

Kamakura
Corporation

KAMAKURA

RISK INFORMATION SERVICES

Kamakura U.S. Bank Model

Version 1.0

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Kamakura U.S. Bank Model Introduction

Kamakura Corporation first introduced its Kamakura Risk Information Services (“KRIS”) public firm model in 2002. The public firm model, now on version 5.0, is used by governments, regulators, banks, insurance firms and fund managers all over the world. The public firm model was followed by the KRIS sovereign default probability model, the world’s first, and then by the KRIS non-public firm model. KRIS models performed very well in the credit crisis, even on a completely out of sample basis. Because of this success and given the large number of failures in the financial services sector, clients asked that a U.S. bank-specific model be developed to supplement the existing public firm model. Kamakura Corporation was exceptionally well prepared to take on this task. Prof. Robert Jarrow, Kamakura Managing Director for Research since 1995, also serves as a senior fellow at the U.S. Federal Deposit Insurance Corporation.

In addition, almost without exception, Kamakura Corporation senior management has extensive banking or insurance experience. Kamakura senior managers have served as chief operating officer, chief financial officer, treasurer, major corporate lending group head, high technology lending group head, derivatives trading manager, asset and liability management and transfer pricing manager, and many other roles. This experience enables Kamakura Corporation to combine very extensive industry-specific knowledge with its industry leading default probability expertise.

The Kamakura default models provide investors, investment managers, dealers, traders, lenders, and auditors a simple, objective means of assessing the credit quality of public firms, non-public firms, sovereigns, and now the non-public bank subsidiaries of publicly traded bank holding companies. Bank credit quality is measured directly by the probability of default of the bank over a full term structure of time horizons. The KRIS U.S. Bank Model is both a “point in time” default probability service and a “through the cycle” default probability service because default probabilities are generated that apply to a horizon of many years.

The KRIS U.S. Bank Model, along with the KRIS Public Firm Model, offers many benefits to organizations that require a testable and reliable means for analyzing the credit quality of both bank subsidiaries and their publicly listed parent firms. Methodological benefits include objective quantification of default risk for both the bank subsidiaries and the parent firm, with a term structure of default by both types of entities. The KRIS model construction process makes maximum effective use of the full range of historical data that is available. Operational benefits include cost-effective high volume credit analysis across a large number of privately held banks and their public bank holding companies with very accurate assessments of default probabilities.

Individual bank default probabilities are re-evaluated and updated daily based on financial information, macroeconomic factors, industry specific attributes, and market inputs. Kamakura’s Public Firm Models provide estimates of the full term structure of default probabilities of an individual bank holding company (or non-bank public firm for that matter) based upon current financial information about the firm, the macro-economic environment, and the absolute and relative variation in the firm’s stock price. The maturities that are available are 1 month, 3 months, 6 months, 1 year, 2 years, 3 years, 5 years, 7 years, and 10 years. The KRIS U.S. Bank Model uses the same basic approach to modeling default as the public firm model, with two very important differences. First, since the banks are unlisted subsidiaries of a publicly listed bank holding company, there is no stock price information relevant to the bank specifically. Secondly, the accounting data available for the U.S. Bank Model is much more detailed and

much higher quality than the accounting data generally available for public firms. This result stems from the fact that the accounting line items are specific to a single industry, not a mix of businesses, and the accounting figures themselves are heavily scrutinized by regulators and banking industry executives.

The KRIS U.S. Bank Model and the KRIS Public Firm Models are part of the Kamakura Risk Information web-based information service, available by subscription.

Kamakura's Managing Director for Research Professor Robert Jarrow has published widely on bank default modeling as part of his role as senior fellow at the FDIC. In the remainder of this section, we summarize the highlights of selected publications in this topic.

Rosalind Bennett, Daniel Nuxoll, Robert Jarrow, Michael Fu, and Huiju Zhang, "A Loss Default Simulation Model of the Federal Bank Deposit Insurance Funds," Proceedings of the 2005 Winter Simulation Conference, M. E. Kuhl, N.M. Steiger, F. B. Armstrong, and J. A. Joines, editors, Federal Deposit Insurance Corporation.

