitative impacts.

Technology

Perform a detailed assessment across the enterprise technology landscape. Assessment will be required across documents, platforms, metadata, codes and data to determine in-house and third-party solutions impacted.

Based on the results of the assessment, insurers should develop an IBOR transition road map for the enterprise as well as product-specific transition plans. The road map will provide a strategic view of the key priorities and timing organized by product design and pricing, legal contracts, models, internal and external communications, technology and operations, risk and finance. We compel insurers to both complete an impact assessment and develop a road map as soon as possible to be ready for a LIBOR cessation.

In our experience, legal contracts, models and technology are the areas that require the most effort to implement. We would like to highlight some considerations contract management. The problem can be divided into two parts: new contracts underwritten using LIBOR and legacy contracts. For new contracts, the priority is to incorporate the enhanced fallback language early to avoid increasing LIBOR exposures that are ill equipped to transition away in an event of a LIBOR cessation. For legacy contracts, the first step is to identify those contracts with inadequate fallback terms. Then prepare to do a client or counterparty outreach to repaper contractual terms, including triggers, rate fallback and spreads. Contracts can be divided into:

- **Client contracts.** The investments team should prepare to engage with the client to initiate the repapering process.

- **Counterparty contracts.** Sell-side counterparties are more likely to start the outreach and repapering process.

- **Contracts with limited probability to successfully renegotiate terms.** There are contracts of certain asset classes that might not have adequate fallback terms and do not have a clear path to change the fallback terms. Changing terms would require certain approvals that are not practical. For example, some structured products might require majority bondholder approval (e.g., MBS, ABS) to change deal terms; obtaining bondholder approvals might not be feasible, as bondholders might be unknown and bondholder incentives might vary depending on what tranche the investor holds. For those contracts, organizations are making business decisions to handle those contracts.

In closing, we expect LIBOR transition to gain additional momentum in the coming months; probably when the ISDA releases its protocol for OTC derivatives later this year, it will

increase the level of attention paid by clients and the users of financial instruments.

Finally, we encourage the insurers to actively participate in public consultations, follow ARRC and trade association guidance and developments, and develop transition plans and allocate resources. ■

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Asset Allocation Contest—June Update (April 1–June 30)

By Greg Roemelt

The June reporting for the 2019 Asset Allocation contest shows significant rebounds for the majority of portfolios in the contest. Strong equity returns brought all of the equity indices back into positive territory and the downward shift of the US Treasury curve was beneficial to the bond indices. With key equity indices hovering around all-time highs and the president pushing the Federal Reserve to reduce interest rates, the remainder of the contest period could provide some interesting results.

In the **Alpha Contest**, Shaohua Guan has taken over the lead from Kyle Retallik. Nick Komissarov has moved into second place and Lee Hakert is holding on to third place. Both Shouhua and Kyle are 100 percent invested in bonds, but Shouhua is over weighted in US investment grade corporate bonds (4.64 percent return in June) resulting in a reshuffling of the leaderboard.

To give an idea of the extent of the June rebound, in the **Accumulation Contest**, we've gone from only three portfolios with positive returns at the end of May to 100 percent positive returns at the end of June. Kyle Retallik leads with an accumulated value of $104,698, but his lead has been narrowed by Pat McCormack to only $859. Weijen Kuo has moved into third place.

In the **Drawdown Contest**, Kyle Retallik maintains his lead, followed by Damon Kuzniar and Weijen Kuo. See Table 1 for all the current contest results.

Thank you for your continuing support and stay tuned for the next update. ■

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Table 1
Asset Allocation Contest Leaderboard

Leaderboard (entry #)					
Alpha		Accumulation		Drawdown	
Shaohua Guan (55)	2.50%	Kyle Retallick (112)	104,698	Kyle Retallick (174)	45,948
Nick Komissarov (46)	2.09%	Pat McCormack (110)	103,839	Damon Kuzniar (139)	45,866
Lee Hakert (34)	1.78%	Weijen Kuo (121)	103,791	Weijen Kuo (183)	45,851

Some Key Insights for Computing Credit Solvency Capital Requirements

By Jérémy Allali, Olivier A. Le Courtois and Mohamed Majri

Editor's note: A full version of the research paper that inspired this contribution was published in the European Actuarial Journal.

According to the Solvency II regulation, insurers need to be able to assess the capital needs that cover the risk of annual losses due to credit risk. The applications can be for own risk and solvency assessments as well as for computing internal model solvency capital requirements (SCRs). Being able to measure credit risk is also an important precondition for the asset management of insurers. This short article describes a framework for the computation of credit capital requirements under the constant position paradigm, taking into account recovery rates. Although the framework described was originally derived under the Solvency II regulation, it can also prove useful under other international regulations. Four important steps should be performed to compute credit SCRs: First, relationships linking risk premium adjustment factors (factors that relate realistic and market-consistent probabilities) should be established consistently with the Jarrow-Lando-Turnbull approach. Then, a procedure for reconstructing constant position market-consistent histories of credit portfolios from quoted Merrill Lynch indices should be established. These reconstructed historical credit values can be modeled via mixed empirical-generalized Pareto distribution (GPD) dynamics, which require a thorough parameter estimation and validation. Finally, credit SCRs can be computed as a result of the previous three steps. The solution shown here makes explicit use of recovery rates, in contrast with the standard formula of the current Solvency II framework.

It is usually impossible to directly build an aggregate index that perfectly reflects the risk profile of the credit portfolio of any given investor. Indeed, the recovery rates of the assets constituting a credit market index are usually quite homogeneous by construction, whereas investors build up credit portfolios by selecting assets with nonstandard recovery rates. For instance, investors can select bonds of low rating and high recovery and bonds of high rating and low recovery. Such a strategy cannot be directly replicated using existing market credit indices. However, to quantify spread risk, it is important to start from credit market indices. We suggest using past available index data to construct pseudo-indices that mimic target credit portfolios in all aspects except recovery risk. These pseudo-indices then constitute an important step toward the reconstruction of market-consistent credit observations, where a final adjustment for recovery risk is made. Using a one-year mixed GPD distribution to model reconstructed credit observations allows one to achieve a quantization of spread risk and to compute SCRs and similar indicators.

In a first step, we provide pricing formulas for portfolios made of bonds with varying rating and maturity classes. For simplicity, we assume that all the bonds of such portfolios pay coupons over the same discrete set of dates (typically at the end of each year or semester). However, these bonds may naturally have differing numbers of coupons.

Let K be the number of rating classes and let M_k be the number of maturity classes for each rating class k, where k ranges from 1 to K. We assume that all the bonds from the rating class k and from the maturity class j are identical and have $N^{j,k}$ cash flows $C_i^{j,k}$ indexed by i and occurring at times T_i. Let also $R^{j,k}$ and $\tau^{j,k}$ be the recovery rate and default time of these bonds, respectively.

Then, a bond portfolio can be valued as follows:

$$V = \sum_{k=1}^{K}\sum_{j=1}^{M_k}\sum_{i=1}^{N^{j,k}} C_i^{j,k} P(0,T_i)\left(R^{j,k} + \left(1 - R^{j,k}\right)\left(1 - Q\left(\tau^{j,k} < T_i\right)\right)\right),$$

where Q is the market-consistent or risk-neutral probability measure. We also have:

$$V = \sum_{k=1}^{K}\sum_{j=1}^{M_k}\sum_{i=1}^{N^{j,k}} C_i^{j,k} P(0,T_i)\left(R^{j,k} + \left(1 - R^{j,k}\right)\left(1 - \psi_{k,K+1}(0,T_i) P\left(\tau^{j,k} < T_i\right)\right)\right),$$

where $\psi_{k,K+1}(0,T_i)$ is a risk premium adjustment factor and P is the realistic or historical probability measure. Then:

$$V = \sum_{k=1}^{K}\sum_{j=1}^{M_k}\sum_{i=1}^{N^{j,k}} C_i^{j,k} P(0,T_i) - \sum_{j=1}^{M_k}\left(1 - R^{j,k}\right)\sum_{i=1}^{N^{j,k}} C_i^{j,k} P(0,T_i)\left[e^{diag(\pi_1,\ldots,\pi_K,1)\Lambda^P T_i}\right]_{k,K+1},$$

where $(\pi_1,\ldots,\pi_K)$ are alternative risk premium adjustment factors and Λ^P is the generator driving the historical rating transitions. These formulas allow us to express bond portfolio values as a function of risk premium adjustment factors and also to derive relationships between the different types of factors introduced.

