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Managing Investment and Liquidity Risks Within Nonfundamental Market Sell-off and Volatility Feedback Loops: A Market Impact Perspective

By Aymeric Kalife

Market impact is an illustration of market inefficiency. Theories of efficient markets typically expect that investors buy and sell assets based on assessments of their intrinsic value, in contrast with large derivatives players who often act based on market price movements, which may not be linked to fundamentals. Market impact risk actually refers to the degree to which large transactions can be carried out in a timely fashion with minimal impact on prices. As a result, managing investment and liquidity risks for large players requires introducing an explicit market impact function; its application to derivatives significantly depends on whether or not there is significant delta hedging activity. In the case of no significant delta hedging activity, risk appetite has significant influence on the optimal execution strategy. With significant delta hedging activity, the optimal trading involves feedback hedging effects, translating into a modified Black-Scholes hedging strategy.

Soaring market volatility necessitates updated hedging strategies. In the last six years, we have had more short-lived but sharp transitions from low volatility to high volatility with no well-known fundamental catalysts than in the prior two

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Chairperson's Corner

By Bryan Boudreau

I'm thrilled to be writing my first Chairperson's Corner. While I can't remember exactly how long I've been an Investment Section member, I'm sure it's been the majority of my 30+ year career. The Investment Section has always provided valuable content and helped to satisfy my interest in understanding both sides of the balance sheet.

The left-hand side of the balance sheet has certainly provided its share of interesting twists and turns. At the early part of my career, I witnessed the stock market crash of 1987 (while studying for exams). Two decades later, I had a front row seat to the demise of Lehman Brothers. In more recent years, we've witnessed an extended bull run in stocks and a period of developed-market interest rates lower than any contemplated when many investment strategies or insurance products were designed.

The growth and maturation of asset liability management as a discipline has been a key nexus for investment actuaries. Several decades ago, assets and liabilities were managed almost independently. Today, we see variable annuity hedge programs modeled with the same sophistication as Wall Street trading desks, with immediate marks to market and rebalancing. We also see pension plans looking at their funding ratios daily and implementing strategies that react to market moves.

While the development of ALM, as well as advanced risk analytics, has been a great leap for insurers and pension funds, the investment markets will always defy prediction. The big turns in the market have generally surprised investors by contradicting widely held views such as "portfolio insurance can protect against market downturns" or "housing prices will never decline." I think these events should teach us to be especially wary of consensus.

As a second-time Investment Section Council member, I can attest that the section leadership is always looking for ways to serve our ultimate goal: to provide useful and relevant investment-related content to our membership. In recent years, our section webcasts were a huge hit. We plan to increase the number for 2019. We also sponsored a number of podcasts; Jeff Passmore's "Becoming an Investment Actuary" was one of the SOA's most downloaded podcasts of all time. Plans are also underway for the 2019 Asset Allocation Contest and the awarding of the section's Redington Prize.

Before signing off, I'd like to give a special acknowledgement to our longtime *Risks & Rewards* editors, Joe Koltisko and Nino Boezio. As the former section liaison to *Risks & Rewards*, I'm continually amazed at the time, effort and dedication that both Joe and Nino give to the newsletter, which is a centerpiece of our section's efforts. Thank you, Joe and Nino!

I encourage all current and future members to check out the section web page (*www.soa.org/sections/investment/investment-landing/*). Please contact me, David Schraub (*dschraub@soa.org*) or any other section council member if you have ideas for how we can do a better job for our section members. ■

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decades[1]—growing evidence that we are in a new volatility regime. Low liquidity and low conviction environments lead to this becoming increasingly more common.

Although fears about growth or sovereign debt sustainability are valid explanations for the significant volatility spikes experienced during the May 2006, May 2010, August 2011, August 2015, June 2016 or February 2018 market sell-offs, they do not fully explain either the extreme magnitude of the shocks or the repeated occurrence at the close in European and U.S. markets. Also, the Volatility Index averaged 11 through 2017—the lowest since 1990, in the context of easy monetary policy, share buybacks and solid fundamental factors such as continued global growth, solid-to-positive earnings and falling unemployment. (There was a short VIX futures strategy profit and loss at +150 percent in 2017, making money every single month that year.)

Derivatives activity by large players might have exacerbated the acuity of such volatility spikes from the illiquidity premium in option markets since the late 1990s[2] stemming from a structural imbalance between supply and demand in derivatives, as illustrated by the 70 percent more put options outstanding than outstanding call positions[1], or the growing hedging of U.S. variable annuities, Asian structured products and U.S. mortgages convexity. Such imbalance in the derivatives markets is at the source of hedging inefficiencies, where market makers tend to sell more as the market drops or buy more as the market rallies, independent of fundamentals.

As a result, the cost of placing one large order to close a position becomes far greater than the sum of infinitely small orders differed in time. For this reason, an explicit modeling is required through a market impact function, the influence of which the agent will try to minimize. The optimal execution turns out to be the sequence of small trades over the course of several days that optimizes a target, (e.g., minimizes the mean cost of trading). In this article, we consider the optimal execution price and strategies of options when market impact is a driver of the option price, which depends on whether the options' delta hedging is significant or not.

- **No or insignificant delta hedging** (like for a life insurance company aiming to minimize the cost of buying a large quantity of put options to hedge liabilities). The optimal execution turns out to be strongly dependent on the risk appetite. Within a mean cost minimization objective, as the maturity approaches, the agent must make faster acquisitions as time passes; in contrast, within a mean-variance risk appetite (where the dispersion of revenues is also taken into account), the agent tends to liquidate her position at the beginning to reduce the P&L variance.
- **Significant delta hedging.** The optimal execution strategy is determined by a no arbitrage framework that incorporates the specific impact of the large trader's hedging activity (**hedging feedback effects**), which translates into a fully nonlinear modified Black-Scholes delta hedging strategy.

In this article, the most observed types of market impact on the investment and liquidity risks within derivatives strategies is illustrated and analyzed from a qualitative perspective. We then examine the optimal strategies in derivatives based on appropriate modeling of the market impact, depending on whether there is significant associated delta hedging activity or not.

EMPIRICAL MARKET IMPACT OF DERIVATIVES STRATEGIES

Hedging Financial Risk of Life Insurance Liabilities

Insurance companies utilize derivatives in a variety of ways to manage and mitigate risks inherent in their liability portfolios, which can be characterized by three main features: medium long-term duration, large volumes and significant market risk exposure. Specifically, guaranteed minimum income and withdrawal benefits greatly increase insurers' risk exposure to market volatility, while pension and other post-retirement benefits could be hurt if equity returns fall short of expected long-term rates of return.

Given the persistent low interest rate environment across the curve since the 2008 financial crisis, these large players need to hedge their liabilities even more, as illustrated by the significant increase in notionals from $786 billion as of fiscal year 2010 to $1,885 billion as of FY 2014. As the guarantees embedded within those liabilities hold a convex risk profile with respect to the underlying stock, traders need to buy some convex equity hedge assets such as options (in contrast to linear instruments like futures) in order to match the liability risk profile to improve hedge effectiveness. In that respect, the use of downside protection options is appropriate, such as put options, which accounted for 44 percent of the transactions (versus 24 percent for the call options) with 90 percent of them purchased, implying the growing cost of hedging.[3]

As equity derivatives are highly sensitive to supply/demand balance, buying large hedge portfolios requires taking into account the transaction size explicitly, which is not considered by traditional models.

Large Derivatives Imbalances

Large derivatives imbalances are likely to imply net short positions in options by market makers, thus synthetic replication with significant delta hedging activity is likely to exacerbate market moves through hedging feedback effects.

Effects on Short-dated Vanilla Options

Investors typically buy index put options as downside protection (with little or no hedging), thus market makers short put options, which they delta hedge by selling futures to be market neutral. If the market suddenly drops, they would need to sell further to adjust, which amplifies the down market move and volatility.

Effects on Long-dated Exotic Options

Autocallables are upside (capped) participation with capital guaranteed (floor) and an embedded-up and knock-out barrier that can cause their gamma to reverse across very small movements as spot rallies toward the barrier while the expiry approaches. This requires the seller to sell large amounts, which tends to prevent the spot market from actually hitting the barrier.

Despite this selling of spot and gamma, the barrier may at some point break, where the option disappears, and the trader is left only with his hedge (i.e., a naked position), which he has to cover by buying back spot and gamma. Delta hedging tends to exaggerate spot moves even more (higher spot → needs to buy → drives spot higher; lower spot → needs to sell → drives spot lower), which will cause the spot market to become more liable to choppy trading and can cause the market to gap higher. Because of leverage in barrier options, the delta amounts grow to multiples of the size of the original option.

The hedging of variable annuities can also be a major driver of such market feedback loops given those embedded life insurance guarantees are upside (capped) participation with capital guaranteed (floor), while their positions tend to leave the variable annuities players "the same way around"—either buying or selling particular types of hedging instruments. As such, insurers buy volatility when it rises and vice versa, exaggerating any move. While the impact on the derivatives markets gamma is still under control given most hedge assets (futures, options, varswaps) are short dated, the vega hedging needs are huge as a result of the very long dated life insurance policies.

OPTIMAL DERIVATIVES STRATEGIES

No Significant Delta Hedging Activity

Here we consider that delta hedging is either nil or negligible in terms of market impact, which is consistent with practice on the main market indices as their exchanged volumes are far larger than for the options contracts. The average shares traded per day for the S&P 500 has grown from 2.3 million to 4.1 billion, with Oct. 10, 2008, the busiest trading day ever for the S&P 500 when a phenomenal 11,456,230,400 shares changed hands. Options contracts exchanged volumes are significantly lower.[4] See Figure 1.

Figure 1
S&P 500 Historical Volume Data
(Jan. 2, 1951, to March 31, 2012)

	Total Shares	Avg. Shares	Correlation	R^2
1950s	5,777,550,000	2,298,150	0.66	0.44
1960s	19,072,060,000	7,656,387	0.73	0.53
1970s	57,655,100,000	22,833,703	0.48	0.23
1980s	306,188,530,000	121,118,881	0.76	0.58
1990s	1,195,610,210,000	473,134,234	0.93	0.86
2000s	7,091,918,888,000	2,819,848,464	(0.07)	0.01
2010s	1,274,419,730,000	4,058,661,561	(0.32)	0.10
Total	**9,950,642,068,000**		**0.72**	**0.52**

Source: Yahoo Finance, CFA Institute

As a result, an agent who is willing to trade a large quantity of options will see the impact as an important dilemma, as the cost of placing one large order to close his position will be far greater than the sum of infinitely small orders differed in time. In practice, the orders are usually broken up into smaller ones and executed over the course of several days.[5] Only 20 percent of the market value of the trades split in their set of data are completed within a day, and 53 percent are spread over four trading days or more.

For this reason, an explicit modeling is made through a market impact function, the influence of which the agent will try to minimize. The market impact function depends on the **temporary impact strength** proportional to the main empirically observed drivers, such as the speed of option trading (i.e., the number of options per unit of time), the equity stock level and the option sensitivity to the equity stock. The optimal execution turns out to be the sequence of trades that optimizes the target (e.g., minimizes the mean cost of trading over a fixed period) or the mean-variance criterion if the volatility of revenues is taken into account.

Market Impact Function, Resulting Option Price

The model is inspired from Leland's option replication with transaction costs[6] incorporated into the option price as an additional variable within the volatility function:

$$\tilde{\sigma}^2 = \sigma^2 + f(t, \dot{x}_t, x_t, \sigma)$$

where σ is the asset volatility and f is the market impact function (dependent on time, volatility, inventory and trading speed).

In terms of market impact function, we follow the approach by Almgren[7] where the price impact is a combination of two components: a permanent component that reflects the information transmitted to the market by the buy/sell imbalance, and a temporary component that reflects the price concession needed to attract counterparties within a specified short time interval. We adapt such approach to derivatives through the **enlarged volatility** expression as follows:

$$\tilde{\sigma}_t^2 = \sigma^2 + (\tilde{\eta}\dot{x}_t + \tilde{\gamma}(x_t - x_0))\sqrt{\hat{T} - t}\sigma$$

where $\tilde{\eta} = \eta\sqrt{\frac{8}{h\pi}}$ and $\tilde{\gamma} = \gamma\sqrt{\frac{8}{h\pi}}$.

And η and γ are constants. The number of shares is x(t) while $\dot{x}_t$, its derivative with regards to time, corresponds to the speed of trading of the security. The term $\eta\dot{x}_t$ corresponds to the temporary or instantaneous impact of trading $\dot{x}_t dt$ shares at time t and only affects this current order. The term $\gamma(x_t - x_0)$ is the permanent price impact that was accumulated by all transactions until time t.