This paper discusses a simulation model that is used in a martingale valuation approach to measure and value the risk of the FDIC deposit insurance funds. The FDIC insurance funds capitalize a portfolio of insurance policies, each issued to depositors of an individual commercial bank. To evaluate this portfolio, our methodology evaluates the insurance policies for depositors at each individual bank and aggregates to obtain the risk of the entire portfolio. To adequately model the risks associated with credit, interest rate, deposit growth, and loss rate, a multi-dimensional system is formulated. The risk measurement and valuation results are based on Monte Carlo simulation of the system risks.

Darrell Duffie, Robert Jarrow, Amiyatosh Purnanandam, Wei Yang, "Market Pricing of Deposit Insurance," Journal of Financial Services Research, 24:2/3 93-119, 2003.

We provide an approach to the market valuation of deposit insurance that is based on reduced-form methods for the pricing of fixed income securities under default risk. By reference to bank debt prices as well as qualitative-response models of the probability of bank failure, we suggest how a risk-neutral valuation model for deposit insurance can be applied both to the calculation of fair-market deposit insurance premia and to the valuation of long-term claims against the insurer.

Robert A. Jarrow, Rosalind L. Bennett, Michael C. Fu, Daniel A. Nuxoll, and Huiju Zhang, "A General Martingale Approach to Measuring and Valuing the Risk to the FDIC Deposit Insurance Funds," Federal Deposit Insurance Corporation Memorandum, November 24, 2003.

This paper presents a general methodology for measuring and valuing the risk of the FDIC deposit insurance funds using the martingale valuation approach. The FDIC insurance funds capitalize a portfolio of insurance policies, each issued against the deposits of an individual commercial bank. To evaluate this portfolio, our methodology evaluates each individual bank's insurance policy and aggregates to obtain the risk of the entire portfolio. Our methodology includes the four relevant risks: interest rate, credit, deposit growth, and loss. To adequately model these four correlated risks, a multi-dimensional system is formulated. The risk measurement and valuation results are based on Monte Carlo simulation. The resulting methodology is flexible and easily modified to incorporate extensions and generalizations.

The KRIS U.S. Bank Model (KDP-BK1) produces current and historical default probabilities for all banks insured by the FDIC. The model has been developed over a 3 year period and has a number of important features that reflect the 11 years of experience since the 2003 publication of the FDIC Loss Distribution Model mentioned in the paragraph above. First, the model reflects the full credit crisis experience, so the data set is more current and has a richer set of failed institutions than was available in 2003. Second, the model reflects the important role of macro-economic factors as drivers of bank defaults. This is consistent with the FDIC Loss Distribution Model, but the understanding of the role of macro-factors by market participants is much more sophisticated because of the credit crisis experience.

The stress testing of the Federal Reserve's 2014 Comprehensive Capital Assessment and Review program and the Dodd-Frank Act Stress Tests are facilitated because the 28 macro-economic factors used by the Fed stress tests have been considered as candidate variables. The KRIS U.S. Bank Model also includes insights from the KRIS public firm model that were not available to researchers at the FDIC in 2003.

Note also that the CAMEL rating, the confidential regulatory safety and soundness rating, was available to the FDIC researchers but is not available to third parties like Kamakura Corporation. Kamakura Corporation believes that the U.S. Bank Model default probabilities would outperform the CAMEL ratings as "early warnings" of failure but that hypothesis can only be fully tested with the assistance of regulators with access to the CAMEL ratings. That work is in progress.

