Backtesting GEMS® Economic Scenario Generator 2020–2022

by Mark Saunders, Director, Conning

Introduction

The period from 2019 to 2023 exhibited an extraordinary range of market volatility.

A global pandemic spawned an economic crisis, destroying market confidence, spiking credit spreads, tanking equity valuations, and exposing the fragility of global supply chains. Subsequently, just as an ailing economy was recovering from the COVID-induced lockdown, war in Europe caused the price of food, energy, and raw materials to soar, and inflation rose to a level not seen for forty years.

The benign "new normal" of low interest rates, nurtured by the loose monetary policy which has been de rigueur since the Global Financial Crisis, was rapidly jettisoned as central banks scrambled to increase interest rates at the quickest pace since the second oil crisis of 1979–80.

As experts in financial and economic modelling, Conning look at this period to see what can be learned. This paper first adds context to the magnitude of market movements before looking at key market variables in turn and examining how well our GEMS® Economic Scenario Generator captured the recent volatility. Finally, any limitations in the current approach are discussed.

Market Turmoil—Relatively Unprecedented?

Between January 2010 and December 2019, the standard deviation of US yields at the 1-year maturity was 0.8%. The 4.2% rise in yields over 2022 is over **five** times the standard deviation—an extremely unlikely occurrence on a pure variance basis. For the UK, the standard deviation of 1-year yields over the 2010s was even lower, at 0.20%. A normal distribution fitted to this data would state that a 3% increase in yields was so highly improbable as to be unimaginable—yet this is exactly what occurred.

There are two interesting points to highlight from the information above: first, that although there have historically been larger *absolute* movements in yields (specifically in 1981–82), the *relative* change in yields observed in 2022 is unprecedented; and second, that calibrating a risk model based on only ten years of market data is likely to lead to poor modelling performance.[1]

Switching focus to inflation: in the year to February 2022, US inflation rose from 1.7% to 7.9%. While the US has experienced higher levels of inflation, the increase of 6.2% is the largest annual increase in 70 years. Companies which (solely) rely on historical events to inform their stress tests are unlikely to have considered the impact of such a large inflation stress; stochastic models should also be used to ensure that novel events are captured within the risk management process.

Analysing the Data

This paper looks at four variables from the US economy in turn: interest rates, inflation, credit spreads, and equity returns.

For each variable, charts display the distributions produced by calibrations as of 31-Dec-2019, 30-Jun-2020, 31-Dec-2020, 30-Jun-2021, and 31-Dec-2021. The observed (actual) value of the variable is overlaid on each of the five charts, with the position of the observed value within the distribution indicating how frequently the calibration would simulate an event of that nature. A table summarizes where the observed variable appears within the distribution on December 31st each year.

Given the severity of recent events, it is expected that several observed variables will fall at the limits of the distribution, and that areas for improvement will be identified.

Yields

This section of the analysis looks at US yields at the 1- and 10-year maturity.

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1 See Conning's white paper, *Parameter Stability in Unstable Markets*, for more discussion on this topic.

Overall, the GEMS® Expert View Parameterization performed well across the 3-year period of extreme movements, with all observed yields captured within the various distributions.

Through 2020, the US yield curve decreased by ~150 basis points (bps), hovering close to the lowest levels on record. The observed yields at end-2020 were in the tails of the 31-Dec-2019 simulated model distribution[2]: the 1-year yield is placed at the 4.7% of the distribution (i.e., roughly a 1-in-20-year event), while the 10-year yield is placed at the 0.6% of the distribution (i.e., approximately a 1-in-200-year event).

By end-2021, yields had increased slightly, bringing them closer to the historical average than they had been 12 months earlier. The observed yields at end-2021 were positioned within the central 90% of all four distributions tested.

Over 2022, 1-year yields increased by over 420 bps, the fastest relative increase ever recorded over a calendar year. 10-year yields increased by 230 bps to 2.5 times their starting level. Observed yields at year-end 2022 were captured within the various distributions, but often in the tails:

- The 1-year yield is at the 99.9% of the 31-Dec-2021 distribution (i.e., a 1-in-1000-year event) and the 10-year yield is at the 99.5% (i.e., a 1-in-200-year event).

- The 1-year yield is at the 99.5% of the 31-Dec-2020 distribution (i.e., a 1-in-200-year event) and the 10-year yield is at the 98.3% (i.e., around a 1-in-50-year event).

- The 1- and 10-year yields are both within the middle 90% of the 31-Dec-2019 distribution—a strong result which was due to the relatively higher initial yield curve and three years of simulation which gave time for the tails of the distribution to "fatten out".

As stated above, the 31-Dec-2021 distribution captured the changes in the 1-year yield, but at the relatively low probability level of a 1-in-1000-year event. While assigning a likelihood to a market crash is notoriously difficult, the rapid increase in yields from a low base experienced over 2022 is perhaps qualitatively more consistent with a 1-in-50-year to 1-in-200-year event rather than a 1-in-1000-year event. The data from 2022 will be used to inform the next review of the GEMS® Expert View parameters, which may also utilize the Global Jump Process[3] to increase the probability of such events.

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2 I.e., the distribution produced by the 31/12/2019 Expert View calibration.

3 The GEMS Global Jump Process is a mechanism for generating tail events which are shared across multiple models and economies. This enables the GEMS® Economic Scenario Generator to better capture the effects of economic crises and tail dependency.

Technical note: Although the GEMS® interest rate model uses a relative volatility approach (i.e., volatility is relative to the level of the yield curve), it also employs a shift function to ensure (among other things) that yield volatility does not tend to zero when rates are low. Models which use a relative volatility approach *without* a shift function may struggle to simulate significant volatility when yields are near zero; in other words, they will not be able to re-create the change in yields observed during 2022.

Conning's Expert View Parameterization

The setting of calibration targets is possibly the most crucial step when using an economic scenario generator (ESG) for risk management. Two of the most important factors in setting calibration targets are historical data and expert judgement.

Consider the judgement involved when selecting the window of historical data to analyze: if the window is too long it will include data which is no longer relevant to the current economic climate, whilst if the window is too short it will not include enough variety to provide a credible target. Moreover, if the window is constantly updated to include the most recent data, any forward-looking analysis produced using the model will change due to short-term fluctuations in data rather than any fundamental changes in economic outlook.