The option effective price is then expressed through a Black-Scholes-like partial differential equation with such modified enlarged volatility in order to compensate for the market impact cost, where buying the option will typically lead to increasing its price. The higher the trading speed and quantity, the higher the volatility and thus the option price:

$$\begin{cases} \partial_u \tilde{P}(u,S) + \frac{1}{2}\tilde{\sigma}_t^2 S^2 \partial_{SS}\tilde{P}(u,S) = 0, & (u,S) \in [t,\hat{T}[\times]0,\infty] \\ \tilde{P}(\hat{T},s) = (K-s)^+. \end{cases}$$

Using a simple Taylor approximation to the first order, we can rewrite the expression as a sum of the Black-Scholes option price and an additional term corresponding to the option market impact:

$$\begin{aligned} \tilde{P}(t,S_t) &\approx P(t,S_t) + (\tilde{\sigma}_t^2 - \sigma^2)\partial_V P(t,S_t) \\ &\approx P(t,S_t) + \frac{1}{2}\{\tilde{\eta}\dot{x}_t + \tilde{\gamma}(x_t - x_0)\}\sqrt{\hat{T} - t}\nu(t,S_t) \end{aligned}$$

where $\nu(t,S_t) = \partial_\sigma P$ is the Black-Scholes vega of the option:

$$\nu(t,S_t) = \sqrt{\hat{T} - t}S_t N'(d_1) = \sqrt{\hat{T} - t}KN'(d_2)$$

$$N'(x) = \frac{1}{\sqrt{2\pi}}e^{-x^2/2},$$

$$d_1 = \frac{\log\frac{S_t}{K} + \frac{1}{2}\sigma^2(\hat{T} - t)}{\sigma\sqrt{\hat{T} - t}},$$

$$d_2 = \frac{\log\frac{S_t}{K} - \frac{1}{2}\sigma^2(\hat{T} - t)}{\sigma\sqrt{\hat{T} - t}} = d_1 - \sigma\sqrt{\hat{T} - t}.$$

We will next develop the framework under the Black-Scholes case as a temporary market impact only, with permanent impact excluded (i.e., $\tilde{\gamma} = 0$). In that case, the effective price is given by:

$$\tilde{P}_t = P_t + \frac{1}{2}\tilde{\eta}\dot{x}_t\sigma S_t^2(\hat{T} - t)^{3/2}\Gamma(t,S_t).$$

Optimal Execution Problem

The optimal execution is a strategy that unfolds over the course of several days [0,T] by means of a dynamic order execution strategy that ought to adapt to changing market conditions. The end user's purpose is to hedge the risk of a complex product (structured product, variable annuity, etc. . . .) indexed on an underlying asset, by acquiring vanilla put options on that same underlying asset.

Let us consider a buying trade execution strategy x(t) in which an amount of options X with fixed strike K and maturity T needs to be bought by a fixed time horizon [0,T] with the conditions x(0) = X and x(T) = 0.

Let $(\Omega, \mathcal{F}, \mathbb{P})$ be the usual probability space on the filtration $(\mathcal{F}_t)_{t\in\mathbb{R}_+}$ satisfying the usual assumptions. In the absence of market impact and under a null risk-free rate, the no-arbitrage price of a put option is defined by $P_t = \mathbb{E}_{\mathbb{Q}}[(K - S_{\hat{T}})^+|\mathcal{F}_t]$ under the risk-neutral probability measure Q in which the asset price is a martingale. At each time t, $\dot{x}_t dt$ options are bought at price $\tilde{P}_t$ which is the option impact price defined by the price equation above. Thus, the cost arising from the strategy x is $\mathcal{C}(x) := \int_0^T \tilde{P}_t\dot{x}_t dt$:

$$\mathcal{C}(x) = \int_0^T P_t\dot{x}_t dt + \frac{1}{2}\tilde{\eta}\int_0^T \dot{x}_t^2\sigma S_t^2(\hat{T} - t)^{3/2}\Gamma(t,S_t)dt,$$

$$\mathcal{C}(x) = -XP_0 - \int_0^T \sigma x_t S_t\Delta(t,S_t)dW_t + \frac{1}{2}\tilde{\eta}\sigma\int_0^T \dot{x}_t^2 S_t^2(\hat{T} - t)^{3/2}\Gamma(t,S_t)dt,$$

where Δ is the Black-Scholes delta of the option.

The agent's objective is then to minimize a certain objective function, which takes into account his risk aversion, and may involve both cost and risk terms. Here we will consider two risk appetite cases:

- The mean cost $\mathbb{E}[\mathcal{C}(x)]$
- A risk/reward criterion, the mean-variance cost case $\mathbb{E}[\mathcal{C}(x)] + \lambda\mathbb{V}ar[\mathcal{C}(x)]$ (which includes the mean case with λ = 0), where λ > 0 is the variance penalty.

The mean cost is usually used for an agent who does not monitor the risk of his strategy:

$$\mathbb{E}[\mathcal{C}(x)] = -XP_0 + \frac{1}{2}\tilde{\eta}\mathbb{E}\left[\int_0^T \dot{x}_t^2 S_t^2(\hat{T} - t)^{3/2}\Gamma(t,S_t)dt\right].$$

Theorem 1. The optimal strategy x^* resulting in minimizing the mean cost under the Black-Scholes framework is characterized by [8]

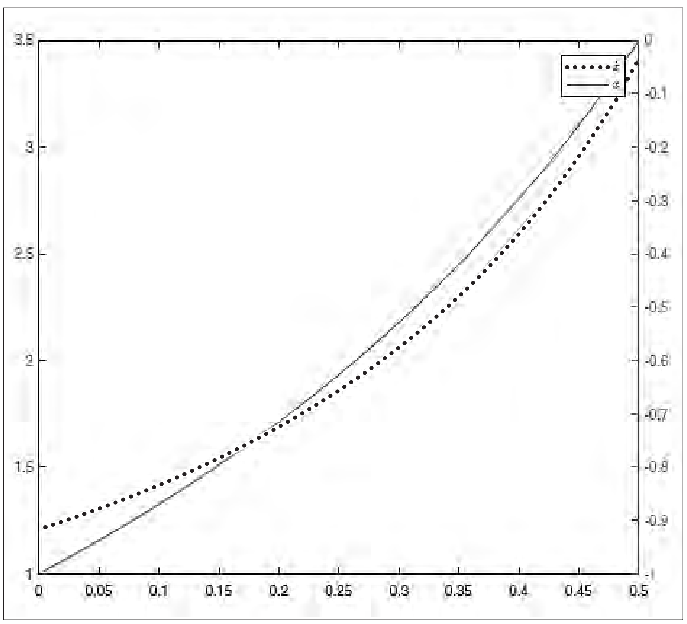
$$\dot{x}^*(t) = \frac{K_1}{(\hat{T}-t)^{3/2}},$$
$$x^*(t) = \frac{K_1}{(\hat{T}-t)^{1/2}} + K_2$$

where

$$K_1 = \frac{X}{2(\hat{T}^{-\frac{1}{2}} - (\hat{T}-T)^{-\frac{1}{2}})}$$
$$K_2 = -2K_1(\hat{T}-T)^{-1/2}.$$

The theorem is illustrated in Figure 2 for t = 1, T = 0.5, X –1:

Figure 2
Optimal Execution Trade Quantity and Speed Depending Residual Time



In summary, the optimal execution strategy to minimize the mean cost provides a rather stable pace of trading. The pace is rather constant at the beginning and then gradually increases as it gets close to maturity, which is intuitive given the fixed quantity to buy within a fixed time period, implying the insurer must acquire at a faster rate as time passes.

We will now develop the optimal execution framework under the mean-variance case, where the optimal strategy turns out to be more sensitive to the underlying price evolution.

Optimal Execution Strategy Depends on Risk Appetite

Investors usually take into account their risk aversion using risk/reward criterion.

For the mean cost case, we are interested in the price impact formulation with temporary impact only. That is, we can easily deduce that the mean-variance objective function can be approximated as:

$$E[C(x)] + \tilde{\lambda} Var[C(x)] \approx E\left[\int_0^T \frac{1}{2}\tilde{\eta}\sigma \dot{x}_t^2 S_t^2 (\hat{T}-t)^{\frac{3}{2}} \Gamma(t,S_t)dt + \tilde{\lambda}\int_0^T x_t^2 \sigma^2 S_t^2 \Delta^2(t,S_t)dt\right]$$

We then set up the dynamic programming problem where we parameterize as before the strategies x by their trading speed or **trading rate** α defined as $-\dot{x}_t : x_t^\alpha := X - \int_0^t \alpha_s ds, \quad 0 \le t \le T.$

We restrict our framework to a Markovian trading rate (i.e., the agent's optimal trading speed at time t is completely determined by the current state). Using the standard procedure of deriving the Hamilton-Jacobi-Bellman equation in stochastic control problems, the solution to the reduced optimization problem solves the following PDE:

$$\partial_t U + \frac{1}{2}\sigma^2 S^2 \partial_{SS} U + \tilde{\lambda} x^2 S^2 \Delta^2(t,S) + \inf_{\alpha \in \mathbb{R}} \left\{ \alpha^2 S^2 (\hat{T}-t)^{3/2} \Gamma(t,S) - \alpha \partial_x U \right\} = 0$$

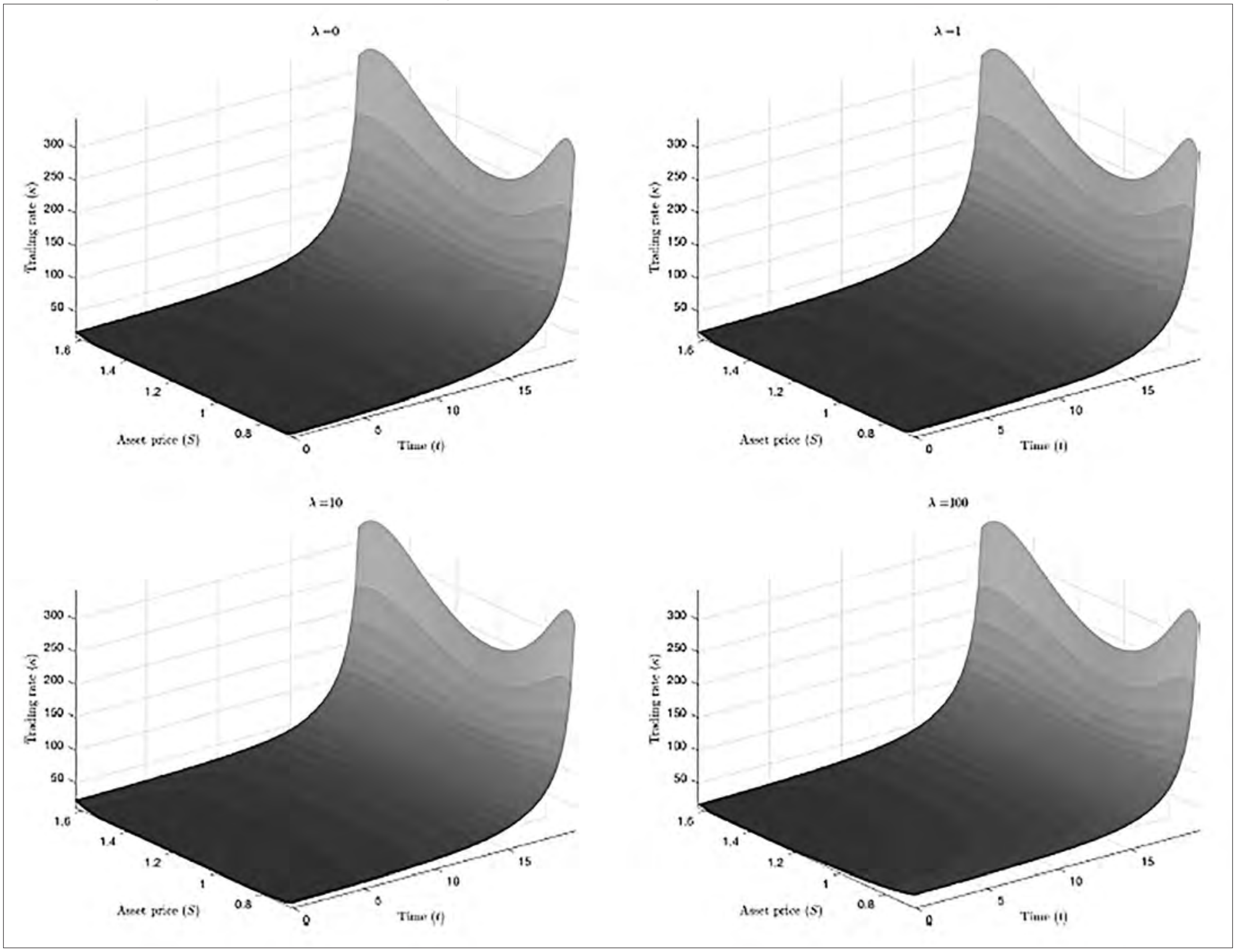
combined with the so-called finite-fuel constraint (i.e., $\int_0^T \alpha_t dt = X$).

Although this minimization problem does not admit a closed-form solution, the quasi-linear PDE can be solved numerically using finite differences methods[8]. Table 1 shows the results for a long position on at-the-money put options.