II. Kamakura U.S. Bank Model Benefits

Benefits of the Kamakura Public Firm Models
Comparing and Ranking Firm Creditworthiness Compare bank default probabilities to determine relative creditworthiness of current and potential counterparties.
Modeling Correlated Default in CDOs and Portfolios Use bank and other default probabilities and default correlations to more realistically model “tail risk” from default in CDOs, trust preferreds, and portfolios of bonds or loans.
Assisting Credit Approval Decisions Reduce credit losses by incorporating bank default probabilities into the credit approval processes.
Monitoring Changes in Firm Creditworthiness Observe changes in bank credit quality to identify credit deterioration prior to its reflection in debt market prices and other losses.
Simulating Credit-Risky Firm Defaults Use bank default models to simulate the timing of potential defaults of financial institutions on a realistically correlated basis.
Estimating Credit-Risky Firm Credit Spreads Use bank firm default models, KRIS implied spreads, and KRIS credit spread data to estimate the credit yield spread required by investors.
Valuing Credit-Risky Firm Obligations Use KRIS credit spread models and Kamakura Risk Manager valuation models to mark bank exposures to market.
Comparing Credit-Risky Trading Opportunities Compare pricing of bank debt priced using bank default probabilities vs. observed market prices.
Simulating Credit-Adjusted Cash Flows and Income Use bank credit models and instrument cash flow and income models to simulate future credit-adjusted cash flow/income.
Hedging Portfolio Value and Cash Flows Use bank default probabilities, credit spreads, correlations and valuation models to improve hedges of credit-adjusted portfolio value and cash flows.
Measuring Portfolio Value at Risk Use bank default probabilities, credit spreads, correlations and valuation models to calculate the probability distribution of credit adjusted portfolio value.
Measuring Portfolio Stochastic Cash Flow and Income Use bank default probabilities, credit spreads, correlation and valuation models to calculate the probability distribution of credit-adjusted portfolio cash flow and income.
Estimating Portfolio Regulatory and Economic Capital Use the credit-adjusted portfolio value distribution to calculate the regulatory and economic capital requirement for the portfolio.

III. Kamakura U.S. Bank Model Applications

Applications of the KRIS U.S. Bank Model and the KRIS Public Firm Model range from relatively simple analyses of firm creditworthiness to credit-adjusted valuation, economic capital calculation and cash flow and net income analyses of a firm’s obligations. Credit-adjusted portfolio risk measurement using Kamakura Risk Manager is a very common end-product of the use of KRIS default probabilities. Investment management firms can use the KRIS U.S. Bank and KRIS Public Firm Models to identify potential trading opportunities. Default probabilities produced by each of the Models can be used to rank firms with the same agency credit rating based on estimated default probabilities. Default probabilities produced by the KRIS U.S. Bank and KRIS Public Firm Models can also be used to estimate fair values for potential investments on a credit adjusted basis, and these estimates can be compared with market pricing to determine investment strategies.

Banking firms can use the KRIS U.S. Bank and KRIS Public Firm Models to satisfy their requirements for a probability of default model for their clients under the Basel II and Basel III guidelines for both the Foundation and Advanced versions of the Internal Ratings Based approaches. Since the KRIS U.S. Bank and KRIS Public Firm Models describe relationships between firm defaults and firms’ characteristics and economic conditions, they can be objectively tested for statistical significance and predictive power. The results of these tests are available to clients in the respective KRIS Technical Guides, which have been widely reviewed with regulatory agencies around the world. These test results and documentation are expressly designed to satisfy the Basel II and III requirements for an internal validation process to assess the performance of the bank’s internal rating and risk quantification systems consistently and meaningfully.

One common use of the KRIS U.S. Bank and KRIS Public Firm Models is to monitor credit quality of frequent counterparties. The graph below compares the 10 year history of the 1 year default probability for both publicly listed Bank of America Corporation (in yellow) and its unlisted subsidiary Bank of America National Association (in blue).



Dealers and other participants in the capital and derivatives markets will find the KRIS U.S. Bank and KRIS Public Firm Models useful in the analysis of both long-term credit risk and short-term settlement

risk of counterparties to their trades. Default probabilities for their counterparties can be combined with measures of future exposure to provide an estimate of expected credit losses across their trading books.

