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RISK SOLUTIONS | WHITE PAPER

Parameter Stability in Unstable Markets

by Matthew Lightwood, Ph.D.

Introduction

When selecting or reviewing the choice of economic scenario generator, one aspect of validation that is often overlooked is parameter stability, and yet the ability of a single set of model parameters to perform consistently in both normal and stressed market environments may be one of the most important ways of assessing the robustness and appropriateness of an economic scenario generator to modeling the future economic and investment environment.

The inflation and interest rate shocks of 2022 are a case in point. These shocks led to increased volatility and uncertainty after a long period of low interest rates and moderate inflation, throwing into the spotlight the limitations of modeling and target-setting approaches that focus solely on the "lower for longer" narrative. In particular, the inability of modeling processes based heavily on the last 5 to 15 years of data (i.e., post-2008) to accurately represent realized risk distributions has required many modelers to drastically reparameterize their models to the new reality.

The effect of these changes on model output and downstream risk capital calculations reaches far beyond mere academic interest. In many situations, there are tangible operational ramifications too, such as managing dramatic shifts in the risk capital assessments of insurers' internal models. As a result, there has been a renewed focus on the importance of parameter stability in financial modeling. By ensuring that parameters are stable and accurately reflect the persistent underlying conditions of the market, financial models should be more robust and better equipped to handle future unexpected changes in the economic environment.

In this whitepaper, we discuss why parameter stability is important and consider the relative robustness of "point-in-time" and "through-the-cycle" parameterizations with respect to this issue.

Why is parameter stability important in financial modeling?

Parameter stability is a vital aspect of risk modeling for insurers because it directly affects the accuracy and reliability of the model, as well as the stability of risk capital calculations. A stable model ensures that the results and predictions generated by the model are consistent and reliable, which is crucial for making informed decisions about the magnitude and materiality of a range of risks. Overall, parameter stability is essential for ensuring that the risk model provides accurate and reliable insights that can be used to make informed decisions about risk through time.

Additionally, parameter stability is a good indication that a model is well specified. If the aim of a model is to adequately represent the true data-generating process of the system under consideration, then it will be considered well specified if its parameters are in some broad sense significant and meaningful. Conversely, if the parameters of the model require frequent adjustments to perform well, then it may be an indication that it is a poor representation of the system. This may prompt the user to consider alternative approaches that are better suited to the problem at hand.

The issue of model change is particularly pertinent for insurance companies in Europe and the United Kingdom under the Solvency II regime and equivalent frameworks. Wholesale reparameterization of a model is likely to constitute a major model change, and major changes to an internal model are subject to prior supervisory approval as stated by EIOPA and laid down in Article 112 of the Solvency II directive. This process is both time-consuming and complex from a testing, documentation, and human resourcing perspective. As such, model changes of this type are best reserved for cases of model improvement rather than short-term imperative.

How does parameter instability arise?

There are several factors which contribute to parameter instability in risk models. These include:

- **Parameterization and calibration algorithms** — If not carefully implemented, the algorithms and techniques for parameterizing a model may lead to significant parameter instability even for small perturbations in the data.
- **Quality and completeness of the data used to train the model** — A model that is parameterized using data that accurately reflects the underlying risks is more likely to be stable and produce reliable results.
- **Model specification** — A model's ability to generalize to new data and its ability to handle changes in the underlying risks over time is important.
- **Target setting** — When building a model, it is often preferable to constrain the statistical properties of simulated risk distributions using a set of assumptions or targets. Target-setting processes which lead to unstable targets over time are more likely to suffer from significant fluctuations in model parameters.

Overall, a combination of high-quality data, robust algorithms, and the ability to adapt to changes in the underlying risks are key factors that contribute to parameter stability in risk models.

Parameter Stability and Performance: A Comparison of Point-in-Time and Through-the-Cycle Methodologies

The differences between so called point-in-time and through-the-cycle model parameterizations have been much discussed in insurance and pension fund risk modeling. Point-in-time parameterizations assume that the future state of the modeled system will be consistent with the current situation or consensus view on the market; on the other hand, through-the-cycle parameterizations attempt to base model output on assumed long-term average or stable behavior.

