

What's New in RiskFrontier and GCorr 2018 Update

Nihil Patel, Atit Wongnophadol, Yiting Xu

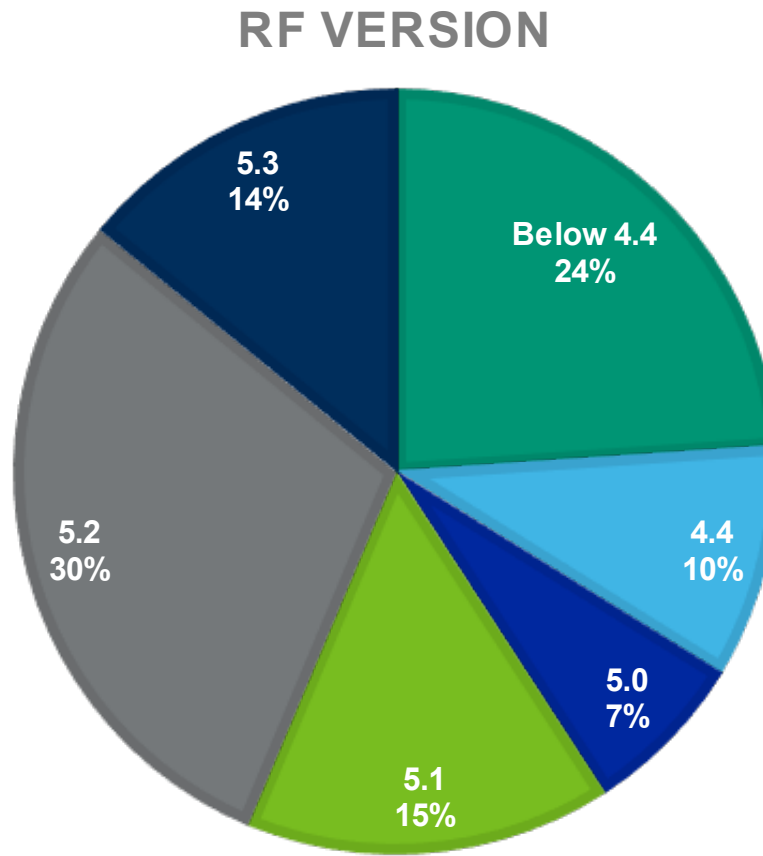
February, 2019

Agenda

1. Features in Recent RiskFrontier Versions
2. Latest Features in 5.3 and 5.4
3. Additional Enhancements
4. Modeling Credit Risk Correlations using Gcorr
5. Understanding and Implications of GCorr Corporate 2018
6. Validation of GCorr Corporate 2018

Current User Versions

More Than Half of Users Are Using RiskFrontier 5.1 or Above

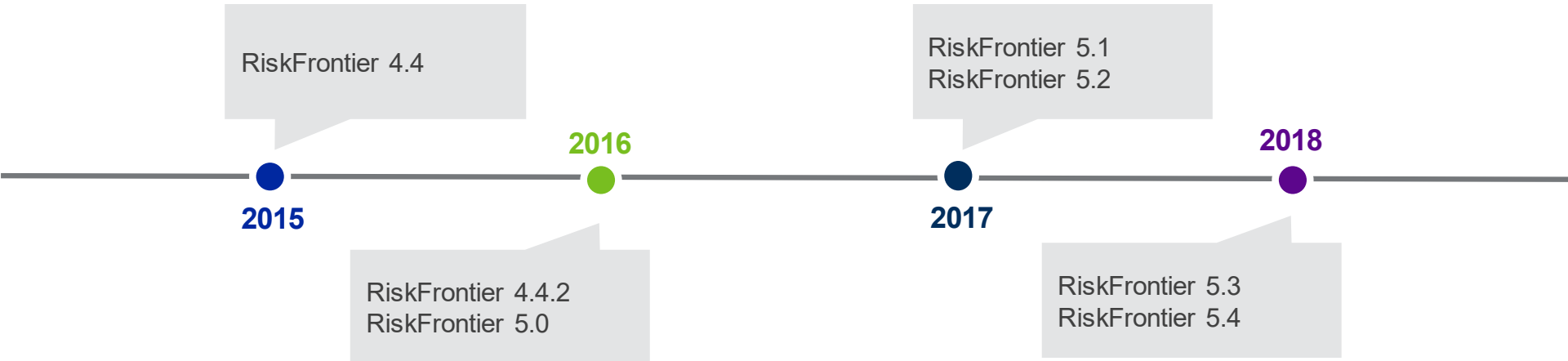


1

Features in Recent RiskFrontier Versions

Recent RiskFrontier Versions

Enhancements Across Usability, Analytics, and Technology



Key Features from Recent Versions

From RiskFrontier 4.4 (Dec'15) to 5.2 (Dec'17)

Usability	Analytics	Technology
Functional enhancements that ease use and help improve process efficiency	Analytic features and model updates that address evolving business needs	Enhancements to technological components for better performance and ease of administration
<ul style="list-style-type: none">» Exposure-Level Market Risk Premium (MRP)» Support for Negative Interest Rates» Monte Carlo Output – filter for default only» Trade Import Feature» Custom Template for Exposure Results Report	<ul style="list-style-type: none">» Composite Capital Measure (CCM)» Credit Earnings Volatility» Update to GCorr Sovereign» New Equity Model	<ul style="list-style-type: none">» Improved Performance for Distributed Setup» Flexibility in Managing the Number of CPU via User Interface» Monte Carlo Output – ability to process data in uncompressed format on the fly

Note: more details in the “Key Features from Recent RiskFrontier™ Releases” document.

2

Latest Features in
5.3 and 5.4

RiskFrontier 5.3 (Jul 5th, 2018)

Enhancements Across Functional Needs

Usability	Analytics	Technology
Functionality enhancements that ease use and help improve process efficiency	Algorithm update in CDO module yields significant gain in performance without altering accuracy of results	Additional options to support newer security protocols for global institutions to securely service and use RiskFrontier
<ul style="list-style-type: none">» Loading of through-the-cycle EDF data» Flagging favorite jobs for reporting» Administrator option to link institution's active directory with RF workgroup	<ul style="list-style-type: none">» Performance improvement of CDO analysis on large homogenous pool» Enhancement to heterogeneity adjustment	<ul style="list-style-type: none">» Support SFTP in RF DataLoader» HTTPS option in RF installer» SHA-256 encryption method for user login

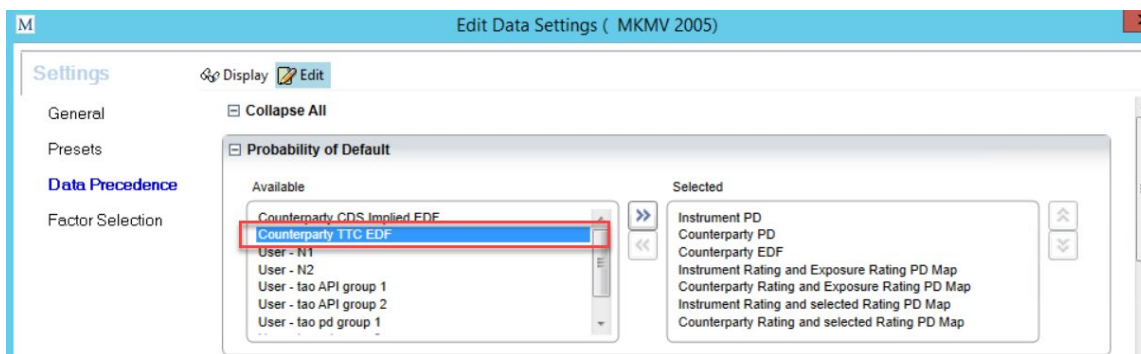
Through-the-Cycle EDF

- » Automated TTC EDF data consumption, via daily DataLoader file called NTE.

Example look of the file

```
1|20180214|99991231|0.02|N
2|20180214|99991231|0.28|N
13|20180214|99991231|0.99|F
16|20180214|99991231|2.34|N
```

- » Counterparty TTC EDF option in the data settings.

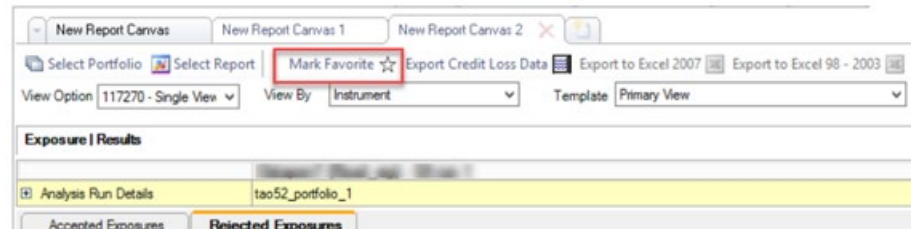


- » Available for public counterparties and viewable in UI.