All types of organizations with credit portfolios can apply the KRIS U.S. Bank and Public Firm Models as a basis for credit-adjusted portfolio risk measures, such as value at risk, economic capital, or earnings at risk. Kamakura Risk Manager can seamlessly employ the KRIS default probabilities for this purpose. For various types of portfolio instruments, the future value, cash flows and net income of a portfolio can be simulated under alternative stochastic scenarios. The required risk measures can then be calculated using the resulting future value, cash flow and net income distributions. This allows the financial risk of large portfolios of loans, derivatives and other instruments with credit exposure to U.S. banks and international public firms to be measured and hedged. The risk measures also provide a basis for calculating the economic capital required to offset potential economic losses for a portfolio of U.S. banks and international public firm obligations.

The technical details of the KRIS U.S. Bank Model are described in the technical specifications section below. Together with the full suite of KRIS default models and Kamakura Risk Manager, subscribers can employ the world's most accurate risk management technology in a seamless and efficient manner.

IV. Kamakura U.S. Bank Model Default Probabilities

It is easiest to describe the KRIS U.S. Bank Model after a brief discussion of the KRIS Public Firm Model. Kamakura's Public Firm Models currently offer four different quantitative approaches to modeling default probabilities: two versions of the Jarrow Chava Model (KDP-jc), the Merton Structural Model (KDP-ms), and the Jarrow Merton Hybrid Model (KDP-jm). Both the fifth generation (version 5.0, released in September 2010) and the fourth generation (version 4.1, released January 9, 2006) of the Jarrow-Chava models are available on the web site at the request of the KRIS client base. All of these approaches incorporate information on market prices of firm equity and macro factors like interest rates so that current market expectations are fully reflected in the default probability estimates. The availability of multiple Public Firm Models provides subscribers with theoretically sound alternative views on the likelihood a particular firm will default.

The term structure of default probabilities is available for both the KRIS U.S. Bank Model and the KRIS Public Firm Model. The chart below compares the term structures of default for both Bank of America National Association and its listed parent Bank of America Corporation on March 31, 2009, the peak of the recent credit crisis.

CREDIT NAME CREDIT PORTFOLIO MACRO FACTOR SENSITIVITY PORTFOLIO MANAGEMENT Hello: dvd | Logout

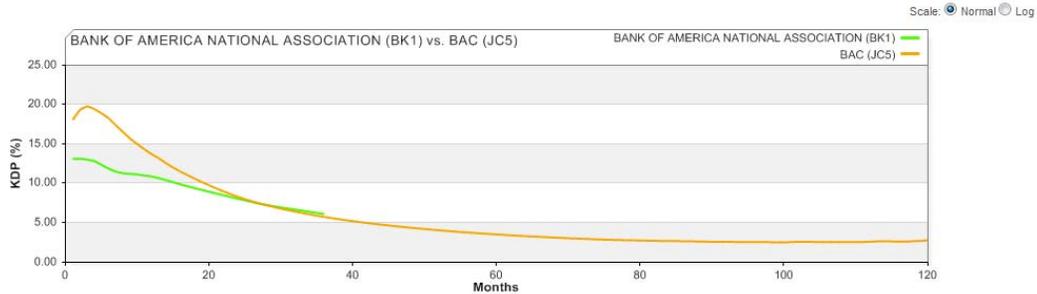
Overview Default Probabilities Bond Spreads Implied CDS Spreads Implied Rating Chart Watch List Download

Credit Class Bank Status Active Location NC Bank Bank of America National Association Go Date 2009 Mar 31 Term Annualized

BANK OF AMERICA NATIONAL ASSOCIATION

Profile Term Structure History

Model	1 Mo (%)	3 Mo (%)	6 Mo (%)	1 Yr (%)	2 Yr (%)	3 Yr (%)	4 Yr (%)	5 Yr (%)	7 Yr (%)	10 Yr (%)
KDP-bk1	13.13	13.05	11.90	10.89	8.09	6.13	-	-	-	-



KRIS also includes credit spreads of large debt issuers, both banks and their listed parent firms. The chart below shows the credit spreads for Citigroup Inc. on May 29, 2014. Please contact your Kamakura Corporation representative for more on this fast moving new product offering from Kamakura Risk Information Services.

