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MODELING METHODOLOGY

Key Steps to Increasing Credit Portfolio Return/Risk

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Abstract

Institutions holding credit portfolios can increase stakeholder value by increasing portfolio return/risk, while also ensuring capital adequacy and regulatory compliance. This paper describes a conceptually-sound quantitative and practical approach to increase portfolio return/risk, details the requisite steps, and shows how they can be effectively performed using Moody's Analytics PortfolioStudio®, a cloud-based, credit portfolio management solution designed with the business user in mind.

Table of Contents

1. Introduction

It is well understood that institutions holding credit portfolios can increase stakeholder value by increasing portfolio return/risk while also ensuring capital adequacy and regulatory compliance. This requires five key steps:

1. Measuring portfolio risk and ensuring capital adequacy
2. Quantifying each exposure's incremental impact on portfolio risk
3. Setting limits to prevent excessive risk concentrations
4. Increasing/decreasing credit exposure to increase portfolio return/risk
5. Pricing and sizing new deals to increase portfolio return/risk

While Steps 4 and 5 ultimately, and most directly, increase stakeholder value, they cannot be effectively performed without first securing regulatory approval, favorable credit rating, and stakeholder confidence by performing Step 1, i.e., measuring portfolio risk and ensuring capital adequacy, then performing Step 2 to quantify each exposure's incremental impact on portfolio risk, and then using the incremental measures to effectively perform Steps 3, 4, and 5. Each of the five steps involves key questions and sub-steps that must be addressed and performed in order to increase portfolio return/risk and, thereby, increase stakeholder value.

Key Steps and Questions

1. Measuring portfolio risk and ensuring capital adequacy
    a. Loss Distribution: How much capital is required to absorb possible portfolio losses?
    b. Stress Testing: What are the expected losses and capital requirements under stress scenarios?
    c. Reverse Stress Testing: What scenarios, borrowers, sectors/regions contribute most to large losses?
    d. Capital Planning: What actions will be taken to maintain capital adequacy as stress scenarios unfold?
    e. Risk Appetite: What are the target levels (risk appetite) and limits (risk tolerances) for risk taking?
2. Quantifying each exposure's incremental impact on portfolio risk
    a. Risk Contribution: What is the increase in portfolio risk per unit increase in exposure notional?
    b. Risk Concentrations: Which borrowers, sectors, and regions impact portfolio risk the most?
    c. Risk Attribution: Which factors cause and explain exposure's Risk Contribution level?
3. Setting limits to prevent excessive risk concentrations
    a. Segment Limits: What is the notional limit given a limit on each segment's Risk Contribution?
    b. Borrower Limits: What is the notional limit given a limit on borrower's Risk Contribution?
4. Increasing/reducing credit exposure to increase portfolio return/risk
    a. Asset Selection: Which exposures should be increased/decreased to increase portfolio return/risk?
    b. Optimal Allocation: Which segments should be grown/reduced and by how much, in order to maximize portfolio return/risk ("Sharpe Ratio")?
5. Pricing and sizing new deals to increase portfolio return/risk
    a. Risk-Based Pricing: What is the deal's Risk Contribution and Sharpe Ratio, i.e., deal's impact on portfolio return/risk, taking account of deal's notional, standalone risk, and correlation with portfolio?

Designed with the business user in mind and delivered as a cloud-based application, and as described in the rest of this document, Moody's Analytics' PortfolioStudio is an agile efficient solution to perform the five steps and their sub-steps and address questions listed above.

We organize the remainder of this paper as follows: Sections 2–6 describe quantitative approaches and methods for performing each of the above listed steps and sub-steps using PortfolioStudio. Section 7 describes additional functionalities of PortfolioStudio. Section 8 concludes.

2. Measuring Portfolio Risk and Ensuring Capital Adequacy

While regulatory requirements and expectations differ based on jurisdiction and institution type, most financial institutions understand the need to assess and ensure capital adequacy from regulatory, accounting, and economic perspectives, together with actual use of the capital adequacy assessment results and metrics. PortfolioStudio's outputs inform, support, and enable regulatory, accounting, and economic decision-making by facilitating stress testing and calculating risk and return using CECL- or IFRS 9-based credit earnings, as well as economic or fair value methods.

Loss Distribution: How much capital is required to absorb possible portfolio losses?

PortfolioStudio uses Moody's extensively validated Global Correlation ("GCorr™") framework, together with bottom-up Monte Carlo simulation, to simulate credit losses (due to credit migration and default) at a future horizon (typically one year) for each exposure, taking into account standalone risk, as well as portfolio correlations and risk concentrations.[1] Exposure losses from each simulation trial are added to generate the probability distribution of portfolio losses at the specified future horizon, and to calculate crucial portfolio[2] risk metrics, including:

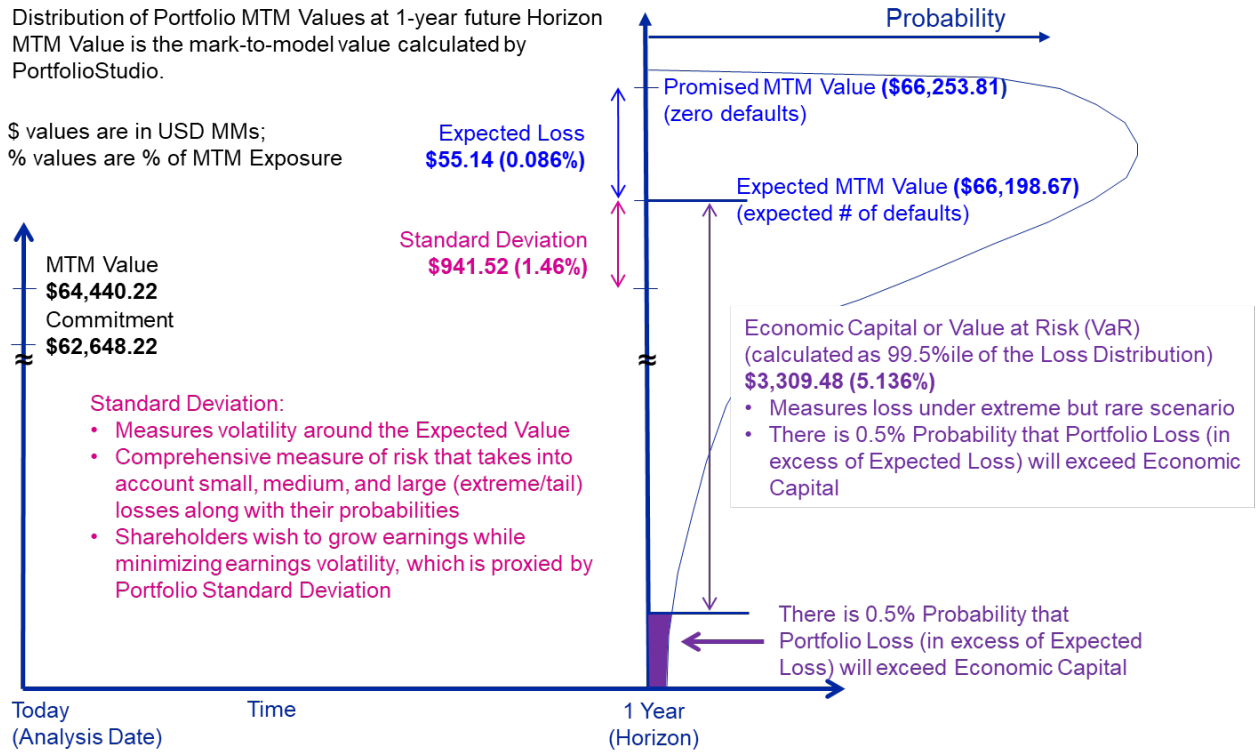
- Loss quantile (aka Credit Value at Risk (CVaR) or Economic Capital ("EC"))
  Example: 99.9 percentile loss corresponds to the capital required to absorb all but the worst 0.1% of portfolio losses and can be compared with available capital (e.g. CET1) to assess capital adequacy. The quantile or confidence level (e.g. 99.9 percentile) or the corresponding target probability (e.g. 0.1%) can be specified in PortfolioStudio to match regulatory or economic requirements or the survival probability corresponding to institution's target credit rating.
- Unexpected loss, i.e., standard deviation or volatility of portfolio losses at a future horizon
  Note: Expected return and expected loss measures are also calculated and reported by PortfolioStudio. Institutions can choose whether PortfolioStudio calculates return and risk measures using loss based on economic or fair value or (optionally) loss based on CECL- or IFRS 9-based credit earnings.
- List of macroeconomic variables ranked by their correlation with portfolio loss

PortfolioStudio's portfolio overview functionality outputs the above risk metrics, together with portfolio loss distribution and other relevant metrics — all of which inform and support an institution's capital adequacy assessment, capital planning and management, risk strategy, risk appetite, and risk tolerance, and are increasingly being reported and communicated both internally and externally.

[1] PortfolioStudio is designed to explicitly analyze a broad range of asset classes (public and private firms, CRE, retail, sovereign, and project finance) and credit instruments (term loans, revolving lines of credit, bonds, CDS, and structured products). GCorr is a multi-factor correlation model — consisting of close to 1,000 geographical, sectoral, and national and regional macroeconomic factors — is updated and validated annually and is based on a long time series of empirical and granular data capturing intra- and inter-asset class correlations. For more information, see "An Overview of Modeling Credit Portfolios" by Levy (2013); "Modeling Credit Correlations: An Overview of the Moody's Analytics GCorr Model" by Huang, Lanfranconi, Patel, and Pospisil (2012); and "Portfolio Management of Default Risk" by Kealhofer and Bohn (2001).

[2] The same simulation is also used to calculate exposure and segment-level risk metrics, including marginal risk contributions and correlation with portfolio, described later in this document.

Figure 1 Distribution of portfolio value at horizon.



Note: PortfolioStudio calculates return and risk measures and loss distribution using loss based on economic or fair value, or (optionally) loss based on CECL- or IFRS 9-based credit earnings.

Stress Testing: What are the expected losses and capital requirements under stress scenarios?

PortfolioStudio's stress testing module uses a Monte Carlo simulation engine, together with the GCorr framework, to capture and calculate systematic factors' (e.g. country and industry factors) and macroeconomic factors' (e.g. GDP, unemployment rate, etc.) impacts on borrower credit quality and the resulting exposure and portfolio losses and credit earnings under user-specified or pre-loaded stress scenarios (e.g. CCAR scenarios). GCorr model coverage continues to expand, and currently includes close to 1,000 total factors, including about 250 national, regional, and international macroeconomic variables.

