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FOR IMMEDIATE RELEASE

New Research Paper from Kamakura Proves 1-factor Interest Rate Risk Models Underestimate Risk by 61% to 83%

Both 1-factor and "Best Practice" Models Use Modern HJM Approach

New York, March 30, 2021: Kamakura Corporation announced to today that it has released a new research paper which proves widely used 1-factor interest rate models underestimate interest rate risk by 61% to 83% percent. The research paper was prepared under the direction of Kamakura Managing Director for Research Prof. Robert A. Jarrow. The paper compares a base model using 10 factors for the U.S. Treasury yield curve with a very sophisticated 1-factor model that outperforms the commonly used 1-factor models in many risk systems. Both models are benchmarked so that 500,000 Monte Carlo scenarios perfectly price the entire U.S. Treasury curve for any number of 91-day time steps over a 30-year horizon. The first factor in both models has the same coefficient values. Both models allow negative rates, produce both risk-neutral (for valuation) and empirical interest rates (for net income simulation), show positive volatility at zero and negative rates, and show volatility that rises as rate levels rise until a ceiling required for no-arbitrage as in Heath, Jarrow and Morton's ("HJM") classic 1992 paper in Econometrica. A copy of the research paper is available at this link:

https://www.kamakuraco.com/2021/03/24/model-validation-proof-that-1-factor-interest-rate-models-underestimate-risk-by-61-to-83/

Martin Zorn, President and Chief Operating Officer of Kamakura Corporation, said Tuesday, "For more than 30 years, Professor Jarrow has pioneered the use of multi-factor models in a no-arbitrage framework. Many banks, however, have continued to rely on 1-factor models for enterprise risk management and total balance sheet risk management for two reasons. First, many risk managers have been unaware of the model validation

problems with one factor models. Second, they rely on legacy systems which cannot efficiently generate no-arbitrage scenarios using multiple factors. This research paper addresses the first issue very clearly. It shows that a best practice 1-factor model will always underestimate real interest rate risk levels as captured by a "true" model that uses all statistically significant variables which drive a particular yield curve. For the base model, the paper uses the current version of Kamakura's 10-factor Heath Jarrow and Morton model for U.S. Treasuries that was released to clients last week."

A link to the U.S. Treasury HJM model is available here.

The research paper was authored by Kamakura founder and CEO Dr. Donald van Deventer with assistance from Daniel Dickler, Theodore Spradlin, and Dr. Xiaoming Wang. A comparison of 1-factor with "all factor" models and a comparison of "one country" models with "all country" models are a standard part of Kamakura's model validation practice. Kamakura Risk Manager has had multiple factor yield curve model simulation capability for more than two decades. Model validation, however, also relies on third-party statistical software to assure that the results are truly "vendor independent" research results.

The data used to benchmark both models was published by the U.S. Department of the Treasury. The daily time series used spans the period from January 2, 1962 through December 31, 2020. Both models use overlapping 91-day time steps with proper adjustment for heteroskedasticity and autocorrelation using generalized linear models subject to "HJM" no arbitrage constraints.

About Kamakura Term Structure Models in KRIS and KRM

The updated Kamakura World and 13-country term structure models provide a more realistic roadmap for predicting the future than a simple extrapolation from current yields, since the models incorporate 88,132 daily observations on government yield movements. The model documentation includes a significant section on Bayesian model validation, in which 500,000 out-of-sample scenarios were used to measure the consistency of the model's predictions, taking into account both expert knowledge and the history of interest rate movements worldwide.

The Bayesian process of model fitting, simulation, and revision is both analytically elegant and eminently practical. The model documentation for the HJM models shows realistic variation in both risk-neutral and empirical interest rates over time. The simulation is consistent with worldwide experience with both negative rates and historical bouts with high levels of inflation and high interest rates.

The Kamakura standard Bayesian out-of-sample model validation provides assurance to risk managers, auditors, regulators and boards of directors that the interest rate simulation technology used in Kamakura Risk Information Services (KRIS) and Kamakura

Risk Manager (KRM) sets a new standard for industry best practice and is exceptionally realistic.

Kamakura's analytical team regularly updates term structure models from all major markets around the world. Model documentation and parameters are available by subscription to Kamakura Risk Information Services' default probability and bond information services. The models are used to mark-to-market observable securities prices for cross-validation on a daily basis under the director of Dr. van Deventer. They provide the basis for very high scenario simulation of correlated risks and for interest rate factor-driven and other macro-factor-driven stress tests using Kamakura Risk Manager, both with and without default modeling.

About Kamakura Corporation

Founded in 1990, Honolulu-based Kamakura Corporation is a leading provider of risk management information, processing, and software. Kamakura was recognized as a category leader in the Chartis Report, Technology Solutions for Credit Risk 2.0 2018. Kamakura was named to the World Finance 100 by the editor and readers of World Finance magazine in 2017, 2016 and 2012. In 2010, Kamakura was the only vendor to win two Credit Magazine innovation awards., Kamakura Risk Manager, first sold commercially in 1993 and now in version 10.1, is the first enterprise risk management system for users focused on credit risk, asset and liability management, market risk, stress testing, liquidity risk, counterparty credit risk, and capital allocation from a single software solution. The KRIS public firm default service was launched in 2002. The KRIS sovereign default service, the world's first, was launched in 2008, and the KRIS non-public firm default service was offered beginning in 2011. Kamakura added its U.S. Bank default probability service in 2014.

Kamakura has served more than 330 clients with assets ranging in size from $1.5 billion to $7.0 trillion. Current clients have a combined "total assets" or "assets under management" in excess of $28 trillion. Its risk management products are currently used in 47 countries, including the United States, Canada, Germany, the Netherlands, France, Austria, Switzerland, the United Kingdom, Russia, Ukraine, South Africa, Australia, China, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Singapore, Sri Lanka, Taiwan, Thailand, Vietnam, and many other countries in Asia, Europe and the Middle East.

To follow risk commentary by Kamakura on a daily basis, please follow:

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