Past portfolio values cannot be used for regulatory and calibration purposes. This is because weights could have markedly changed in the history of the portfolio. Therefore, it is necessary to recompute past portfolio values coherently with existing market indexes, but noting that the recovery rates of those indexes may differ a lot from the actual recovery rates of the bond portfolio of the insurer. We suggest the following algorithm for reconstructing benchmarked past values of the portfolio and of the factors $\pi_{k=1,..,K}$:

- Extraction of historical monthly subindex data.
- Computation of the current value of the portfolio and its components.
- Computation of initial portfolio weights.
- Computation at time 0 of the risk premium adjustment factors $\pi_{k=1,..,K}(0)$ that relate the historical and risk-neutral measures.
- Reconstruction of past portfolio returns based on subindex data and initial portfolio weights.
- Estimation of the average recovery rate of the index. Then, computation of an initial pseudo-portfolio value whose recovery rate is that of the index.
- Computation of the past values of the pseudo-portfolio.
- Use of the pseudo-portfolio to compute at any time t the risk premium adjustment factors $\pi_{k=1,..,K}(t), t \leq 0$.
- Computation of the reconstructed historical portfolio values using actual recovery rates.

After conducting this procedure, we obtain a database of historical reconstructed portfolio values and risk premium adjustment factors. However, this database may not be sufficiently long, and some smoothing of extreme values may be required. Beyond that, the question arises as to which is the best dynamic representation of bond portfolios and risk premium adjustment factors. In a common approach, the evolution of risk premium adjustment factors is modeled with Cox-Ingersoll-Ross processes. If we look at the profile of monthly benchmarked bond portfolio increment autocorrelations (Figure 1), we see that while monthly increments display some degree of autocorrelation, annual bond portfolio increments can be assumed i.i.d. This visual deduction can be confirmed by performing ad hoc statistical tests. The main idea here is that if we are interested only in yearly simulations of balance sheets, then we can neglect autocorrelation effects; therefore, it is not necessary to use mean-reverting processes, such as the CIR process. Thinking now in terms of probability distribution, we suggest using mixed GPD, where the core of the empirical probability distribution is kept and the tails are smoothed using the GPD approach.

We construct the bond portfolio in Table 1 for conducting our illustration. Note that we purposely choose low-rated bonds with high recovery rates. This is in contrast to classic portfolios for which the recovery rate usually decreases when the rating worsens. So, our illustrative portfolio differs from quoted bond indexes in terms of recovery behavior. We are interested in seeing the impact of such a choice on SCRs. For the tails of this

Figure 1
Autocorrelations of Bond Portfolio Increments

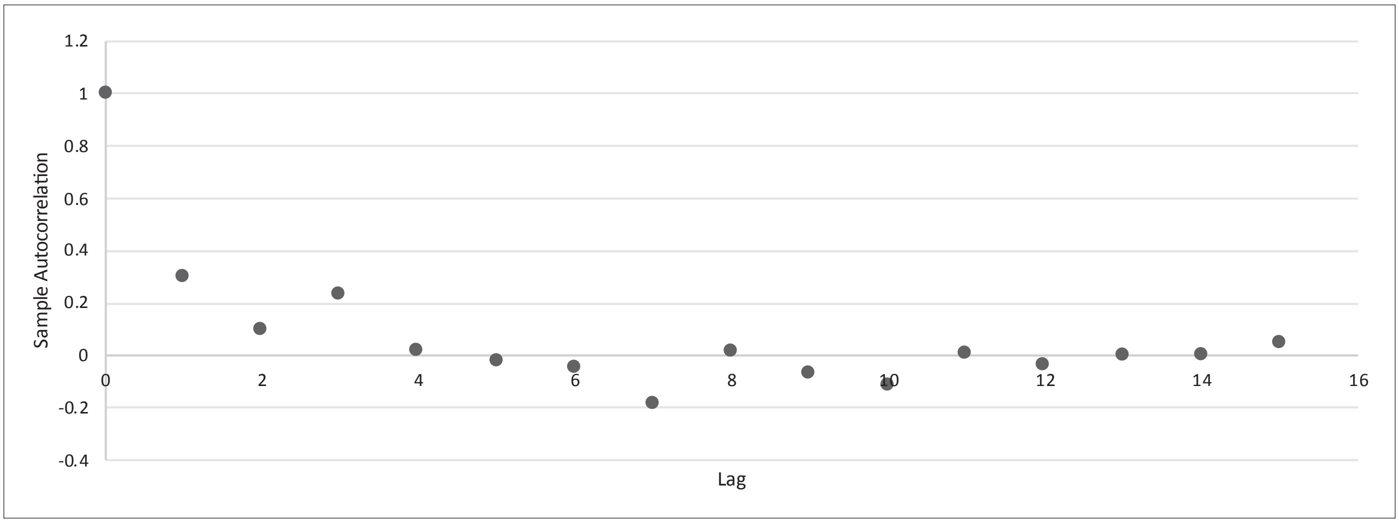

Table 1
Bond Data set as of 12/31/14

Issuer	Ranking	Recovery Rate	Maturity	Coupon	Dirty Price	Mod. Duration
BEI	AAA	Full	11/10/2016	8%	115.49	1.7
FINANCEMENT FONCIER	AAA	Full	29/12/2021	5.62%	121.62	5.9
KFW	AAA	Full	21/01/2019	3.875%	119.08	3.7
GERMANY	AAA	Full	15/08/2023	2%	114.46	8
OAT	AA	Full	25/10/2019	3.75%	117.96	4.5
PROCTER	AA	44%	24/10/2017	5.125%	114.91	2.7
STATOIL	AA	40%	10/09/2025	2.875%	117.38	9.3
COMMONWEALTH	AA	40%	10/11/2016	4.25%	108.09	1.8
AIRBUS GP FIN.	A	55%	12/08/2016	4.625%	108.47	1.6
AIRBUS GROUP FIN.	A	55%	25/09/2018	5.5%	120.48	3.4
AIR LIQ.FIN	A	56%	15/10/2021	2.125%	110.02	6.3
CREDIT AGRICOLE	A	61%	22/12/2024	3%	101.01	8.4
PIRELLI INTER	BBB	64%	18/11/2019	1.75%	101.10	4.4
SEB	BBB	65%	03/06/2016	4.5%	107.71	1.4
VEOLIA	BBB	65%	24/05/2022	5.125%	131.83	6.3
URENCO FINANCE	BBB	60%	02/12/2024	2.375%	101.33	8.6

portfolio, and after applying the eight-step algorithm described earlier, we estimated the parameters of the well-known GPD:

$$C_{u,\xi,\sigma}(x) = 1 - \left(1 + \frac{\xi}{\sigma}(x-u)\right)^{-\frac{1}{\xi}},\ x > u$$

using an improved Hill method. It is possible to check the values estimated using a maximum likelihood approach, Lorenz curves, Gini coefficients, POT graphs and a Kolmogorov-Smirnov test, to cite only a few methods. The latter test yields the results in Table 2.

Table 2
Kolmogorov-Smirnov Statistics and P-Values

θ^n	θ^n_c	$p-value^n$	θ^p	θ^p_c	$p-value^p$
0.07	0.14	0.80	0.17	0.35	0.74

Here the statistics θ^n and θ^p (n stands for the negative tail and p for the positive one) are always inferior to their respective critical values and the p-values are high. Using classic statistical vocabulary, this test says that we cannot exclude that the GPD is appropriate for modeling bond portfolio tails.

We obtain Table 3, whichcompares the SCRs of the total portfolio and of the subportfolios of given ratings using the standard Solvency II formula and the GPD smoothed model.