PortfolioStudio's single-period stress testing simulates portfolio loss and credit earnings to calculate, conditional upon a set of macrovariables at horizon, portfolio expected loss (or expected credit earnings) and loss quantile (or credit earnings at risk), which capture the uncertainty in loss (or credit earnings) due to uncertainty in factors other than those specified in the single-period stress scenario.

PortfolioStudio's multi-period stress testing is used to calculate expected losses, loss distribution, and capital requirements for future quarters, given a user-specified multi-quarter macroeconomic scenario. PortfolioStudio first calculates stressed PDs for each borrower, at each period of the scenario, and then, using the stressed PDs as inputs, performs risk analysis and calculates results for each period during the multi-period scenario, thus yielding a term structure of expected loss (or credit earnings), loss quantiles (credit earnings at risk), and capital requirements.

Single-period and multi-period stress testing results from PortfolioStudio can be used to:

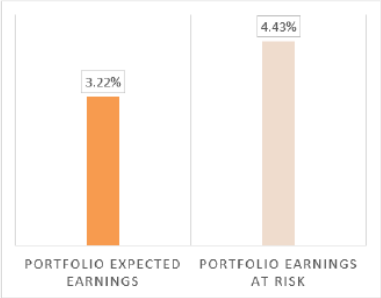
- Calculate expected loss, loss volatility, and capital requirements under stress scenarios
- Benchmark similar results from alternative models or estimates
- Assess capital adequacy, e.g. estimate the probability of exhausting the capital surplus by comparing distribution of portfolio loss and credit earnings and capital demand and supply under stress scenarios
- Meet regulatory and internal requirements for stress testing, communication, and disclosures
- Hedge assets, rebalance portfolio, set risk limits, and price risk based on sensitivity to stress

Figure 2 Stress testing using PortfolioStudio.

Access portfolio performance under a macro scenario.

Multi-Variate Scenario Analysis	
Selected Macro Variable	US Equity
US Equity Growth Rate	-5.00%
Selected Macro Variable	Asia GDP
Asia GDP Growth Rate	0.00%
Selected Macro Variable	Germany GDP
Germany GDP Growth Rate	1.00%
Selected Macro Variable	NA
#N/A	
Selected Macro Variable	
#N/A	

US House Price Index
US CRE Index
US VIX
Eurozone GDP
Eurozone Inflation
Eurozone FX (EUR/USD)
Asia GDP
Asia Inflation



Portfolio earnings are most sensitive to these macro variables	
Macro Variable Names	
US Long Rate	42%
US Retail Sales	39%
Eurozone Equity	38%
Copper	38%
Hong Kong Equity	38%
UK Equity	37%
US Equity	37%
Canada FX (USD/CAD)	-36%

Identify macro variables portfolio earnings most sensitive to.

Around 100 macro variables available for selection.

Macro-Variable Name	MV Code	Format	Q0	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
US GDP	MV0001	Percentage Point	2.7	-4.7	-8.9	-6.8	-4.7	-3.6	-1.3	-0.2	2.8	3.5	4	4.2	4.5	4.5
US Nominal GDP	MV0002	Percentage Point	5.0	-2.3	-7.1	-5.1	-3	-1.8	0.3	1.4	4.3	4.8	5.2	5.3	5.5	5.4
US Equity	MV0011	Level	27673.2	13465.6	11631.4	10575.2	10306.1	9689.4	10099.8	10948.6	12031.1	13234.4	14712.7	16323.1	18143.2	20168.3
US House Price Index	MV0012	Level	194.4	185.7	171.1	159.4	150.7	143.4	139	136.1	136.1	136.2	137.3	138.8	140.7	143
US CRE Index	MV0013	Level	278.7	261.9	234.1	211.8	195.1	181.1	172.8	167.2	167.2	167.3	169.5	172.3	176	180.5
US VIX	MV0014	Level	13.1	50.7	62.4	59.5	52.8	47.4	37.9	29.7	23.5	19.8	17.5	16	15	14.4
Eurozone GDP	MV0015	Percentage Point	2.3	-4	-5.2	-4.3	-3.3	-1.6	-0.1	1	1.7	2.1	2.4	2.4	2.4	2.3
Eurozone Inflation	MV0016	Percentage Point	1.7	0.1	-0.7	-1.1	-1.2	-0.8	-0.5	-0.1	0.3	0.6	0.8	1	1.1	1.2
Asia GDP	MV0018	Percentage Point	5.9	-1.5	-0.8	1.5	2.9	4.9	5.9	6.2	6.2	6.3	6.4	6.5	6.5	6.6
Asia Inflation	MV0019	Percentage Point	2.6	0.3	-1	-1.7	-2.2	-2.1	-1.8	-1.4	-1	-0.6	-0.3	0	0.4	0.8
Asia FX	MV0020	Level	91.0	99.5	103.5	105.9	107.5	106.3	105	103.7	102.5	101.1	100	98.9	98.1	97.4
Japan GDP	MV0021	Percentage Point	1.8	-3.8	-7.4	-9.9	-11.4	-9.8	-7.3	-5	-3.2	-1.7	-0.5	0.3	0.9	1.3
Japan Inflation	MV0022	Percentage Point	0.9	-2.6	-3.7	-5	-5.8	-5.2	-4.5	-3.7	-3	-2.3	-1.7	-1.2	-0.7	-0.3