CREDIT NAME CREDIT PORTFOLIO MACRO FACTOR SENSITIVITY PORTFOLIO MANAGEMENT Hello: dvd | Logout

Overview Default Probabilities Bond Spreads Implied CDS Spreads Implied Rating Chart Watch List Download

Credit Class Public Firm Ticker: c United States Go From 2014 May 29

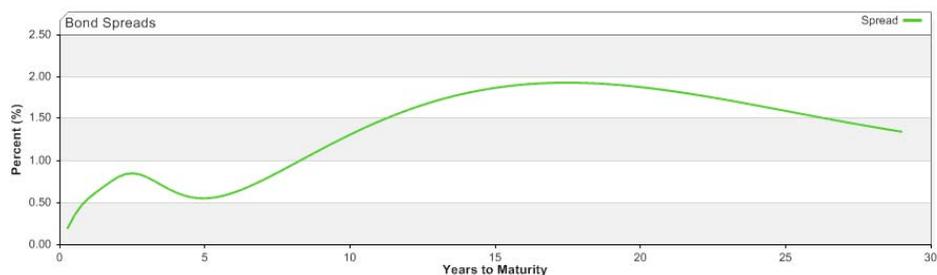
CITIGROUP INC

Term Structure Spread

Currency USD

Download

1 Month	3 Month	6 Month	1 Year	5 Year	10 Year	20 Year	30 Year
	0.19	0.36	0.56	0.56	1.32	1.88	



KRIS also includes “implied spreads,” the predicted level of 5 year credit default swaps, for all 37,000 public firms covered by KRIS, even though less than 900 firms weekly have any credit default swaps traded on their name. Only 13 legal entities affiliated with U.S. banks have had at least 1 credit default swap trade since the Depository Trust & Clearing Corporation began weekly reporting in July 2010. The chart below shows the predicted credit default swap levels for Bank of America Corporation for the last decade.

CREDIT NAME CREDIT PORTFOLIO MACRO FACTOR SENSITIVITY PORTFOLIO MANAGEMENT Hello: dvd | Logout

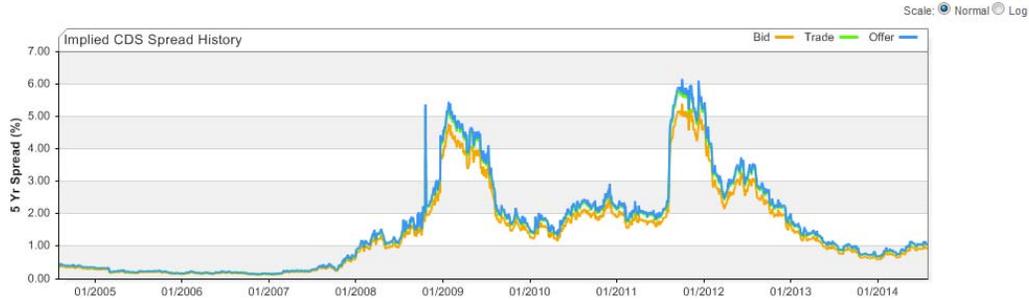
Overview Default Probabilities Bond Spreads Implied CDS Spreads Implied Rating Chart Watch List Download

Credit Class Public Firm Ticket bac United States Go Date: 2014 Jul 29 Quote USD 5 year

BANK OF AMERICA CORP

Profile Confidence

Type	5 Yr Spread (%)	1 Day Chg	1 Mo Chg	3 Mo Chg	6 Mo Chg	1 Yr Chg
Bid	0.91	-0.03	-0.04	0.05	0.15	0.10
Trade	1.03	-0.04	-0.04	0.06	0.17	0.12
Offer	1.05	-0.04	-0.04	0.06	0.17	0.12