Table 1
Long Position on ATM Put Options

Parameter	Value
σ	30%
T (the strategy horizon)	1/12 (years)
$\hat{T}$ (the option maturity)	1 (years)
μ	0
r	0
S_0	1
K	S_0
Action	Buy
x_0	–1
$\tilde{\eta}$	0.05
Trading frequency	4 trades per day
λ	0, 1, 10, 100

Figure 3
Rate of Trading as a Function of Underlying Price S, Time t for Different Values of λ



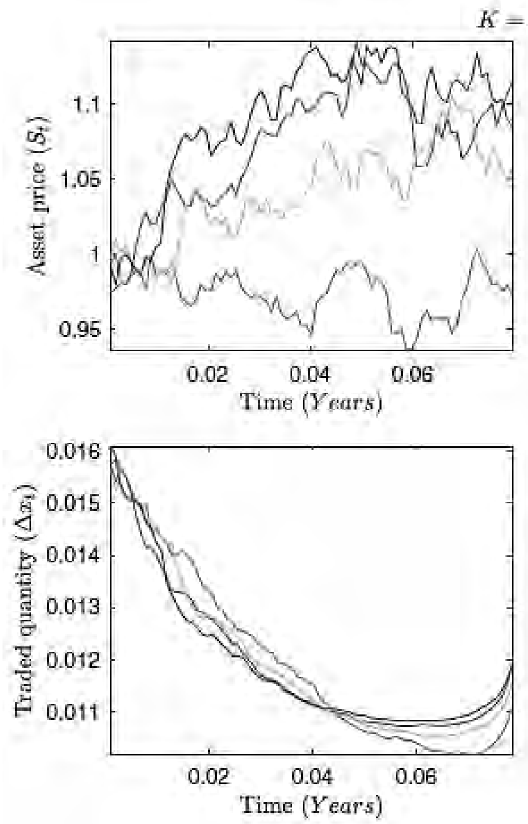
Note: Mean objective (λ = 0, top left) or mean-variance (λ = 1, top right; 10, bottom left; 100, bottom right)

Figure 3 illustrates the optimal execution strategy through the rate of trading as a function of the underlying price S and time t. The strategy hardly depends on the trader inventory position. However, as time increases, the trading rate increases (convex in time). As the maturity approaches, the agent must acquire faster as time passes, with a shape of an inverse function of time.

The mean case ($\lambda = 0$) is the least affected by the spot variation. In contrast, this representation allows seeing that the mean-variance (i.e., $\lambda \neq 0$) with a high-risk aversion is most sensitive to price movements. The agent tends to liquidate her position at the beginning to reduce the P&L variance that plays a non-negligible role in her choice. To gain additional insight, in Figure 4 (Pg. 9), we plot four paths of the underlying price together with the rate of trading, the inventory and quantity to be traded, where adding the variance pushes the agent to adapt the strategy to the underlying level. As the risk aversion parameter increases, the traded quantity tends to be larger at the beginning.

In contrast, within the mean-variance case where the dispersion of the profit and loss becomes an additional driver of the risk appetite, the optimal execution strategy significantly depends on the stock path, with a faster pace when the stock level is low compared to when the stock level is high. Indeed, as the stock decreases, the cost of the put option increases. This prevents the insurance company from waiting until maturity to trade a large quantity, and instead favors a decreasing trading pace as time passes.

Figure 4
Sample Paths of Evolution of Price, Rate, Inventory and Quantity



Significant Delta Hedging Activity

We consider here the interaction of one "large trader" whose action affects prices and many price-takers or "small traders"; the usual no arbitrage condition[9] doesn't apply. We use a continuous time version of Jarrow's no market manipulation strategies[10], which requires additional but relevant required assumptions:

- The asset price is independent of the large trader's past holdings
- Real wealth (as if the holdings were liquidated)
- Synchronous markets condition
- Prices adjust instantaneously across underlying and derivatives
- Absence of corners

Effects on Option Prices

Large dealers are net writers of options and thus need to neutralize the risk by synthetically replicating options. As a result, an additional process—the number of underlying assets held by the large trader—needs to be introduced, which gives rise to nonlinear feedback effects.[11]

Actually, traded options exist only for well established markets and relatively short maturities. For very long dated options, dynamic replication is the only way for market makers to hedge a short-put position. They do this by taking an offsetting position in the underlying asset; the required size changes with the price of the underlying asset.

More precisely, to compensate for an increase in the price sensitivity of a call option, a hedge position in the underlying asset must be made larger as well, in return affecting its price process. If the transaction size in the underlying asset becomes very significant, thus implying market impact, this mechanism generates the potential for positive feedback in price dynamics because the hedge adjustment is to buy (sell) the underlying asset after its price rises (falls), as the transactions could introduce further upward (downward) pressure on prices after an initial upward (downward) shock to asset prices.

The underlying asset price dynamics can be modeled as

$$d\tilde{S}_t = \sigma_t \tilde{S}_t dW_t + \rho_t \lambda\left(\tilde{S}_t\right)\tilde{S}_t d\alpha_t$$

where λ is a continuous function called **market liquidity profile**, used to retrieve a particular shape of the implied volatility smile, while ρ represents the intensity of the liquidity impact. A possible choice is the ratio of change in the price of the underlying to the quantity traded, which is observable given an order book. So $\frac{1}{\rho\lambda_t\left(\tilde{S}_t\right)\tilde{S}_t}$ represents the market depth at time t, (i.e., the order flow required to move prices by one unit).

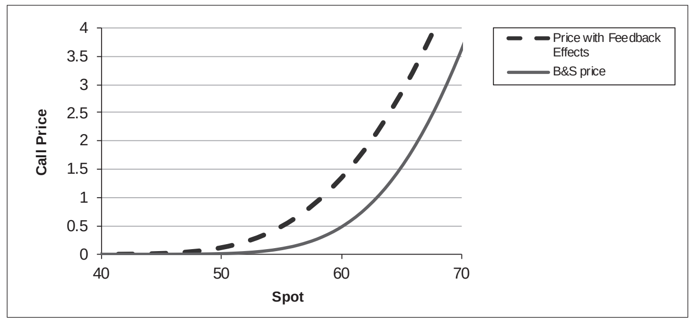
If we now apply the Black-Scholes methodology, under a zero risk-free interest rate (for simplicity of notation), we obtain a modified Black-Scholes PDE:[12]

$$\begin{cases} u_t\left(t,\tilde{S},\gamma\right)+\frac{1}{2}\frac{1}{\left(1+\rho\lambda\left(\tilde{S}\right)\tilde{S}u_{\tilde{S}\tilde{S}}\left(t,\tilde{S},\gamma\right)\right)^2}\sigma^2\tilde{S}u_{\tilde{S}\tilde{S}}\left(t,\tilde{S},\gamma\right)=0 \\ u\left(T,\tilde{S},\gamma\right)=nh\left(\tilde{S}\right) \end{cases}.$$

This modified Black-Scholes equation is a fully nonlinear parabolic PDE, requiring specific numerical implementation ensuring accuracy, flexibility and stability. [13]

Actually, as the large trader sells European calls, she has to buy a large amount of the underlying assets to hedge synthetically, which makes the underlying asset price rise, thus the short delta decreases, implying a short gamma, so the feedback volatility rises. Consequently, the option unit price turns out to be higher than the usual price-taker Black-Scholes price. This can be seen in Figure 5.

Figure 5
European Call Price With Feedback Effects vs. Black-Scholes Price



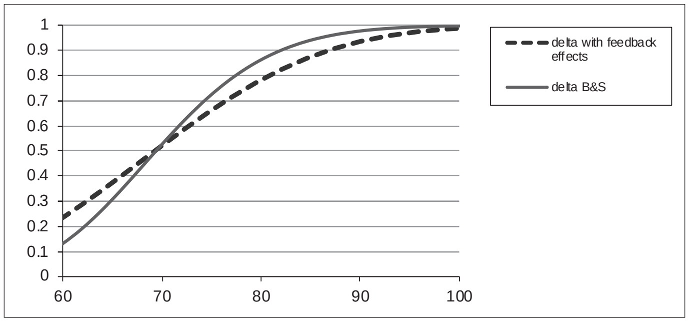
An apparent paradox arises in empirically observed markets in regard to large traders' transactions: Selling a large amount of calls causes the price to rise. In fact, when a large amount of options is used in such trading strategies, the market dynamics may be affected by the trading strategy itself, leading to potentially destabilizing price paths.

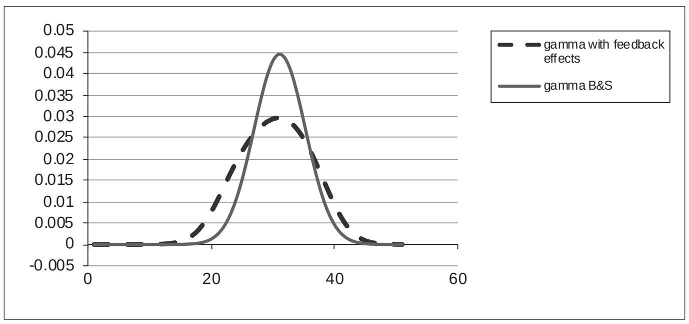
Illiquidity appears as an endogenous trading cost compensating for the sharing of risks measured here by the spot market volatility. By buying with rising prices, the large trader's demand is procyclic. Therefore, the apparent paradox is just a consequence of the positive feedback effect induced by the dynamic hedging of the large trader through its portfolio insurance strategy, designed to protect the capital during a market downturn by replicating option positions. In fact, this positive feedback effect stems from the absence of sufficient natural counterparts to meet the demand for puts and calls, where large dealers can meet the demand by selling puts and calls. In doing so, they become short the option. They can neutralize their net risk exposure by synthetically replicating long option positions, which requires selling as the market falls and buying as it rises. This ensures the hedge position is sufficient to cover the option rising exposure, which introduces transactions large enough to amplify the initial price shock. It generates precisely the kind of vicious feedback loop that destabilizes markets.

Effects Impact on Greeks

The gap caused by the hedging feedback effect (tracking error) is always positive, so the Black-Scholes delta hedging strategy always implies a loss, directly linked to the difference of volatilities, while growing with the gamma (i.e., the large trader hedging activity) and with lower liquidity (higher ρ).

Figure 6
Optimal Delta and Gamma Greeks under market impact vs. Delta and Gamma Greeks under Black-Scholes model





In terms of delta hedging, we distinguish three effects:

- **A positive moneyness effect.** The large trader buys more underlying assets for in-the-money calls (more likely to be exercised).
- **A negative volatility effect.** For in-the-money calls, a higher volatility implies a higher probability to leave out of the money, which reduces the delta.
- **A negative time to maturity effect.** As residual time to maturity decreases, the optimal quantity to hedge is more predictable, which reduces the delta.

CONCLUSION

Market impact risk refers to the degree to which large size transactions can be carried out in a timely fashion with minimal impact on prices. As a result, managing investment and liquidity risks for large players requires introducing an explicit market impact function, and applying to derivatives significantly depends on whether or not there is significant delta hedging activity. In the case of no significant delta hedging activity, the risk appetite has significant influence on the optimal execution strategy. In the case of significant delta hedging activity, the optimal trading involves feedback hedging effects translating into a modified Black-Scholes hedging strategy. ■

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Highlights on SOA Report "Reinvestment Strategies for Life Insurance Products in a Changing Economic Environment"

By Gabriella Piscopo

Life insurance annuities are in force for many years and contain embedded options of very long duration, during which periods of rapid economic change and sustained extreme economic conditions can occur. In March 2017, the Society of Actuaries proposed research investigating possible reinvestment strategies for life insurance companies experiencing periods of such change. The result of that research[1] suggests a rule for the investment/reinvestment strategies in a changing economic environment. We propose a dynamic approach where year by year the reinvestment strategy is defined to maximize the expected result of the following year, taking into account its conditional tail expectation.

The problem with the long duration of life insurance products during periods of extreme financial scenarios has been exacerbated by the increasing presence of guarantees. The sustained low interest rate environment that began in 2009 endangered the sustainability of life insurance products with embedded options because the primary account values of policyholders was performing poorly over the period, while their shadow accounts were remaining positive over a longer part of that time.

To handle this situation, it was necessary to rethink the investment and reinvestment strategies for these products on a more frequent basis. The SOA sought an in-depth analysis based on asset liability management modeling for the original investment strategy, repeated with stochastic scenarios to evaluate new reinvestment strategies and compare the results. To accomplish this, they suggested considering two sets of stochastic scenarios: the most current corporate assumptions and where the mean reversion target of the interest rates should be identical to the starting yield assumption. In the instance of a sustained low interest rate environment, the first set of scenarios could represent the company outlook and the second set could consider the impact of interest rates continuing to remain low far into the future. A side benefit of using two sets of scenarios for this analysis is the comparative value of understanding status quo environment results against the corporate philosophy embedded in the company assumption results.

