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7 April, 2022

To: Scott O'Neal

From: Jack Cheyne, Senior Director - Scenario Generator Product Management

Subject: Comments and Feedback on the "Recommended Models for ESG Field Testing"

Moody's Analytics appreciates the opportunity to provide comments on the Treasury Model, Equity Model and Corporate Model candidates under consideration for field testing in June 2022 as described in "Recommended-Models-for-ESG-field-testing_031722.pdf ".

This note provides comments and feedback on the proposed models that will form part of the NAIC field test in June 2022. In particular we present the following main comments for consideration:

- The NAIC has proposed adjustment to the underlying Cox-Ingersoll-Ross (CIR) methodology to address limitations of this model and calibration approach. These adjustments include the "Generalized Fractional Floor" or the "Alternative Calibration and Shadow Floor", to allow the modeling to meet the required acceptance criteria as defined by the NAIC and regulators.
- In our experience, these types of 'ad-hoc' adjustments to mathematical models are not common practice among insurers. It is our view that such adjustments are undesirable as, in effect, they alter the model structure in a way that is not transparent. A simple model with well-understood limitations is generally preferable to a model which is more complex, but not fully understood.
- Additionally, we do not believe that such an approach is required. There are alternative short rate models that can meet the NAIC's calibration criteria without the need for ad-hoc modeling adjustments to the stochastic model.
- The choice of Treasury model (and in particular these adjustments proposed to the CIR model) will have an impact on the capital and reserves held by Insurers. The NAIC could consider including a wider selection of model/calibrations in the field test to gain a deeper understanding of the impact of model/calibration choices on these key results.
- If the NAIC is considering a model-adjustment to introduce a floor and move away from a standard 3-Factor CIR model, then it is important to note that these model adjustments may affect some of the model's fundamental characteristics. A full validation of the key model output and properties should be considered, for example:
    - What level of arbitrage do these adjustments introduce?
    - Does this have a fundamental impact on reserves or capital?
    - How do these adjustments impact the stability of the model and the stability of the reserves and capital?
- The level and frequency of negative long maturity rates may have a strong impact on reserving calculations, particularly when firms are using long-term bond portfolios to back their liabilities with a guaranteed level of return. The NAIC could consider carefully the calibration criteria with respect to 10, 20 or 30 maturity rates distribution and may benefit from looking at alternative calibrations with different severities of long maturity negative rates as part of the field test. We have observed that this part of the model and calibration has been under increased scrutiny by insurers following the large downward shocks to the Treasury yield curve which were seen between December 2019 and March 2020. Over this period both the short-term rates and long-term rates dropped by over 100 basis points. It is important to ensure that the model captures realistic dynamics for the level of variation in long term rates when the reserves and capital are sensitive to these assumptions.

» The link between the equity model and the Treasury model is a common feature in many stochastic modeling frameworks used by insurer's globally. Many insurers adopt a very similar approach to that outlined by the NAIC, but some institutions consider more complex stochastic models and may extend the model to include a dynamic equity risk premium. This dynamic equity risk premium reacts to whether the equity market is over/under priced. It is important to note that there is not an academic consensus on either a single modeling approach or an assumption-set governing these dynamics of the equity risk premium. The literature in this area can be quite broad and varied.

» We would recommend that the NAIC choose a Credit Modeling approach that is transparent and supported by clear documentation on the model, assumptions, calibration approach and validation. If this is not possible with the currently proposed corporate model, then we would encourage the NAIC to consider other modeling approaches even if some of these related to simpler models.

The following sections provide feedback and more detailed commentary around these key considerations.

Interest Rate Modeling – Treasury Rates

Globally we observe that insurers and regulators consider a range of different arbitrage free pricing models depending on the specific stochastic calculations and applications they are tackling. For example, firms may choose different models with specific characteristics/properties when considering (1) risk-neutral valuation of complex insurance liabilities, (2) 1-year single timestep capital calculation or (3) multi-timestep capital/reserving calculations.

In each instance, firms will generally consider the following steps:

1. Identify the key features and calibration criteria that are relevant to the desired calculations. The calibration criteria can be a mix of qualitative and quantitative requirements on the modeling outcomes.
2. Select a model that has the desired features and the flexibility to be calibrated to meet the specified criteria.

This may lead to insurers considering a range of models and making a choice based on model performance. In general, insurers look to ensure:

» The models are well understood, and their implementation is based upon standard approaches and academically recognized techniques.