V. Kamakura Default Probability Correlations

The tens of billions of losses in the CDO market during 2007-2009 made it clear to most observers that the Merton Model and closely related copula approach to credit portfolio analysis was deeply flawed. *The Wall Street Journal* reported on August 12, 2005 about the very large hedge fund loss in May 2005, when GM and Ford were downgraded. Many traders held long positions in the bond and short positions in the common stock, a common hedging strategy for those who believed that the Merton model of risky debt is an effective hedging tool. Unfortunately the Merton implication that stock prices and debt prices move in the same direction is true only about half the time (see van Deventer and Imai, *Credit Risk Models and the Basel Accords*, John Wiley & Sons, 2003) and traders suffered large losses from this kind of strategy in the GM and Ford cases.

Kamakura Risk Information Service (KRIS) users asked Kamakura to develop pair-wise default probability correlations that go far beyond the basic Merton and copula approach. The KRIS web site offers pair-wise default correlations for all companies in the universe for all maturities and for all models. The KRIS web site includes coverage of 35,000 public companies in 61 countries. KRIS also includes approximately 7,000 U.S. banks as part of the KRIS U.S. Bank Model. KRIS default probability histories can be downloaded and historical correlations derived from that history. For public firms, a direct calculation of the pair-wise correlation of default probabilities can be done on the KRIS website.

VI. KRIS Subscriber Information

Subscribers may obtain KRIS default probabilities in two ways:

- The KRIS web site provides individual firm inquiry and Excel download capability by entering a firm's ticker symbol on the KRIS website, as shown above for the term structures of default for Bank of America Corporation.
- The second method for using the KRIS default probability service is file transfer protocol. Kamakura's KRIS power users make use of this technology to download the entire KRIS default probability history back to 1990 in order to scan for arbitrage opportunities. Most power users download all new default probabilities daily.

Technical Specifications

Model Type

Statistical hazard rate ("reduced form") model implemented via a series of linked logistic regressions.

Default Database

874 bank defaults, FDIC seizures, and effective failures in the United States.
2,382,928 monthly observations from December 1992 through June 2013.

Model Test Results and Parameters Fully Disclosed

The KRIS U.S. Bank Default Model Technical Guide includes ROC accuracy ratios, forward ROC accuracy ratios, van Deventer and Wang test for cyclical consistency of expected and actual defaults, Falkenstein and Boral test, and k-fold cross validation. A "leave one out" validation is available upon request.

Reference Names Covered

All banks currently or previously insured by the U.S. Federal Deposit Insurance Corporation.

Statistical Estimation Methodology

Multi-period logistic regression with financial ratio and macro-factor inputs.

Statistical Performance

All regression parameters are statistically significant at the 95% level.

About Kamakura Corporation

Founded in 1990, Honolulu-based Kamakura Corporation is a leading provider of risk management information, processing and software. Kamakura was named to the World Finance 100 by the Editor and readers of *World Finance* magazine in 2012. In 2010, Kamakura was the only vendor to win 2 *Credit Magazine* innovation awards. Kamakura Risk Manager, first sold commercially in 1993 and now in version 8.1, is the first enterprise risk management system with 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 has served more than 220 clients ranging in size from \$1.5 billion to \$1.6 trillion in assets. Kamakura's risk management products are currently used in 37 countries, including the United States, Canada, Germany, the Netherlands, France, Austria, Switzerland, the United Kingdom, Russia, the Ukraine, Eastern Europe, the Middle East, Africa, South America, Australia, Japan, China, Korea, India and many other countries in Asia.

Kamakura has world-wide alliances with Fiserv (www.fiserv.com) and SCSK Corporation

(http://www.scsk.jp/index_en.html) making Kamakura products available in almost every major city around the globe.

For more information, please contact

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