According to this suggestion, we evaluate, at the beginning of each year, the investment strategy in terms of the optimal portfolio weights, looking at the stochastic evolution of the cash flows during the prior year. We do not evaluate the cash flows during the whole maturity of the contract, to avoid the problem of choosing a single discounted rate. In a contest of stochastic evolution of interest rates, the choice of a constant discounted rate deeply shows its weakness because valuing liability cash flows with any single interest rate loses the interest rate sensitivity of the cash flows and the tail distribution of the results. Instead, this research explicitly evaluates this sensitivity and tail distribution to inform the reinvestment strategy. In particular, we design a dynamic strategy where, at the beginning of each year, we evaluate how to modify the investment strategy on the basis of the results realized during the prior year. The aim of this model is to select the investment/reinvestment strategy dynamically, with a continuous fit to a given set of criteria, like the optimization of an opportune objective function. The function of the maximization problem could be defined according to the goals of the strategic asset allocation. In our model, we decided to deal with the maximization of the expected value of the distributable earnings, taking into account also the dispersion of the simulated distribution. Another way to take into account the dispersion could be the maximization of the expected value minus the expected loss in the CTE. From a practical point of view, we have evaluated the statutory reserve in terms of working reserve as required by the National Association of Insurance Commissioners' Actuarial Guideline 43, the projected cash flows achieved on the asset side, and the difference in terms of accumulated deficiency, its mean and dispersion under different strategies.

THE MODEL

Let $\pi_t = \left(\pi_t^1,\ \pi_t^2, \ldots, \pi_t^j\right)$ be the weights of the portfolio composed by j asset classes with statutory bounds $\pi_t^1 \le b^i$. Let W_0 be the premium paid by the policyholder and invested in the portfolio after the initial expenses. Let A_t be the value of the assets at the end of the year t, with $A_0 = W_0$, and R_t be the statutory reserve at the end of the year t influenced by $g(t)$, the amount guaranteed at t. Starting from $t = 0$, we simulate B path of the evolution of the assets and the contractual obligations, considering the interaction of financial, demographic and behavioral factors. For each path at the end of each year, we calculate the statutory reserve able to achieve the future contractual obligations according to the statutory prescriptions and evaluate the investment portfolio. Based on the investment returns achieved on the asset, the accumulated deficiency is calculated.

We define the optimization problem as follows:

$$\begin{cases} max_{\pi_t} \left(E\left[A_{t^+} - R_{t^+}\right] | SD\left[A_{t^+} - R_{t^+}\right] \right) \ for \ each \ t \\ \pi_t^i \le b_i \\ \pi_t^1 + \pi_t^2 + \ldots + \pi_t^j = 1 \end{cases}$$

where the decision of a target allocation is done at the inception of each year t based on the simulated value of assets and reserve at the end of the same period t^+. In this formulation, the model produces different results depending on how the standard deviation is constrained—for example, fixing a given level of risk the insurer is willing to assume. The problem can be standardized considering the following formula:

$$\begin{cases} max_{\pi_t} \ E\left[A_{t^+} - R_{t^+}\right] | SD\left[A_{t^+} - R_{t^+}\right] \ for \ each \ t \\ \pi_t^i \le b_i \\ \pi_t^1 + \pi_t^2 + \ldots + \pi_t^j = 1. \end{cases}$$

An alternative optimization formula follows:

$$\begin{cases} max_{\pi_t} \left(EA_{t^+} - R_{t^+} - CTE(70)_{t^+} \right) \forall t \\ \pi_t^i \le b_i \\ \pi_t^1 + \pi_t^2 + \ldots + \pi_t^j = 1 \end{cases}$$

where $CTE_{(70)}$ is the conditional tail expectation of the simulated distribution of the accumulated deficiency.

The model is flexible and can be modified to meet specific needs. The central idea is that the strategy is dynamic based on the results obtained during the year for whatever formula you decide to maximize.

Following the ALM models, we project asset and liability cash flows based on financial and demographic assumption at the valuation date. The model takes into account the interaction of the following variables:

- **Financial variables.** Interest rate and return of other investments
- **Demographic variables.** Lapse and death
- **Investment choices by management**

NUMERICAL SIMULATIONS

The financial variables are simulated through the Financial Scenario Generator Version 7.1.201805 developed by the American Academy of Actuaries. The generator produces scenarios for the future paths of interest rates for U.S. treasury securities and several kinds of investment portfolios, including both equity and fixed-income portfolios. The U.S. Treasury yields are generated using the C-3 Phase I interest rate model designed by the American Academy of Actuaries. The model simulates Treasury bond yields according to a stochastic variance process with mean reversion under real-world probability measures. The equity return scenarios are generated from a monthly stochastic local volatility model wherein the natural logarithm of the annualized volatility follows a strong mean-reverting stochastic process and the annualized drift is a deterministic quadratic function of volatility. This model is able to capture many of the dynamics observed in the equity market data: the negative skewness and positive kurtosis ("fat tails") over short holding periods, the time-varying volatility and volatility clustering, and the increased volatility in bear markets.

The model is implemented through two financial sets of stochastic scenarios. In the first, the mean reversion target of the interest rates is derived by the yield curve of December 2016, while in the second set, the reference point for the interest rate curve is December 2000 before the financial crisis. In the instance of a sustained low interest rate environment, the first set of scenarios could represent the company's prudent outlook while the second set could consider the impact of interest rates not remaining low far into the future. Table 1 shows the parameters of the Financial Scenario Generator for the two sets of scenarios.

Table 1
Scenario Parameters

Starting date	December 2016	December 2000
Yield curve on starting date		
3 months	0.51%	5.89%
6 months	0.62%	5.70%
1 year	0.85%	5.32%
2 years	1.20%	5.11%
3 years	1.47%	5.06%
5 years	1.93%	4.99%
7 years	2.25%	5.16%
10 years	2.45%	5.12%
20 years	2.79%	5.59%
30 years	3.06%	5.46%
Mean reversion to		
	3.75%	6.50%

Table 2
Product Features

Policyholder	U.S. male, 50 years old	
Projection period	30 years? 40 years?	
Premium	10,000	
Percentage of investment in fixed account	20%	
Fund chosen for the variable account	Balance fund	
Separate account fund expense	0.01	
Fixed account credited rate formula	Min (New Money Rate – Base Expense Margin + Inversion Adjustment; 0%)	
Base expense margin	0.024	
Inversion adjustment	0.25% when the 10-year Treasury is less than the 2-year Treasury and the 10-year Treasury is less than 5.00%; 0.00% otherwise	
Guaranteed rate	0.01	
Administrative fee (on VA)	0.0015	
Mortality and expense (on VA)	0.0125	
Fixed account credited rate	Set to the maximum of the rate determined by the fixed account credited rate formula and the guaranteed interest rate; the credited rate is reset each policy anniversary	
GMDB	0.04	
Surrender charges	1 year	7%
	2 years	6%
	3 years	5%
	4 years	4%
	5 years	3%
	6 years	2%
	7 years	1%
	8 years+	0
Annuitization	No annuitization assumed	
Partial withdrawal	No partial withdrawal assumed	

LAPSE RATE	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years	10 years
	0.007	0.0142	0.0214	0.0286	0.0358	0.043	0.05	0.22	0.15	0.05

Regarding the demographic variables, a deterministic mortality model is assumed justified by the fact that mortality risk can be diversified in a large portfolio; a prudent approach would be to use the appropriate projected mortality tables. Instead, the risk of lapse is not fully diversifiable. Both academics and practitioners try to explain and model the policyholder behavior and the factors driving the choice to lapse or not. From a financial point of view, during the period of decreasing markets, the value of the underlying fund will decrease and consequently the economic value of the guarantee will rise, with a potential incentive to not exercise the surrender option. In reality, insurance companies usually do not assume this behavior for all policyholders because some of them may not be rational or aware agents or well versed with the economic value of the guarantee. There could also be exogenous factors driving policyholder actions, such as the need for liquidity. A survey conducted by the Society of Actuaries in 2011 shows that "'company experience studies' continue to be the most popular source of lapse assumptions."[2] Based on this

Table 3
Initial Investment Strategies

	STR I	STR II	STR III	STR IV
Cash	5%	5%	5%	5%
U.S. Treasury (2 year)	30%	30%	30%	30%
U.S. Treasury (10 year)	60%	50%	40%	30%
INT.R EQUITY	5%	15%	25%	35%

consideration, we consider the evolution of lapse rate in line with the SOA study.

Starting from these assumptions, we have implemented our model considering the following variable annuity with guaranteed minimum death benefit option as seen in Table 2 (Pg. 14). The projection period is 10 years.

RESULTS

At t = 0, we evaluate different strategies in terms of proportion of investment in bond and equity and chose to follow a more or less aggressive strategy. Once the strategy has been chosen, the assets and liabilities are simulated and the values of distributable earnings at the end of the first year are collected for each path. The simulations are repeated for both sets of financial scenario. At the end of the year, a reinvestment strategy has to be defined. We consider that when positive distributable earnings occurs, it is not actually distributed but invested in additional assets according to the following reinvestment strategies.

A. **Base strategy.** Assets are only bought/sold when there are net positive/negative distributable earnings at the end of the year, maintaining the same proportion of assets as in the initial strategy.

B. **Base strategy + shift to aggressive equity fund.** When positive distributable earnings occur, assets are bought and the equity investment profile becomes aggressive.

C. **Base strategy + shift to balanced equity.** When negative distributable earnings occur, assets are sold and the equity investment profile becomes balanced.

D. **Combination of strategies B and C.** When distributable earnings are positive, assets are bought and the profile of investment in equity becomes aggressive, while when distributable earnings are negative, assets are sold and the equity investment profile becomes balanced.

E. **Base strategy + interest rate swap.** The company hedges the U.S. 10-year Treasury assets, paying the U.S. 10-year swap rate (historical value at December 2016) and receives the variable U.S. 10-year interest rate.

The costs of rebalancing are ignored. In practice, other more sophisticated investment strategies could be implemented but we have limited this example to theses five strategies for illustrative purposes.

We generate 10,000 paths of the asset liability cash flows for both scenarios considered. At t = 0, the insurer chooses the first asset allocation and calculates for each of the selected scenarios the distributable earnings at the end of the first year. In the second step, at the end of the first year, given the results obtained for each path, the insurer uses the results to simulate the distributable earnings at the end of the following year and chooses the reinvestment strategy (A through E) that produces the best results. The policyholder can choose the risk/return investment profile of the separate account; we assume the policyholder opts for a diversified, balanced allocation portfolio. We simulate the liability cash flows of both fixed and variable accounts, taking into account the features of the product described in Table 2 and the guarantees, the investment choice of the policyholder, the occurrence of mortality and the lapse.

The aim of this model is to select the investment/reinvestment strategy dynamically, with a continuous fit to a given set of criteria, like the optimization of an opportune objective function.

On the asset side, we assume that at the inception of the contract, four explanatory investment strategies vary the proportion of investment between bonds and equity according to the parameters shown in Table 3. When compared to U.S. Treasury bonds with 2- and 10-year maturities, the equity asset class is the riskiest. At t = 0, the insurer chooses the first allocation between strategies I–IV.

Table 4
Simulated results at the end of the first year according to the investment strategies I-IV

	Scenario 2000				Scenario 2016			
	STR I	STR II	STR III	STR IV	STR I	STR II	STR III	STR IV
Mean	570.6482	613.2906	655.933	698.5754	323.294	392.6313	461.9686	531.3059
SD	812.9938	854.2247	932.6598	1039.915	784.647	827.3418	908.1488	1018.032
Mean/SD	0.70191	0.71795	0.703293	0.671762	0.412025	0.47457	0.508693	0.521895

Table 5
Simulated results at the end of the second year according to the reinvestment strategies A-E

	Scenario 2000					Scenario 2016				
	A	B	C	D	E	A	B	C	D	E
Mean/SD	0.678204	0.68023	0.67450	0.67657	0.78247	0.3691	0.37422	0.3608	0.36594	0.388479
E-|CTE|	446.9291	454.726	429.466	439.044	877.632	–752.541	–741.222	–802.006	–789.912	–683.806

The expected value and deviations of the simulated distributable earnings for each strategy are summarized in Table 4.

Under the hypothesis of scenario 2016, according to which the interest rates will remain low in the future, starting strategy IV has the greatest mean/SD, while under the hypothesis of scenario 2000, the second strategy dominates the others. Considering that the second strategy is more sensitive to the changes in interest rates that represent the focus of this research and also is more realistic given the real constraints to the asset allocation, we decided to implement the second strategy at the inception of the contract. Following this initial plan, we followed the path evolutions of assets and liabilities under both scenarios and evaluated the distributable earnings at the end of the first year. For each path of each scenario, starting with the results obtained from the first year, reinvestment strategies A–E were implemented to evaluate the distributable earnings at the end of the second year. Results are shown in Table 5.

Under both the scenarios, strategy E produces the best results in terms of expected mean of distributable earning per unit of risk measured by the standard deviation and in terms of expected mean of distributable earning minus the expected loss in the tail according to the requirements of AG43 (CTE).