» The models and calibrations are stable and robust to changes in the input market conditions/assumptions. This ensures that the final capital/reserving/liability-values are stable and do not fluctuate or vary over time due to modeling/calibration artifacts.

» The models are transparent and open to challenge and feedback from auditors/validators both internally and externally.

This approach aligns very closely with the approach taken by the NAIC and the calibration criteria specified by the NAIC is an excellent example of this - where some qualitative and quantitative criteria covering the following elements are considered:

» Low for Long Interest Rates

» Prevalence of High Rates, Upper Bounds on Treasury Rates

» Lower Bounds on negative rates

» Initial Yield Curve Fit, Yield Curve Shape in Projection and steady state yield curve shapes

In addition, to these criteria we typically see insurers looking to constrain and express a quantitative view on the **volatility** and **dispersion** of both short maturity and long maturity interest rates along with **correlation targets** for the movement of interest rates of different maturities.

There are a range of textbook pricing models that could be used to meet these criteria. The relative performance of these models will depend on the model implementation and the calibration approach. We understand, from the analysis produced so far by the NAIC, that the 3-Factor CIR model implementation that the NAIC has considered is not flexible enough to meet all of these criteria even though a range of different calibration approaches have been considered. This has led the NAIC to consider adjustments to this model to allow it to meet the needed criteria. These adjustments include the "Generalized Fractional Floor" or the "Alternative Calibration and Shadow Floor", due to the fundamental limitations of the underlying Cox-Ingersoll-Ross (CIR) methodology forcing artificial adjustments to meet the required acceptance criteria as defined by the NAIC and regulators.

In our experience, insurers generally avoid making significant post-processing adjustments to meet calibration criteria. In many instances the post processing adjustment can fundamentally change the nature of the interest rate model. This can mean that some of the key model dynamics can break down e.g. the model is no longer arbitrage free or the distributions may not be stable from one valuation date to the next. When adjusting a model it is important to consider that the adjusted "model" may be fundamentally different from the original textbook model. This puts the onus on a robust validation of the new model's properties, stability and behavior to ensure that the model owner fully understands the impact and performance of the model. In particular, it is important to quantitatively assess the key areas below.

» What level of arbitrage do the adjustments introduce? This can have implications for projected returns on Treasury bonds over different horizons. By adjusting the model there is a risk that these changes to the yield curve will lead to strategies where unrealistic or inconsistent returns are produced by the model for certain bond portfolios/strategies.

» Do the adjustments have a fundamental impact on reserves or capital?

» How do the adjustments impact the stability of the model and the stability of the reserves and capital?

ALTERNATIVE MODEL CHOICES

It is important to note that alternative models (variations of the arbitrage free pricing models like the CIR model) can meet the NAIC's specified calibration criteria without the need for ad hoc model adjustments.

These alternative models could be considered for inclusion in the Field Test or the NAIC could consider allowing insurers to use alternative models as long as they meet the NAIC's prioritized acceptance criteria. This could have the following added benefits.

» The NAIC are only required to maintain calibration criteria on a regular basis rather than a full suite of models, calibrations and scenarios. The NAIC could naturally continue to offer a standard set of scenarios for firms who wished to use the NAIC prescribed models.

» Validation is still simple for each state regulator as insurers would be required to provide summary statistics attesting to compliance with criteria.

» Insurers can leverage existing toolkits, automated processes etc. to produce reserves and capital in an efficient way.

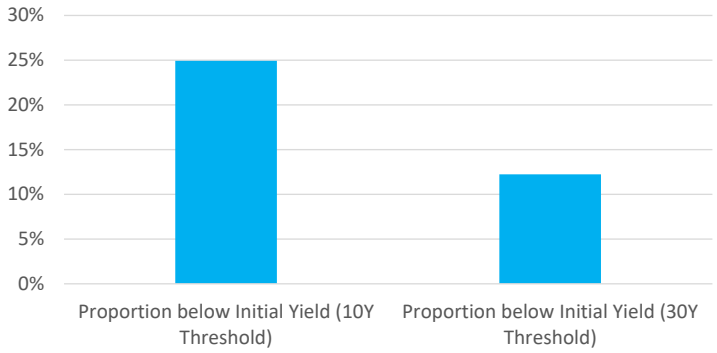
This type of approach to stochastic modeling regulation is common in many other countries and avoids insurers being constrained to models that may have significant limitations in the scope of applicability.