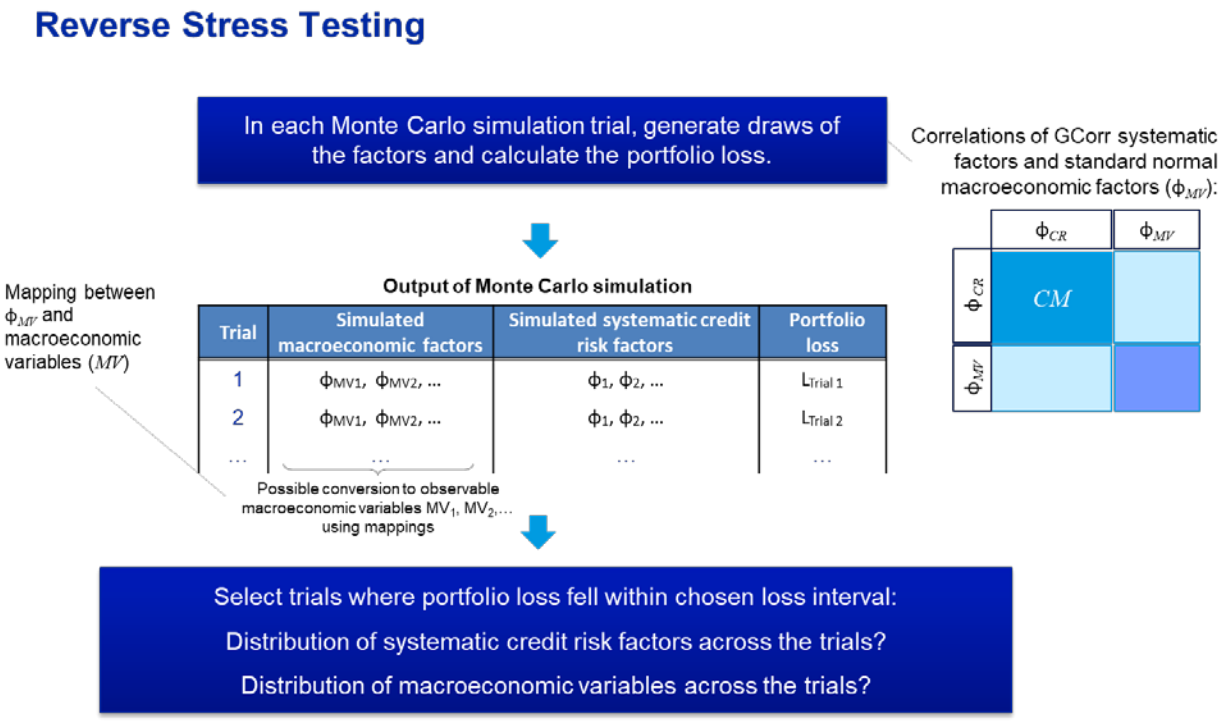
Allows for multi-period analysis under a macro scenario.

Reverse Stress Testing: What scenarios, borrowers, sectors/regions contribute most to large losses?

PortfolioStudio's reverse stress testing module utilizes simulation results (including portfolio loss, tail risk contributions, and GCorr systematic and macroeconomic factor realizations) to:

- Identify macroeconomic scenarios corresponding to a given level of portfolio loss or credit earnings
- Identify sectors and borrowers contributing most to such portfolio loss or credit earnings
- Reveal and plan for hidden vulnerabilities in the portfolio
- Benchmark against regulatory or other internal stressed scenarios
- Select macroeconomic variables for stress testing

Figure 3 Reverse stress testing approach using Monte Carlo simulation results.



Capital Planning: What actions will be taken to maintain capital adequacy as stress scenarios unfold?

Stress testing and reverse stress testing results from PortfolioStudio can be used to:

- Project capital demand and capital supply and assess capital adequacy under stress scenarios
- Plan and determine management actions (e.g. capital increase or risk/exposure reduction) that will be taken to prevent and to recover from possible capital deficiencies, if and as stress scenarios unfold
- Use such capital planning as part of internal capital adequacy assessment process and discussion with regulators, supervisors, and stakeholders.

Risk Appetite: What are the target levels (risk appetite) and limits (risk tolerances) for risk taking?

Prior sections describe how PortfolioStudio can be used to measure portfolio risk (loss distribution, volatility, quantile, etc.) and perform stress testing and reverse stress testing to assess and ensure capital adequacy. Portfolio risk and capital adequacy assessment results and metrics from PortfolioStudio can then be used to estimate capital demand and supply and compare them with market opportunity and risk strategy to inform and determine:

- Risk capacity, i.e., the maximum amount of risk that the institution is able to take on
- Risk appetite, i.e., the target amount or range of risk that the institution is willing to take on to pursue its risk strategy; risk appetite is lower than risk capacity to allow for safety margin
    - example: risk appetite to have AA S&P rating and CET1/EC of 250%
- Risk tolerance and risk limits, i.e., boundaries of risk taking within which the institution is willing to operate; risk appetite is more qualitative and at aggregate level whereas risk tolerances are more quantitative and granular, e.g. borrower and segment limits
    - example of segment risk limit: automotive segment expected loss under CCAR adverse scenario shall not exceed 20% of total portfolio's expected loss under CCAR adverse scenario

This section describes how PortfolioStudio can be used to measure portfolio risk, assess and ensure capital adequacy, and thereby secure regulatory approval, favorable credit rating, and stakeholder confidence — not just from the normative (i.e., regulatory or accounting) perspective but also from internal economic perspective. In the next section, we describe the next key step in increasing portfolio return/risk.