Begin Date	End Date	Term	PD	Data Source
31/01/2007	27/02/2007	2.00	0.146 %	Moody's Analytics
		3.00	0.171 %	Moody's Analytics
		4.00	0.196 %	Moody's Analytics
		5.00	0.232 %	Moody's Analytics
31/12/2006	30/01/2007	1.00	0.166 %	Moody's Analytics
		2.00	0.205 %	Moody's Analytics
		3.00	0.221 %	Moody's Analytics
		4.00	0.236 %	Moody's Analytics
		5.00	0.250 %	Moody's Analytics
14/02/2018	31/12/9999	1.00	0.280 %	Moody's Analytics TTC EDF

Mark Favorite Jobs

- » Enables users to designate selected reports as favorite
- » Allows users to quickly and easily access those reports
- » Mark Favorite button is available in Portfolio Overview and Exposure Results in single-view mode.
- » Favorite jobs are user-specific.



This screenshot shows the 'Select Portfolio Analysis' table. The first row is selected, and the 'Mark Favorite' button (star icon) is highlighted with a red rectangle. The table has columns for Job ID, Portfolio, Analysis Date, Holdings Date, Analysis Settings, and Data Settings.

	Job ID	Portfolio	Analysis Date	Holdings Date	Analysis Settings	Data Settings	An
<input checked="" type="checkbox"/>	117270		31/05/2018	31/05/2018			
<input type="checkbox"/>	117260		11/05/2018	11/05/2018			
<input type="checkbox"/>	117299		10/11/2008	10/11/2008			
<input type="checkbox"/>	117298		31/08/2015	31/08/2015			

Linking AD Group with RF Workgroup

- » RF system admins can now sync up the latest users with the organization's Active Directory security group by associating it to RF workgroup, on a one-to-one mapping.

Authentication Authority Detail

Display Edit

Authority Type: Active Directory

Name: Active Directory

Authority Binding: analytics [Check](#)

Admin Login:

Password:

Link Security Groups

☒ Yes ☐ No

Active Directory Security Group	RiskFrontier Permission Workgroup
MA Software Engineering - SF	System Administrators

Create Link Delete Link

Save Close

The screenshot shows a Windows-style dialog box titled "Link Active Directory Group to RF Workgroup". It has a blue header bar with a close button (X) in the top right corner. The main area contains a label "Enter first part of AD group name" followed by a text input field containing "MA". To the right of this field is a "Search" button. Below this is another label "Active Directory (AD) group(s) found:" followed by a scrollable list box. The list box contains several entries, all starting with "MA-", which are mostly blurred. At the bottom of the list box is a small downward-pointing arrow. Below the list box is a label "RiskFrontier permission workgroup" followed by a dropdown menu currently showing "100_PEFPORT". At the very bottom of the dialog are two buttons: "Add Link" and "Cancel".

Data Management Feature

» Removal of unused counterparty and instrument data

- » Counterparty Financials
- » Counterparty PD
- » Counterparty Rating
- » Instrument PD
- » Instrument Rating

The screenshot displays the 'Data Management' section of the RiskFrontier application. The left sidebar contains a navigation menu with 'Portfolios' (selected), 'Market / Supporting Data', 'Reporting', and 'Database Maintenance'. The main content area has a header with 'Refresh' and 'Run' buttons. Below this, there are two main sections for data removal. The first section, titled 'Select market and/or supporting data to remove all historical data on and before the date specified.', includes a date picker set to '28/06/2015' and a list of checkboxes: 'Delete Exchange Rates', 'Delete Yield Curves', 'Delete Counterparty Financials', 'Delete Counterparty PD', 'Delete Counterparty Rating', 'Delete Instrument PD', and 'Delete Instrument Rating'. The last four checkboxes are grouped within a red rectangular box. The second section, titled 'Select instruments and/or counterparties to remove those that have no association to a portfolio.', includes checkboxes for 'Delete Orphan Instruments' and 'Delete Orphan Counterparties'.

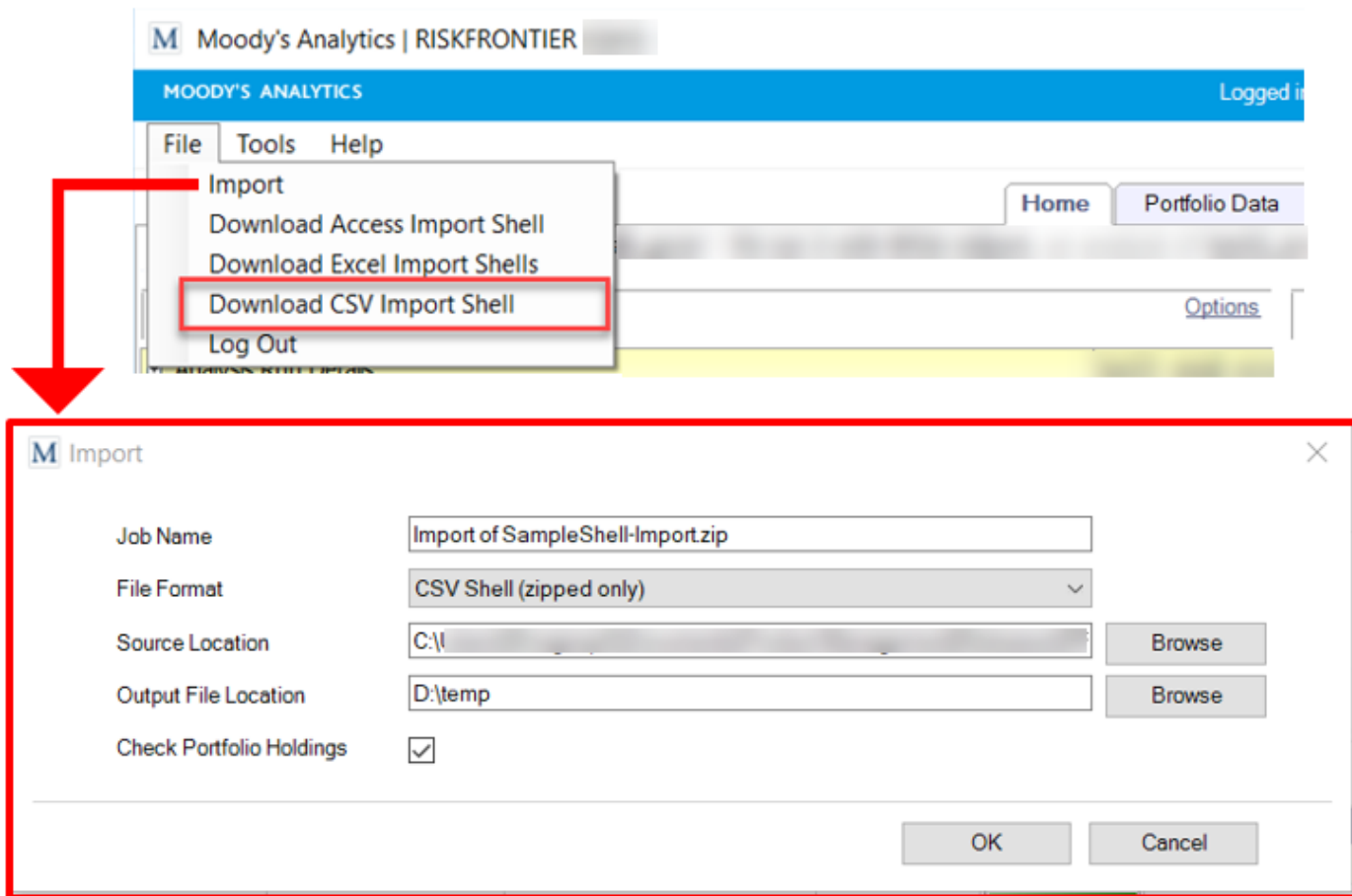
RiskFrontier 5.4 (Dec 19th, 2018)

Enhancements Across Functional Needs

Usability	Analytics	Technology
Functionality enhancements that ease use and help improve process efficiency	CDO Valuation Enhancement	Enhancements to better support RiskFrontier installation on Amazon Web Services
<ul style="list-style-type: none">» CSV Import Feature» Improved import performance for bond, loan and lease instrument types	<ul style="list-style-type: none">» Improved value grid construction for the CDO module to consider active collateral loans that mature before horizon	<ul style="list-style-type: none">» Remove path check of rf_tempfiles folder» Remove path check of SQL data and log paths» Remove CoreSRV and Reporting SRV linked server objects