One example of a model that can meet the criteria specified by the NAIC without any model adjustment is the Displaced 2-Factor Black Karasinski (D2FBK) model. This model is widely used by the insurance industry for multi-timestep real-world projections, and its calibration flexibility and stability mean this model can be used for a wide range of applications.

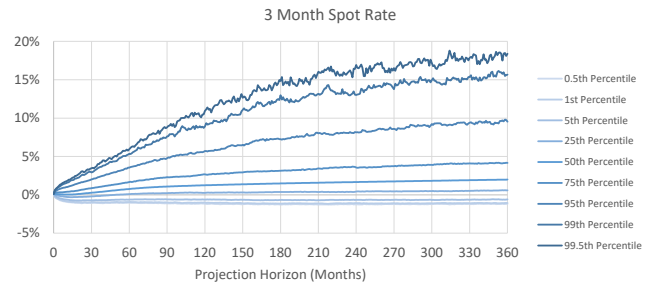
This model goes beyond the traditional log-normal Black Karasinski model that was limited to strictly positive rates. The implementation of the D2FBK model that we have considered addresses these limitations through the inclusion of a displacement factor which changes the shape of the distribution (limiting the probability of very high rates) and ensures the model captures negative interest rates in a controlled and integrated manner with the models pricing dynamics. Shifting the distribution from strictly log normal addressed some of the limitations of the log normal models while maintaining the benefits of the 2FBK model, such as more realistic yield curves, reasonable calibration analytics, and flexible term premium modeling. This D2FBK model provides for negative interest rates and at the same time it provides more realistic rate distributions in the low-rate environment, which are the fundamental calibrations defined by the NAIC.

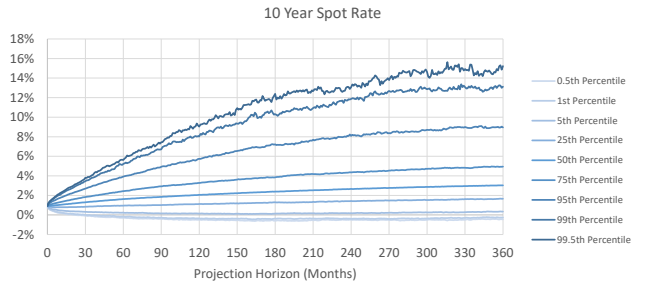
The D2FBK model can be easily parameterized in its current form to meet the success criteria set out by the NAIC for interest rate modeling without the need to alter the structure of the model or sacrifice other important characteristics of the model output. These include the stability of the distribution of rates across different calibration dates, the ability of the model to project realistic risk/return profiles of government bonds and the ability of the model to accurately capture target average paths for the projection of different points on the yield curve.

The table below illustrates the flexibility of the D2FBK model by illustrating an end-Dec 2020 calibration. This highlights that the calibration criteria specified by the NAIC can be comfortably met by this type of interest rate model without the need for ad hoc adaptations to the model structure.

'Low for Long': At least 10% of Scenarios should have a 10-year geometric average of the 20-year UST that is below the initial rate and at least 5% of Scenarios should have a 30-year geometric average of the 20-year UST that is below the initial rate.	Moody's Comment: The chart below shows the proportion of 20-year treasury rates that are below the initial 20-year rate when we consider a geometric average over a 10 year and 30 year time horizon. It is important to note that these metrics are strongly dependent on the choice of calibration approach for the volatiltiy and dispersion of long term interest rates in any model. The validations below are based on calibrations to a global data set, however by choosing a more US-centric data set as a basis for the calibration will lead to validation statistics close to the 10% and 5% thresholds the NAIC have specified. PASS
	

'Prevalence of High Rates': (a) The scenario set should reasonably reflect history with some allowance for more extreme and low interest rate environments. (b) Upper Bound (i) 20% is >=99th percentile 3M yield fan chart, and no more than 5% of scenarios have 3M yields that go above 20% in the first 30 years. (ii) 20% is >=99th percentile 10Y yield fan chart, and no more than 5% of scenarios have 10Y yields that go above 20% in the first 30 years.	Moody's Comment: (a) The distributional targets (volality and disperson) for both short maturity and long maturirty rates are set using available historical data from around 30 economies covering periods of high and low/negative rates. PASS (b) (i) See charts below for 3-month Spot Rate percentile distribution covering the 0.5th to the 99.5th percentiles. PASS (b) (ii) See charts below for 10-year Spot Rate percentile distribution covering the 0.5th to the 99.5th percentiles. PASS