The results given in this report are for explicative purposes only. More realistic strategies might be considered and different constraints introduced; other investment strategies may be optimal under different scenarios.

FINAL REMARKS

Taking into account the statutory requirements for products with variable accounts and guarantees, this paper has proposed a dynamic strategy for maximizing distributable earnings year by year. The risk measure introduced is inspired by the statutory requirements. We have analyzed the mean of distributable earnings and the CTE for two complementary metrics using the maximization formula; however, the model appears flexible, and other risk measures can easily be introduced. The stochastic simulation of the statutory reserve and investment portfolio permits us to consider the complex interaction of assets and liabilities, taking into account the relationship between financial, demographic and behavioral factors. ■

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ENDNOTES

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Sustainable Portfolios Under Climate Change: A Framework for Managing Investment-related Climate Change Risks

By Mingyu Fang, Ken Seng Tan and Tony Wirjanto

Global climate change is posing a complex set of emerging risks to both insurance companies and pension funds. While the impact of climate change on insured risks has gained some attention among actuarial organizations, relatively little interest is directed toward the asset side of the balance sheet. This article summarizes the key findings of a recent research study sponsored by the Society of Actuaries on investment-related climate change risk, with a focus on risk quantification, management and construction of sustainable portfolios under the changing climate.[1] For simplicity, the scope of discussion is limited to equity investments, but the conclusions and methods presented here can be extended to fixed income, alternative investments and other derivatives.

HOW DOES CLIMATE CHANGE AFFECT INVESTMENT RETURNS?

Climate change impacts an investment portfolio through two channels: first, it directly elevates weather-related physical risk to real properties and infrastructure assets, which extends to increased market risk in equity holdings with material business exposures in climate-sensitive regions. Second, it indirectly triggers stricter environmental regulations and higher emission costs in a global effort for emission control, which induces downturns in carbon-intensive industries in which a portfolio may have material positions. In the latter case, climate change is effectively transformed into a political risk affecting particular asset classes and is often referred to as the investment carbon risk.

PORTFOLIO DECARBONIZATION: A VISION FOR THE FUTURE

Due to the gradual yet irreversible nature of global warming, managing the climate change risk in investments is a long-term strategy that requires prudent considerations into the next 30 or 50 years. This poses a significant challenge to risk quantification using standard actuarial approaches. Instead, a combination of visions, theories and cross-disciplinary models are needed. The result of portfolio climate change risk management is an optimal asset allocation where we move away from sectors expected to underperform in the climate change scheme (e.g., the carbon-intensive sectors), while putting more stakes in the ones expected to outperform. This leads to a process called portfolio **decarbonization**. While the term is self-explanatory, it is based on two major premises that can be verified empirically:

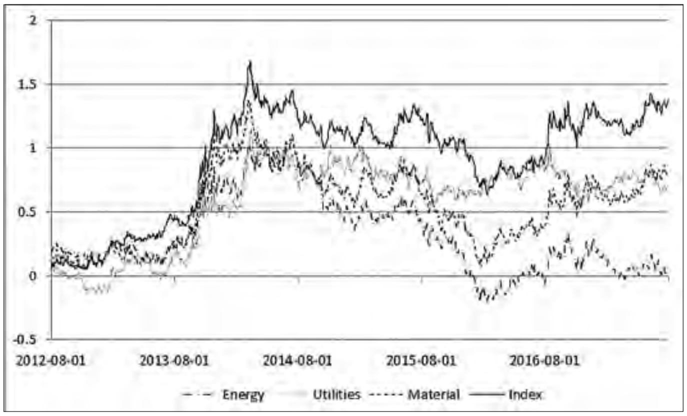
1. Carbon risk has not yet been priced by the stock market in carbon-intensive industries, which shall experience downturns when the risk pricing takes place.
2. The carbon-intensive industries do not provide strong enough returns to be considered indispensable portfolio return enhancers.

The first premise can be verified by an inter-temporal analysis of stock returns for a sample of 36 publicly traded large emitters and related sector indices from Europe and North America around the ratification of major climate protocols (i.e., the implementation of the European Union Emissions Trading Scheme and the ratification of the Paris Agreement). A linear factor model is used to filter out the systematic portion of returns. Event study techniques and statistical testing are conducted to detect structural downward shifts in stock returns around the aforementioned regulatory events, which imply market pricing of carbon risk. Under this approach, only nine out of the 36 samples displayed recognizable carbon pricing.

> Climate change… indirectly triggers stricter environmental regulations…

The second premise can be verified by comparing the historical performance of the emission-heavy sectors (e.g., energy, utilities and material) against those of the other sectors. Risk-adjusted returns measured using Sharpe and Treynor ratios[2] are calculated on both a rolling window and an average basis. The carbon-intensive sectors consistently ranked at the bottom of the list across the metrics and underperformed the market indices for both Europe and North America. As an illustration, Figure 1 (Pg. 19) shows the five-year rolling Sharpe ratio for U.S. sector and benchmark indices. Notice the lines representing the three emission-heavy sectors' returns near the bottom of the chart, which are well below the red line representing the S&P 500 index.

Figure 1
Five-Year Rolling Sharpe Ratio for U.S. Carbon-intensive Sector and Benchmark Indices



RISK MEASUREMENT AND QUANTIFICATION

We focus on three risks for which quantitative measurements are developed.

Carbon Risk

Carbon risk is a general term referring to the risk in an investment or portfolio by having significant stakes in emission-heavy companies. Carbon risk of a stock is best measured by the carbon intensity of the issuing company, which is basically the company's average normalized annual emission amount where the normalization factor may be the annual sales or profit Figure (must be positive). The latter is preferred since the net profit portion of the earnings should directly contribute to stock value. The required financial information is readily available, while the emission figures for most large public companies are available on the CDP (formerly the Carbon Disclosure Project)[3] database. The carbon risk of a portfolio is measured by a weighted average of the carbon intensities of the constituents.

Stranded Asset Risk

Stranded assets refer to a broad class of assets that may not deliver the expected returns due to regulatory, technological and other socio-economic reasons related to the climate change risk. For instance, many fossil fuel (e.g., coal, oil or gas) reserves cannot be deployed further due to regulatory emission caps or heavy taxation. Hence, capital invested today in future oil, gas and coal production is at risk of being stranded, leading to significantly reduced returns from those originally expected. This translates to asset devaluation and stock price depreciation, which we refer to as stranded asset risk. Quantification of SAR requires modeling at the individual stock level and therefore requires much effort. In general, SAR is driven by three factors: the probability that the asset becomes stranded, the percentage loss in asset value given the stranding and the recoverable amount. Our suggested method adopts a parametric approach to model a threshold exploitation level beyond which the fuel reserve becomes stranded. For brevity, the details are not presented here. Interested readers can refer to our report for more details.

Climate Change Risk

Unlike carbon and stranded asset risks, climate change risk may be quantified at the sector level or at the individual stock level. Quantification of climate change risk requires a scenario-based approach using integrated assessment models and subjective inputs. IAM is a set of scientific models used in environmental sciences and environmental modeling, integrating knowledge and methodologies across multiple disciplines. The approach requires several steps:

1. Select climate change risk factors and IAM.
2. Assign factor sensitivities for each stock or sector considered.
3. Select a projection horizon over which the portfolio is managed.
4. Generate factor value scenarios using the selected IAM for the projection horizon.
5. For each stock/sector under each scenario:
    a. Convert the factor values, at each projection point, to climate risk exposure given by the sum product of the sensitivities and the corresponding factor values.
    b. Calculate the change in CRE between the current point and a target end date for the portfolio.
    c. Convert the CRE difference to stock return impacts using proper grading methods.
6. Average the estimated return impacts across scenarios.

There are several technical considerations at play here. For example, the factors of interest may be represented by different output variables available from the selected IAM, whose simulated values must be properly mapped to relative scales to allow proper calculations (i.e., we cannot add Celsius degrees to dollar prices of emission abatements). Linear transformations can be used as the simplest case, while more complex factor paths must be captured using nonlinear models. We do not discuss these details here. Tables 1, 2 and 3, and Figure 2 are excerpts from an illustrative example used in our report based on the World Induced Technical Change Hybrid, or WITCH, model,[4] one of the most commonly used IAMs. Factor values are obtained using linear grading of selected proxy output variables under each scenario, while the conversion of CRE differences to return impacts are done using piecewise-linear mapping. Stocks in the same sector are assumed to have the same risk exposures.

Table 1
Sample Climate Change Risk Factors

Company	Description	Proxy 1	Proxy 2
Technology (T)	The rate of progress and investment in the development of technology to support the low-carbon economy	Investment in advanced biofuel (USD)	Investment in energy efficiency (USD)
Political (P)	The coordinated developments in climate policy to reduce carbon emissions	Greenhouse gas abatement (ton CO_2/yr)	None
Climate Impact (C)	Tangible impacts from shifts in extreme weather incidence and severity, as well as resources that are at risk of becoming scarcer or, in rarer cases, more abundant	Radiative forcing (RF) (W/m^2)	Global mean temperature change (deg Cel)

Table 2
Sample Sector Level Sensitivities to Factors in Table 1

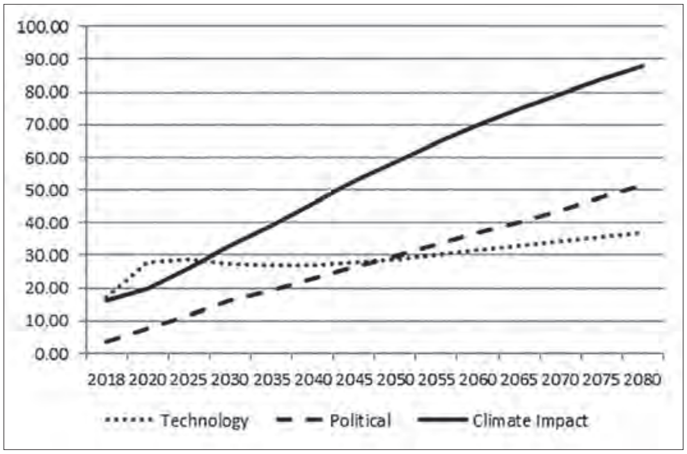
Industry Sector	T	C	P
Consumer discretionary	0	0	–0.25
Consumer staples	0	–0.25	0
Energy	–0.5	–0.5	–1
Financials	0	–0.25	0
Health care	0.25	–0.25	0
Industrial	0	–0.75	–0.5
Information technology	0.25	0	0
Materials	0.25	–0.25	–0.75
Real estate	0	–1	0
Telecommunications	0	–0.25	0
Utilities	–0.25	–0.5	–0.75

Table 3
Sample Climate Change Risk Quantification

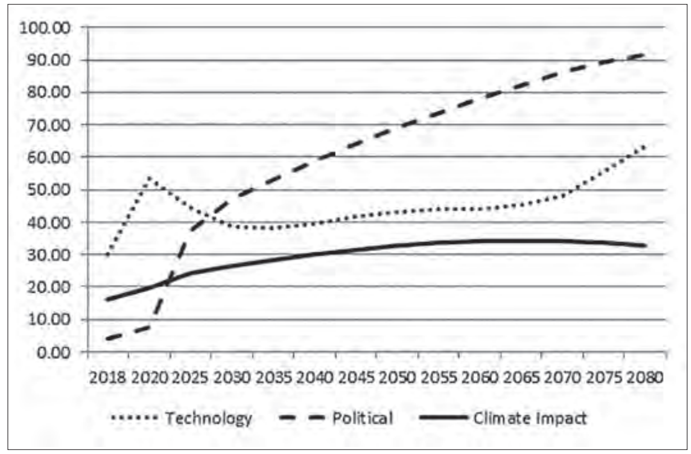
Industry Sector	ΔCRE	Δr (annual)
Consumer discretionary	8.14	–0.0814%
Consumer staples	7.92	–0.0792%
Energy	115.53	–2.7553%
Financials	18.80	–0.1880%
Health care	7.92	0.2790%
Industrial	84.48	–1.0448%
Information technology	–10.88	0.6088%
Materials	50.06	–0.9006%
Real estate	75.18	–1.5518%
Telecommunications	18.80	–0.1880%
Utilities	90.61	–1.7061%

Figure 2
Sample Factor Value Paths Under WITCH Model Scenarios

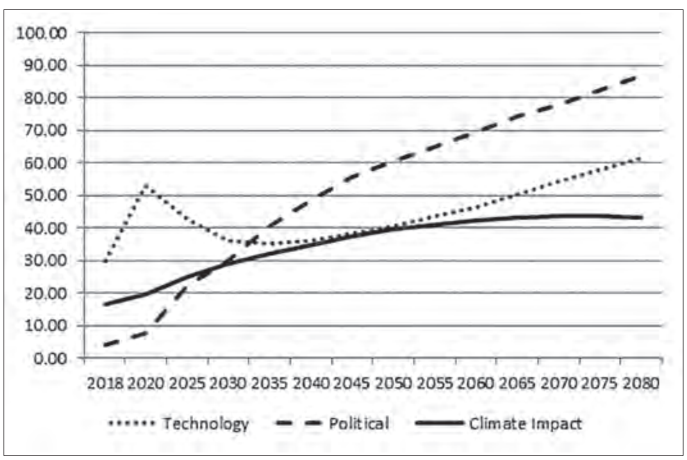
1) Fragmentation (weak pledge)