CSV Import Feature


RiskFrontier 5.4 Allows Data Import in CSV Format





CSV Import Feature


28 Commonly Used Tables are Available in RiskFrontier 5.4


Reference


 cashflow.csv


 counterpartyRating.csv


 creditExposure.csv


 importAsOfDate.csv


 portfolioDetail.csv


 ratingPdMapDtl.csv


 retailLoan.csv


 termLoanAmortizing.csv


 yieldCurve.csv


 bond.csv


 counterparty.csv


 counterpartyRSquared.csv


 exchangeRate.csv


 instrumentPortfolioInfo.csv


 putSchedule.csv


 ratingSystem.csv


 revolver.csv


 termLoanBullet.csv


 yieldCurveHistory.csv


 callSchedule.csv


 counterpartyFinancials.csv


 covarianceModelFactorCoefficients.csv


 exposureProfile.csv

 portfolio.csv

 ratingCategory.csv

 retailCreditLine.csv

 sinkSchedule.csv

 version.csv

CSV Import Feature

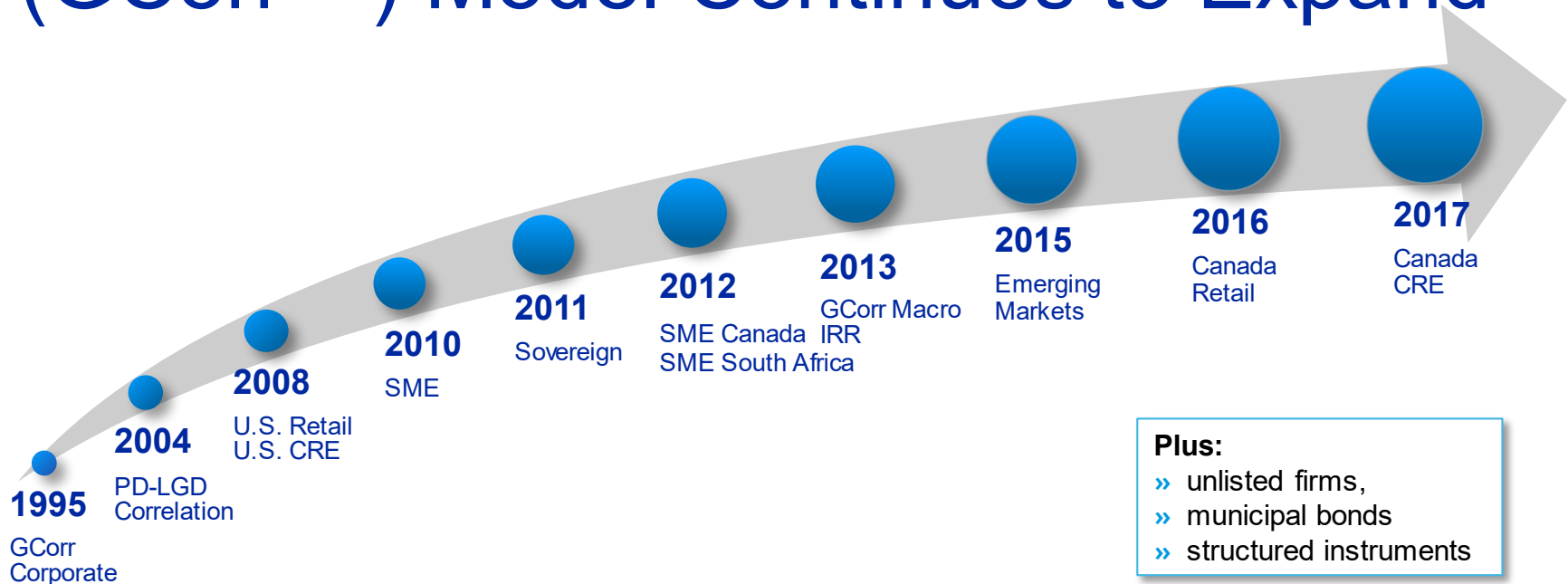
Input and Format Requirements

- » **Column headers** are required in the CSV file. If any one of the column headers is missing, users will receive an error
- » The input values are **comma separated** (,) and we recommend that quotes are added (") for input value that have a comma in between (e.g., a country name that has comma).
- » The date format is **YYYYMMDD**.
- » RF processes only the **CSV filenames** recognized as one of the staging tables. For example, counterparty.CSV is recognized and will be processed in the import workflow. Cpty.csv is not recognized and will not be processed in the import workflow. In the latter case, RF would simply skip the unrecognizable file without throwing any error.
- » After import job is initiated, data loading and validation will be the same as in the access shell and staging import. RF will provide **error output files** in CSV to a user-specified location.

3

GCorr 2018 Update

Moody's Analytics Global Correlation (GCorr™) Model Continues to Expand



- » GCorr – a multi-factor model of correlations among Issuers' asset returns
 - GCorr includes several asset classes: corporate (listed firms), CRE, retail, SMEs, sovereigns
 - Correlations for unlisted firms, municipal bonds and structured instruments can be also determined within GCorr
- » GCorr Corporate – a forward-looking multi-factor model of asset correlations among about 47,000 listed firms from over 70 countries and a wide range of industries

GCorr 2018 Highlights

- » Models are updated using market information through March 31st, 2018
 - GCorr Corporate
 - › Empirical correlations are higher than the last year's level. We predict future correlations will also be higher than previous levels.
 - GCorr US Retail and Canada Retail
 - GCorr US CRE and Canada CRE
- » GCorr Macro now includes 114 macrovariables, which covers Equity, GDP, Unemployment Rate, Credit Spread, House Price Index, and Inflation variables in US, Europe, Asia, Canada, and other economies
- » Models that were made compatible with GCorr 2018: SME, Sovereign and PD LGD model



Modeling Credit Risk Correlations using GCorr

How to Think of Correlations in Credit risk?

- » Portfolio credit risk analysis has two parts:
 - Stand-alone credit risk of debt instruments in the portfolio
 - Correlations (or more generally a dependence structure) of changes in credit qualities of firms
- » One way to approximate correlations of credit quality changes is to use asset returns and their correlations (i.e. asset correlations).
- » An adequate correlation model should be able to quantify diversification and concentration effects within a credit portfolio.
 - Moody's Analytics GCorr model (Global Correlation Model)

Moody's Analytics Global Correlation (GCorr™) Model Continues to Expand

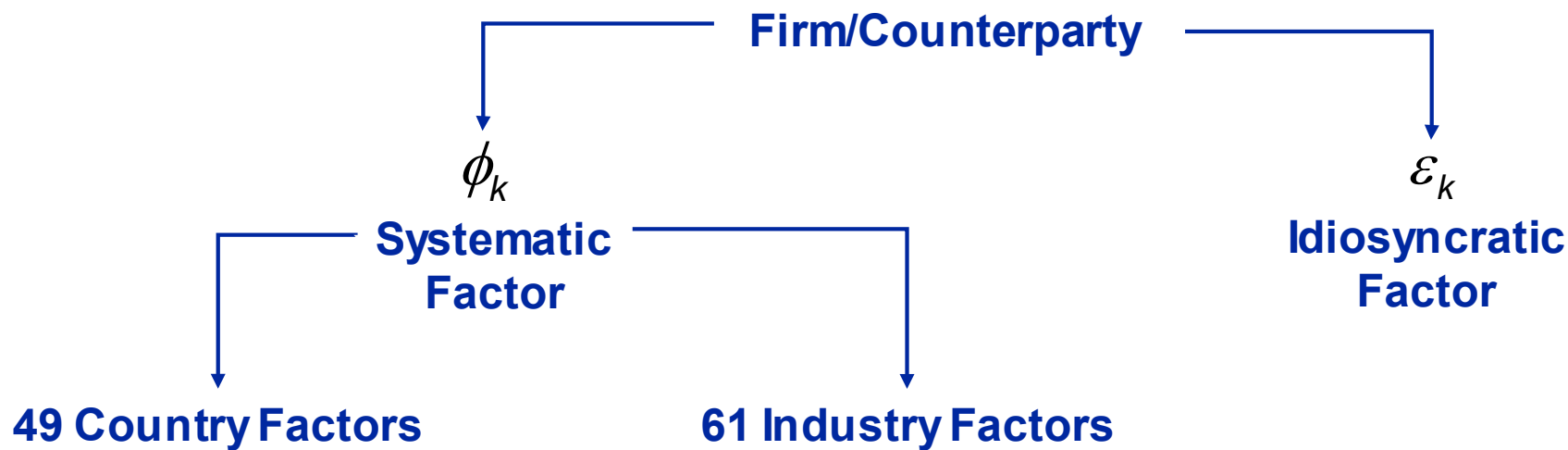
- » GCorr Model continue to expand in terms of both asset classes and global coverage, and number of factors in the model has more than doubled since 2010.