'Lower Bound on Negative Rates, Arbitrage-Free Considerations

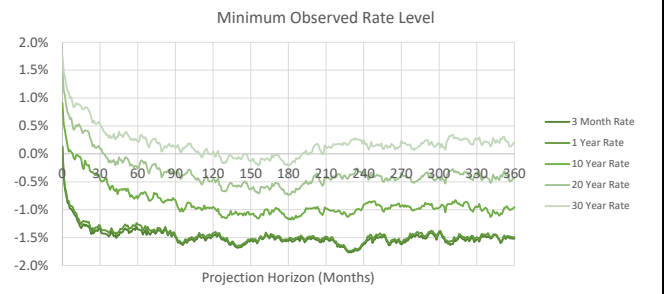
(a) All maturities could expereience negative rates
(b) Interest rates may remain negative for multi-year time periods.
(c) Rates should generally not be lower than -1.5%

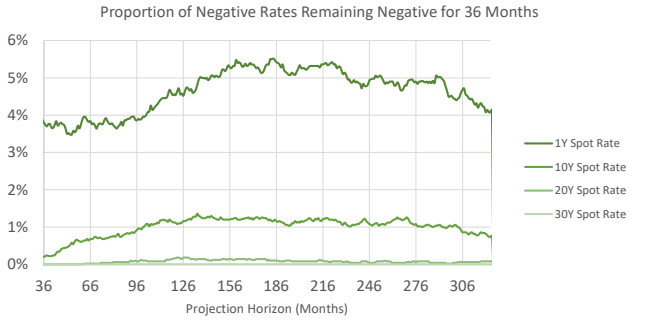
Moody's Comment:

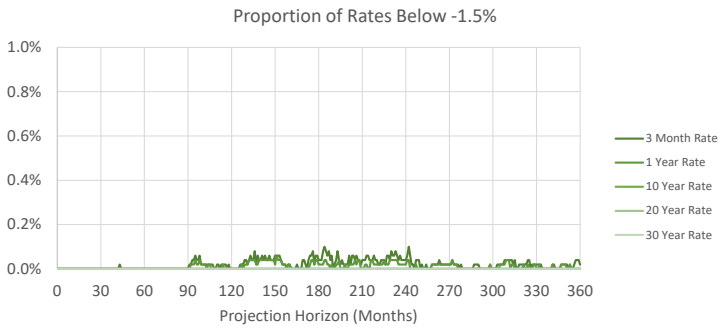
(a) As can be seen in the chart below, the minmum observed interest rate for all maturities 1 to 20 years is negative. With the 30 year matuirty rates very close to zero. PASS

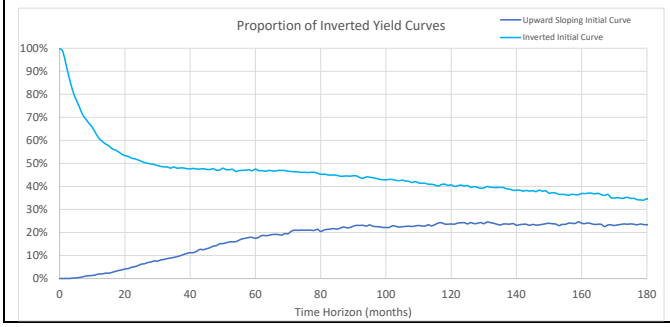
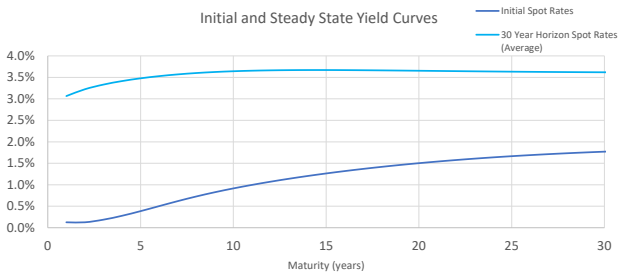
(b) The chart below highlights the proportion of negative rates that are persistently negative for at least 36 months. PASS

(c) The chart below highlights that only a very small proportion of rates < 0.1% are below -1.5% PASS