Conning's Expert View methodology was designed to result in steady-state targets which remain stable through time and do not require regular updating every quarter. In theory, this "through the cycle" calibration should be better equipped to model market crashes than "point in time" calibrations which only react to sudden market volatility after the event has occurred.

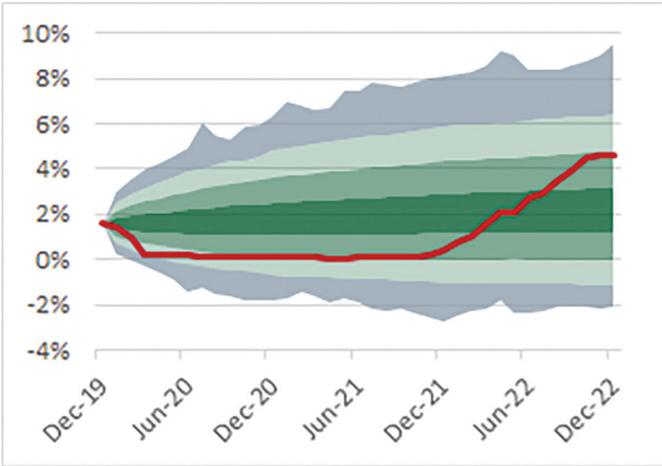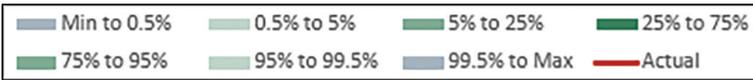This paper tests that theory, analyzing how well the models performed over the last few years.

Figure 1: US yields, 1-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2019.
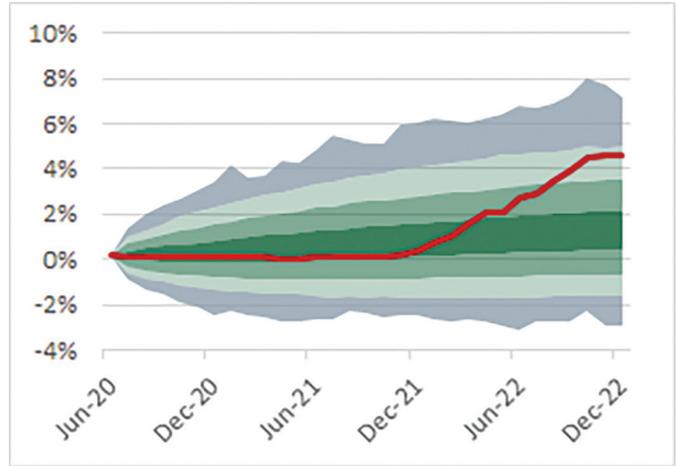

Figure 2: US yields, 1-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2020.
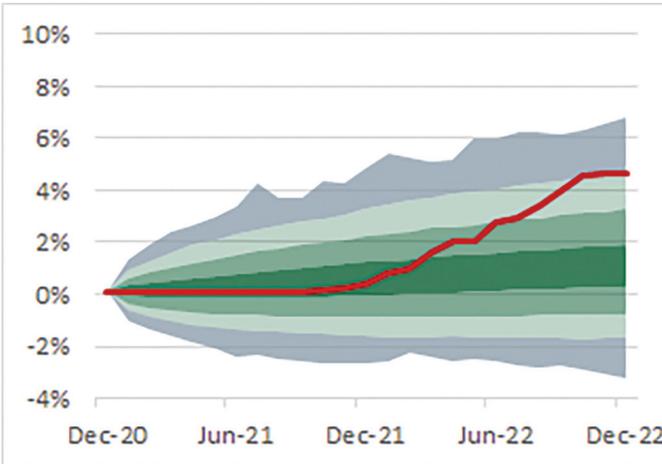