	GCorr 2010	GCorr 2011	GCorr 2012	GCorr 2013	GCorr 2014	GCorr 2015	GCorr 2016	GCorr 2017	GCorr 2018
Corporate	110	110	110	110	110	110	110	110	110
CRE	78	78	78	78	78	78	78	78	78
Retail - US	57	57	57	57	57	57	57	57	57
Macro	-	-	-	62	77	91	100	103	114
IRR	-	-	-	3	3	3	3	3	3
EM	-	-	-	-	161	161	161	161	161
Lambda	-	-	-	-	-	9	9	9	9
Local	-	-	-	-	-	102	138	156	156
Macrovariables	-	-	-	-	-	-	-	-	-
Retail - Canada	-	-	-	-	-	-	24	24	24
CRE - Canada	-	-	-	-	-	-	-	23	23
Total Factors	245	245	245	310	486	611	680	724	735

→
Increase of number of GCorr factors

GCorr 2018 Corporate Factor Structure

$$r_k = \sqrt{RSQ_k} \phi_k + \sqrt{1 - RSQ_k} \varepsilon_k$$



Systematic factors of firms i and k are correlated through their exposure to country and industry factors.

» Given the model assumptions, the asset correlation between firms i and k is:

$$\text{corr}(r_i, r_k) = \sqrt{RSQ_i} \sqrt{RSQ_k} \text{corr}(\phi_i, \phi_k)$$

In this factor model, asset correlations are given by two sets of inputs: R-squareds and custom index correlations.

GCorr Corporate is Updated and Expanded Annually

» GCorr 2018 Corporate includes the dynamics of the most recent available weekly asset returns.

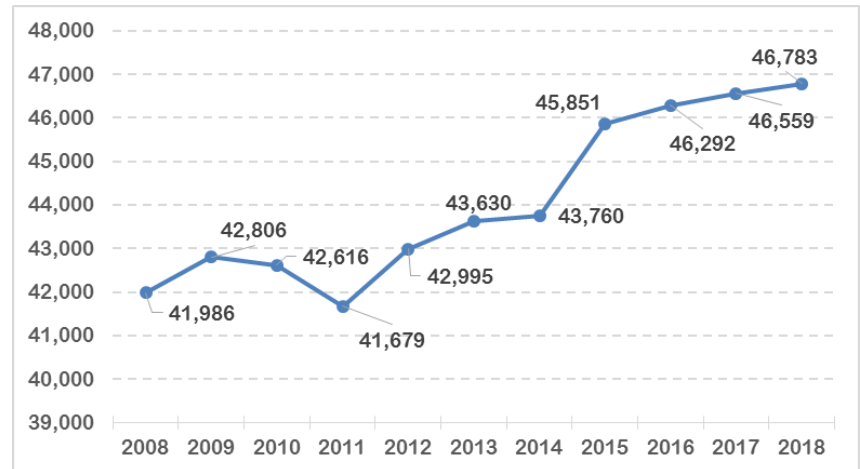
- Data used for R-squared estimation – a three-year window: **April 2015 – March 2018**

GCorr 2017 Corporate: April 2014 – March 2017

- Data used for estimation of systematic factor correlations: **July 1999 – March 2018**

GCorr 2017 Corporate: July 1999 – March 2017

Number of Firms Covered by GCorr Corporate



Empirical Asset Correlation

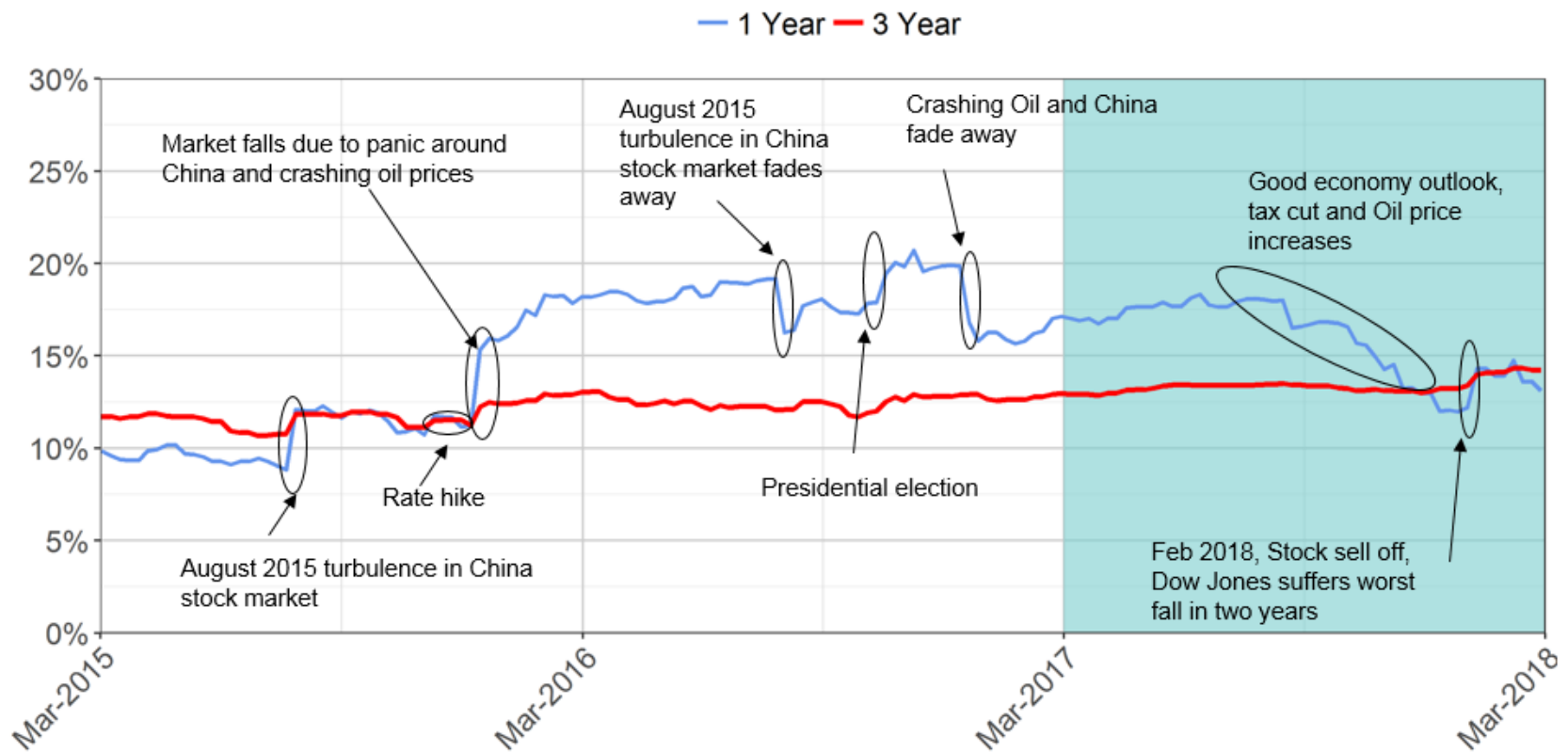
Asset Correlation in April 2015 – March 2018 window is higher than the asset correlation in April 2014 – March 2017

North American Financials (802 Firms)



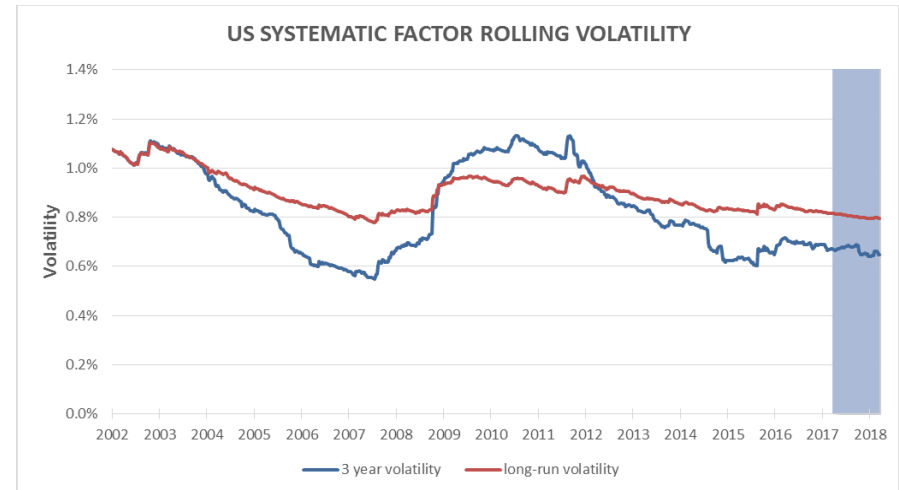
North American Financials

North American Financials (802 Firms)