Table 3
Credit SCRs

	Standard Formula	GPD-Smoothed Model
Total Portfolio	5.5%	7.2%
Subportfolio AAA	1.4%	0%
Subportfolio AA	3.2%	8.5%
Subportfolio A	6.1%	10.6%
Subportfolio BBB	11.8%	10.4%

Note that the numbers shown in Table 3 are, in fact, simplifications of SCRs because we did not make any assumptions on the contracts issued by the firm, and we did not incorporate retroaction effects of credit risk on liabilities. We see that for this portfolio, the model most often predicts higher SCRs than the standard formula. However, when top-quality bonds are public or semipublic and present virtually no credit risk, the model

consistently predicts a null SCR. Also, when low-rated bonds have high recovery rates, the model predicts lower SCRs than the standard formula. Indeed, the current standard formula does not take into account recovery effects; therefore, the framework suggested in this article permits extension of the standard formula at least in terms of recovery risk. Finally, observe that credit SCRs cannot be straightforwardly approximated by ratings. This is a confirmation that credit risk is polymorphic in essence and cannot be captured by one or two proxy variables. ■

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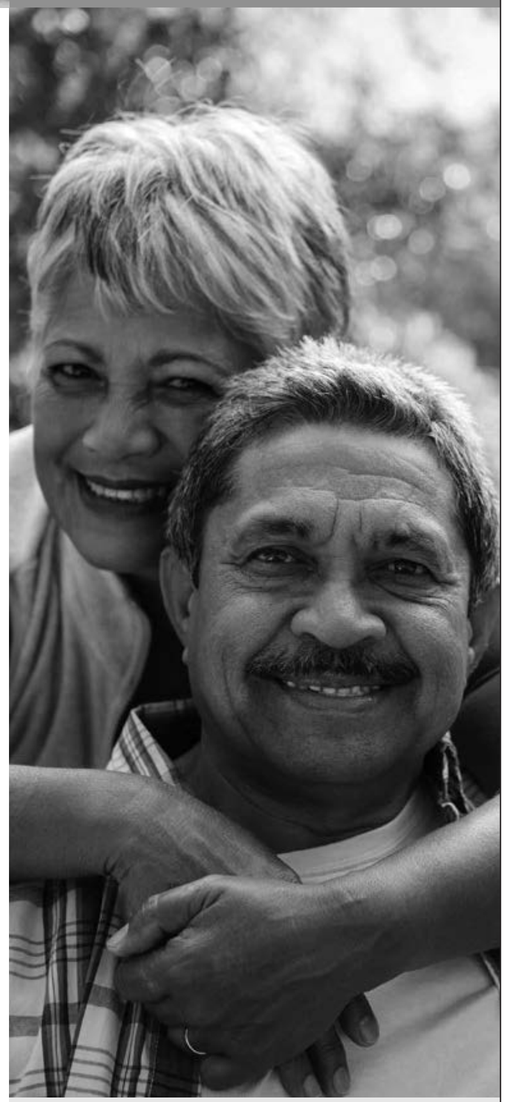

The Emerging Patchwork of Investment Advice Regulation

By Clifford Kirsch and Bria Adams for Eversheds Sutherland

Financial institutions are subject to various laws and regulations designed to provide protection to their customers. For financial institutions engaged in the business of providing investment advice or recommending securities or insurance products, the laws and regulations governing customer protection may be issued by one of many regulatory bodies, including the U.S. Securities and Exchange Commission (SEC), the U.S. Department of Labor (DOL), the Financial Industry Regulatory Authority, state securities regulators and state insurance regulators. For actuaries who work alongside financial institutions under the watch of these regulators, this article seeks to provide a glimpse into recent changes to various standards of care owed to customers that will undoubtedly have a significant impact on the products and services offered by many financial institutions. First, we provide a quick look at the current regulatory landscape:

- SEC-registered (or federal) investment advisers owe a fiduciary duty to their clients, which means that investment advisers have an affirmative obligation of utmost good faith and full and fair disclosure of all material facts to their clients as well as a duty to avoid misleading them. This standard, outlined in more detail later, aligns with state standards of care governing state-registered investment advisers.

- Fiduciaries under employee retirement plans owe duties of loyalty, prudence and diversification and must refrain from engaging in transactions with "parties in interest," acting with a self-interest or conflicted interest, and receiving payments from third parties.

- Broker-dealers must act in the best interests of their customers and refrain from placing broker-dealers' interests ahead of customers' interests.

- While state laws and rules applicable to insurers and insurance producers vary, many states have adopted some form of a suitability rule that requires insurance producers (or insurers where no producer is involved) to have reasonable grounds for believing that, among other things, a recommendation is suitable for a customer based on the facts disclosed by the customer as to his or her investments or other insurance and his or her financial situation and needs, including information such as the customer's age, income, financial objectives, time horizon, liquidity needs, risk tolerance, etc.

On June 5, 2019, the SEC adopted its Regulation Best Interest (Regulation BI), creating the best interest standard of care described earlier for broker-dealers. In the months to come, we will likely see reactions to Regulation BI and the advancement of a number of laws and regulations related to investment advice and recommendations by state legislatures and state securities regulators. Any new state laws and regulations will add to the existing regulatory landscape in this area, which now includes the SEC's and states' longstanding fiduciary duties for investment advisers, the SEC's new Regulation BI, the DOL's longstanding fiduciary standard under the Employee Retirement Income Security Act of 1974 (ERISA) and New York's recently adopted regulation governing insurance producers. So far, New Jersey and Nevada (the latter not outlined in Table 1) have proposed new standards of care governing both broker-dealers and investment advisers, and additional states are expected to follow suit. Firms subject to state laws and regulations will face compliance challenges, including the possibility that state laws and regulations may conflict with one another. Moreover, these new obligations could result in limits on the availability of advice or certain products and will surely lead to increased costs for financial institutions. Table 1 is intended to provide a glimpse into the emerging framework that has already started to shape the activities of firms in the securities and insurance space and, as a result, will influence the work of the actuarial professionals who work alongside these firms.

Table 1
Emerging Investment Advice Framework

	SEC- and State-Registered Investment Advisers	SEC-Registered Broker-Dealers (Under SEC Regulation Best Interest)	Proposed New Jersey Securities Regulation	ERISA Fiduciaries Subject to DOL Rules	Producers and Insurers Subject to New York Regulation 187
What is the duty owed to customers and clients?	Investment advisers are fiduciaries; they owe a duty of care and a duty of loyalty, and they must act in the best interests of clients and cannot place their own interests ahead of the interests of their clients.	Broker-dealers must act in the best interests of their retail customers at the time recommendations are made, without placing the financial or other interests of the broker-dealer ahead of the customers' interests.	Broker-dealers and investment advisers owe a fiduciary duty to customers, which requires them to satisfy both the duty of care and the duty of loyalty.	ERISA fiduciaries are subject to duties of loyalty, prudence and diversification; also prohibitions on transactions with "parties in interest" (which includes a broker-dealer) on acting with a self-interest or conflicted interest and on receiving payments from third parties.	A producer (or insurer where no producer is involved) must act in the best interests of the consumer, and only the interests of the consumer shall be considered in making recommendations.
When is the duty triggered?	Establishing an advisor-client relationship.	Making recommendations of any securities transaction or investment strategy involving securities (including account recommendations) to a retail customer.	When providing investment advice or recommending to a customer an investment strategy; the opening of any type of account; the transfer of assets to any type of account; or the purchase, sale or exchange of any security. Also, when providing investment advice and when acting: (i) with discretionary authority over a customer's account; (ii) with a contractual fiduciary duty; or (iii) as an adviser.	When providing investment advice for a fee to an ERISA plan or participants, or exercising discretion in the investment of ERISA plan assets within the meaning of ERISA.	When making recommendations to consumers for a sales transaction or an in-force transaction with respect to life insurance or annuity policies delivered or issued for delivery in the state of New York.
Who is covered?	Investment advisers subject to the Advisers Act or corresponding state laws as well as supervised persons of such investment advisers.	Broker-dealers, as well as any persons associated with the broker-dealer (i.e., registered representatives and principals), when making recommendations of a securities transaction or investment strategy involving securities (including account recommendations) to retail customers.	All SEC-registered broker-dealers who are also registered in New Jersey and state-registered advisers. SEC-registered advisers are not covered.	"Fiduciaries" who provide investment advice for a fee or have discretion in the investment of plan assets within the meaning of ERISA. Discretionary advice is and has always been fiduciary activity.	Insurance producers (and insurers where no producer is involved).