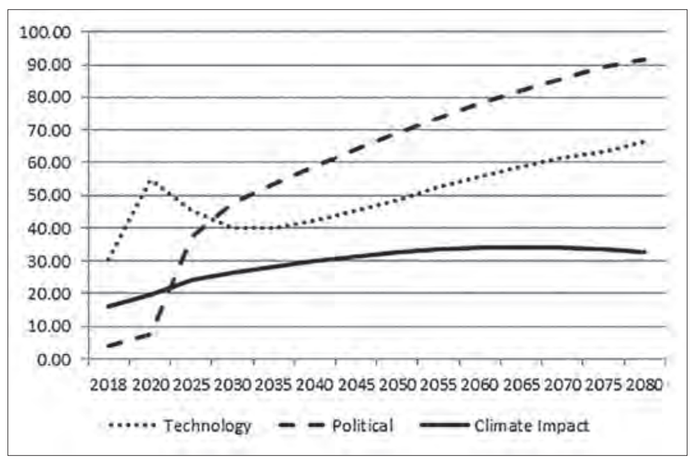
3) Transformation (450 ppm, with permit)



2) Coordination (500 ppm)



4) Transformation (450 ppm, no permit)



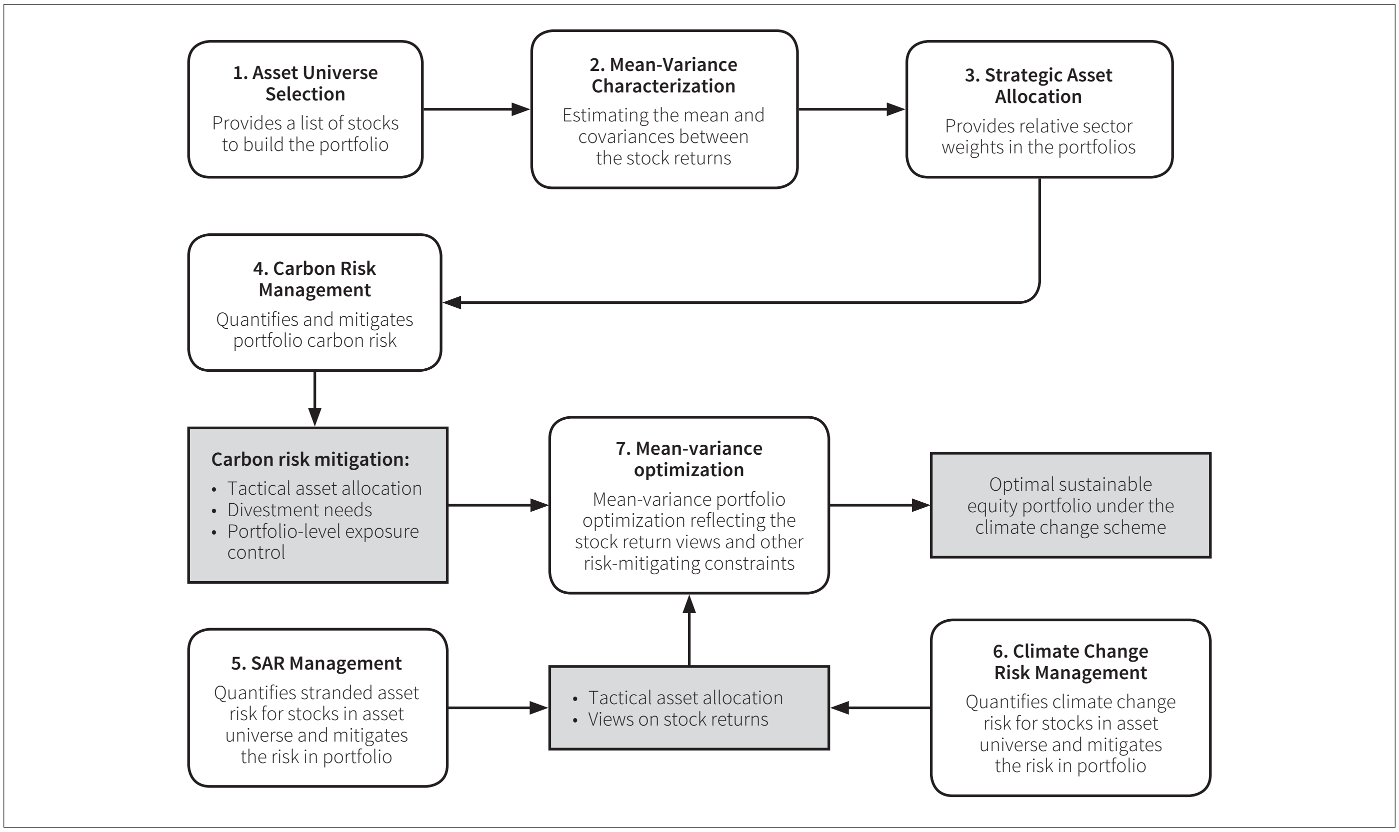
Notice that in the result summary in Table 3, the health care and IT industries are actually expected to benefit from climate change. This is an advantage of the scenario-based approach in which impacts from the risk are assessed fairly by considering both the upside and downside.

THE FINAL CHAPTER: BUILDING A SUSTAINABLE PORTFOLIO

The complete framework for constructing a sustainable portfolio is summarized in Figure 3 (Pg. 22).

The framework assumes the traditional mean-variance approach in a portfolio optimization, where the minimum variance portfolio is desired given a target portfolio return. Modules 1 to 3 are existing components of the algorithm, where a universe of investible stocks is selected with strategic allocations reflecting regulatory constraints and other internal policies or preferences. The mean and covariance matrices of the stocks in the universe are estimated. Without considering sustainability, we have all the inputs to run the optimization after Module 3. This would normally be the end of the story.

Figure 3
Framework for a Sustainable Portfolio

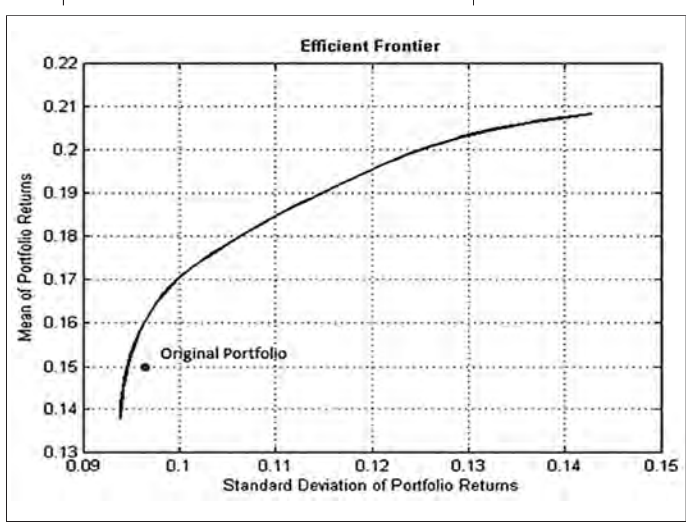


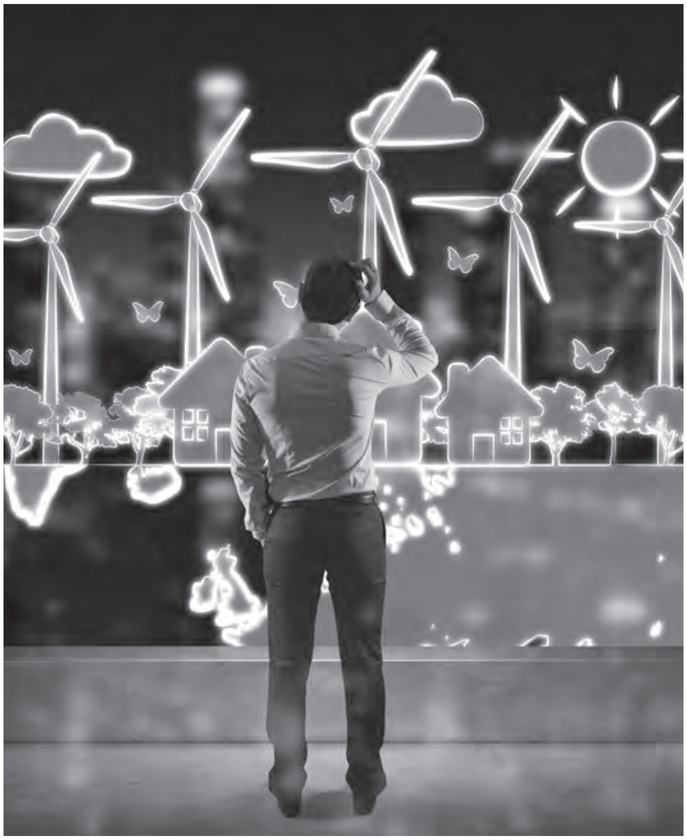
Sustainability concerns under climate change are addressed through modules 4 to 6, where relevant risks are quantified and managed. The key outputs from these modules are:

1. Tactical asset allocations, which adjust the original strategic asset allocations to reduce the various risk exposures at the portfolio level
2. Proper divestments from carbon-intensive industries
3. Imposition of a portfolio-level cap on carbon risk exposure
4. A view matrix for returns of stocks in the asset universe, reflecting their climate change risk exposures estimated using the approach introduced previously

Items 1 to 3 above result in updated constraint equations to the optimization algorithm, while item 4 leads to a new mean return matrix (to avoid complexity, we assume the return covariance structure is not materially impacted by climate change). A mean-variance optimization is finally performed to obtain the weights of the optimal sustainable portfolio. Figure 4 is an excerpt from the illustrative examples in our report showing that the original minimum-variance portfolio (the dot, assuming 15 percent target portfolio return) falls below the efficient frontier when climate change risks are considered.

Figure 4
Sample Efficient Frontier Under the Proposed Framework





CONCLUSION

Optimal sustainable portfolios under the global climate change scheme can be built through a proper quantification and management of the associated risks, led by the investment carbon risk, the stranded asset risk and climate change risk. Overall, for equity portfolios, global climate change is expected to modify the risk-return profiles of many industry sectors in the long term (e.g., the green energy sector vs. the oil producers), rendering existing portfolios "suboptimal." The framework presented in this article is fully flexible and can be added to existing platforms in the insurance and pension industries to enhance various investment and risk management practices. We hope that it invites more attention and inspires more studies in the area of climate change risk as well as sustainable investing, which shall benefit the actuarial profession and other stakeholders as the world is gradually warming. ■

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ENDNOTES

1 Tan, Ken Seng, Tony S. Wirjanto and Mingyu Fang. 2018. "Managing Climate and Carbon Risk in Investment Portfolios." Society of Actuaries. *www.soa.org/Files/resources/research.../managing-climate-carbon-risk.pdf.*

2 In simple words, Sharpe ratio is the ratio of the asset's expected excess return to its return volatility, while Treynor ratio is the ratio of the asset's expected excess return to its beta (i.e., the systematic risk).

3 The CDP voluntary emission reporting database can be accessed at *www.cdp.net/en/climate*.

4 Simulator is publicly accessible at *www.witchmodel.org/simulator/*, where detailed descriptions of the four WITCH model scenarios referred to in Figure 2 are available.

Taking Stock: Trump, Trade and Financial Volatility

By Nino Boezio

Regardless of what one may think of President Donald Trump, most would likely agree he is not a lazy individual. He is also not someone to back down on a course of action; rather, he doubles down when the going gets tough.

During political campaigns, candidates propose long lists of agenda items as part of their platforms. If elected, they may abort a number of these items, not because of political dishonesty, but because the policies may pose severe damage to the economy and are faced with strong (political and international) opposition. The policies now appear too impractical to implement. However, President Trump has been willing to pursue a variety of his pre-election agenda items despite backlash and possible economic risks.

Trade has been one of those controversial issues. Disruptions in the status quo may be very damaging to the United States, its trade partners and the global economy. However, from my Canadian perspective, I believe President Trump has a valid premise for his arguments on trade. His tough stance produces financial market volatility, but such pain may be worth it as he tries to fix some fundamental flaws in trade between countries. Otherwise, a country such as the United States could find itself in too big a financial hole and no longer able to borrow expeditiously to cover trade gaps.

Growing up in the 1970s, I recall how the Canadian economy was flooded with cheap Japanese cars. My father, an auto mechanic, considered such cars (at the time) to be of poor quality and advised anyone he could not to buy such vehicles. But the low price of such cars was just too compelling for many consumers. I also recall a relative, a part-time farmer, who bought a Soviet-made tractor because the price was too good to pass up. He later had trouble servicing it and getting parts. Foreign products can be quite inexpensive based on the lower labor and production costs in those countries. Government subsidies may play a part. In the case of products that came from the former Soviet Union, production costs did not necessarily have to tie into the sale price.