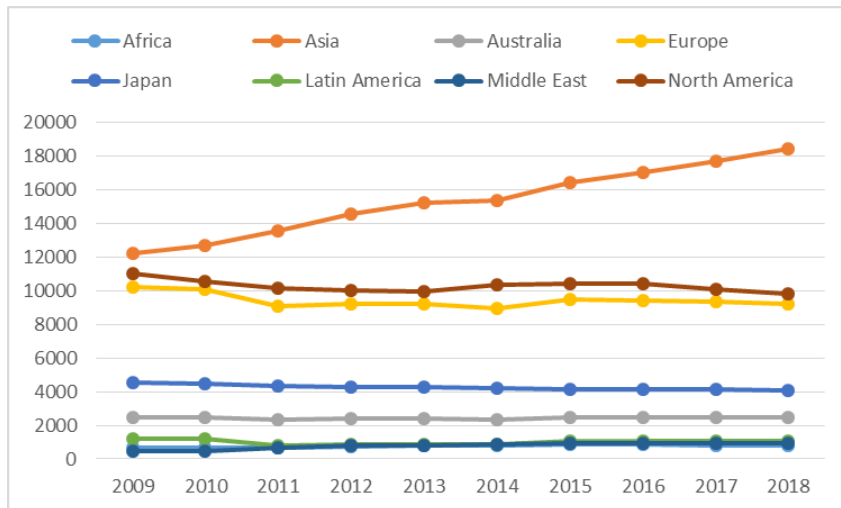
Short Run Volatility is Below the Long Run Volatility

- » Potential increase in volatility levels in next few years:
 - Volatility calculated over April 2015 – March 2018 window is lower than volatility over July 1999 – March 2018 window. If we expect volatility to be mean-reverting, then three-year rolling volatility can potentially increase in next couple of years.

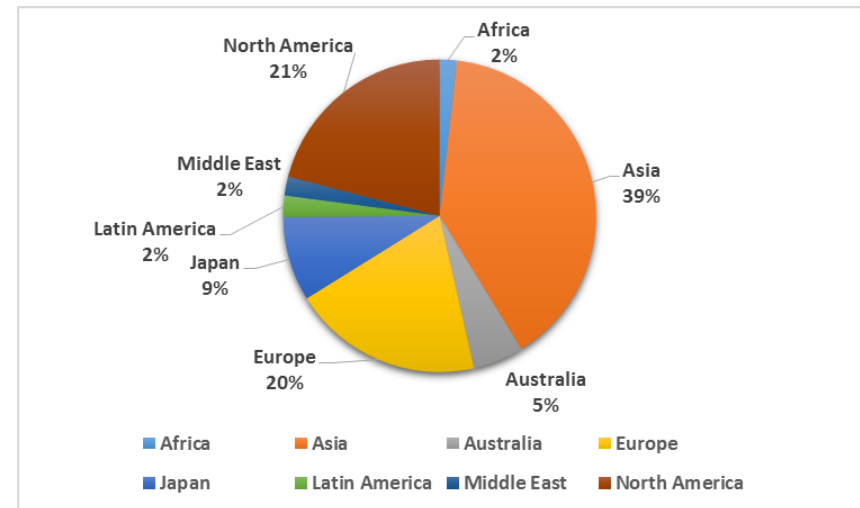


GCorr 2018 Covers Many Firms from Asia, North America, and Europe

Number of Firms by Region



Regional Coverage in GCorr 2018



4

Understanding and Implications of GCorr 2018 Corporate

Key Findings

- » GCorr 2018 asset correlations are on average slightly higher than GCorr 2017 asset correlations.
- » GCorr asset correlations are impacted by:
 - » Factor correlations: unchanged
 - » R-squared values: slightly increase
- » Results vary by region, sector, and size of firms

Overall, GCorr Asset Correlations are Slightly Higher Than the Previous Model

Global Random 5000 Firms: GCorr Asset Correlations

	Mean	Std	Min	Q1	Med	Q3	Max
GCorr2017	8.61%	5.54%	0.18%	5.07%	7.20%	10.38%	65.00%
GCorr2018	8.75%	5.65%	0.22%	5.13%	7.32%	10.58%	65.00%
GCorr2018 - GCorr2017	0.14%	1.29%	-14.57%	-0.39%	0.04%	0.71%	17.92%

Levels: On average, the asset correlations are slightly higher than GCorr 2017.

* Row "Differences" provides statistics for pair-wise differences between GCorr 2018 and GCorr 2017 correlations. Thus, it is not determined by subtracting statistics in the first row from those in the second row.

Overall, GCorr Factor Correlations are Unchanged & RSQs are Slightly Higher

Global Random 5000 Firms: GCorr Factor Correlations

	Mean	Std	Min	Q1	Med	Q3	Max
GCorr2017	44.3%	17.3%	1.1%	32.4%	41.5%	52.8%	100.0%
GCorr2018	44.3%	17.2%	1.5%	32.4%	41.4%	52.7%	100.0%
GCorr2018 - GCorr2017	0.0%	1.5%	-62.3%	-0.2%	0.0%	0.2%	46.7%

Global Random 5000 Firms: GCorr RSQ

	Mean	Std	Min	Q1	Med	Q3	Max
GCorr2017	21.4%	14.0%	10.0%	10.0%	15.3%	29.3%	65.0%
GCorr2018	21.8%	14.1%	10.0%	10.0%	15.7%	30.1%	65.0%
GCorr2018 - GCorr2017	0.4%	4.1%	-10.0%	-0.9%	0.0%	2.0%	10.0%

* Row "Differences" provides statistics for pair-wise differences between GCorr 2018 and GCorr 2017. Thus, it is not determined by subtracting statistics in the first row from those in the second row.

Asset Correlation Changes in Different Regions and Sectors

Random 1000 Firms in Different Regions: Average GCorr Asset Correlation Change

	All	Financial	Industrial
United States	0.36%	0.54%	0.40%
Europe	-0.13%	0.21%	-0.15%
Japan	1.13%	0.32%	1.20%
Asia	0.33%	0.26%	0.33%
Global	0.14%	0.25%	0.19%

Asset correlation increased for Japan Industrials

Asset correlations remained similar across most sectors and regions.

Factor Correlation and R-Squared Value Changes in Different Regions

Random 1000 Firms in Different Regions:
Average Factor Correlation Change

Random 1000 Firms in Different Regions:
Average R-Squared Change

	All	Financial	Industrial		All	Financial	Industrial
United States	0.12%	0.01%	0.19%	United States	0.37%	0.56%	0.40%
Europe	-0.24%	-0.10%	-0.03%	Europe	-0.19%	0.37%	-0.33%
Japan	0.03%	0.05%	-0.02%	Japan	1.05%	0.04%	1.24%
Asia	0.13%	0.24%	0.14%	Asia	0.65%	0.35%	0.69%
Global	-0.03%	0.05%	-0.06%	Global	0.38%	0.37%	0.54%

Asset correlation change in Japan Industrials is mostly driven by R-squared changes

GCorr Asset Correlation Changes Vary by Size

Average Asset Correlation Change by Size (Largest versus Random)

	Financial		Industrial		
	Largest 100	Largest 1000	Largest 100	Largest 1000	Random 1000
United States	-1.50%	0.66%	-1.13%	-0.92%	0.35%
Europe	-1.17%	0.08%	-1.02%	-0.97%	-0.22%
Japan	-2.38%	0.32%	-1.24%	0.34%	1.24%
Asia	-2.47%	0.07%	-0.57%	0.08%	0.43%

The asset correlation decreased in largest firms globally.

Impact on Portfolio Statistics

Region	Portfolio	Number of Firms	R-squared Change	Asset Correlation Change	Unexpected Loss Change	Economic Capital Change
Global	Non-Financials	30,335	0.5%	0.2%	2.6%	1.7%
	Non-Financials, EDF < 100 bps	17,838	0.4%	0.2%	1.7%	1.9%
	Financials	6,176	0.2%	0.2%	2.0%	1.8%
	Financials, Assets > \$25 billion	630	-1.7%	-0.9%	-3.2%	-1.8%
US	Non-Financials	3,907	0.2%	0.2%	0.5%	1.5%
	Non-Financials, EDF < 100 bps	2,160	0.2%	0.2%	0.7%	1.5%
	Financials	1,288	0.7%	0.6%	3.4%	3.5%
	Financials, Assets > \$25 billion	114	-0.5%	-0.5%	-0.7%	0.0%
Europe	Non-Financials	5,021	-0.4%	-0.2%	-0.5%	-2.8%
	Non-Financials, EDF < 100 bps	3,299	-0.5%	-0.3%	-2.5%	-3.7%
	Financials	1,588	0.6%	0.3%	2.6%	6.0%
	Financials, Assets > \$25 billion	159	-0.7%	-0.5%	-1.0%	0.0%
Asia/Australia	Non-Financials	18,603	0.9%	0.4%	2.9%	3.5%
	Non-Financials, EDF < 100 bps	10,997	0.9%	0.4%	3.9%	3.4%
	Financials	2,363	0.3%	0.2%	2.5%	1.6%
	Financials, Assets > \$25 billion	272	-2.5%	-1.4%	-3.6%	-4.4%