CONTINUED ON PAGE 28

Table 1
Emerging Investment Advice Framework, *continued*

	SEC- and State-Registered Investment Advisers	SEC-Registered Broker-Dealers (Under SEC Regulation Best Interest)	Proposed New Jersey Securities Regulation	ERISA Fiduciaries Subject to DOL Rules	Producers and Insurers Subject to New York Regulation 187
Can the scope of the duty owed to clients be modified via client consent?	An investment adviser's responsibilities and the scope and nature of services provided can be altered with client consent, but the fiduciary duty cannot be waived or changed by clients.	Unable to modify scope of best interest duty via client consent.	Not expressly addressed in regulation.	May specify by agreement the type and scope of services to be provided (e.g., manage the fixed-income sleeve of a defined benefit plan or advise as to the investment options for a defined contribution plan) but may not modify the statutory fiduciary duty.	No.
Is there an ongoing duty to monitor a client's account?	Generally yes, unless altered with client consent.	No ongoing duty to monitor investment performance. Duty extends only to the specific recommended securities transaction or investment strategy involving securities.	For broker-dealers, the fiduciary obligation extends through the execution of the recommendation. If a broker-dealer also provides investment advice in any capacity, has discretionary authority over a customer's account or a contractual fiduciary duty, the fiduciary duty will be applicable to the entire customer relationship, regardless of the customer account type.	Primarily a matter for agreement with the investor, although DOL has suggested a duty to monitor may be inherent in recommending more complex investments.	No.

Table 1
Emerging Investment Advice Framework, *continued*

	SEC- and State-Registered Investment Advisers	SEC-Registered Broker-Dealers (Under SEC Regulation Best Interest)	Proposed New Jersey Securities Regulation	ERISA Fiduciaries Subject to DOL Rules	Producers and Insurers Subject to New York Regulation 187
Can firms receive compensation from product issuers and other third parties?	Permissible to receive compensation from third parties if client consent is obtained and conflicts are mitigated. However, compensation cannot be paid for distribution or offering activity conducted on behalf of issuers without being registered as a broker-dealer and without such activity being subject to requirements applicable to broker-dealers.	Permissible if broker-dealers implement procedures to: (i) identify and at a minimum disclose, or eliminate, all conflicts of interest associated with recommendations; and (ii) identify and mitigate any conflicts of interest associated with recommendations that create an incentive to place the interests of the broker-dealer ahead of the interests of the customer.	There is a presumption of a breach of the duty of loyalty for offering or receiving direct or indirect compensation for recommending the opening of a specific type of account; the transfer of assets to a specific type of account; or the purchase, sale or exchange of a specific security that is not "the best of the reasonably available options." However, broker-dealers may receive transaction-based fees, provided that: (i) the fees are reasonable; (ii) the fees are the best of the reasonably available fee options; and (iii) the duty of care is satisfied.	Fiduciaries must not receive compensation from product issuers and other third parties unless a statutory or DOL-prohibited transaction exemption is applicable, which tend to be product-specific. Fiduciaries may avoid prohibited conflicts by crediting any value of the third-party compensation back to the plan, including through fee offsets or additional services.	Insurance producers may receive compensation from product issuers and other third parties so long as the amount of the compensation or the receipt of the incentive does not influence the recommendation. Insurers may maintain within and across product lines variations in compensation or other incentives that comply with New York insurance laws and regulations, provided the insurer's compensation and incentive practices, when taken as a whole, are designed to avoid recommendations by producers that are not in the best interests of consumers.

CONTINUED ON PAGE 30

Table 1
Emerging Investment Advice Framework, *continued*

	SEC- and State-Registered Investment Advisers	SEC-Registered Broker-Dealers (Under SEC Regulation Best Interest)	Proposed New Jersey Securities Regulation	ERISA Fiduciaries Subject to DOL Rules	Producers and Insurers Subject to New York Regulation 187
Are firms required to manage conflicts?	Yes. Investment advisers are required to eliminate or at least expose through full and fair disclosure all conflicts of interest, which might incline an investment adviser—consciously or unconsciously—to render advice that was not disinterested.	Yes. Broker-dealers must: (i) identify and at a minimum disclose, or eliminate, all conflicts of interest associated with recommendations; (ii) identify and mitigate any conflicts of interest associated with recommendations that create an incentive for a broker-dealer to place the interests of the broker-dealer ahead of the interests of the customer; (iii) identify and disclose any material limitations placed on the securities or investment strategies involving securities that may be recommended to a customer and any conflicts of interest associated with such limitations and prevent such limitations and associated conflicts of interest from causing the broker-dealer to make recommendations that place the interests of the broker-dealer ahead of the interests of the customer; and (iv) identify and eliminate any sales contests, sales quotas, bonuses and noncash compensation.	Yes. Broker-dealers and agents must make a reasonable inquiry, including risks, costs and conflicts of interest related to any recommendation or investment advice, and the customer's investment objectives, financial situation, needs and any other relevant information. Additionally, broker-dealers' and investment advisers' recommendations or advice must be made without regard to the financial or any other interests of the broker-dealer, agent, adviser, any affiliated or related entity and its officers, directors, agents, employees, contractors or any other third party.	Yes. Prohibited conflicts are allowable only to the extent permitted under an applicable statutory or DOL-prohibited transaction exemption, which regularly include conflict-mitigation conditions.	No express requirement imposed under the regulation to manage compensation-related conflicts. However, insurers are required to establish, maintain and audit a system of supervision that is reasonably designed to achieve the insurer's and producer's compliance with the best interest standard. Moreover, producer compensation arrangements and product-offering limitations are subject to specific disclosure requirements.

Table 1
Emerging Investment Advice Framework, *continued*

	SEC- and State-Registered Investment Advisers	SEC-Registered Broker-Dealers (Under SEC Regulation Best Interest)	Proposed New Jersey Securities Regulation	ERISA Fiduciaries Subject to DOL Rules	Producers and Insurers Subject to New York Regulation 187
Are firms required to make disclosures?	Required by fiduciary duty and also specific requirement in Form ADV.	Prior to or at the time the recommendations are made, the broker-dealer must provide, in writing, full and fair disclosure of all material facts relating to the scope and terms of the brokerage relationship, including: (i) that the broker-dealer is acting as a broker-dealer with respect to the recommendation; (ii) the material fees and costs that apply to the customer's transactions, holdings and accounts; and (iii) the type and scope of services provided to the retail customer, including any material limitations on recommendations, and all material facts relating to conflicts of interest associated with the recommendation. Form CRS also would impose additional disclosure requirements for broker-dealers at the outset of the relationship.	No.	Prohibited conflicts are allowable only to the extent permitted under an applicable statutory or DOL-prohibited transaction exemption, which often require disclosures.	The best interest standard requires, among other things, that there be a reasonable basis to believe that the consumer has been reasonably informed of certain features of the policy and potential consequences of the transaction, both favorable and unfavorable.

CONTINUED ON PAGE 32

Table 1
Emerging Investment Advice Framework, *continued*

	SEC- and State-Registered Investment Advisers	SEC-Registered Broker-Dealers (Under SEC Regulation Best Interest)	Proposed New Jersey Securities Regulation	ERISA Fiduciaries Subject to DOL Rules	Producers and Insurers Subject to New York Regulation 187
Can clients consent to activity that constitutes a conflict of interest?	Yes. Client consent is needed to proceed with activity that constitutes a conflict. Such consent may often be satisfied by full and fair disclosure.	Client consent not needed to proceed with activity that constitutes a conflict, although certain conflicts will need to be disclosed, mitigated or eliminated, regardless of client consent.	Not necessarily. There is no presumption that disclosing a conflict of interest in and of itself will satisfy the duty of loyalty.	No. Prohibited conflicts are allowable only to the extent permitted under an applicable statutory or DOL-prohibited transaction exemption, which often require consent from an independent fiduciary or plan participant.	Client consent is not needed to proceed with activity that constitutes a conflict.

Products and advisory services that present conflicts of interest for financial institutions are the impetus of the flurry of regulatory activity in this space. As a result, the regulations included in Table 1 could significantly alter the ways in which firms engage their customers, including the availability of certain product offerings or investment advice. Actuarial professionals should plan to be responsive to the needs of their financial institution partners as the emerging patchwork of investment advice regulation continues to develop.