Traditionally it has been assumed that point-in-time modeling is more appropriate to shorter modeling time horizons (e.g., 1 month or 1 year), whilst through-the-cycle is better suited to medium- and long-term modeling tasks such as strategic asset allocation (SAA). However, recent experience has led many to reassess this view. The double crisis of the COVID-19 pandemic and the war in Ukraine, and the subsequent uptick in interest rate and inflation levels and volatility, has precipitated widespread failure of point-in-time models to adequately span the realized risk distributions. Simultaneously, these models have required significant reparameterization, resulting in parameter instability, with all the drawbacks that that entails.

To demonstrate the extent of the problem, we compare these two commonly used approaches to parameterizing interest rate models by estimation based on the following methodologies:

- **Point-in-Time (PIT)** — The mean yield curve at the one-year horizon is simulated to match the market-implied forward curve at the calibration date. The volatility is based on the historical volatility over the previous five years. To balance the need for capturing the current volatility environment with parameter stability, the volatility target is only changed if it increases or decreases by more than 5% relative to the previous target.
- **Through-the-Cycle (TTC)** — Yields are fitted to the prevailing market conditions and then allowed to revert to a stable set of long-term targets for the mean and standard deviations based on the last 25 to 30 years of data. Behavior at intermediate time horizons such as the one-year are determined by the trajectory from the initial market curve to these long-term targets. Typically, parameter stability is built-in and model inputs change infrequently over time.

The two approaches are compared based on a test spanning the thirteen quarters between December 31st, 2019, and December 31st, 2022, using output from a three-factor Cox-Ingersoll-Ross model of the form:

$$dX_i(t) = (\theta_i - \kappa_i X_i(t))dt + \sigma_i \sqrt{X_i(t)} dW_i(t)$$

Where, κ_i, θ_i and σ_i are the model parameters which control the evolution of each of the three state variables, $X_i(t)$. We can say that parameter stability has been achieved when κ_i, θ_i and σ_i remain constant through the test period.

The test compares the point-in-time and through-the-cycle methodologies described above, comparing the performance of these models for the US economy, in terms of their ability to span the market outcomes one year ahead as well as parameter stability.

The simulated 1-year-ahead distributions of both the through-the-cycle (green color scale) and point-in-time (grey color scale) parameterizations are shown in **Figure 1** for different parameterisation dates and points on the yield curve. Also shown is the realized market value of the yield one year in the future from the parameterization date.

Firstly, we observe that whilst the mean of the TTC parameterisation fluctuates according to changes in the initial yield curve, the width of the simulated distribution is relatively stable over time. This contrasts with the PIT parameterization, where for different tenors we observe significant changes in the risk distributions through time, usually corresponding to market dislocations and crises (e.g., the 3-month yield in 2020Q1 and the 5- and 10-year yields in 2021Q3). Perhaps more problematic is that whilst both approaches have limitations in terms of being able to capture the entirety of the yield curve movements at the 1-year horizon, the TTC consistently outperforms the PIT parameterization over this test period. Despite frequently reparameterizing the PIT models to the new market reality, the realized value one year ahead was outside of the 0.5th or 99.5th percentile on 13 occasions, almost twice as frequently as the TTC parameterization.

The through-the-cycle parameterization also has the feature of absolute parameter stability; in other words, the parameters of the model did not change at all through the test period. By design, the opposite is true of point-in-time parameterizations, which must always be updated to reflect the new forward curve and the changes to market volatility assumptions. **Figure 2** shows the magnitude of the parameter changes over time required to keep the United States model aligned with the underlying assumptions of the point-in-time methodology.