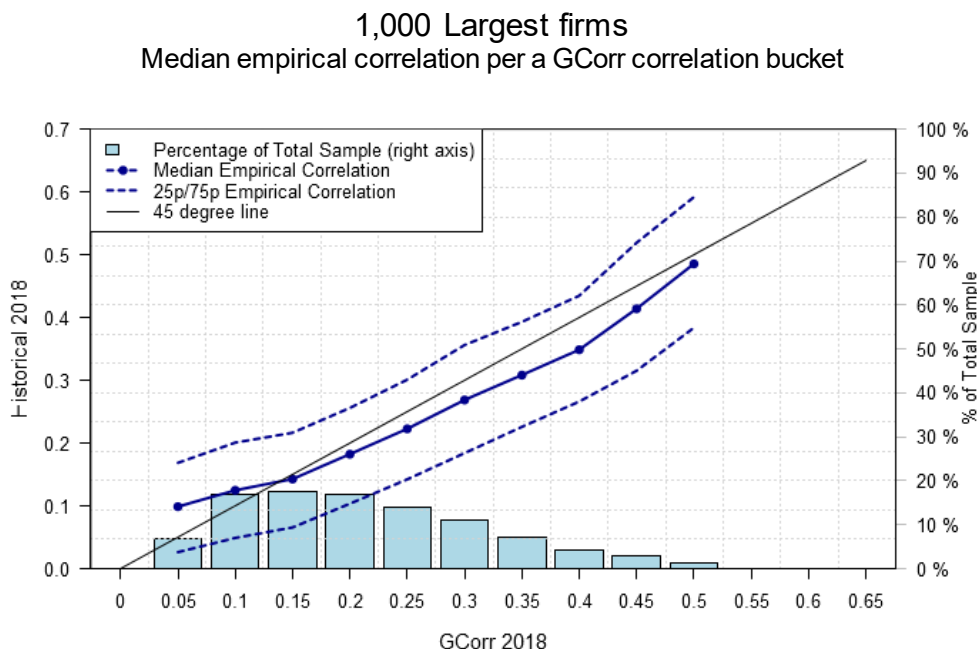
In general, directional change of unexpected loss and capital will be in line with asset correlation change

5

Validation of GCorr
Corporate 2018

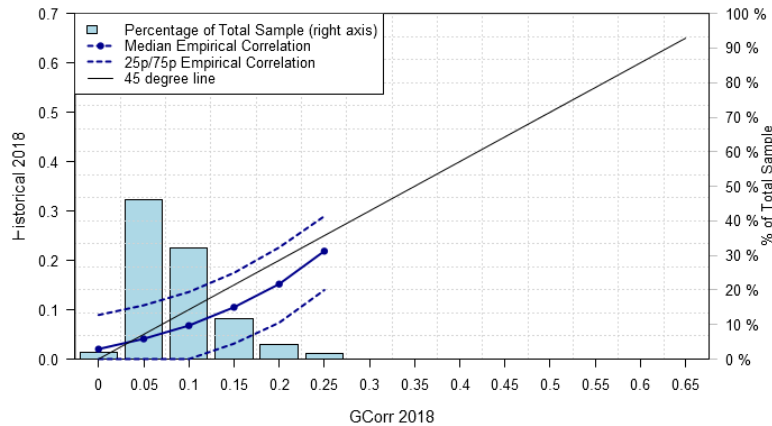
Comparison of Forward-Looking GCorr Correlations and Historical Correlations

- » Asset correlations and R-squared values produced by GCorr 2018 Corporate are higher than the empirical levels over April 2015 – March 2018:
 - Recent volatilities are low compared to the long-run average, so GCorr predicts future correlations to be slightly higher than what we observe historically