For more commentary regarding the emerging landscape related to the standards of conduct for investment professionals, visit Eversheds Sutherland at *www.fiduciaryregulatory.com*. ■

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Variable Annuities: Best Practices for Managing Financial Risks and Regulatory Updates

By Jeremy Lachtrupp

This is an exciting time for variable annuity valuation and modeling, as both Statutory (Stat) and Generally Accepted Accounting Principles (GAAP) regulatory regimes are making significant changes to their governance framework within a similar timeframe. Stat changes will become effective as of Jan. 1, 2020, and GAAP updates will be binding as of Jan. 1, 2021. The industry is still interpreting these changes, so it is too early to know what the exact impact will be; however, valuable insight can be gained from reviewing the major changes to Stat's VM-21 and the variable annuity (VA)-relevant portion of GAAP's Accounting Standards Update 2018-12, *Targeted Improvements to the Accounting for Long-Duration Contracts*.

In general, the methodologies of Stat and GAAP standards are moving closer together and converging toward a more economic view of VA guarantees. Since GAAP and Stat will now more truly reflect the economics of the liability, reserves should be more sensitive to market movements. This has many implications, including increased transparency in results, standardization among the three balance sheets, and a stronger focus on net income. Stat and GAAP standards are now more favorable toward hedging activities, and we expect that this will lead to increased hedging by VA writers. These changes support better VA financial risk management practices and afford insurers the opportunity to leverage technological advancements to more accurately manage variable annuity risk.

OVERVIEW OF VARIABLE ANNUITY PRODUCT STRUCTURE

Before discussing an appropriate framework for managing VA risk, we need to look at the complexity associated with the VA riders that drives the need for a sophisticated model. Variable annuities are deferred annuities with two distinct phases: the accumulation phase and the annuitization phase. In the accumulation phase of the policy, the policyholder has contributed funds via premium payments, and the account value grows based on the mix of funds (separate account mutual funds and bond funds). In the annuitization phase, the policyholder elects to annuitize the policy and begin receiving benefits.

It is important to note that during the accumulation phase, the insurer collects revenue in the form of rider fees, mortality charges, expense charges, etc., and these charges are deducted from the policyholder's account value. Herein lies a major consideration in the modeling of VAs: the significant mismatch in timing between when revenues are collected by the insurance company and when the corresponding benefit payments are made to the policyholders. Of course, this risk isn't unique to variable annuities; this is a problem that must be addressed for nearly all life insurance products. What is unique to VAs are the complex riders that often accompany the base contract. The four main flavors of these riders are guaranteed minimum death benefit (GMDB), guaranteed minimum accumulation benefit (GMAB), guaranteed minimum income benefit (GMIB) and guaranteed minimum withdrawal benefit (GMWB).

> There are no assets in the market to replicate the benefits associated with (these) riders.

From a modeling perspective, a vanilla GMAB rider is the simplest of the four guarantees. A GMAB essentially provides a floor on the account value for a certain period, and the floor is typically equal to the premium net of any withdrawals. This can be modeled as a European put option that the insurer has written to the policyholder and can be hedged as such. The same argument can be made for GMDBs, although the enhanced benefits associated with these death benefits can complicate the situation. Neither of these riders demand the need for dynamic replication hedging and stochastic-on-stochastic projections.

On the other hand, the more complex GMWB rider offers a policyholder a dynamic, path-dependent strike price, so to speak. In addition to this, the benefits themselves can be paid over a very long time period, introducing additional risk. A GMWB provides the insured with a guaranteed income stream that can be taken over a certain time period or over the policyholder's lifetime. The annual withdrawal amount is set at a minimum percentage of the policy's benefit base. This benefit base can be equal to the premium, but it is often enhanced with "step-ups" and "ratchets," which significantly add to the modeling complexity. There are no assets in the marketplace to replicate the benefits associated with this rider.

The nature of the VA liability guarantee—combined with the ALM strategy required to hedge and manage it—makes it extremely difficult to capture the risk using traditional means. Companies often employ replicating portfolios to quantify market and investment exposure associated with certain blocks of business. While this is certainly appropriate for simple products like term or whole life insurance, this methodology does not capture the risk associated with certain variable annuity riders.

KEY RISKS

Given these complex product features, there are many types of risk that interact with each other and must be accounted for in a variable annuity capital model. The majority of the risk—therefore, what drives the economic capital—is driven by potential adverse movements in capital markets. Given this key driver of capital, this article will focus on the VA market risk components; however, it is important to be aware of the additional risk drivers. The assumptions for nonfinancial risks, such as lapses, policyholder efficiency and mortality, are crucial to the results of the model. Robust assumption development is critical, and there are many considerations around applying these assumptions to the model. Should best-estimate assumptions be used, or should the model reflect prudent assumptions to protect against adverse deviations in these nonstochastic components?

The three major financial risk components are **interest rate risk**, **credit spread risk** and **equity risk**. Interest rates drive the stochastic discounting of path-dependent liabilities and the calculation of greeks associated with the liabilities and the hedge assets. Since a large portion of the separate accounts are invested in corporate bonds, credit spread risk is extremely important and warrants the use of a robust credit model when modeling VA. Lastly, equity risk is the most crucial driver of the values of guaranteed living benefits. Much of the separate accounts are invested in mutual funds, and the inherent volatility associated with these investments drives the value of the riders.

The correlation among the three financial risk factors must also be accounted for. Of course, another major consideration is the substantial increase in correlation among factors under an economic stress, which results in a shrinking of the diversification benefit for scenarios that determine capital. Sophisticated interest rate, equity and credit models should be leveraged in order to calibrate correlation in the tail of the deficiency distribution, and this applies to the correlation among all VA factors (both financial and nonfinancial) as well as the relationship between VA and the company's business as a whole. For instance, fixed-index annuities can serve as a natural hedge against the financial risk associated with VAs.

The next question we must ask: *Considering the intricacies of the VA riders and the risks associated with them, how do we summarize the component of the liability that needs to be hedged?* The most significant risk assumed by the insurer is that the benefits paid to policyholders will exceed the account value. Said another way, a situation can arise where the account value drops to zero but the insurance company is still required to pay benefits to the policyholders. The probability of paying these excess claims is elevated during periods of sustained poor market performance or a market crash. It is these excess claims that need to be hedged in a robust VA risk management framework

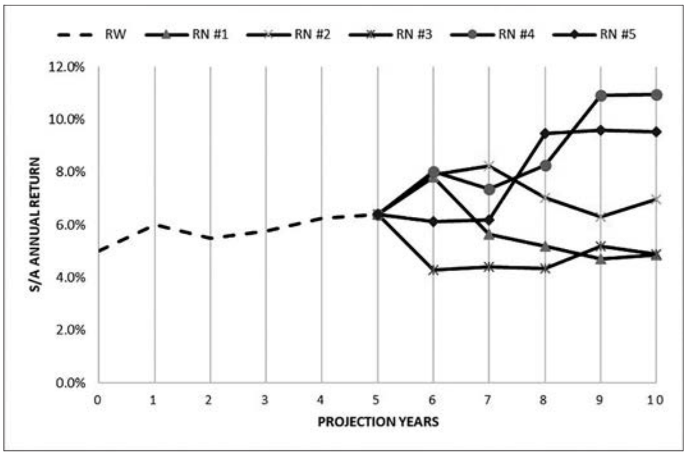
COMPUTATIONAL CONSIDERATIONS IN A NESTED STOCHASTIC FRAMEWORK

The risk associated with these tail claims can be managed with a dynamic replication-hedging strategy. The strategy should target the net present value (NPV) and Greeks associated with excess claims, which in turn is modeled using a stochastic-on-stochastic simulation. Nested stochastics are an essential part of a robust VA ALM framework, but this approach requires high-performance computing techniques. For example, a standard 30-year monthly projection composed of 1,000 real-world outer-loop scenarios with 1,000 risk-neutral inner loops at each time step would require 360 million projections. However, recent technological advancements (such as cloud computing) allow for projections such as this to be completed in a reasonable amount of time. This ultimately allows for a more robust quantification of the risks associated with variable annuity riders.