Figure 3: US yields, 1-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2020.
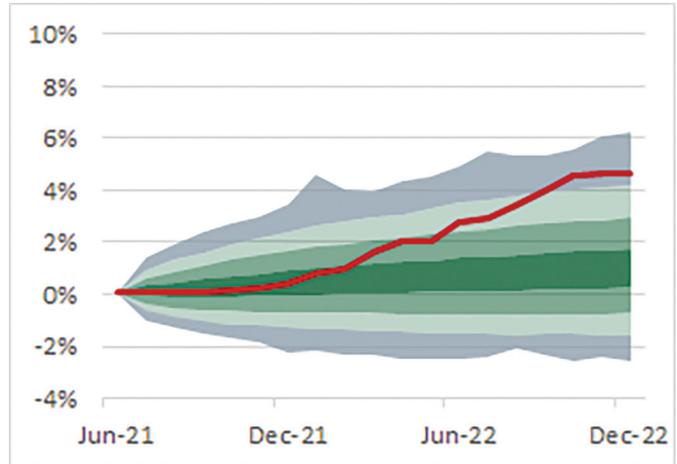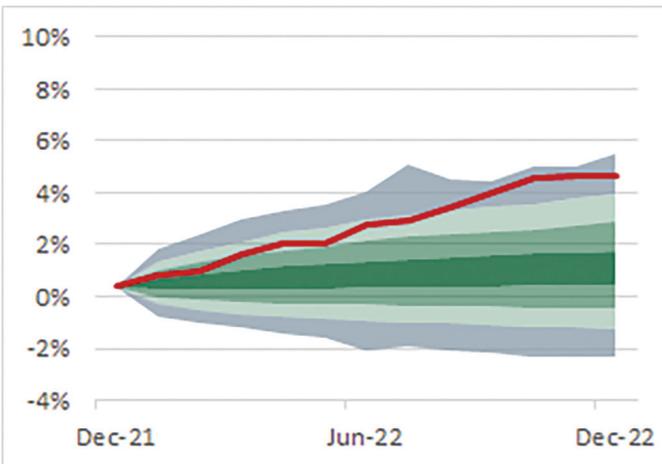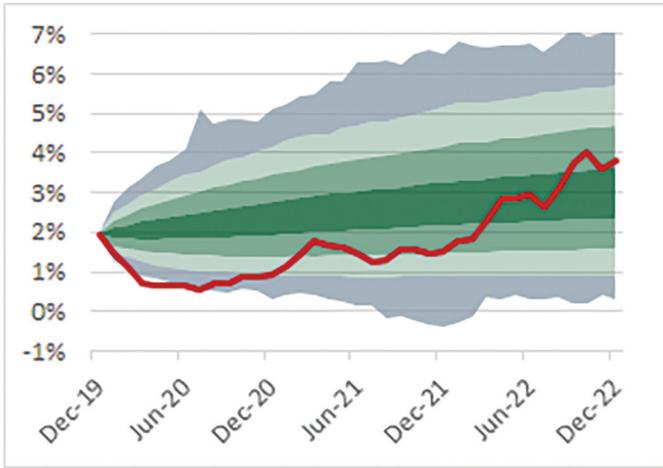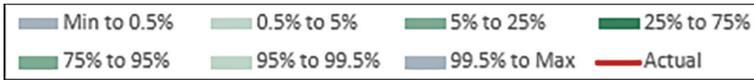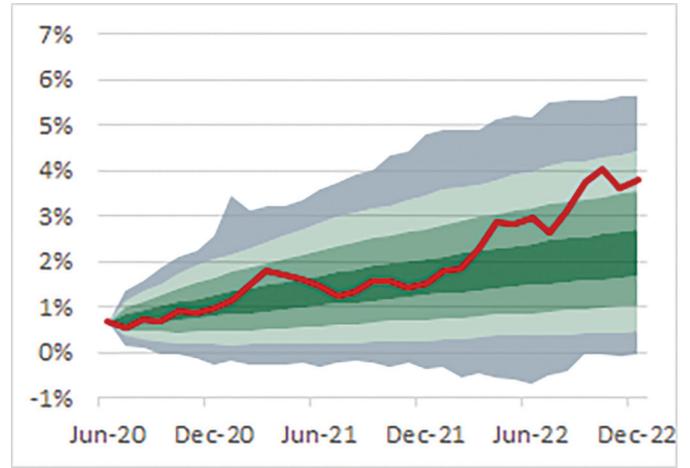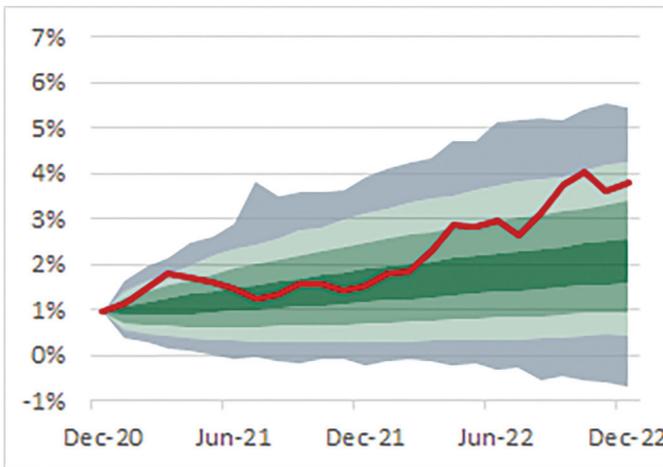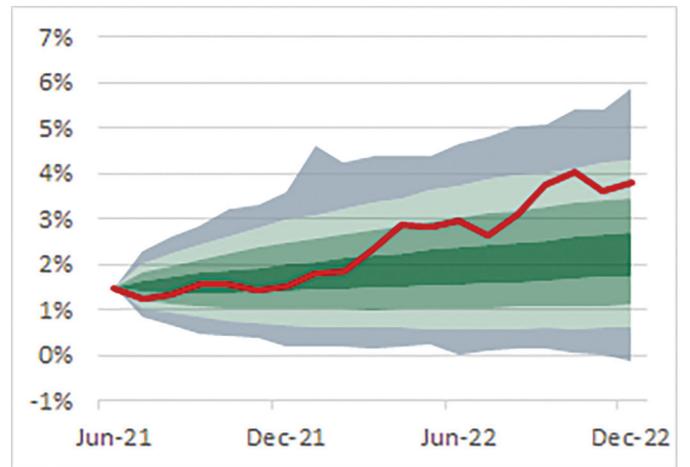

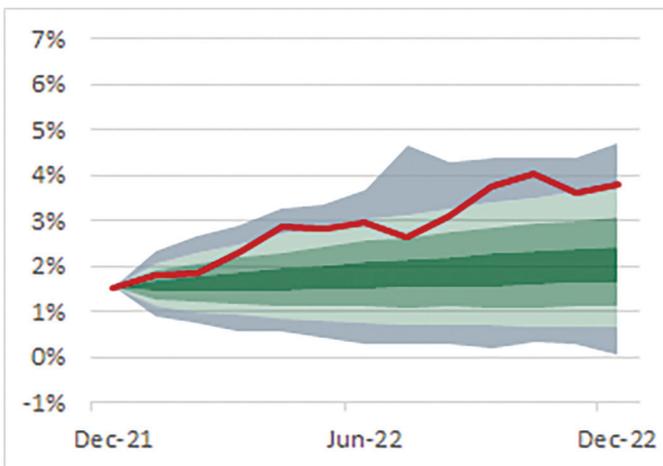Figure 4: US yields, 1-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2021.

Figure 5: US yields, 1-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2021.

	2020M12	2021M12	2022M12
US Yield 1y	Dec-20	Dec-21	Dec-22
Actual	0.10%	0.39%	4.62%
Calibration as of:			
Dec-19	4.7%	10%	94%
Jun-20	37%	34%	98.9%
Dec-20		41%	99.5%
Jun-21		49%	99.77%
Dec-21			99.89%

Figure 6: Position of US 1-year yields at 31-Dec-20, 31-Dec-21, and 31-Dec-22 within GEMS® Economic Scenario Generator projections using calibration as of 31-Dec-19, 30-Jun-20, 31-Dec-20, 30-Jun-21, and 31-Dec-21.

Figures 1–6: Prepared by Conning, Inc. Sources: GEMS® Economic Scenario Generator scenario and ©2023 Bloomberg, L.P.

Legend: Min to 0.5% | 0.5% to 5% | 5% to 25% | 25% to 75% | 75% to 95% | 95% to 99.5% | 99.5% to Max | Actual

Figure 7: US yields, 10-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2019.

Figure 8: US yields, 10-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2020.

Figure 9: US yields, 10-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2020.

Figure 10: US yields, 10-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2021.

Figure 11: US yields, 10-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2021.

	2020M12	2021M12	2022M12
US Yield 10y	Dec-20	Dec-21	Dec-22
Actual	0.94%	1.53%	3.82%
Calibration as of:			
Dec-19	0.6%	6%	80%
Jun-20	42%	42%	97.4%
Dec-20		51%	98.3%
Jun-21		35%	97.9%
Dec-21			99.52%

Figure 12: Position of US 10-year yields at 31-Dec-20, 31-Dec-21, and 31-Dec-22 within GEMS® Economic Scenario Generator projections using calibration as of 31-Dec-19, 30-Jun-20, 31-Dec-20, 30-Jun-21, and 31-Dec-21.