Over the past several decades, Canadians have seen many strong and healthy industries fall apart due to the import of various products. Many imports had artificially low prices due to foreign government financial assistance and from lower operating costs due to less stringent regulations in that economy. As an example, recall that some products from China posed health risks because China did not have sufficient standards in place to address safety, as would be found in the United States and Canada. In various aspects, China is still an emerging economy so it still needs to develop some of its national qualitative standards; we need to be patient with it in that regard. In the meantime, less regulation and fewer controls means lower operating costs.

Our Canadian industries suffered from the influx of very cheap imports, and our own government would often do very little about it. It may have been perceived to be too big an undertaking to fight back against "unfair" trade; the local voices of dissension were perhaps not loud enough; it smacked of protectionism to do something; we may have had tremendous faith in our own people to competitively fight back; and our local politicians would still get elected even if the issues were ignored (hence, no dire consequences). But many Canadians lost good jobs because other Canadians wanted to get a cheap deal (I admit, I was also lured into buying a very cheap foreign product). The U.S. environment and consumer psychology was similar.

Trade agreements had not fully removed the artificial trade barriers a country has established that work to the detriment of another country (hence trade imbalances can result).

According to Investopedia, "Free trade is a policy to eliminate discrimination against imports and exports. Buyers and sellers from different economies may voluntarily trade without a government applying tariffs, quotas, subsidies or prohibitions on goods and services. Free trade is the opposite of trade protectionism or economic isolationism."[1] However, free trade in practice has often been a combination of free trade and protectionism (a sort of hybrid), yet it has still been called free trade (many would not be against free trade in principle, but it has become a misleading label in our economic jargon). Trade agreements had not fully removed the artificial trade barriers a country has established that work to the detriment of another country (hence trade imbalances can result). Therefore, a new term has been introduced called fair trade. One would think that free trade and fair trade would be consistent, but they are not interchangeable given the practices of many countries today. President Trump has emphasized this difference in understanding (given that free trade is not completely applied), since his contention is that the United States has been put unfairly on the losing end of many business transactions far too often.

To fix decades of free trade that had not been fair trade would require strong political resolve—and produce dislocation in many industries and sectors. This, of course, translates into volatility in financial markets, as previous correlations and economic relationships are forced to change. The imposition of tariffs is unpleasant and the consumer ultimately has to pay for them, but it should be a temporary measure until other trade impediments are resolved. Various countries have not played fair, imposing duties and other charges on products that entered their economy (and have done so for decades). Foreign companies also may attempt to copy U.S. products while being protected locally from U.S. competition.

The United States, with its sizable economy, cannot continue to stay strong with such large trade deficits (some other developed economies face similar issues but likely on a smaller scale). The sooner this problem is addressed, the less painful the repairs will be. Fortunately, these adjustments are being made when the U.S. economy is robust. How successful the reforms will be is still hard to see, but I would argue that at least there is a movement in the right direction.

THE U.S. AS A PAYER OF LAST RESORT

Being from Canada, I do not have a political axe to grind in favor of one U.S. political party or another. However, it seems to me that the United States usually gets stuck with having to pay for much of everything. Carrying extra financial responsibilities (for any country) results in a combination of higher taxes (for both corporations and individuals), higher debt and higher interest rates. Extra costs will invariably make any country less economically competitive.

The U.S. is a major funder of the United Nations and many of its agencies. It supports multiple nations with grants and subsidies. Yet many of these nations, openly and without impunity, turn around and criticize the United States and its allies for a wide array of policies (and may even support activist and military groups that could put American citizens and soldiers in harm's way). There are often little to no repercussions from American politicians for the detrimental actions of these adversarial countries. Rather the money flow continues. There seems to be this strange sort of thinking in North America, that if we give money to people who hate us, they may like and respect us someday, but if we cut them off, they will just hate us more. (I would not give money to my enemies; they can use it against me and they may never change. I would rather engage enemies through diplomatic means.)

The United States is a major polluter, but I often feel it is being disproportionately singled out and is being expected to pay too much, unlike the case for all other countries who also create pollution. It sometimes seems that we give developing countries a free pass, even though they have a major part to play in contaminating our planet. I recall at one conference, pollution or climate change was described as a global problem, but in terms of the solution, the ultimate target became the developed economies (particularly the U.S.) and the domestic companies. The countries and companies were expected to cut back, thus saddling each economy with more requirements and regulation. A uniform solution was not applied to all countries.

And what about military defense? This is also a very large expenditure. If a country is not paying its fair share (such as for NATO), that country can divert its financial resources elsewhere, potentially benefitting the country as a whole. For decades, Canada has neglected its military to the point where it is not able to take care of many of its security needs and commitments and has been largely relying on its close neighbor, the United States, to respond to any major military conflict. I do occasionally feel sorry for how the U.S. is often stuck with all sorts of military burdens (granted, the United States sometimes has made some ill-advised and costly decisions, such as its past actions in Iraq). The globe has been experiencing peace in large part because of U.S. military commitments abroad. I always respect how many average Americans salute their armed forces in public places such as airports because military service is a sacrifice that not many people are willing to make, just as many countries chose not to sacrifice their resources to support the military.

KICKING THE CAN DOWN THE ROAD

The Society of Actuaries, jointly with the Canadian Institute of Actuaries, sponsored a recent study on Canadian health care.[2] Among other things, the news release for the report stated: "Using the current Canada Health Transfer (CHT), health care expenditures will equal 97 percent of total revenues available to provinces and territories at the end of 25 years. . . ."[3] A very alarming result, that also, by implication, indicates Canadian provinces will not—after paying for health care—be able to afford much of anything else.

How did Canadian provinces respond to the SOA/CIA research project? Was the study widely read? Even if one had not seen the research, the average Canadian citizen likely realizes that with an aging population, health care costs are going to increase, probably dramatically.

But in the June 2018 election for the Canadian province of Ontario, the incumbent Liberal party promised "expanded" health coverage and more health benefits. Many observers conceded it was an effort to win votes, even if the province could

not afford to make more health care commitments (Ontario today has a debt about twice that of the state of California and at least 4.5 times California's debt on a per capita basis[4]). But unless an issue becomes front and center in the public's mind, it will not get enough attention, and politicians are normally not going to bring it up. At a pension conference, I recall speaking to a man in his 70s about the exorbitant costs of Canadian health care that will come 20 years from now, and he kept saying, "I don't care, I don't care. . . . I should be dead by then." Whether it is heath care, pollution, national security or something from a whole host of issues, we may not be able to solve these matters immediately and in an efficient way. But we should not consign ourselves to an attitude of not caring if it does not affect us personally and in our future wellbeing.

Unfortunately, some have this short-term oblivious attitude with trade. No one wants to worry about trade imbalances until their effects stare us in the face. In the meantime, kick the can down the road. Let another generation worry about it. We have dodged bullets before, so we can do it again. We will find a solution around the problem somehow, "down the road." But I hate to rely on being lucky or on the prospect of human ingenuity—it is like planning for retirement by buying a lottery ticket.

UNFAIR TRADE COSTS MONEY

Unfair trade can bring an economy down. Any country would like to be on the winning side of any transaction. Perhaps a country is just initially motivated to build up it foreign currency reserves, and the United States dollar is an important and valuable reserve currency. But if a trade imbalance becomes too large and this trend is protracted for too long, both sides will suffer. I sometimes wish Canadian politicians took a greater stance against unfair trade the way President Trump is doing. We can ignore the matter of unfair trade and let financial markets continue to appreciate in value—but, under the surface, our financial environment is unhealthy and will explode into something serious one day.

Volatility in financial markets can be expected as painful adjustments in trade agreements and relationships are made. That volatility is not too dire a price to pay. It is necessary to take action on trade as the trade imbalance issue has been going on far too long and the matter needs to be resolved one way or another. ■

This article is the sole opinion of the author and not of the Society of Actuaries or of the Financial Services Commission of Ontario.

Nino Boezio, FSA, FCIA, is currently with the Financial Services Commission of Ontario. He can be contacted at *nino.boezio@fsco.gov.on.ca*.

ENDNOTES

1 *https://www.investopedia.com/terms/f/free-trade.asp*

2 Levert, Stephane. 2013. Sustainability of the Canadian Health Care System and Impact of the 2014 Revision to the Canada Health Transfer. Canadian Institute of Actuaries and Society of Actuaries report. Document 213075. *www.cia-ica.ca/docs/default-source/2013/213075e.pdf*.

3 Canadian Institute of Actuaries. Canada's current health care system is not sustainable; action needed to maintain the system's survival: actuarial research shows just how fast action is needed. News release. Sept. 17, 2013. *www.cia-ica.ca/docs/default-source/2013/213076e.pdf*.

4 Veldhuis, Niels, and Jason Clemens. Ontario vs. California: Who's really in debt? *Toronto Sun, Opinion page*. Feb. 1, 2013. *torontosun.com/2013/02/01/ontario-vs-california-whos-really-in-debt/wcm/a94a2b5e-3d36-4cf4-884d-c4e256d08db1*.

Staff Corner

By David Schraub

The Society of Actuaries mission statement reads: "Through education and research, the SOA advances actuaries as leaders in measuring and managing risk to improve financial outcomes for individuals, organizations and the public." The Investment Section newsletter is an example of how the SOA provides practical, high quality educational material. This is largely done through volunteers, as is the research that the SOA conducts.

My staff corner this month is focused on SOA research. It provides an overview of how it is conducted and describes the recent introduction of Strategic Research Programs. I hope to also encourage you to become involved in SOA research by either volunteering your time to help oversee a report or doing some research yourself.

Essentially, there are two broad types of SOA research: topical research focused on advancing actuarial practice (practice research), and research that analyzes industry data and usually results in the creation of tables (experience studies).

Practice research can be done either in-house or externally. If conducted in-house, an SOA staff member primarily conducts research guided by a team of volunteers (called a modeling oversight group) by accessing industry databases and other resources. If done externally, normally the SOA hires an outside party through a request for proposal. The process for developing and issuing a request for proposal is overseen by a research committee that is another type of volunteer group with broad knowledge on a specific practice area.

For investment related projects that support Investment Section members, the Committee on Finance Research vets research proposals on a variety of finance and investment topics. The research is generally conducted under the supervision of a project oversight group. This group is comprised of dedicated volunteers with expertise on the specific topic covered by the request for proposal. The group is recruited to provide meaningful comments to the researcher along the way to produce a high-quality report. It is truly a collaborative process that benefits from the partnership of expert volunteers and highly qualified researchers. SOA research staff helps to support the process from the initial idea to the resulting publication.

USEFUL LINKS: FINANCE RESEARCH

https://www.soa.org/research/topics/finance-res-report-list/
https://www.soa.org/research/topics/finance-exp-study-list/

The SOA conducts experience studies to provide actuaries with robust data that can be used for pricing and reserving. Experience studies have been undertaken for the major product lines of life insurance companies, as well as for more specialized financial products and subsidiary benefits. The SOA also sponsors continuing studies of the experience of public and private sector pension plans. Many of the SOA's studies have been conducted on a recurring basis over an extended period of time. Usually, the process includes study feasibility, study design, data vendor/researcher selection, data collection, data validation and aggregation, data analysis, report development, and report publication and closure.

Topics of research undertaken by the SOA are aligned with the practice area expertise and work experience of the individual research committees. These research committees develop ideas and oversee the process leading to publication of reports. Historically, research topics were broadly categorized by the

Fellow of the Society of Actuary tracks. To further leverage the research the SOA has traditionally conducted, the SOA Board approved in October 2017 the introduction of five strategic research programs. The advantage of the programs is to take a more holistic approach to select research themes resulting in even more impactful information and enhancement of the reputation of actuaries. Moreover, the programs are intended to raise awareness of the skillset of actuaries to the general public and continue to demonstrate the thought leadership of the SOA. And they will help to make actuaries even more relevant in an evolving society. They include practice research and experience studies as appropriate. These five strategic research programs, to be launched one at a time, include the following research themes:

- **Aging and retirement.** Reviews the societal impact of aging populations and the solutions for mitigating risks.
- **Actuarial innovation and technology.** Highlights the evolution of technology as it applies to the actuarial profession, industry and population trends.
- **Mortality and longevity.** Examines the factors impacting models and mortality predictions, and the analysis of longevity trends.
- **Health care costs.** Focuses on the forces that shape health care cost and utilization, and the changes over time.
- **Catastrophe and climate.** Studies climate trends and their impact on extreme and catastrophic events.

In addition to the strategic research programs, there are other ways research is conducted by the SOA. Going forward there will be a special pool of funding for research that meets the needs of current events from all areas of practice in which members of the SOA are involved. Examples of current events would include research performed to better understand aspects of principle-based reserves and new developments to the Affordable Care Act (commonly referred to as Obamacare). In addition, SOA sections will continue to sponsor research for the benefit of their members and other audiences. This is what the Investment Section has done and will do through the Committee on Finance Research and the Section Council. Lastly, the SOA also supports academic research through a grant program.