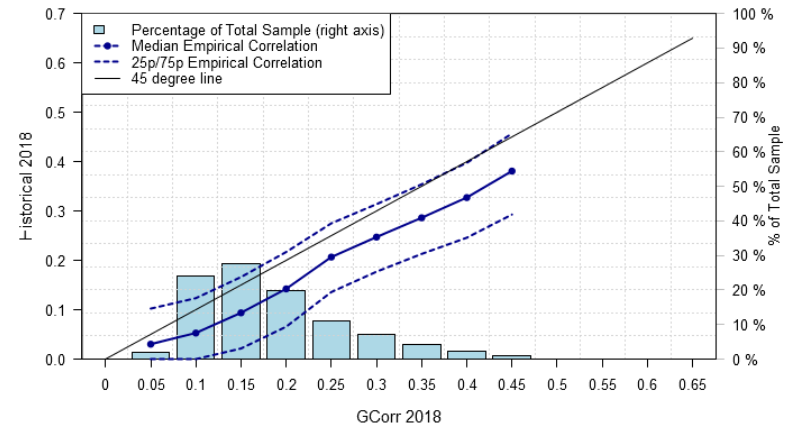


Median Analysis for Various Regions

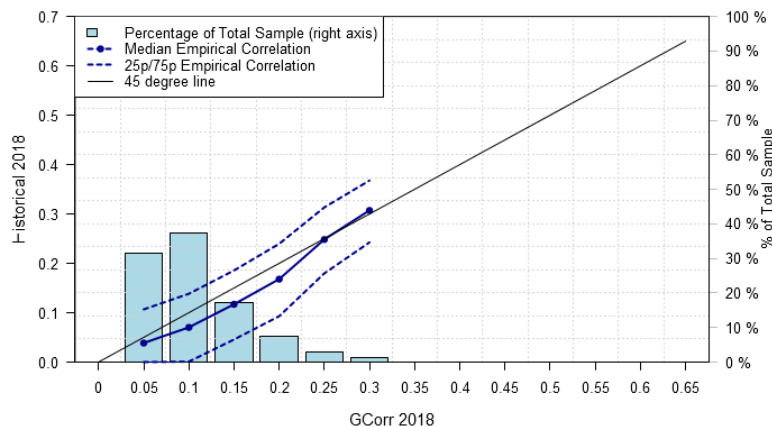
1000 Random – Global



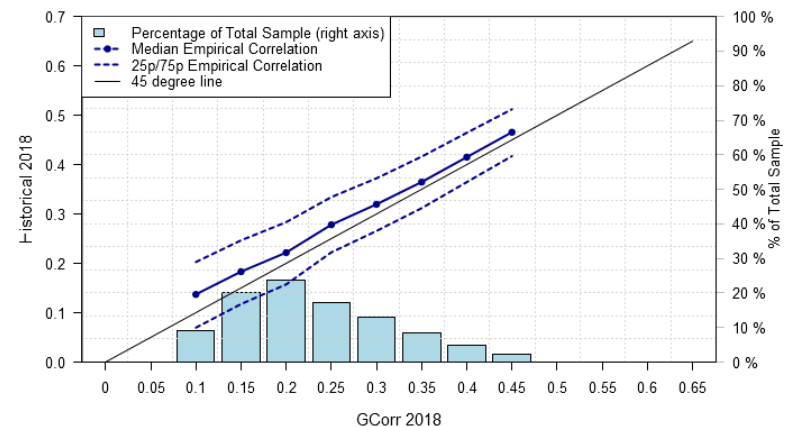
1000 Random – US



1000 Random – Europe

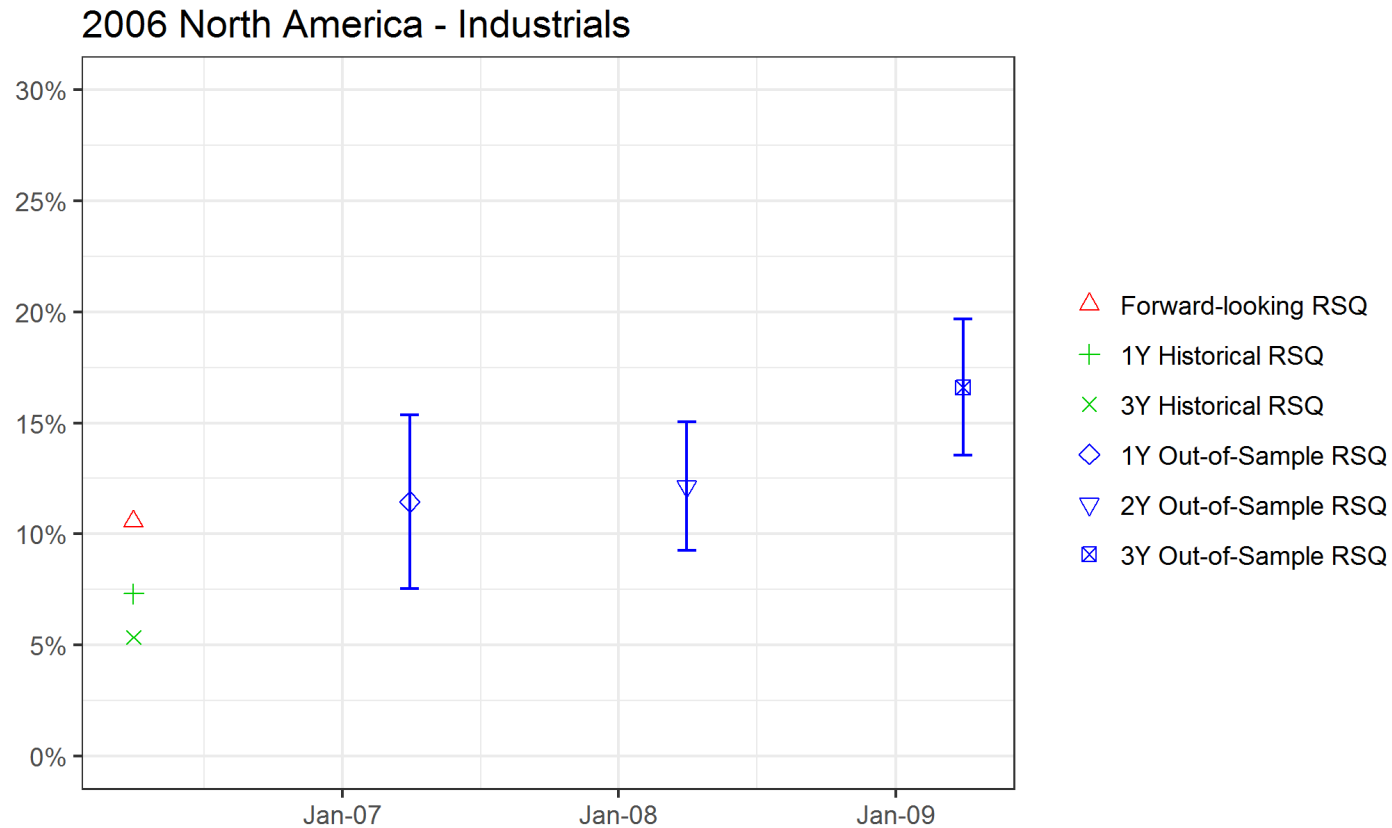


1000 Random – Japan



Out-of-Sample RSQ Prediction

Pre-Crisis



Validation of GCorr Corporate

- » In-sample validation of GCorr 2018 Corporate
 - Comparing GCorr 2018 asset correlation level to 3 year historical asset correlations.
- » Out-of-sample validation
 - Comparing forward-looking R-squareds to out-of-sample empirical R-squareds.
- » Asset correlations implied by empirical default rates
 - Research paper by Moody's Analytics – *Asset Correlation, Realized Default Correlation, and Portfolio Credit Risk*.
 - GCorr asset correlations were generally higher than the default implied asset correlations.
- » Correlations as an input of a portfolio credit risk model
 - Research paper by Moody's Analytics – *Navigating Through Crisis: Validating RiskFrontier® Using Portfolio Selection*
 - Using GCorr Corporate correlations results in ex-ante Unexpected Losses which perform better in identifying more and less risky portfolios than alternative correlation measures, such as empirical asset correlations.
 - Portfolio losses estimated using ratings-based PDs and Basel II correlations result in a less conservative view of economic capital than parameterization using public EDF and GCorr measures

Summary of GCorr 2018 Corporate

- » Trends in asset correlations:
 - Empirical asset correlations are higher than last year's level for most of the regions and sectors.

- » Main features of GCorr 2018 Corporate:
 - GCorr 2018 asset correlations are higher than GCorr 2017

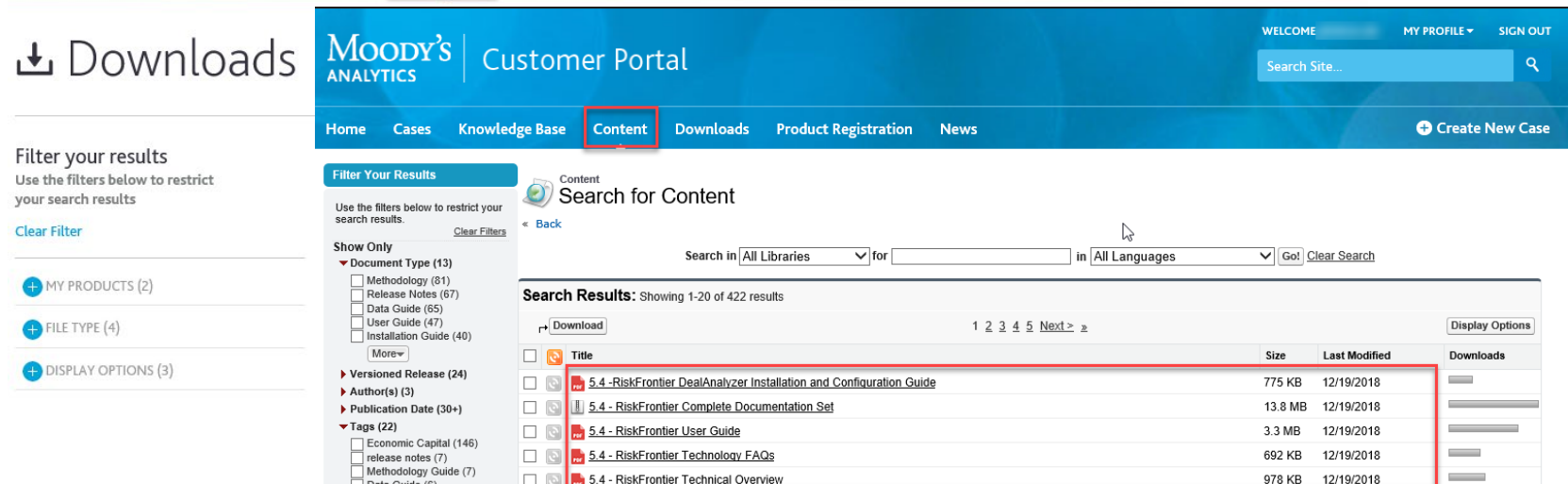
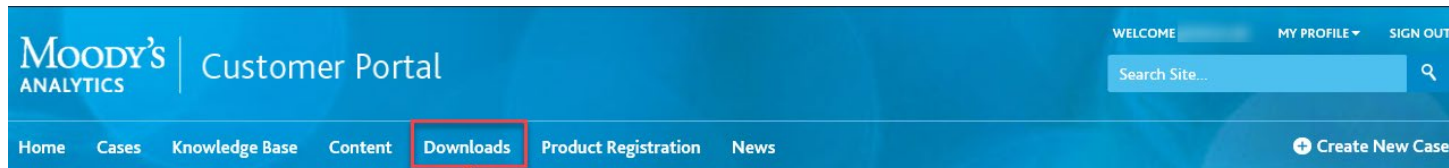
- » Prediction by GCorr 2018 Corporate:
 - We predict next year's empirical correlations to be higher than this year's

6

Next Steps

Visit Customer Portal

- » Tell your colleagues about the latest RiskFrontier version 5.4
- » Check out Moody's Analytics Customer Portal
 - Download installation files and standard product documentation



Support and Additional Resources

- » For ongoing day-to-day all product related questions, MA's client support team via:
 - Email: MA_support@moodys.com
 - Phone: +1 212 553 1653
 - Customer Support Web: <http://moodysanalytics.com/support>
- » RiskFrontier Methodology Document: “Modeling Credit Portfolios”
- » RiskFrontier product documents can be downloaded via the Customer Support Web.
- » Future RiskFrontier education via trainings and seminars conducted by Moody's:
 - RiskFrontier Methodology and Business Use Training (2 days)
 - Credit Portfolio Models and Validation (2 days)
 - New Research in Portfolio Modeling (1 day)
- » Moody's Conferences to interact with other MA clients of RiskFrontier:
 - Portfolio User Group
 - MA Summit



MOODY'S

ANALYTICS

Nihil Patel
Senior Director - Product
Moody's Analytics
Nihil.Patel@moodys.com

Atit Wongnophadol
Assistant Director – Product
Moody's Analytics
Atit.Wongnophadol@moodys.com

Yiting Xu
Assistant Director – Research
Moody's Analytics
Yiting.Xu@moodys.com

moodysanalytics.com

© 2017 Moody's Corporation, Moody's Investors Service, Inc., Moody's Analytics, Inc. and/or their licensors and affiliates (collectively, "MOODY'S"). All rights reserved.