3. Quantifying Each Exposure's Incremental Impact on Portfolio Risk

Having measured portfolio risk and assessed and ensured capital adequacy, as described in Section 2, the institution can then focus on increasing portfolio return/risk, which naturally and practically can only be done by taking incremental actions on a select few exposures or borrowers at a time. Selecting which exposures to increase or decrease requires calculating each exposure's incremental impact on portfolio return/risk (aka "Marginal Contributions"), and then increasing those with the most favorable impact on portfolio return/risk and decreasing those with the least favorable impact on portfolio return/risk.

As incremental measures of exposure's impact on portfolio return and risk, Marginal Contributions:

- Enable continual improvement of the portfolio from current state towards the optimal state (maximum return/risk), even as the optimal state changes in time as portfolio characteristics change;
- Transcend limitations and conflicts of siloed measures, e.g. a risk measure calculated based on exposure's impact on a business line (sub-portfolio) may increase return/risk for that business line, but actually decrease return/risk for the overall institution (portfolio);
- Are most practical, actionable, and optimal measures for selecting which exposures to increase or decrease in order to continually increase portfolio return/risk.

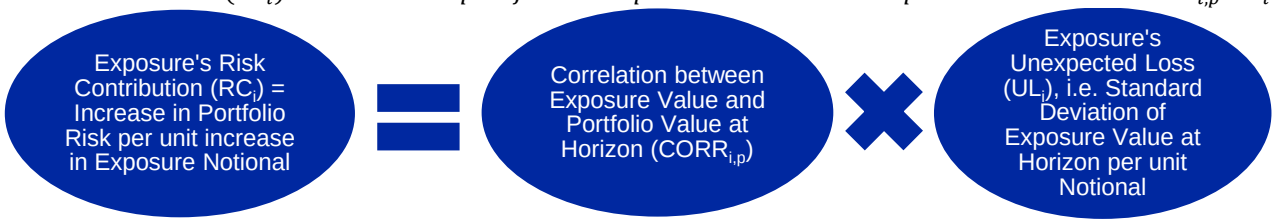
While a tail measure of portfolio risk such as 99.9 percentile loss (i.e., EC or CVaR) focuses on extremely large but rare losses and is used to assess capital adequacy, shareholders are more focused on measuring and minimizing loss volatility (i.e., standard deviation of losses at future horizon), accounting for the full range of losses (small, medium, large, and extremely large) together with their respective probabilities. In this document, an exposure's Marginal Contribution to portfolio tail risk (e.g. EC or a user-specified probability interval (e.g. 99.9 +/- 0.1 percentile) of the loss distribution) is termed "Tail Risk Contribution," whereas, an exposure's Marginal Contribution to portfolio standard deviation (volatility) is termed "Risk Contribution". PortfolioStudio calculates and reports both: Risk Contributions and Tail Risk Contributions.

Risk Contribution: What is the increase in portfolio risk per unit increase in exposure notional?

Exposure's Risk Contribution ("RC_i"), defined as the increase in portfolio risk (i.e., standard deviation of portfolio value at horizon) per unit increase in exposure's notional, can be shown to equal the exposure's standalone risk per unit notional, i.e., standard deviation of exposure value at horizon per unit notional (aka "unexpected loss" or "UL_i"), multiplied by the correlation between exposure value and portfolio value at horizon ("$CORR_{i,p}$").

Figure 4 Risk contribution equation.

$$Risk\ Contribution\ (RC_i) = Increase\ in\ portfolio\ risk\ per\ unit\ increase\ in\ exposure\ notional = CORR_{i,p} * UL_i$$



Only the correlated portion of the exposure's standalone risk (UL_i) contributes to and impacts the portfolio risk; the remaining portion of UL_i, being uncorrelated with the portfolio, is diversified away. Exposure value's correlation with portfolio value ($CORR_{i,p}$), and, resultantly, exposure's Risk Contribution (RC_i), both increase as any of the following increase, all else equal:

- Exposure's size, i.e., notional
- Exposure's unexpected loss (UL_i), i.e., standalone risk (standard deviation of exposure value at horizon) per unit notional; note: UL_i generally increases as exposure's PD, LGD, and maturity increase
- Exposure's R-squared, i.e., % of borrower's asset value risk that is systematic
- Correlation between sector and region of the exposure with those of the portfolio

PortfolioStudio calculates each exposure's standalone risk (UL_i) using its PD, LGD, maturity, etc., and then calculates portfolio risk measures (including UL_p and EC) and instrument risk measures (including $CORR_{i,p}$ and RC_i) using bottom-up, exposure-level, GCorr-based correlated simulation, taking into account each exposure's notional, standalone risk per unit notional (driven mostly

by PD, LGD, and maturity), as well as correlation with other exposures in the portfolio, regardless of the source of correlation or risk concentration, e.g. borrower, sector, or region, thus eliminating the need for any concentration add-on (relative to an assumed benchmark for a supposedly well-diversified portfolio). Exposure-level Risk Contributions can then be appropriately weighted and averaged across borrowers or sub-portfolios (or segments) to calculate borrower- or segment-level Risk Contributions.