In a nested stochastic framework, assets and the liability in force are projected along the real-world outer loop. Associated cash flows are updated based on capital market changes and best-estimate assumptions for drivers, such as policyholder behavior, surrenders, mortality, etc. At each time step along the outer loop, the risk-neutral inner loops are used to calculate the net present values for hedge assets as well as liability hedge targets and Greeks. The hedge asset portfolio will be rebalanced based on the mismatch between asset and liability Greeks. The use of nested stochastic techniques allows for the market-consistent valuation of liability Greeks and NPVs, and this is what drives the rebalancing of the hedge asset portfolio.

Figure 1 provides a simplified illustrative example of a stochastic-on-stochastic projection. In Figure 1, one real-world scenario projects the separate account fund value for five years along the outer loop—at which point, five risk-neutral scenarios project the account value for an additional five years along the inner loops. This is a basic example. However, in practice, risk-neutral scenarios would branch off at each time step—monthly, quarterly or maybe even annually, but certainly more often than every five years.

Figure 1
Nested Stochastic Example



Fortunately, current regulatory changes are making it easier for companies to reap the benefits of an ALM framework that incorporates dynamic hedging and nested stochastics. As stated earlier, the Stat and GAAP accounting standards are converging toward a true economic view of VA, and this will result in reserves under both regimes that are more sensitive to market movements. From a modeling standpoint, scenarios that drive tail claims will be more intuitive and will not be a result of regulatory constraints on a Stat and GAAP basis. This balance sheet alignment will reduce the need for painful adjustments between regimes to facilitate management's understanding. Also, the decision as to whether to hedge Stat or GAAP capital will not be as difficult, as they will be converging.

With the maximum hedge effectiveness (HE) factor increasing on the Stat side, companies will now be able to take more credit for hedging. Additionally, statutory changes are increasing the focus of the stochastic conditional tail expectation (CTE) component of the VA calculation by eliminating the current standard scenario; this deterministic scenario will be replaced with a more benign calculation that will serve as a true floor on the reserve. This increased focus on hedging and stochastics will inspire companies to expand their hedging programs and leverage increasingly sophisticated modeling techniques to capture the ALM benefits.

Meanwhile, the evolving GAAP changes should produce increased transparency and limit the need for economic-to-GAAP adjustments to reflect performance. The goal of GAAP financials is to make decision-useful information available to potential contributors of capital. With increased transparency, the cost at which investors and analysts comprehend the standards will be lower. Conveying a better understanding of the economic reality to investors at a lower cost should result in higher P/E ratios, increased earnings and more efficiency.

The most impactful GAAP change from a hedging perspective is that all riders are now classified for fair value accounting, and all guarantees moving to fair value on a GAAP basis should result in increased hedging activity. This is particularly important for GMIB contracts, which may have previously been subject to a standard that was not market-consistent, SOP-03-1, and valued as accrual reserves. Moving to fair value means that these riders will be far more sensitive to market movements, and this in turn increases the need to hedge these guarantees.

SAMPLE VA ECONOMIC CAPITAL MODEL

The financial crisis caused VA writers to experience substantial losses, and it created increased concern around the management of the risks associated with variable annuities. After the crisis, several companies exited their VA operations altogether, while remaining writers adjusted their management of VAs by expanding their hedging strategies and introducing mechanisms like volatility (vol) target funds or vol control funds. Under these strategies, algorithms to transfer money in and out of equities are embedded in funds based on a targeted level of realized volatility. Advancements in VA risk-management techniques such as these led to the need for a more complex modeling framework.

Considering this, the key components of a VA risk-management framework are real-world scenarios, risk-neutral scenarios, the calculation of ALM and capital metrics, modeling considerations and, lastly, guidelines for hedging decisions.

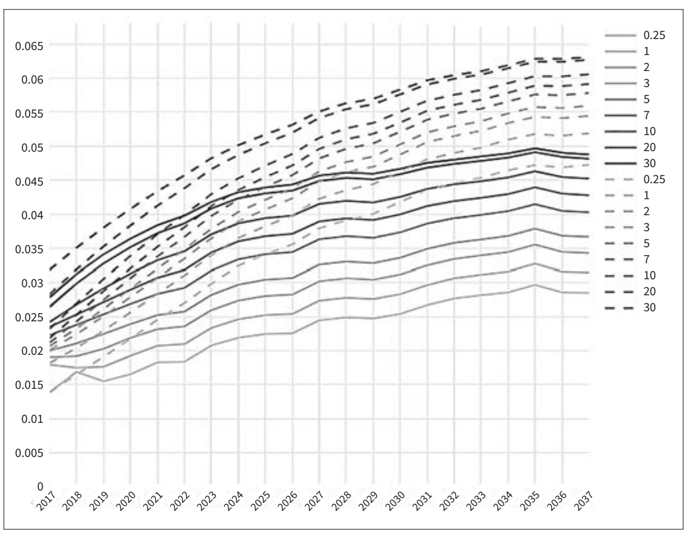
Real-world scenarios are used to project assets and liability in-force cash flows along the outer loop. These scenarios are

retrospective and are calibrated to historical data to produce realistic paths for economic variables. Along each outer-loop path, cash flows will be updated based on the capital market changes as well as best-estimate insurance assumptions. Preferably, these will not be the VM-20 AAA stochastic log volatility scenarios but, rather, custom-calibrated scenarios that reflect the company's specific risks and views of the economy.

Given the current low interest rate environment, the problem we see with calibrating purely to historical rates is that doing so will produce significantly rising yields, and this can have undesirable effects on the simulation and the analysis of VAs. From a VA perspective, much of the value of the guarantees is driven by movements in interest rates. Using a distribution in which rates are consistently rising can cause the optionality associated with VAs to be understated. Additionally, VA reserves generally tend to be lower when rates are higher, since insurers are then able to discount these long-dated liability benefits at a higher rate. It is more reasonable to curb this sharp increase in yields by using strategically calibrated models.

Figure 2 illustrates the average yield for Treasuries across a 1,000-path simulation for various maturity buckets. Dashed lines reflect the purely historically calibrated yields, and the solid lines reflect what we call the "initial to normative" (I-to-N) calibration. The I-to-N is a customized calibration that is based on history but also on factors in the long-term assumptions for future economic variables. In short, it reflects expert judgment of some kind. As we can see, the historically based scenarios produce a much steeper increase in yields, particularly in the earlier stages of the simulation, as opposed to the strategically calibrated scenarios.

Figure 2
Average Yields by Maturity



At each outer-loop time step, there will be a set of **risk-neutral scenarios** that are used to guarantee a market-consistent valuation of the liability Greeks. Unlike the outer loop, these scenarios are prospective and should be calibrated to reproduce the prices of a market basket of options (swaptions, caplets, puts, etc.). The rebalance of the hedge asset portfolio will be driven by this mismatch between the asset and liability Greeks.

In the economic lens, **ALM and capital for each outer-loop path** will be determined by the emerging deficiency while fully accounting for hedging. Then the average of the worst tail number of deficiencies determines the total asset required (TAR) and reserve. To be consistent with the recent statutory regime changes, TAR should be calculated based on the CTE 98 level of deficiencies, and CTE 70 becomes the basis for the reserve. Resulting capital will be the difference between the TAR and the base reserve.

Focusing on the CTE 70 and stochastic component of the calculation and ignoring the deterministic floor, the reserve is based on the 30 percent of the outcomes with the worst greatest present value of deficiencies (GPVADs).

For each scenario, a deficiency between assets and liabilities is calculated at each year, and the largest of those deficiencies becomes the GPVAD. Hedging is permitted to be included in this calculation based on the hedge effectiveness factor. In the absence of risk-neutral scenarios, the hedging calculation is simplified in the statutory lens; it is modeled in a similar way to reinsurance, with a certain percentage of the guaranteed living benefits claims being ceded away, so to speak. Including hedging in the reserve requires the simulation to be run twice. The first iteration includes the estimated impact of hedging, and the next iteration assumes no hedging. The two resulting CTE amounts are plugged into the following calculation to arrive at the reserve.