Figures 7–12: Prepared by Conning, Inc. Sources: GEMS® Economic Scenario Generator scenario and ©2023 Bloomberg, L.P.

Inflation

This section of the analysis looks at the year-on-year (annual) inflation rate based on US CPI data.

The GEMS® Expert View Parameterization had mixed performance over the different periods analyzed: the rapid increase in inflation over 2021 was not captured at the 1-year horizon in the 31-Dec-2020 distribution, while the 30-Jun-2020 distribution only captured the movement at the outer edge of the tail.

Over 2020, CPI declined from 2.3% to 1.4%, a benign movement which was near the center of the 31-Dec-2019 distribution.

Over 2021, CPI increased from 1.4% to 7.0%. This decidedly unbenign change was not captured within the 31-Dec-2020 distribution for two reasons: firstly, because the increase was so rapid—it was the largest increase in inflation since the 1973-74 oil crisis—and secondly, because the initial CPI was low and structurally a lower rate of CPI will generate lower volatility in the model. It is worth noting that, over longer simulation horizons, the tails of the distribution "fatten out" considerably, so that by the end of 2021 the CPI rate of 7.0% is captured within the tails of the earlier 31-Dec-2019 distribution as a 1-in-100-year event.

Over 2022, the CPI inflation rate was stable, and so was positioned near the center of the 31-Dec-2022 distribution.

As mentioned above, the rapid increase in CPI over 2021 was not captured in the distribution. This data point will be used in the next review of the GEMS® Expert View parameters.

Note: On some charts, the starting level of observed CPI (red line) and the GEMS® distributions are not precisely equal. This is because GEMS® uses CPI estimates as of the time of the calibration, whereas the observed CPI is often revised later, after the calibration has been released.

Credit Spreads

This section of the analysis looks at spreads for US A and BBB rated bonds at the 5-year maturity.

Overall, the performance of the Expert View Parameterization was good. At each year end, all observed spreads were cap-tured within the various distributions.[4] However, one observed spread fell outside the distribution at a shorter horizon.

In March 2020:

• A rated spreads briefly spiked to 1.73%, which was above

the maximum level of 1.67% produced three months into the 31-Dec-2019 distribution.

• BBB rated spreads increased to the 99.9% of the 31-Dec-2019 distribution.

Even though the model can produce significant widening of credit spreads at the three-month horizon, the magnitude of the increase is not enough to capture the observed spreads. By end-2020, spreads had returned to the lower levels at which they started the year.

Changes to spreads were close to zero over 2021, and so were within the middle of the various distributions shown.

Over 2022, spreads increased by around 80% in relative terms but only by 40 to 60 bps in absolute terms. This movement remained within the central cone of the GEMS® distributions.

Reflecting on credit spread behavior over 2020–22, it can be seen that an increase in model volatility or a longer tail at short time horizons might be justified—further work will be undertaken to identify what is feasible.

Equity

This section of the analysis looks at price levels of the S&P 500 index.

The Expert View calibration performed well over the period being analyzed. All movements were captured within the central 99% of the various distributions.

Over 2020, the S&P 500 index rose by 16%, a large but unexceptional increase which was captured close to the middle of the 31-Dec-2019 distribution.

Over 2021, the index rose by another 27%, for a total 48% cumulative rise over the 2-year period to December 31, 2021. This strong post-COVID rally in prices drove observed values to the 95th to 99th percentiles of the various distributions. This is the only period during which the index value pushed into the tails of the distribution. Given the magnitude of the price rise (and coupled with the fact the increase was on the positive side—i.e., it is not a scenario that would cause solvency issues) the model performance seems reasonable.

Over 2022, the index dropped by 17%. The end-2022 observed value landed at the 4% of the 31-Dec-2021 distribution, equivalent to a 1-in-25-year event. The observed value was closer to the center of earlier distributions because the growth from previous years offset the price fall in 2022.

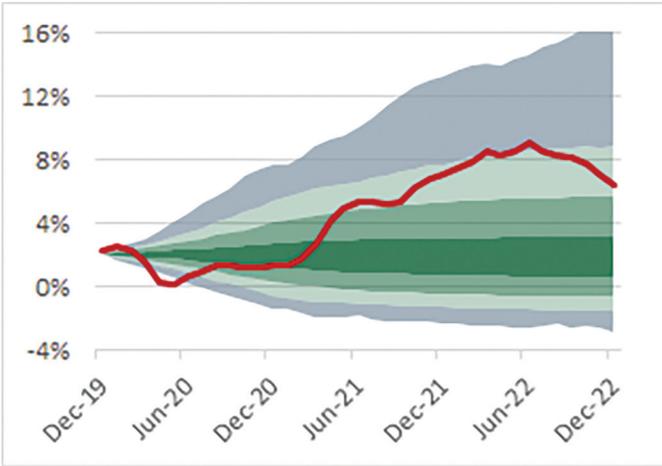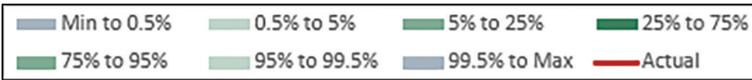Given the performance described above, no changes are likely to be made to the equity calibration.

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4 The Expert View calibration is designed to produce realistic results at, and above, a 1-year horizon.