Risk Concentrations: Which borrowers, sectors, and regions impact portfolio risk the most?

Risk Contribution (RC), being the portfolio risk impact per unit ($) change in current exposure notional, is useful in deciding where to add/reduce the next $ of exposure. While RC changes as the exposure notional changes, current RC multiplied by current exposure notional, hereafter, termed "$ Risk Contribution" or "$RC," is indicative of the approximate increase or decrease in portfolio risk, if the current exposure notional is doubled or zeroed respectively, and it can be used together with RC to identify risk concentrations and exposures that could cause large losses to portfolio, and where to add/reduce exposure to increase diversification and reduce risk concentration and portfolio risk.

PortfolioStudio outputs RC and $RC together with PD, LGD, maturity, standalone risk (UL_i), R-squared, notional, weight (notional as % of portfolio notional), and correlation with portfolio ($CORR_{i,p}$) (collectively "risk drivers") for each exposure and segment and can be used to measure, manage, and price risk and take incremental actions to reduce risk concentrations and increase portfolio return/risk, as discussed in later sections. The following figures list RC and risk drivers for the top15 borrowers and sectors ranked by RC. PortfolioStudio generates them in order to facilitate monitoring and analysis of risk concentrations, including borrower (name) and sector concentration, as shown below via illustrative examples for an example portfolio.

Figure 5 Sources of borrower concentration.

Borrower Concentration: Top 15 Borrowers by Risk Contribution (RC)

Sub-Portfolio	Sector	Borrower	Notional	Risk Contribution	Correlation w/Portfolio	R-Squared	Stand-Alone Risk	PD	LGD	Maturity
		(Ranked by high RC)	($)	(% of Notional)	(Corr[VHi, VHp])	(Systematic Risk %)	(Std Dev as % of Notional)			(Year)
CRE	CRE Multi Family Housing	CRE 1371	3,968,000	9.80%	34.11%	34.35%	28.73%	32.85%	56.0%	3.16
CRE	CRE Multi Family Housing	CRE 1370	6,485,000	8.58%	32.85%	30.57%	26.12%	31.83%	56.0%	1.83
Large C&I	TRANSPORTATION EQUIPMENT	Large C&I 236	25,000,000	7.08%	39.73%	27.21%	17.81%	20.07%	25.0%	7.49
CRE	CRE Multi Family Housing	CRE 285	2,457,000	6.82%	34.59%	34.21%	19.72%	14.57%	53.0%	6.08
CRE	CRE Office	CRE 1432	3,527,000	6.82%	24.99%	28.03%	27.28%	24.05%	65.0%	2.16
CRE	CRE Office	CRE 1202	5,216,000	6.14%	26.59%	31.01%	23.08%	15.39%	63.0%	3.41
Large C&I	TRANSPORTATION EQUIPMENT	Large C&I 237	14,030,000	5.94%	30.43%	27.35%	19.52%	38.34%	25.0%	0.74
Large C&I	FINANCE	Large C&I 244	30,872,000	5.77%	43.97%	31.49%	13.11%	2.49%	50.0%	12.00
CRE	CRE Industrial	CRE 1080	2,064,000	5.71%	31.16%	34.49%	18.32%	8.66%	61.0%	6.08
CRE	CRE Retail Property	CRE 1530	10,877,000	5.65%	20.14%	19.22%	28.07%	41.83%	50.0%	2.75
CRE	CRE Multi Family Housing	CRE 335	8,795,000	5.27%	36.56%	35.39%	14.42%	7.35%	51.0%	5.91
CRE	CRE Multi Family Housing	CRE 1963	2,630,000	5.25%	32.56%	28.73%	16.13%	9.16%	51.9%	6.66
CRE	CRE Office	CRE 45	6,207,000	4.66%	23.45%	28.52%	19.89%	14.82%	63.0%	1.83
CRE	CRE Office	CRE 3	4,237,000	4.59%	23.32%	29.11%	19.70%	15.50%	63.0%	1.66
CRE	CRE Office	CRE 2095	3,138,000	4.45%	23.53%	29.71%	18.90%	14.45%	51.0%	7.49
		Total Portfolio		0.69%	10.44%	10.78%	4.93%	1.96%	38.5%	5.70

- Most of the high RC borrowers can be explained in terms of their very high PD, LGD, and R-Squared (Systematic Risk %) relative to Portfolio average PD of 1.96%, LGD of 38.5%, and R-Squared of 10.78%.
- One would expect the highlighted Finance sector "Large C&I 244" borrower, whose PD (2.49%) is much lower than that of the other borrowers on this list, to have a lower RC. But it has a higher RC because of its much higher "Correlation with Portfolio" (43.97%), which itself is driven by:
  - Its large Book Exposure ($30.8Million), which creates large idiosyncratic risk that is not diversified away
  - Its high R-Squared, i.e. Systematic Risk % (31.49%)
- Reducing exposure to these high RC borrowers will reduce Risk Concentration and decrease Portfolio Risk (i.e. Portfolio Standard Deviation as a % of Portfolio Notional).