Statutory View Assuming Hedging

$$CTE\ Amount = HE \times CTE\ Amount_{\text{with hedging}} + (1 - HE) \times CTE\ Amount_{\text{without hedging}}$$

Currently, the hedge effectiveness factor is capped at 70 percent, but this is going to increase in the future to allow insurers to reflect a larger benefit from their clearly defined hedging strategies. The key point here is that this framework does not mandate risk-neutral inner loops, so the valuation is not explicitly modeling hedging. Under this assumption, the deficiency in all real-world scenarios is calculated based on the same hedge effectiveness factor. This is not a realistic assumption, as hedge effectiveness can vary drastically scenario by scenario, particularly in tail scenarios that are driving capital. Liquidity can dry up in these tail scenarios, driving up the cost of hedging.

Leveraging nested stochastics in the economic lens allows for the explicit modeling of the dynamic hedge strategy, and this provides a much more realistic view of the risk. The economic calculation can be broken down into three major components:

1. **PV (unhedged cash flows)** are the cash flows that are excluded from the dynamic hedging strategy. These would include base contract cash flows, like mortality and expense fees, surrender charges, death benefits and any portion of the living benefit riders not being hedged.

2. **Initial hedge target** is the expected present value of excess guaranteed minimum living benefits claims at the valuation date. This reflects the expected cost of hedging.

3. **Hedge breakage** reflects the unexpected cost of hedging that emerges throughout the projection. This is driven by the frictional costs introduced by maintaining key-rate duration and delta hedge targets.

Economic View

Deficiency or TAR = PV (unhedged cash flows) + Initial Hedge Target + PV (hedge breakage)

In general, the unhedged cash flows should be negative, representing a negative deficiency. Companies should be making money from the base contract. The hedge target will be a fixed positive contribution to the TAR, and the emerging breakage will typically further contribute to the deficiency, particularly in the tail scenarios.

There are many additional **modeling considerations** that impact the nested-stochastic-based capital calculation. Adjustments must be made for the additional hedge breakage that cannot be captured in the model. Sources of additional breakage include:

- **Fund basis risk** is particularly important in extreme market events. Mutual fund performance can differ significantly from its benchmark in a tail scenario and, thus, increase hedge losses.

- From a **liquidity risk** perspective, demand for derivatives can dry up in volatile markets, and the cost of rebalancing can be very expensive when the bid-ask spread widens.

Assumptions around other key insurance modeling factors also play a huge role in the results. Best-estimate assumptions are traditionally used in an EC model, and this emphasizes the importance of a robust model-development framework. VA modelers should also consider using more prudent assumptions or holding additional capital for certain risks.

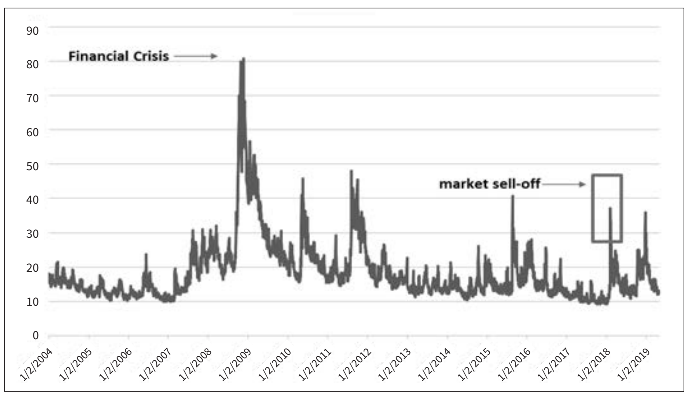
VOL TARGET FUNDS

A major modeling consideration is the volatility target funds that have been embedded within variable annuities since 2011. The goal of these funds is to limit equity exposure by transferring money out of equities and into fixed income when market volatility rises. Strategies typically have a volatility floor, target and ceiling. When the volatility ceiling is breached, money is transferred out of equities subject to the fund's equity vol target, and vice versa. These algorithms have introduced substantial complexity to VA modeling frameworks. Quantifying the impact these funds have on the cost of the VA guarantees can be extremely difficult. It is heavily dependent on the assumed effectiveness of the trading algorithms used to produce stable volatility in realized returns. Modeling results for these transfer funds are also very sensitive to the choice of equity model and volatility measurement convention.

Target volatility funds are remapping the risk profile of variable annuities. In tail scenarios where equity has declined significantly, situations arise where such a significant portion of the fund value has been transferred out of equities that these scenarios will be dominated by rate and credit exposure. This results in VA capital that is more interest rate and credit spread driven with very little delta impact.

It is interesting to note that several equity analysts and market strategists partially blamed these vol target funds for the market sell-off that occurred in early February 2018. Figure 3 tracks the VIX—a popular measure of expected stock market volatility—back to 2004. The financial crisis is represented by the large spike in volatility in 2009, which ultimately contributed to the creation of volatility managed funds. The much smaller spike in February 2018 represents the market sell-off that some journalists claim was exacerbated by the existence of these funds. It is interesting—but not at all surprising—that analysts are paying attention to how the management of the billions of dollars of VA fund value is impacting the market as a whole.

Figure 3
VIX Index Level



The decision of what to hedge is paramount. There are many questions that need to be addressed:

- Are hedge targets based on key rate durations and deltas, or are additional Greeks targeted?
- Do you incorporate macro hedges to provide further protection in the event of a credit crisis or equity market decline?
- Are claims fully hedged, or is stop-loss (deductible) strategy employed or, contrarily, a first-loss hedging strategy?
- Do you hedge fees?

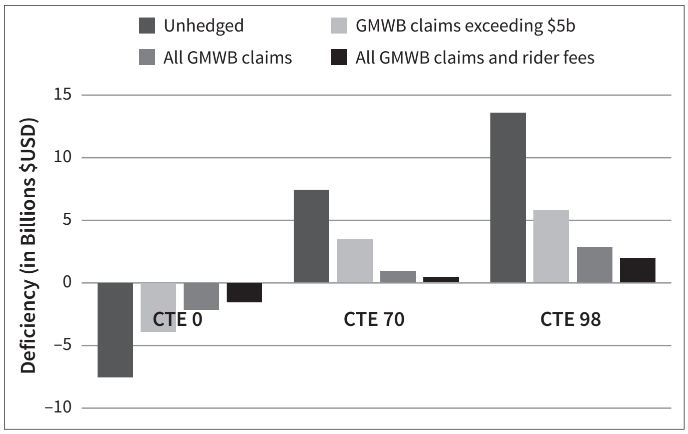
Sensitivity tests to assess the impact of various hedging strategies can help compare the costs and benefits of each strategy.

Figure 4 illustrates both the cost of various hedging strategies when looking at the average of the deficiency distribution, and the benefit of hedging strategies when focusing on the tail of the distribution. This average cost of hedging is reflected in the left portion of the graph, which is the CTE 0 or average of the distribution of deficiencies for the four candidate strategies.

- Under the unhedged strategy, no attempt is made to protect against losses due to excess rider claims. No dynamic or static hedging is assumed; however, traditional ALM for the base contract is still performed. The goal is to isolate the impact of various dynamic hedging strategies, so traditional duration matching ALM via fixed-income instruments is constant throughout all four approaches.
- "GMWB claims exceeding $5b" is a stop-loss hedging strategy. Under this approach, the insurer sets a deductible of excess liability claims that it is willing to accept and leave unhedged. Only GMWB claims that exceed this deductible will be hedged.
- Obviously, the lower the deductible, the closer results will be to the third approach, which attempts to dynamically hedge all GMWB claims.
- The last ALM approach is the "fully hedged" strategy that incorporates all excess GLB riders as well as the associated rider fees.

Figure 4 demonstrates how much hedging costs you on average as well as the significant protection it provides in the tail.

Figure 4
Deficiency (TAR) by Strategy



In conclusion, regulatory changes are bringing Stat and GAAP regimes closer to a true economic view of variable annuities. This has many positive implications, including improved transparency in the results, greater market sensitivity and an increased focus on stochastics. More importantly, the changes will incentivize insurers to increasingly take advantage of technology to manage the complex risks associated with VAs. ■

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Staff Corner

By David Schraub

The newsletter is one of our section members' most valued assets. This result has shown up in all the section surveys I have seen during my six-year tenure with the Society of Actuaries (SOA). This Staff Corner will shed some light on how newsletters are produced. Let's open up the hood and check it out.