Sometimes a particular project will have resource needs too great for an individual research committee or will span several practice areas. In such cases, the work is usually financed through collaboration of several SOA research committees or sections. And, often there will be funding or other support provided by external parties like the Canadian Institute of Actuaries, Casualty Actuary Society or others.

Through education and research, the SOA advances actuaries as leaders in measuring and managing risk to improve financial outcomes for individuals, organizations and the public.

An important part of the research process is the dissemination of the final reports and other material such as Excel workbooks and data files. Depending on the topic, the SOA organizes webcasts, podcasts (*https://www.soa.org/resources/podcasts/#research-insights*) or newsletter articles to publicize the work. The article from Gabriella Piscopo[1] in this edition is a good example of such outreach; another example is the article from Mingyu Fang, Ken Seng Tan, and Tony Wirjanto in this edition, as well as the webcast organized in December 2018 around a February 2018 climate change and carbon risk research report.[2]

Two kind words: The first goes to the research department and particularly Steve Siegel and Ronora Stryker. Thank you for the great work you do for the section and the SOA in general, and for me by reviewing this Staff Corner. Second goes to you, reader of the newsletter. Thank you for your interest. Please consider this as an open invitation to raise your hand with an idea, or if you have interest in helping on a research committee or a project oversight group. Contact me at *dschraub@soa.org*, and I will be more than happy to point you in the right direction. ■

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

ENDNOTES

1 Gabriella Piscopo. 2018. "Reinvestment Strategies for Life Insurance Products in a Changing Economic Environment" Society of Actuaries. *https://www.soa.org/resources/research-reports/2018/2018-reinvestment-strategies-life-insurance-prod/*

2 Tan Ken Seng, Tony S. Wirjanto and Mingyu Fang. 2018. "Managing Climate and Carbon Risk in Investment Portfolios." Society of Actuaries. *https://www.soa.org/Files/resources/research-report/2018/managing-climate-carbon-risk.pdf*

Best 2018 *Risks & Rewards* Article Winners Announced

By Jim Kosinski

Member feedback consistently rates the Investment Section newsletter *Risks & Rewards* one of the most-valued benefits of the section. The newsletter's success owes a lot to our dedicated editors, Nino Boezio and Joseph Koltisko, and the contributions of all the authors who share their expertise and insight.

The Investment Section Council has set up an annual award for the best *Risks & Rewards* article published in the year, with the goal of both encouraging more authors to contribute to *Risks & Rewards* and giving special recognition to the very best articles. For the 2018 award, a three-member jury considered and scored 17 articles under the criteria intellectual rigor, practical significance, investment content, educational value and originality, and has awarded the following prizes:

- $500, for "Hedging Variable Annuities: How Often Should the Hedging Portfolio be Rebalanced?" by Maciej Augustyniak and Mathieu Boudreault (February issue)
- $500, for "Optimizing CPPI Investment Strategy for Life Insurance Companies: A Risk-Reward Analysis," by Aymeric Kalife and Saad Mouti (August issue)

These two articles were chosen jointly as best *Risks & Rewards* articles of 2018. Please join us in congratulating the authors and thanking them for their contributions to *Risks & Rewards*!

Have an idea you want to share with the Investment Section? We are always looking for educational, thought-provoking, innovative content. Articles for the August 2019 newsletter are due by the end of May; send your submissions to David Schraub (SOA staff partner, *dschraub@soa.org*) and Joseph Koltisko (August newsletter editor, *jkoltisko@nyl.com*). Maybe the best 2019 *Risks & Rewards* article will be yours! ■

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Mark Your Calendars for the **2019 Investment Seminar**

The Investment Symposium is evolving in 2019 with changes to the name, date and duration. Instead of taking place in March as a separate two-day event, the 2019 Investment Seminar will be tied to the SOA 2019 Annual Meeting & Exhibit. The invest seminar will take place on Sunday, Oct. 27 in Toronto, ON. This now one-day-long seminar will focus on the issues and questions faced by investors and risk managers, especially related to insurance companies and retirement plans.

Investment Section—Redington Prize Nominations

By Jim Kosinski

The Investment Section Council is seeking nominations for the 2019 Redington Prize, which recognizes the best paper written by an actuary on an investment-related topic during the last couple of years. The prize is sponsored by the Investment Section and is named after F. M. Redington, the eminent British actuary who developed the concept of "interest rate immunization" in a 1952 paper published in *Journal of the Institute of Actuaries*.

The 2017 Redington Prize winning paper was "Lapse-and-Reentry in Variable Annuities" by Thorsten Moenig and Nan Zhu.

The criteria for selection and basic participation details are as follows:

PUBLICATION YEARS

The paper must have been published during calendar years 2017 or 2018.

AUTHOR(S)

The author of the paper must be a member in good standing of the Society of Actuaries, Casualty Actuarial Society, American Academy of Actuaries, Conference of Consulting Actuaries, American Society of Pension Professionals and Actuaries, Canadian Institute of Actuaries, or Institute and Faculty of Actuaries; must be a legal resident of the U.S., Canada or the United Kingdom; and must be at least 18 years of age. Additional eligibility requirements (including requirements relating to papers with multiple authors) are set out in the official rules, available through the hyperlink below.

CONTENT

The topic of the paper must be judged to be original, practical, and be primarily of investment nature and of substantial value to SOA members and to other investment professionals.

SOURCE AND LANGUAGE

The paper must be published in a peer-reviewed journal that can include but is not limited to *North American Actuarial Journal*, *The Journal of Portfolio Management*, *Financial Analysts Journal*, *The Journal of Finance*, and *Journal of Financial and Quantitative Analysis*. The paper must also be drafted in English.

JUDGING

The selection criteria include intellectual rigor, practical significance, investment content, educational value and originality. The council reserves the right to choose not to award a prize.

NOMINATION

Papers must be submitted via email to *sections@soa.org* or mailed to the SOA, ATTN: Investment Section, 475 N. Martingale Rd., Suite 600, Schaumburg, IL 60173 USA.

PRIZE

One grand prize of US$5,000 will be awarded to the winning paper's eligible author(s).

ADDITIONAL DETAILS

The submission period opens at 12:01 a.m. CST March 1, 2019, and closes at 11:59 p.m. CDT June 2, 2019. Other restrictions may apply. See official rules for eligibility, odds of winning, how to enter and other details: *www.soa.org/redingtonrules2019*. ■

Jim Kosinski, FSA, CFA, MAAA, Ph.D., is vice president in the Actuarial Department at Guggenheim Insurance in Indianapolis. He can be reached at *jim.kosinski@guggenheiminsurance.com*.

EBSCO Available to Investment Section Members

By Hal Pedersen

Would you like to have access to a broad range of finance and investment articles? If so, you have it as an Investment Section member through EBSCO!

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- access electronic books.

Here are some examples of the publications that Investment Section member can access content from.

- *Journal of Risk and Insurance*
- *Journal of Fixed Income*
- *Journal of Portfolio Management*
- *Scandinavian Actuarial Journal*
- *Review of Financial Studies*
- *Journal of Forecasting*

If you would like to explore this terrific resource, please contact Dee Berger (*lberger@soa.org*). ■

Hal Pedersen, ASA, Ph.D., is managing director for Conning. He can be contacted at *hal.pedersen@conning.com*.

The Bulletin Board

Updates on important events related to the Investment Section

RECENT MEETING

SOA Annual Meeting & Exhibit 2018

The annual meeting of the investment section is a place of gathering, where we take stock on where the section is and what it does for its members. Year after year, it is the place where the section leaders and section members mingle with one another and network. This two-way dialogue is very important to guide the section for the upcoming year.

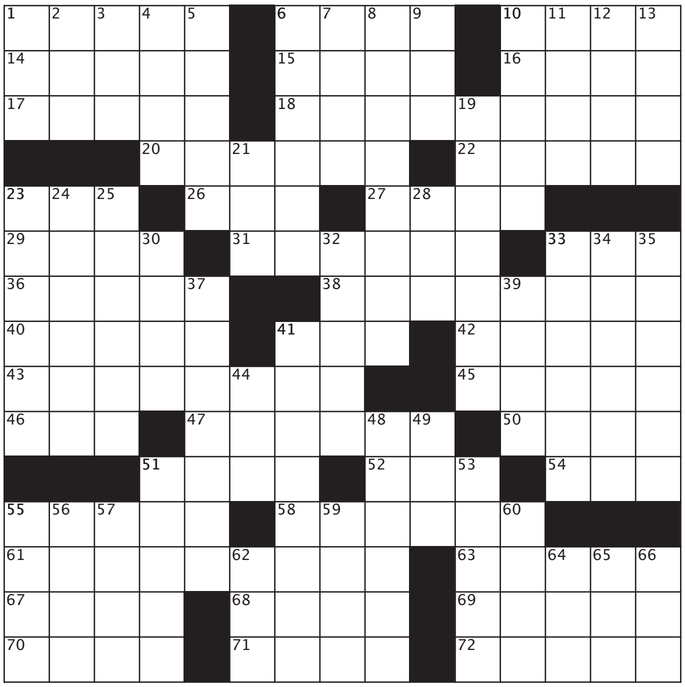
After some words about what the section did, and plans to do in 2019, we presented a few awards to the winners of various contests the section organizes. We finished the time together with speed-networking where each participant was paired five times for a four-minute conversation. Fun way to get to know people! ■

Jim Kosinski, Guggenheim Insurance, and Kelly Featherstone, Alberta Investment Management Corp., during the Investment Section breakfast at the 2018 Annual Meeting.

Jim Kosinski, Guggenheim Insurance, on left, and Justin Owens, Russell Investments, on right, present Nathan Luepke with his asset allocation contest prize.

Crossword Puzzle: Big Data

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 *enews@soa.org* by May 31, 2019.

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

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Across

1 Seventh month of the Islamic calendar
6 Winged insect
10 Australia's FBI
14 Norse god of poetry
15 Diamond stats
16 Former Chinese premier
17 A child in London
18 UNCERTAIN
20 Vitreous
22 Notched and jagged
23 Other famous resident of Messi's hometown
26 I knew it!
27 Feeble
29 Indian nurse
31 Ancient region in Asia Minor
33 Time saver at work: abbr.
36 Surfeits
38 AFFLUENT
40 Winged
41 Created by the Treaty of Rome
42 "We Call ______": Elvis Presley
43 ENDOWED
45 Southwestern Indian
46 Dijon donkey
47 Voisin ou Arabie Saoudite
50 Means ______ end
51 Mideast capital
52 Ride the waves
54 Super Bowl 2027
55 Having a line of symmetry
58 Small palm native to southeastern Asia
61 CONCEITED
63 Dell
67 City of western Colombia
68 Turkish currency
69 Place of refuge
70 Social rebuff
71 Bard's river
72 Ultracompetitive

Down

1 NFL playmakers
2 Dada pioneer
3 Jolt
4 Thunderstruck
5 INFLATED
6 Hogfish
7 SALT concerns
8 Prophetic
9 Upsilon follower
10 Like some skies
11 Scram!
12 Letters of credit?
13 River of York
19 Gnu
21 Thespians' org.
23 Honeydew kin
24 Glassy translucent substance
25 Fodder
28 2008 TARP recipient
30 Eighth Hebrew letter
32 Falstaffian
33 Trounce
34 It makes some runners faster
35 Founder of the Ottoman dynasty
37 Coastal plant
39 Army group
41 England's first Yorkist King
44 Nice way to say no?
48 Nigerian metropolis
49 Dreidel
51 Hindu master
53 IGNORANT
55 Basic facts
56 Capital of China's Shaanxi province
57 Inuit abode: Var.
59 Deli option
60 Crack up
62 In the manner of
64 Cleopatra's killer
65 Cubes
66 Pamplona pronoun

A Bit(coin) of Trivia

B	A	K	U		B	T	U	S		P	S	A	L	M
R	U	H	R		R	I	N	D		H	A	N	O	I
A	R	A	B		I	L	L	S		I	T	E	M	S
N	A	K	A	M	O	T	O		F	L	O	W	E	R
T	S	I	N	E		H	O	P	E	I	S			
			V	L	F		S	U	L	P	H	I	D	E
P	I	N		B	E	W	E	L	L		I	D	Y	L
I	Z	A	N	A	M	I		G	I	B	S	O	N	S
N	A	P	A		A	R	C	A	N	E		L	E	E
T	R	E	M	B	L	E	R		I	G	S			
			E	G	E	R	I	A		A	P	A	C	E
P	R	E	C	I	S		P	R	O	T	O	C	O	L
L	A	B	O	R		R	P	M	S		O	R	L	O
A	P	R	I	L		A	L	I	S		K	E	E	P
N	E	O	N	S		J	E	N	A		S	S	S	S

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