Figure 6 Sources of sector concentration.

Sector Concentration: Top 15 Sectors by Risk Contribution (RC)

Sector	Notional	Risk Contribution	Correlation w/Portfolio	R-Squared	Stand-Alone Risk	PD	LGD	Maturity
(Ranked by high RC)	(% of Portfolio)	(% of Notional)	(Corr[VHi, VHp])	(Systematic Risk %)	(Std Dev as % of Notional)			(Year)
TRANSPORTATION EQUIPMENT	0.14%	6.67%	36.39%	27.26%	18.42%	26.64%	25.0%	5.07
FINANCE	0.23%	3.01%	25.34%	25.23%	8.08%	2.44%	42.3%	6.09
CRE Hotel Full Service	0.45%	2.39%	29.39%	49.02%	7.62%	5.10%	32.4%	4.14
CRE Multi Family Housing	4.60%	1.58%	23.16%	31.27%	6.09%	2.29%	49.1%	4.04
REAL ESTATE	6.64%	1.58%	15.56%	7.77%	10.06%	4.27%	39.2%	3.46
CONSTRUCTION	12.27%	1.50%	14.85%	6.45%	10.17%	4.39%	39.1%	3.42
CRE Office	2.16%	1.48%	17.18%	27.27%	7.35%	3.50%	49.3%	4.35
CRE Retail Property	1.35%	1.40%	18.31%	28.00%	6.73%	3.62%	46.0%	3.69
CRE Industrial	1.75%	1.36%	18.55%	31.26%	6.53%	4.09%	49.8%	3.36
MINING	0.64%	1.30%	20.67%	29.37%	5.30%	1.73%	39.7%	2.83
CONSUMER PRODUCTS	0.35%	1.26%	23.48%	24.33%	4.98%	2.04%	26.4%	3.51
LESSORS	1.98%	1.06%	10.50%	5.03%	8.17%	3.75%	40.1%	3.53
AEROSPACE & DEFENSE	0.35%	1.03%	20.19%	35.07%	4.23%	1.66%	35.2%	2.17
TELEPHONE	0.84%	0.78%	16.28%	25.59%	3.71%	4.76%	28.8%	2.46
BUSINESS SERVICES	3.23%	0.71%	10.99%	10.70%	6.02%	2.28%	37.1%	2.78
Total Portfolio	100.00%	0.69%	10.44%	10.78%	4.93%	1.96%	38.5%	5.70

- Comparing Transportation Equipment and Construction:
  - Transportation Equipment has a lower MTM (0.14% vs. 12.27%) but higher RC (6.67% vs. 1.5%), which is driven by higher PD (26.64% vs. 4.39%) and higher R-Squared, i.e. Systematic Risk % (27.26% vs. 6.45%).
  - The borrowers in Transportation Equipment are large C&I firms, which have high Systematic Risk %.
  - Most borrowers in Construction are small SME firms, which have very low Systematic Risk %.
- Reducing exposure to Transportation Equipment will be more effective in reducing Risk Concentration and decreasing Portfolio Risk (i.e. Portfolio Standard Deviation as a % of Portfolio Notional).

Risk Attribution: Which factors cause and explain exposure's Risk Contribution level?

Users often want to understand why an exposure's Risk Contribution (RC) is higher or lower and what drives the changes. Users can use PortfolioStudio's Risk Attribution functionality to better understand, communicate, and act upon the reported risk measures for any exposure via:

i. An annotated flowchart relating the inputs and risk drivers to intermediate and final risk outputs and showing their levels.
ii. A table comparing the risk drivers and outputs of the chosen exposure with those of the relevant sector, geography, segment, and portfolio.
iii. An automated commentary describing the dynamics in simple business terms.

Figure 7 Risk attribution flowchart.