Legend: Min to 0.5% | 0.5% to 5% | 5% to 25% | 25% to 75% | 75% to 95% | 95% to 99.5% | 99.5% to Max | Actual

Figure 13: US CPI, year-on-year Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2019.
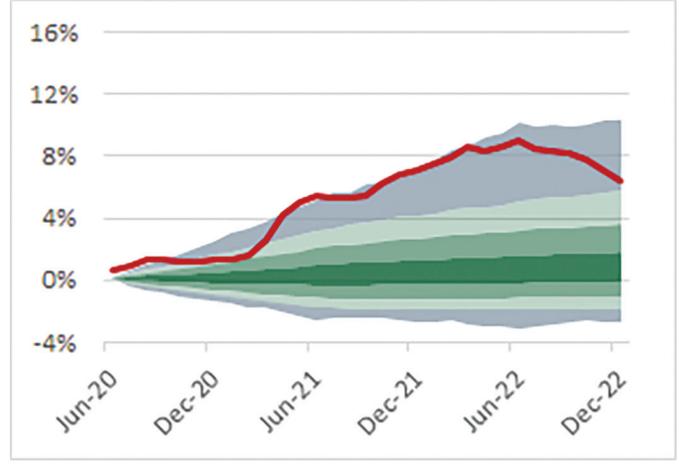
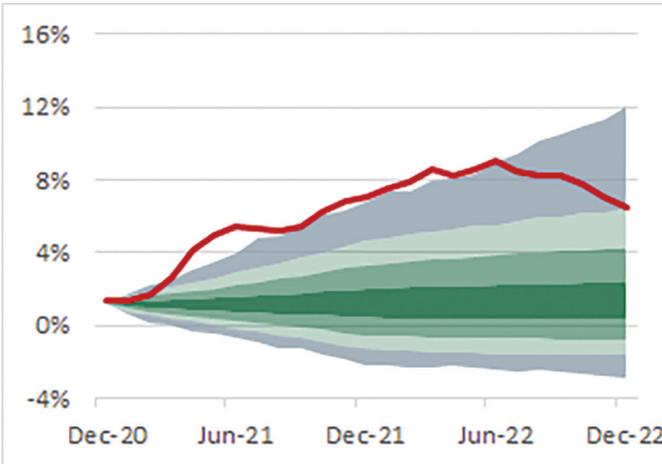Figure 14: US CPI, year-on-year. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2020.

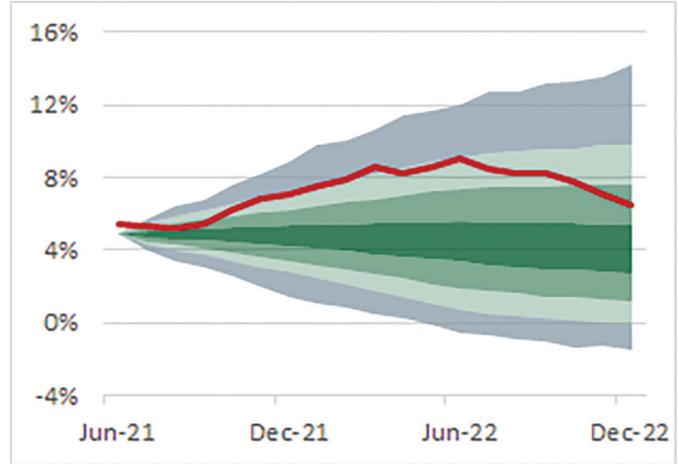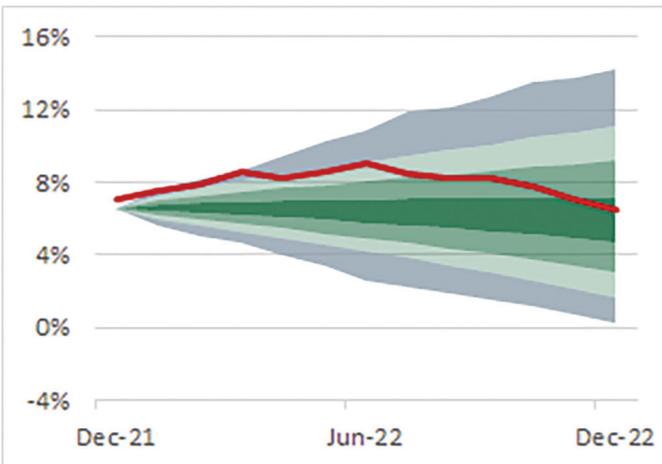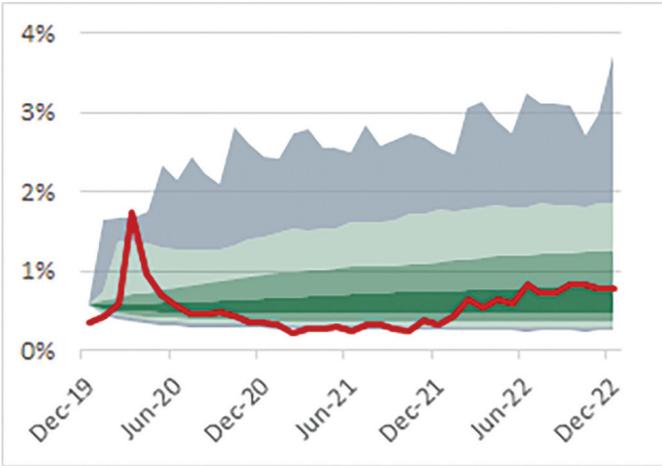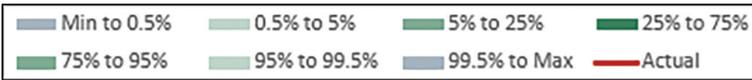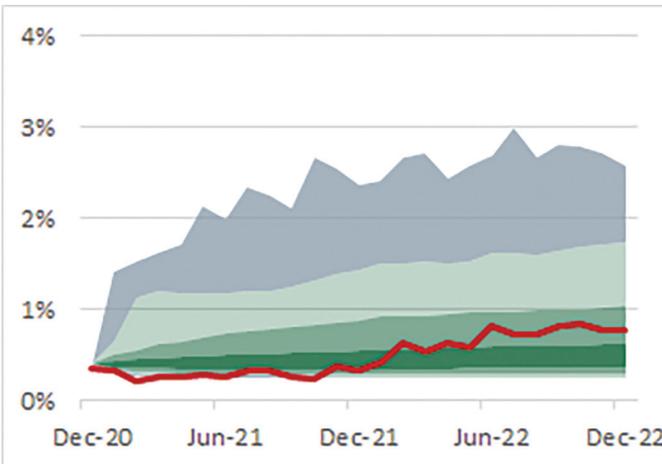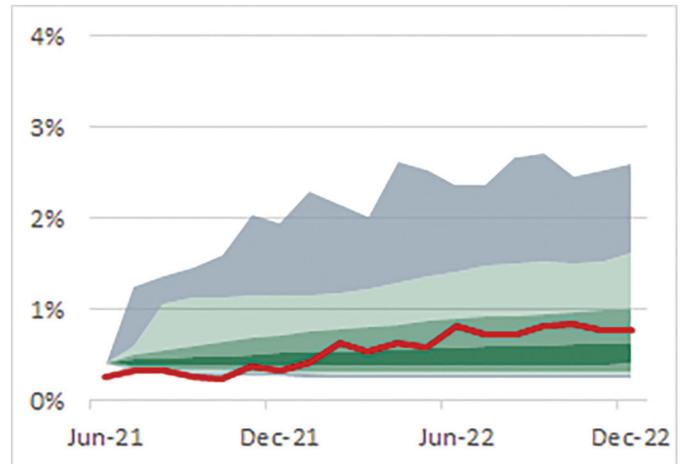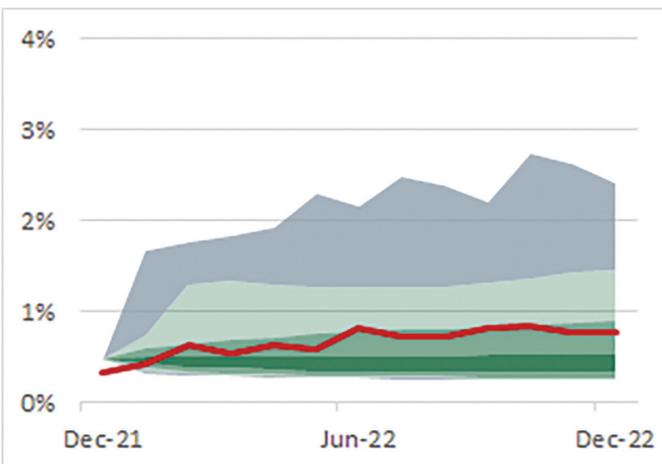Figure 15: US CPI, year-on-year. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2020.