CREDIT RATINGS ISSUED BY MOODY'S INVESTORS SERVICE, INC. AND ITS RATINGS AFFILIATES ("MIS") ARE MOODY'S CURRENT OPINIONS OF THE RELATIVE FUTURE CREDIT RISK OF ENTITIES, CREDIT COMMITMENTS, OR DEBT OR DEBT-LIKE SECURITIES, AND MOODY'S PUBLICATIONS MAY INCLUDE MOODY'S CURRENT OPINIONS OF THE RELATIVE FUTURE CREDIT RISK OF ENTITIES, CREDIT COMMITMENTS, OR DEBT OR DEBT-LIKE SECURITIES. MOODY'S DEFINES CREDIT RISK AS THE RISK THAT AN ENTITY MAY NOT MEET ITS CONTRACTUAL, FINANCIAL OBLIGATIONS AS THEY COME DUE AND ANY ESTIMATED FINANCIAL LOSS IN THE EVENT OF DEFAULT. CREDIT RATINGS DO NOT ADDRESS ANY OTHER RISK, INCLUDING BUT NOT LIMITED TO: LIQUIDITY RISK, MARKET VALUE RISK, OR PRICE VOLATILITY. CREDIT RATINGS AND MOODY'S OPINIONS INCLUDED IN MOODY'S PUBLICATIONS ARE NOT STATEMENTS OF CURRENT OR HISTORICAL FACT. MOODY'S PUBLICATIONS MAY ALSO INCLUDE QUANTITATIVE MODEL-BASED ESTIMATES OF CREDIT RISK AND RELATED OPINIONS OR COMMENTARY PUBLISHED BY MOODY'S ANALYTICS, INC. CREDIT RATINGS AND MOODY'S PUBLICATIONS DO NOT CONSTITUTE OR PROVIDE INVESTMENT OR FINANCIAL ADVICE, AND CREDIT RATINGS AND MOODY'S PUBLICATIONS ARE NOT AND DO NOT PROVIDE RECOMMENDATIONS TO PURCHASE, SELL, OR HOLD PARTICULAR SECURITIES. NEITHER CREDIT RATINGS NOR MOODY'S PUBLICATIONS COMMENT ON THE SUITABILITY OF AN INVESTMENT FOR ANY PARTICULAR INVESTOR. MOODY'S ISSUES ITS CREDIT RATINGS AND PUBLISHES MOODY'S PUBLICATIONS WITH THE EXPECTATION AND UNDERSTANDING THAT EACH INVESTOR WILL, WITH DUE CARE, MAKE ITS OWN STUDY AND EVALUATION OF EACH SECURITY THAT IS UNDER CONSIDERATION FOR PURCHASE, HOLDING, OR SALE.

MOODY'S CREDIT RATINGS AND MOODY'S PUBLICATIONS ARE NOT INTENDED FOR USE BY RETAIL INVESTORS AND IT WOULD BE RECKLESS AND INAPPROPRIATE FOR RETAIL INVESTORS TO USE MOODY'S CREDIT RATINGS OR MOODY'S PUBLICATIONS WHEN MAKING AN INVESTMENT DECISION. IF IN DOUBT YOU SHOULD CONTACT YOUR FINANCIAL OR OTHER PROFESSIONAL ADVISER.

ALL INFORMATION CONTAINED HEREIN IS PROTECTED BY LAW, INCLUDING BUT NOT LIMITED TO, COPYRIGHT LAW, AND NONE OF SUCH INFORMATION MAY BE COPIED OR OTHERWISE REPRODUCED, REPACKAGED, FURTHER TRANSMITTED, TRANSFERRED, DISSEMINATED, REDISTRIBUTED OR RESOLD, OR STORED FOR SUBSEQUENT USE FOR ANY SUCH PURPOSE, IN WHOLE OR IN PART, IN ANY FORM OR MANNER OR BY ANY MEANS WHATSOEVER, BY ANY PERSON WITHOUT MOODY'S PRIOR WRITTEN CONSENT.

All information contained herein is obtained by MOODY'S from sources believed by it to be accurate and reliable. Because of the possibility of human or mechanical error as well as other factors, however, all information contained herein is provided "AS IS" without warranty of any kind. MOODY'S adopts all necessary measures so that the information it uses in assigning a credit rating is of sufficient quality and from sources MOODY'S considers to be reliable including, when appropriate, independent third-party sources. However, MOODY'S is not an auditor and cannot in every instance independently verify or validate information received in the rating process or in preparing the Moody's publications.

To the extent permitted by law, MOODY'S and its directors, officers, employees, agents, representatives, licensors and suppliers disclaim liability to any person or entity for any indirect, special, consequential, or incidental losses or damages whatsoever arising from or in connection with the information contained herein or the use of or inability to use any such information, even if MOODY'S or any of its directors, officers, employees, agents, representatives, licensors or suppliers is advised in advance of the possibility of such losses or damages, including but not limited to: (a) any loss of present or prospective profits or (b) any loss or damage arising where the relevant financial instrument is not the subject of a particular credit rating assigned by MOODY'S.

To the extent permitted by law, MOODY'S and its directors, officers, employees, agents, representatives, licensors and suppliers disclaim liability for any direct or compensatory losses or damages caused to any person or entity, including but not limited to by any negligence (but excluding fraud, wilful misconduct or any other type of liability that, for the avoidance of doubt, by law cannot be excluded) on the part of, or any contingency within or beyond the control of, MOODY'S or any of its directors, officers, employees, agents, representatives, licensors or suppliers, arising from or in connection with the information contained herein or the use of or inability to use any such information.

NO WARRANTY, EXPRESS OR IMPLIED, AS TO THE ACCURACY, TIMELINESS, COMPLETENESS, MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE OF ANY SUCH RATING OR OTHER OPINION OR INFORMATION IS GIVEN OR MADE BY MOODY'S IN ANY FORM OR MANNER WHATSOEVER.

Moody's Investors Service, Inc., a wholly-owned credit rating agency subsidiary of Moody's Corporation ("MCO"), hereby discloses that most issuers of debt securities (including corporate and municipal bonds, debentures, notes and commercial paper) and preferred stock rated by Moody's Investors Service, Inc. have, prior to assignment of any rating, agreed to pay to Moody's Investors Service, Inc. for appraisal and rating services rendered by it fees ranging from \$1,500 to approximately \$2,500,000. MCO and MIS also maintain policies and procedures to address the independence of MIS's ratings and rating processes. Information regarding certain affiliations that may exist between directors of MCO and rated entities, and between entities who hold ratings from MIS and have also publicly reported to the SEC an ownership interest in MCO of more than 5%, is posted annually at www.moody's.com under the heading "Investor Relations — Corporate Governance — Director and Shareholder Affiliation Policy."

Additional terms for Australia only: Any publication into Australia of this document is pursuant to the Australian Financial Services License of MOODY'S affiliate, Moody's Investors Service Pty Limited ABN 61 003 399 657/AFSL 336969 and/or Moody's Analytics Australia Pty Ltd ABN 94 105 136 972 AFSL 383569 (as applicable). This document is intended to be provided only to "wholesale clients" within the meaning of section 761G of the Corporations Act 2001. By continuing to access this document from within Australia, you represent to MOODY'S that you are, or are accessing the document as a representative of, a "wholesale client" and that neither you nor the entity you represent will directly or indirectly disseminate this document or its contents to "retail clients" within the meaning of section 761G of the Corporations Act 2001. MOODY'S credit rating is an opinion as to the creditworthiness of a debt obligation of the issuer, not on the equity securities of the issuer or any form of security that is available to retail investors. It would be reckless and inappropriate for retail investors to use MOODY'S credit ratings or publications when making an investment decision. If in doubt you should contact your financial or other professional adviser.

Additional terms for Japan only: Moody's Japan K.K. ("MJKK") is a wholly-owned credit rating agency subsidiary of Moody's Group Japan G.K., which is wholly-owned by Moody's Overseas Holdings Inc., a wholly-owned subsidiary of MCO. Moody's SF Japan K.K. ("MSFJ") is a wholly-owned credit rating agency subsidiary of MJKK. MSFJ is not a Nationally Recognized Statistical Rating Organization ("NRSRO"). Therefore, credit ratings assigned by MSFJ are Non-NRSRO Credit Ratings. Non-NRSRO Credit Ratings are assigned by an entity that is not a NRSRO and, consequently, the rated obligation will not qualify for certain types of treatment under U.S. laws. MJKK and MSFJ are credit rating agencies registered with the Japan Financial Services Agency and their registration numbers are FSA Commissioner (Ratings) No. 2 and 3 respectively.

MJKK or MSFJ (as applicable) hereby disclose that most issuers of debt securities (including corporate and municipal bonds, debentures, notes and commercial paper) and preferred stock rated by MJKK or MSFJ (as applicable) have, prior to assignment of any rating, agreed to pay to MJKK or MSFJ (as applicable) for appraisal and rating services rendered by it fees ranging from JPY200,000 to approximately JPY350,000,000.

MJKK and MSFJ also maintain policies and procedures to address Japanese regulatory requirements.