Several groups of people take part in this initiative:

- **Article authors.** SOA members and nonmembers who volunteer to write articles.
- **Newsletter editors.** Volunteers who solicit and peer-review the articles and provide feedback to authors and SOA staff.
- **SOA section staff partner.** The liaison between the section, the volunteer newsletter editor and the newsletter staff. This person oversees reputation risk management and offers guidance as needed.
- **SOA staff editor.** An in-house editor who guides the newsletters from copyediting to publication. This person is the gatekeeper of the newsletter.
- **SOA graphic designer.** The person responsible for design and layout of the newsletters. The graphic designer also ensures the quality of graphics and tables.

In chronological order, the newsletter process looks like this:

1. Authors write articles. Generally, either the newsletter editor reaches out to potential authors with a request for an article on a specific topic, or an author reaches out to the newsletter editor and offers to write an article on a given topic. In some cases, authors are asked to republish an article that is already written.
2. Newsletter volunteer editors peer-review articles. They assess their fit within the newsletter regarding quality and topic and provide feedback on the content of each article.[1] For example, the topic of an article may be a better fit for a different section than originally intended. In that case, that article is forwarded to the other section's newsletter editor. After a few weeks of back-and-forth to firm up the content, the articles (along with author bios, head shots and figure and table source files) reach the staff partner. For a previously published article, the back-and-forth is replaced with a reach to the owner of the copyright for reprint permission.
3. The section staff partner reviews all the articles to assess whether there is any reputation risk regarding their content (e.g., self-advertising, lobbying or other pitfalls). This step sometimes takes place slightly later in the process.
4. The staff editor receives the finalized content and oversees copyediting for grammar and editorial style, as well as production of the newsletter. This is where the i's get dotted. The editor monitors the schedule, nudges volunteers as needed, and sends metadata[2] and copyright forms to the authors.
5. The staff editor and volunteer newsletter editor work together to address any challenges that go beyond punctuation. The newsletter editor answers the staff editor's questions directly or turns to the authors as needed. Common questions include, "Who should approach the coauthor to soften the tone of the conclusion, which is a bit too self-serving?" "Do we still have time for a last-minute announcement?" "Did anyone receive Jane Doe's article she promised us a while back?" "Should we keep that article for the next issue as it is not quite ready, and we have a lot of content already?" "Do we have head shots and authors'

names correctly aligned?” This back-and-forth can take time, but multiple pairs of eyes are key to the quality of the newsletter.

6. The staff graphic designer makes the content look great. The newsletter editor and authors review the page proofs for any typos and readability of the graphs, while the staff editor proofreads the full newsletter one more time. This is where loose ends are tied.
7. The staff editor sends the newsletter to the printer and/or digital vendor after green lights from all. Printing and shipping take place (as appropriate), the digital edition is created and, finally, the PDF version and links to the digital version are posted on the SOA website. This is the time to update the section’s landing page with a link to the newsletter. For printed newsletters, readers at home receive their copies a few weeks later.

Toward step 5 of the current newsletter is when volunteer editors begin to gather articles for the next issue, whether it’s the promise of an article or articles that are already in hand. Then the process begins all over again.

Want to join the fun? We are always looking for editors and authors to improve our content. ■

David Schraub, FSA, CERA, AQ, MAAA, is a staff actuary for the SOA. He can be contacted at *dschraub@soa.org*.

ENDNOTES

1 For some newsletters, the volunteer authors and volunteer editors are blended. For example, *Taxing Times* has a large group of newsletter editors who peer-review and cross-check every statement of every author (there are lawyers in the group).

2 Metadata includes topics, country of relevance, and keywords for each article. Topics and country of relevance are filters on the SOA website and help get readers to the content faster. Keywords are additional hints for search-engine optimization.

The Bulletin Board

Join us for the 2019 Investment Seminar! The Investment Section is pleased to invite you to the 2019 Investment Seminar, to take place on Sunday, Oct. 27, in Toronto, Ontario, immediately prior to the SOA 2019 Annual Meeting & Exhibit. The Investment Seminar replaces the Investment Symposium that was previously held as a stand-alone event in March. Attaching the seminar to the annual meeting allows for more networking and continuing education with less travel.

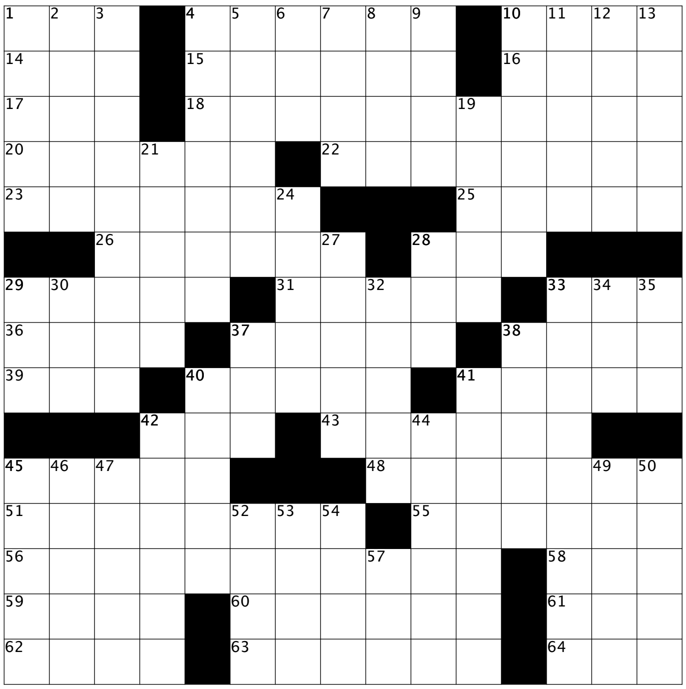
The restructured Investment Seminar is a daylong event that features two general sessions and eight breakout sessions as well as a network gathering to get to know your peers. Make your plans to come to Toronto a day earlier and attend sessions discussing topics such as:

- The low interest rate environment
- Concentration of corporate credit risk
- Equity return premium
- Risk management and deficiencies remaining to be addressed
- Liability-driven investing
- Other current topics—and a panel discussion featuring CIOs talking about strategies, challenges, opportunities and concerns.

You do not want to miss it! ■

Crossword Puzzle: PBR

By Warren Manners



The solution will be provided in the next issue of *Risks & Rewards* along with the names of those who were able to successfully complete it. Submissions should be made to *e-news@soa.org* by Nov. 30, 2019.

Congratulations to those able to complete last issue's puzzle! 100% perfect: Mary Pat Campbell. ■

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Across

1 Gym unit
4 Law of parsimony philosopher
10 Jam
14 Scull
15 Horn of Africa resident
16 Atmosphere
17 Oklahoma Native American group
18 PBJ
20 Taffeta or chiffon
22 Firmed up
23 Very cool
25 Ural people and the language they speak
26 Visa holder
28 OPEC meas.
29 Heffalump creator
31 Ampoules
33 "____, 'twill be this hour ere I have done weeping": Shakespeare
36 Editor's mark
37 Dutch pottery
38 Unrivaled
39 Lang. of Luther
40 Hawaiian tree
41 Conveyers of genetic info.
42 1/6 fl. oz.
43 Inattentive
45 Impersonate
48 Home of the GOAT
51 Former name of modern day Incheon
55 Arrange
56 PBC
58 Kind of cat
59 Punjabi prince
60 Capital on the Tanshui River
61 Harry's successor
62 Smidgen
63 Implant
64 ____ sportif (shooting sports in France)

Down

1 Gambrel and dormer
2 Wear away
3 PBA
4 Ear bone
5 Strepto or staphylo suffix
6 Speedometer abbr.
7 Confusion in Bucharest
8 Heaps
9 Eight furlongs
10 Near the tail
11 Squabble
12 Maple trees in Madrid
13 Islamic prophet
19 Yeanlings
21 Jolly
24 Come clean
27 Linden tree genus
28 Short order?
29 Food enhancer
30 Believer suffix
32 USAF branch
33 PBS
34 Cabrerra or Navarro
35 Jon Anderson was their frontman
37 Fist bump
38 Zones
40 Assyrian god
41 Field utensils
42 Large metal gong
44 Temporary ride
45 Ghana capital
46 Mountebank
47 Title of Japan's chief of state
49 Basra resident: Var.
50 Tim Matheson role
52 Sol-do bridge
53 Aim
54 Ties in Tokyo
57 Lout

Big Data Solution From February 2019

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