Figure 16: US CPI, year-on-year. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2021.

Figure 17: US CPI, year-on-year. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2021.

	2020M12	2021M12	2022M12
US CPI YoY Ra	Dec-20	Dec-21	Dec-22
Actual	1.36%	7.04%	6.45%
Calibration as of:			
Dec-19	30%	99.0%	97.0%
Jun-20	98.5%	99.99%	99.76%
Dec-20		OUT	99.53%
Jun-21		99.3%	88%
Dec-21			62%

Figure 18: Position of US CPI at 31-Dec-20, 31-Dec-21, and 31-Dec-22 within GEMS® Economic Scenario Generator projections using calibration as of 31-Dec-19, 30-Jun-20, 31-Dec-20, 30-Jun-21, and 31-Dec-21.

Figures 13–18: Prepared by Conning, Inc. Sources: GEMS® Economic Scenario Generator scenario and ©2023 Bloomberg, L.P.
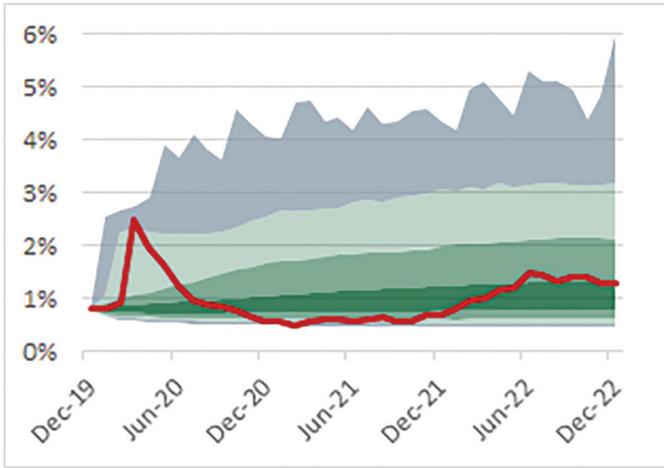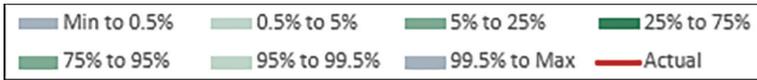
Figure 19: US A rated spreads, 5-year maturity Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2019.
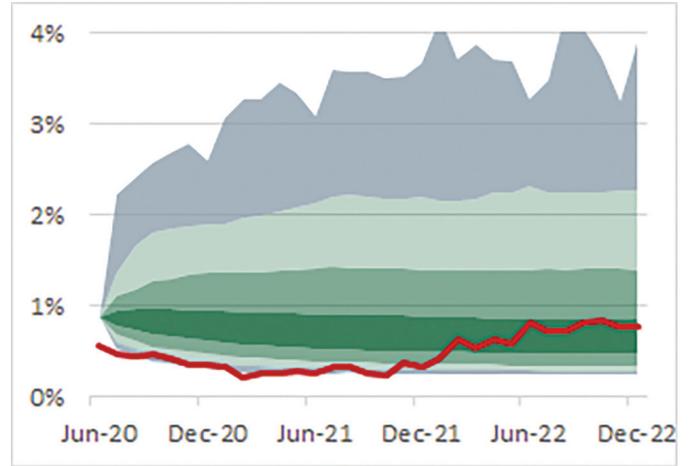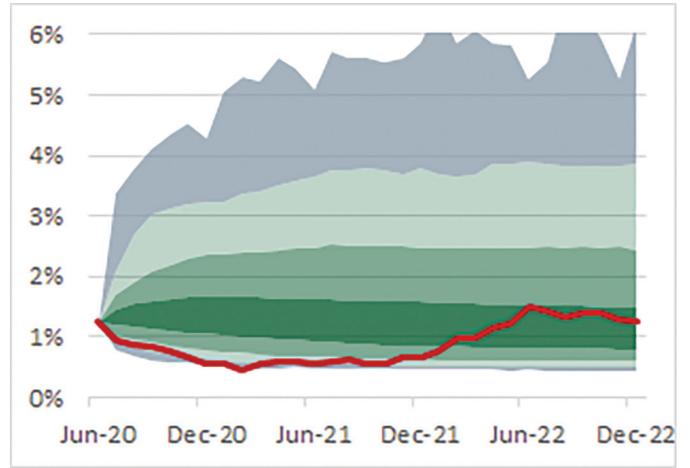
Figure 20: US A rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2020.
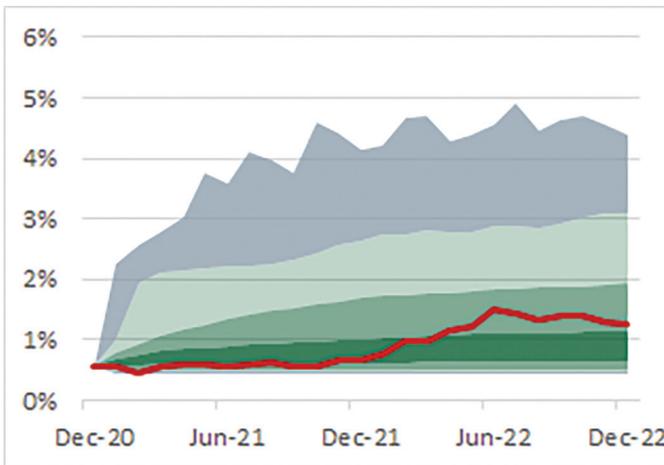
Figure 21: US A rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2020.
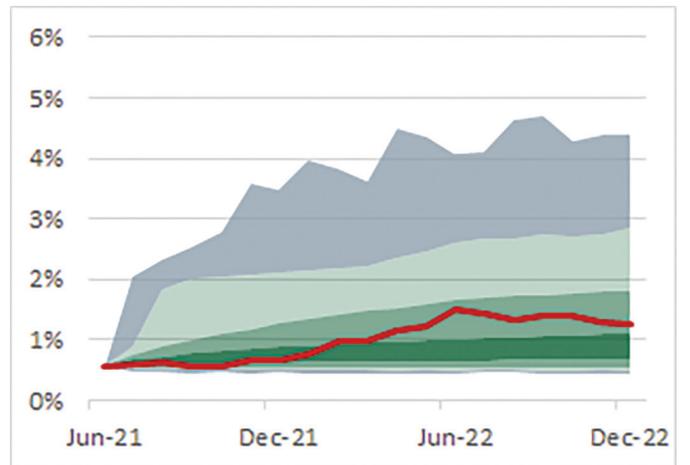
Figure 22: US A rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2021.
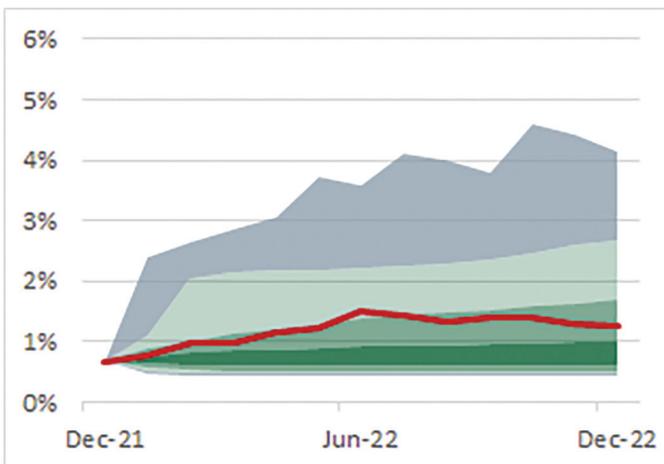
Figure 23: US A rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2021.