The result shows the percentage change in the parameter value through time for each of the three state variables defined in the equation above. We note that some highly significant changes to model parameters were intermittently required. In particular, we observed some significant parameter instability as interest rates moved at the onset of the COVID-19 pandemic (2020Q1 and 2020Q2) and through the tail end of 2022. This parameter instability coincided with more frequent failures of the point-in-time parameterization to adequately capture the unfolding events. This implies that users of this point-in-time approach would have been subjected to the dual issues of poor model performance and parameter instability at precisely the time when the robustness of risk management processes was critical.

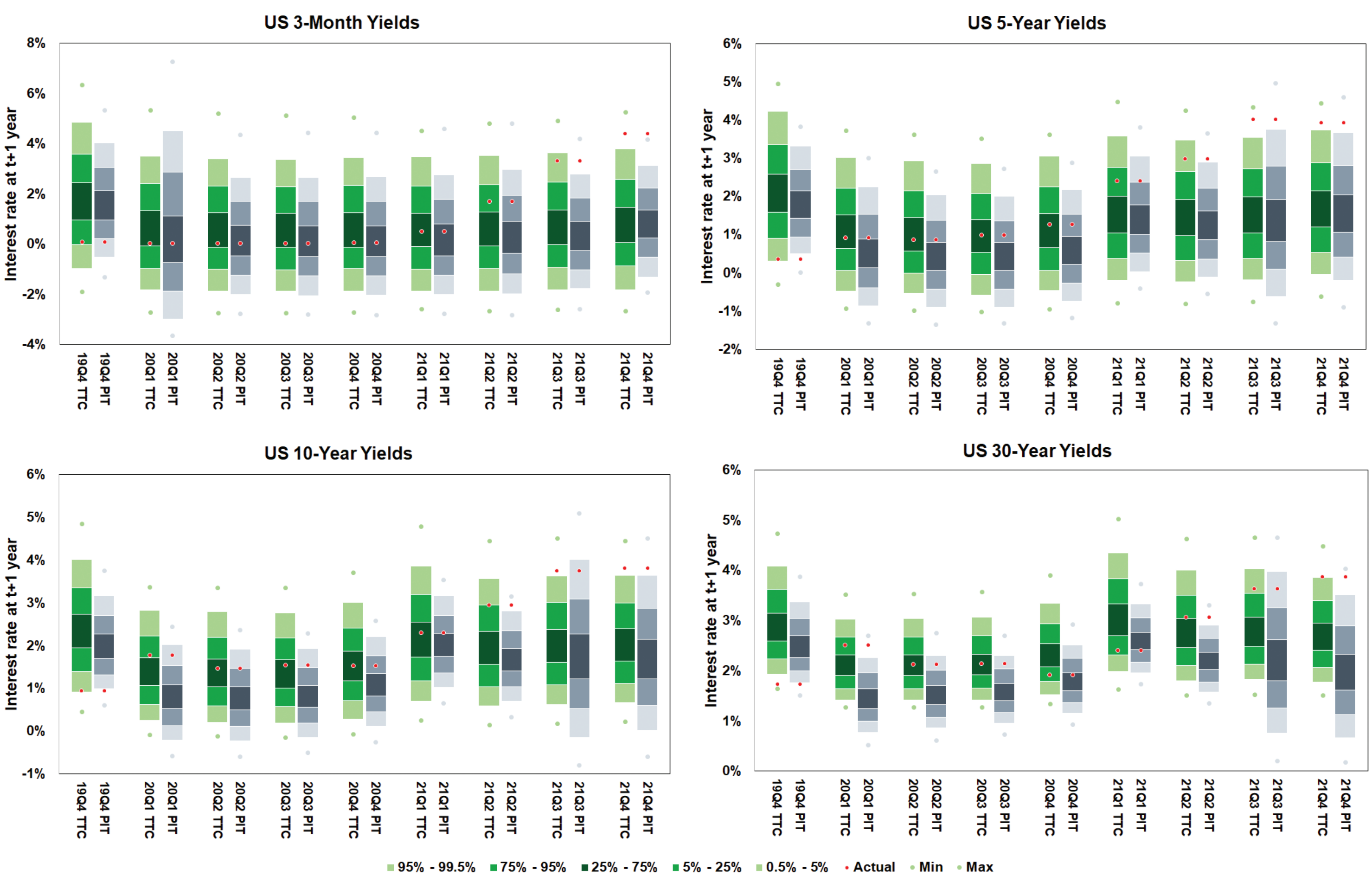

Figure 1: Simulated one-year-ahead distributions of a through-the-cycle (TTC) (green scale) and point-in-time (PIT) (grey scale) parameterization of United States Treasury yields, compared to the realized market value of yields one year in the future from the parametrization date (red dot). Prepared by Conning, Inc., Sources: ©2023 Conning, Inc. and ©2023 Bloomberg, L.P.