Initial Yield Curve, Yield Curve Shapes and the Steady-State Yield Curve: (a) Review initial actual vs.fitted spot curve differences (b) The frequency of yield curve shapes in early durations should be reasonable considering the shape of the starting yield curve. (c) The steady state curve has normal shape (not inverted for short maturities, longer vs shorter maturities, or between long maturities.)	Moody's Comment: (a) The model uses the spot rate curve as a direct input and hence the model exactly replicates any specified spot curve. PASS (b) The average path of modelled rates of different maturities is targeted such that the market-implied path of rates is closely followed over the first few years of the projection. This results in yield curves shapes at short time horizons that are strongly informed by the shape of the initial market yield curve. The chart below highlights the level of inversions observed in the model for a strongly inverted initial curve and an upward sloping curve over different time horizons. PASS (c) The initial and long-term steady state curve are shown below. The steady curve has an upward sloping shape PASS
	

The D2FBK model illustrated here is just one example of a model that is well suited to the calibration criteria that the NAIC have specified. However, it is important to note that there may be other models that are able to meet the criteria without the need for an adjustment/flooring mechanism that disrupts the original model dynamics.

The NAIC could consider allowing some flexibility in the choice of model that insurers are allowed to use in these calculations. Such flexibility may enable insurers who are currently using stochastic models to have continuity in their modeling and calibration approach (provide they meet the NAIC specified criteria). This has the added benefit of enabling insurers to use the same interest rate model for different applications within the same company (e.g. pricing, business planning, strategic asset allocation exercises, 1-year VaR solvency calculations etc.). The alternative would require insurers to use a simple model for the reserves and capital calculation. However, the limitations of the model would prevent them using it for other business decisions due to the unrealistic dynamics or assumptions. We believe that the NAIC could consider allowing insurers to choose their own interest rate model for inclusion in the forthcoming field test providing it meets all of the specified calibration/validation criteria.

Additional interest Rate Model Validation Criteria

The NAIC has focused on some of the key validation criteria around the performance of the rate distribution and dynamics. If the NAIC is looking to adjust the CIR model to constrain the floor it is important to broaden the validation of the model to cover a wider set of outputs. This will help ensure the model is behaving coherently when the rates are used to calculate asset returns for government bond strategies.

The following additional validation tests would allow the NAIC to demonstrate the robustness of the asset returns and help provide insight into the impact of the model changes on the arbitrage-free properties of the model.

» Martingale Tests – Scenario sets can be produced where the risk premiums (term premiums) in the model are set to zero. An asset martingale test can be performed on bond portfolio strategies of different maturities (e.g. 1, 3, 5, 10 ,15, 20, 25, 30-year maturities, with either zero-coupon or bond-at-par coupon assumptions). It should be observed that all portfolios return the same as the risk-free rate on average.

» Asset Return Tests – This would cover the validation of the expected return and volatility of asset portfolios of 1, 3, 5, 10, 15, 20, 25, 30-year maturity bond portfolios. This allows the NAIC to assess the relative behavior and stability of expected returns and volatilities from one valuation date to the next.

In addition to these tests the stability of the model outcomes could be impacted by the introduction of a floor. The NAIC could benefit from assessing the stability of the distributions, asset returns and ultimately the capital and reserves under different input assumptions or initial conditions. For example, the NAIC could gain confidence in the robust nature of the model by considering the following validation examples.

» Assessment and comparison the distributions, asset returns and modeling outcomes (capital and reserves) on multiple valuation dates and under stresses to the initial conditions:

    - Extreme high and low historical yield curve from across the globe (Germany, Switzerland, Japan, South Africa, etc…)
    - Ad hoc stresses to the initial conditions of the model e.g. plus/minus 50 or 100 basis points to the initial curves.

We appreciate the range of possible validation criteria can be extensive, but it would add clarity to the model performance and impact of the flooring adjustment if the NAIC could present validation analysis of this nature.

Equity Modeling

The equity modeling approach proposed by the NAIC – where the equity returns are based on a constant equity risk premium in excess of a risk free (short term Treasury rate) coupled with a stochastic process for excess returns - is similar to the modeling approaches considered by many insurers globally. This approach is relatively straight forward and allows insurers to set a clear assumption on the equity risk premium and to incorporate this into the modeling in a direct and transparent manner.