	2020M12	2021M12	2022M12
US Spread A	Dec-20	Dec-21	Dec-22
Actual	0.35%	0.33%	0.77%
Calibration as of:			
Dec-19	2.1%	2.7%	71%
Jun-20	0.13%	1.9%	69%
Dec-20		18%	86%
Jun-21		6%	87%
Dec-21			92%

Figure 24: Position of US A rated spreads at 31-Dec-20, 31-Dec-21, and 31-Dec-22 within GEMS® Economic Scenario Generator projections using calibration as of 31-Dec-19, 30-Jun-20, 31-Dec-20, 30-Jun-21, and 31-Dec-21.

Figures 19–24: Prepared by Conning, Inc. Sources: GEMS® Economic Scenario Generator scenario and ©2023 Bloomberg, L.P.

Figure 25: US BBB rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2019.

Figure 26: US BBB rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2020.

Figure 27: US BBB rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2020.

Figure 28: US BBB rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2021.

Figure 29: US BBB rated spreads, 5-year maturity. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2021.

	2020M12	2021M12	2022M12
US Spread BE	Dec-20	Dec-21	Dec-22
Actual	0.58%	0.67%	1.26%
Calibration as of:			
Dec-19	1.8%	13%	71%
Jun-20	0.10%	8%	64%
Dec-20		34%	80%
Jun-21		36%	83%
Dec-21			87%

Figure 30: Position of US BBB rated 5-year spreads at 31-Dec-20, 31-Dec-21, and 31-Dec-22 within GEMS® Economic Scenario Generator projections using calibration as of 31-Dec-19, 30-Jun-20, 31-Dec-20, 30-Jun-21, and 31-Dec-21.

Figures 25–30: Prepared by Conning, Inc. Sources: GEMS® Economic Scenario Generator scenario and ©2023 Bloomberg, L.P.

Legend: Min to 0.5% | 0.5% to 5% | 5% to 25% | 25% to 75% | 75% to 95% | 95% to 99.5% | 99.5% to Max | Actual
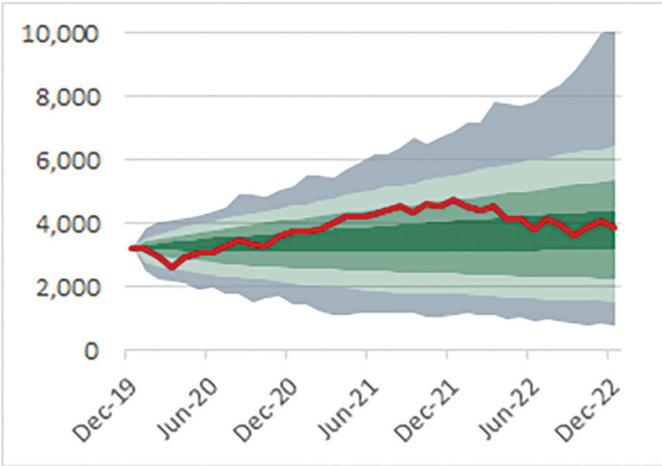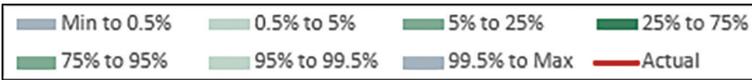
Figure 31: US S&P 500 price index. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2019.
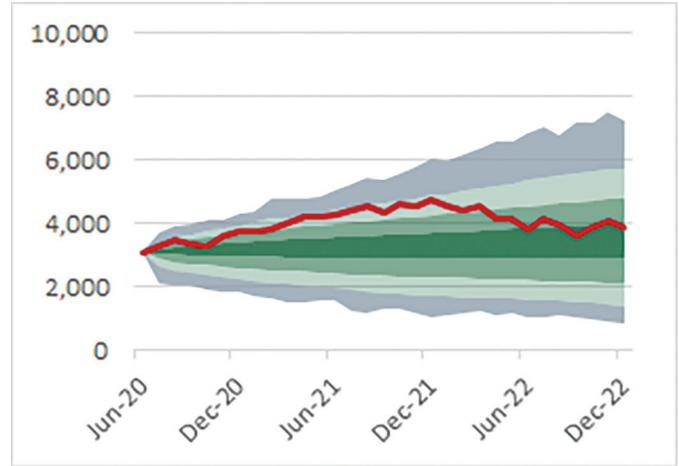
Figure 32: US S&P 500 price index. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2020.
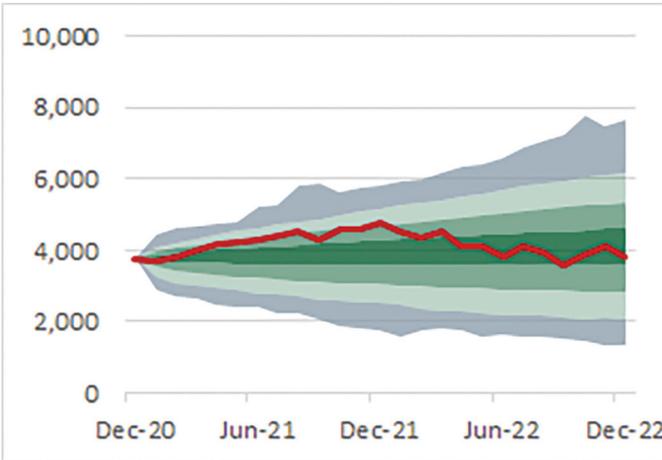