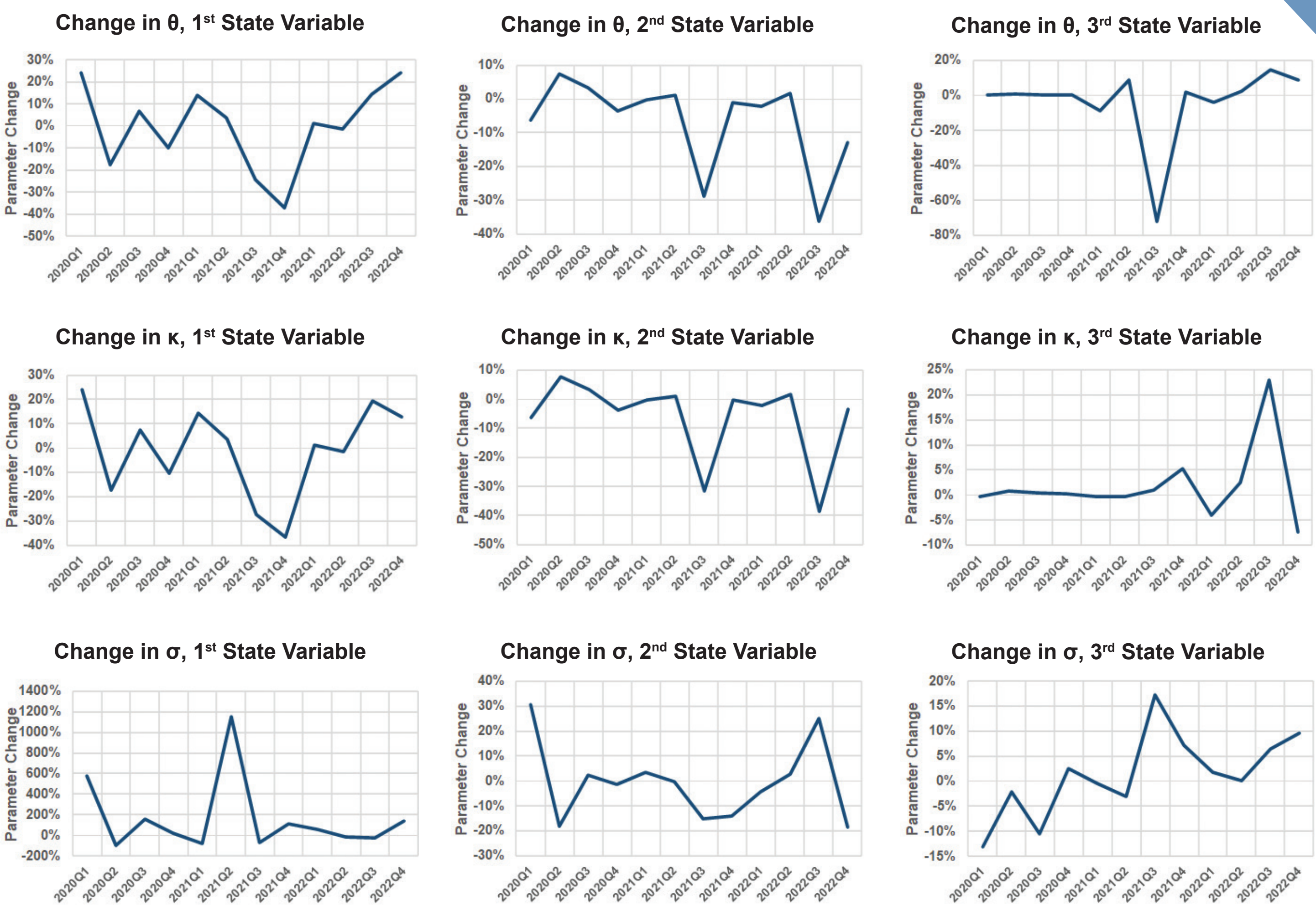

Figure 2: The change in the value of model parameters through time for the point-in-time parameterization of a 3-factor Cox, Ingersoll, Ross interest rate model for the US economy. The change is expressed as a percentage increase or decrease in the parameter value relative to the previous quarter. The through-the-cycle parameterization had stable parameters (i.e., parameter change = 0) for the entire test period. Prepared by Conning, Inc., Source: ©2023 Conning, Inc.

Summary

In choosing a model and parameterization methodology for a particular purpose, parameter stability is often overlooked as a critical factor in the practical application of stochastic models. Yet it is only during periods where stable and reliable model output is most needed, namely during market turmoil, that the practical implications of parameter stability become clear. A degree of parameter instability could perhaps be justified if it demonstrably led to improved model performance. However, recent crises and events have made clear that point-in-time approaches, which assume the future will look like the present or recent past are, by design, destined to fail during market dislocations.

This is perhaps most starkly illustrated by the widely held belief that interest rates would remain "lower for longer." Through-the-cycle parameterizations, which incorporated low and negative interest rate levels as part of the simulated distributions but rejected it as the central assumption, have significantly outperformed point-in-time models in the last three years. The GEMS® Expert View Parameterization from Conning is one such through-the-cycle calibration, with parameter stability as a stated design criteria since its inception. Across multiple asset classes and global currency regions the models have performed consistently well in both normal and crisis conditions. Following a well-defined and documented procedure for target setting, the GEMS® Expert View Parameterization successfully balances the need for robust model performance with parameter stability across interest rates, credit spreads, inflation and many more asset types. As demonstrated in this whitepaper, the GEMS® Expert View Parameterization methodology resulted in output that consistently captured extreme market outcomes and with few exceptions required no reparameterization of the core models either post-2020 or 2022.