Where firms are looking to go beyond this modeling approach, we have seen insurers look to incorporate a dynamic equity risk premium that accounts for the over (or under) pricing of the equity market. For example, this dynamic equity risk premium would vary through the projections i.e. in each scenario where the equity price grows strongly the equity risk premium reduces and when the equity market falls sharply the equity risk premium increases. This provides a few added benefits to the modeling:

» The total average return in equity is no longer a function of interest rates and a constant risk premium. In addition to these two components the risk premium will change depending on a dynamic risk premium component which is linked to a view on whether the market is over/under priced.

» The average risk premium over the first few years of the projection can change from one valuation period to the next leading to a more direct conditional view on the performance of equities relative to fixed income assets. The short-term risk premium can go up or down depending on the market conditions.

» The dynamic equity risk premium approach will narrow the extreme tails of the cumulative return distributions (both on the upside and the downside) as the extreme scenarios where markets grow will be associated with a lower subsequent equity risk premium and scenarios where the market falls will be associated with a higher equity risk premium.

Naturally the challenges with the dynamic equity risk premium approach relate to the choice of model and mechanism to set the level of over/under pricing in the equity market. In addition, the assumption and calibration of the model may require some expert judgement (rather than a purely data driven approach) as there is not an academic consensus on a single modeling approach or assumption set governing these dynamics of the equity risk premium. The literature in this area can be quite broad and varied.

In general, the most appropriate approach to equity risk premium modeling is dependent on the nature of the insurance product and the specifics of the risk/capital/reserving calculations. We have seen a mix of the constant risk premium and dynamic equity risk premium approach used by institutions globally.

Credit Modeling

The credit modeling documentation shared last year by the NAIC alluded to a complex model with several different model structures (e.g. spread, defaults, rating transitions etc…) that appeared more complex (both in terms of model dynamics and calibration) than the interest rate and equity models.

In general, we would advocate for as much transparency as possible, and the importance of this transparency increases when using more complex models which may embed strong and material assumptions.

If it is not possible for the NAIC to share further documentation on the corporate model that is under consideration, then we would suggest the NAIC consider adopting an alternative more streamlined corporate model. It should be noted that the current AIRG Generator corporate fund model (that includes a simple credit return adjustment) could be used in conjunction with the NAIC's new interest rate and equity model choices.

In addition, the current scenario set requirements are based on producing fund returns for a set of corporate bond funds – rather than the need for a full stochastic projection of spreads, transition and defaults. The key requirements could be focused on ensuring that

- The model captures an appropriate level of conditionality on current market conditions, i.e. it captures current spread levels and hence return levels for the funds
- The model is successful in quantifying a reasonable level of asset return volatility and correlation of other risk factors which may not necessitate a complex modeling approach.

For certain applications having granular information about the movement of spreads, transitions and defaults at individual bond/sector/country level can be critical for quantifying asset risk and diversification across ratings and maturities. However, this might not be a key requirement if the focus is solely on asset return modeling for a small number of corporate bond portfolios.

We are aware that the ESG Drafting Group is considering other modeling options and we value any options that support full transparency on the model, calibration methods, assumptions and validation performance of the corporate model.

Summary

We have discussed the NAIC's proposed approach to interest rate and equity modeling, along with the corporate bond model, and would highlight the following suggestions for consideration by the NAIC.

- We respectfully request consideration for using alternative Treasury model representations in the field study that meet the NAIC calibration requirements. This could be achieved by allowing insurers to use additional scenario sets as part of the field test based on alternative models that meet the NAICs calibration criteria. Alternatively, the NAIC could consider providing additional static sets of scenarios for each of the field testing valuation dates covering alternative model choices. This may help demonstrate to regulators that defining a prescribed set of Treasury model acceptance criteria may be considered, rather than prescribing any single Treasury model that may have some limitations.
- Furthermore, we would highlight the benefits to the NAIC of broadening the validation assessment criteria of the scenarios to include assessment of the impact of the calibration/model choice on bond portfolio asset returns that are derived from the Treasury model scenarios.
- In addition, we would strongly encourage the NAIC to choose a model for corporate bond returns that is transparent, documented and well understood rather than an approach that is provided with no documentation on the model, calibration methods, assumption or validations of the key model features.

We greatly appreciate the opportunity to engage with the NAIC and regulators in this initiative and we are hopeful the comments and insights we have shared can be used to support the upcoming Field Test and the ESG Working Group's activities.

Sincerely,

Jack Cheyne PhD
Senior Director - Scenario Generator Product Management,
Moody's Analytics