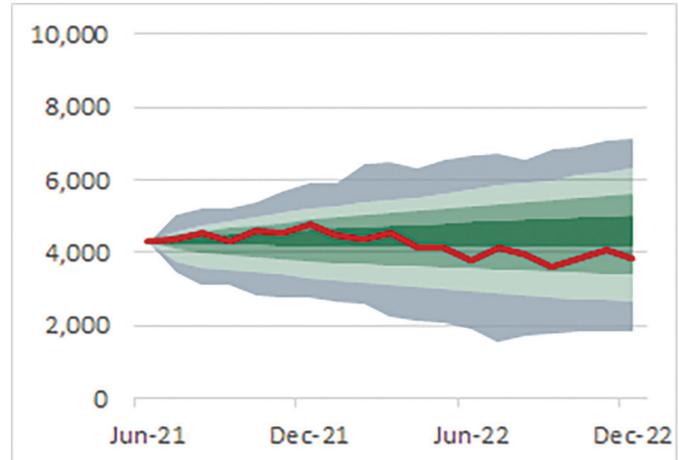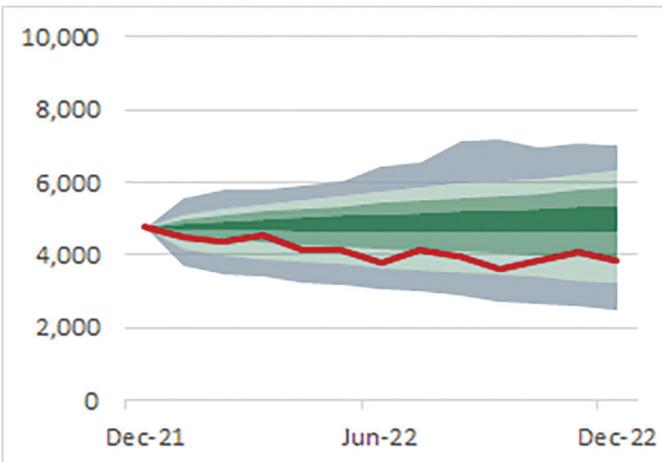Figure 33: US S&P 500 price index. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2020.

Figure 34: US S&P 500 price index. Actual vs. GEMS® Economic Scenario Generator projection as of 30th June 2021.

Figure 35: US S&P 500 price index. Actual vs. GEMS® Economic Scenario Generator projection as of 31st December 2021.

US SP 500 Level	2020M12 Dec-20	2021M12 Dec-21	2022M12 Dec-22
Actual	3,756	4,766	3,840
Calibration as of:			
Dec-19	78%	95.3%	52%
Jun-20	97.5%	99.2%	69%
Dec-20		96.4%	36%
Jun-21		88%	13%
Dec-21			3.7%

Figure 36: Position of US S&P 500 price index at 31-Dec-20, 31-Dec-21, and 31-Dec-22 within GEMS® Economic Scenario Generator projections using calibration as of 31-Dec-19, 30-Jun-20, 31-Dec-20, 30-Jun-21, and 31-Dec-21.

Figures 31–36: Prepared by Conning, Inc. Sources: GEMS® Economic Scenario Generator scenario and ©2023 Bloomberg, L.P.

Conclusion

As discussed at the beginning of this paper, the market movements over the last few years were in many ways unprecedented, underlining the benefit of using novel scenarios generated by stochastic models within the risk management process. Given the extreme changes in financial markets, the Expert View calibration performed well, capturing most variables within the distributions analysed.

One of the reasons the model performed as well as it did is that approximately 25 years of data are used to calculate the targets for the mean, with longer histories often used to estimate targets for the standard deviations of simulated distributions. This data window allows for more than one economic regime, and, specifically, does not focus solely on the ultra-low volatility period post Global Financial Crisis.

The analysis does not paint a perfect picture, however: clearly at short time horizons (e.g., 3 months to 1 year) there are some areas which could be improved by the inclusion of the Global Jump Process mentioned earlier, which will be considered when the GEMS® Expert View Parameterization is next reviewed. In particular, this is likely to be useful in capturing the jump in interest rates from a very low base which occurred in 2022, the rapid increase in CPI over 2021, and the magnitude of spread increases in 2020.

About the Author

Mark Saunders, FIA, CERA, leads Conning's European Risk Solutions operation who are responsible for providing capital modelling and strategic asset allocation services to firms across the UK and Europe. Before joining Conning, Mark was an actuary at AXA where he worked in capital modelling and commercial finance roles. Mark has a degree in Mathematics and Philosophy from the University of Bristol, is a Member of the Chartered Institute for Securities & Investment, and is a Fellow of the Institute and Faculty of Actuaries.

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