About GEMS® Economic Scenario Generator

Conning's GEMS® Economic Scenario Generator is a state-of-the-art stochastic economic scenario generator with leading-edge economic and financial models, including alternative assets and a wide range of derivatives. GEMS® provides a comprehensive analysis of the risks that firms face, the relationship between those risks, and the potential rewards in retaining them. GEMS® Economic Scenario Generator offers both real-world and risk-neutral functionality and supports integrated economies and capital markets in North and South America, Europe, Asia, and Australia. The software comes with a comprehensive set of parameterized asset classes that is unrivaled by other ESGs, and further asset classes can easily be added through built-in system functionality.

GEMS® Economic Scenario Generator is distinguished by its ability to simulate realistic tail risk events due to the structure of the stochastic models and the methodology used to calibrate the models. Additionally, the modeled correlation between variables within GEMS® means that its simulations are robust and consistent within economies, across economies, and over multiple time horizons.

About the Author

Matthew Lightwood, Ph.D, BSC (HONS), is a Director at Conning where he is responsible for product management, quantitative modeling and providing technical expertise in economic modeling to support both prospective and new clients using the GEMS® Economic Scenario Generator. Prior to joining Conning in 2010, he was employed as a Senior Risk Consultant, where he was responsible for financial modeling as well as managing and implementing large professional services projects for financial clients. Matthew is a graduate of the University of Manchester and University College London, where he earned a BSC (HONS) in Physics with Astrophysics and a Ph.D in High Energy Particle Physics.

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