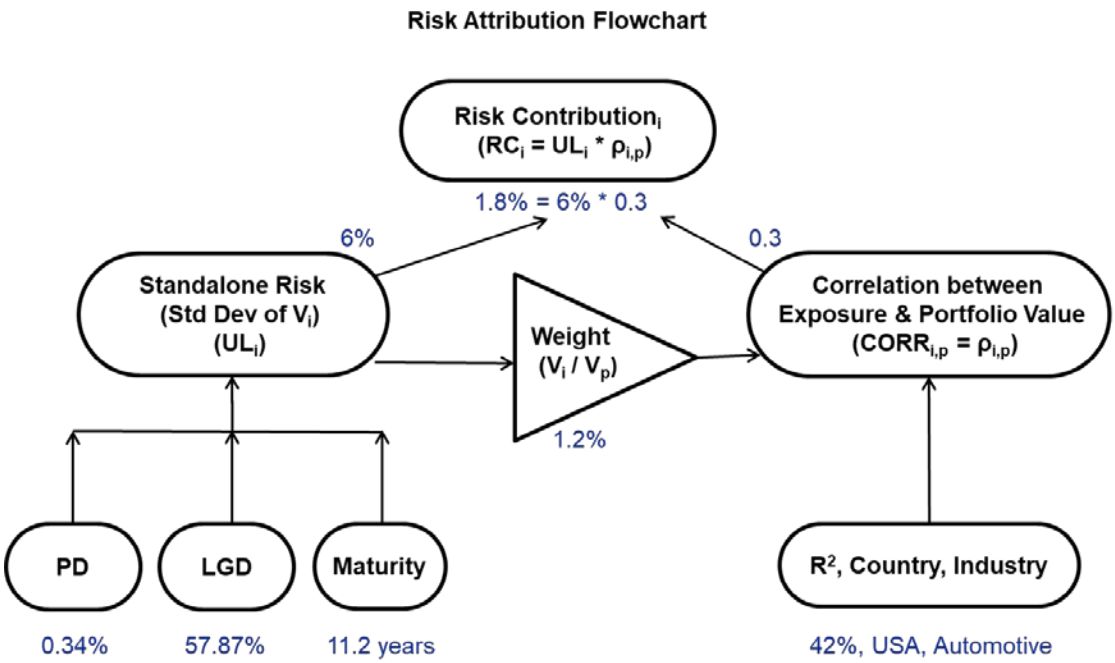


Figure 8 Risk attribution comparison table and commentary.

Risk Attribution: Comparison Table & Commentary

	Notional (% of Portfolio)	Risk Contribution (per $ Notional)	Correlation with Portfolio ($CORR_{i,p}$)	Systematic Risk Fraction (RSQ)	Standalone Risk per $ Notional (UL)	PD	LGD	Maturity (years)
Borrower: Nikola Inc.	1.00%	1.80%	0.30	45.22%	6.00%	0.34%	57.0%	11.2
Industry: Automotive	10.00%	3.60%	0.40	50.00%	9.00%	0.68%	58.0%	5.32
Segment: Commercial	40.00%	1.50%	0.30	35.00%	5.00%	0.25%	50.0%	5.00
Portfolio Total	**100.00%**							
Portfolio Average		**2.31%**	**0.33**	**35.00%**	**7.00%**	**0.50%**	**50.00%**	**5.10**

Risk Attribution: Commentary

- Nikola Inc. has a PD of 0.34%, compared to PD of 0.68% for Automotive, 0.25% for Commercial, and 0.5% for portfolio.
- Nikola Inc. has an LGD of 57% compared to 58%, 50, and 50% for Automotive, Commercial, and portfolio respectively.
- Nikola Inc.'s maturity is 11.2 years compared to 5.32, 5, & 5.1 years for Automotive, Commercial, & portfolio respectively.
- As a result of its PD, LGD, and maturity, Nikola Inc.'s Standalone Risk (UL) is 6% compared to 9%, 5%, and 7% for Automotive, Commercial, and portfolio respectively.
- Nikola Inc.'s R-Squared (systematic risk fraction) is 45% compared to 50%, 35%, and 35% for Automotive, Commercial, and portfolio respectively.
- Nikola Inc.'s commitment weight of 1%, UL of 6%, and R-squared of 45%, together with its industry automotive (with a 10% weight) results in a correlation with portfolio of 0.3 compared to .4, .3, and .33 for Automotive, Commercial, and portfolio respectively, causing its RC per $ commitment to be 1.8% (= UL * correlation w/ portfolio = 6% x 0.3) compared to 3.6%, 1.5%, and 2.31% for Automotive, Commercial, and portfolio respectively.

To review, PortfolioStudio can be used to (i) calculate each exposure's incremental impact on portfolio risk, (ii) identify sources of risk concentration and diversification, and (iii) better understand, communicate, and act upon the reported risk measures for any exposure, borrower, or segment. We now turn to the next key step in increasing portfolio return/risk.

4. Setting Limits to Prevent Excessive Risk Concentrations

Exposure- and segment-level return/risk measures, calculated as expected return divided by Risk Contribution (RC), can be used not only to increase portfolio return/risk via asset selection, as described in Section 5, but also to monitor return/risk and prevent excessive risk concentrations by rejecting deals or reducing exposures that have high RC and low return/risk and that would decrease portfolio return/risk. Doing so requires reliable tools and metrics and unflinching discipline.

As a practical, conservative alternative and/or supplementary approach, and as a backstop to the aforementioned return/risk-based monitoring and limit setting, most institutions also calculate and enforce absolute notional limits in order to prevent excessive risk concentrations and to keep risk levels consistent with risk appetite and risk strategy. Limits based on notional exposure are a good start, but they have significant limitations:

- They do not account for borrower or segment-specific risk.
- They do not account for the impact of borrower's or segment's correlation and concentration relative to the portfolio.
- They are more qualitative and subjective, and thus prone to subjective bias, and not easily defendable.
- They involve a manual process and are difficult to update frequently.
- They are not dynamic; they generally remain fixed despite changes to portfolio holdings and profile.

PortfolioStudio overcomes these limitations by using a quantitative and risk sensitive approach. It uses analytic formulas, together with Monte Carlo simulation results, to calculate the relationship ("Risk vs. Notional Curve") between a borrower's or segment's "Notional Weight" and the corresponding "Risk Contribution Weight," i.e., borrower's or segment's contribution to portfolio risk as a % of portfolio risk, for varying levels of borrower's or segment's Notional Weight, assuming no change to the rest of portfolio.

Segment Limits: What is the notional limit given a limit on each segment's Risk Contribution?

Given a set of user-specified Sector Risk Contribution Weight Limits and using the aforementioned Risk vs. Notional Curve, PortfolioStudio calculates the corresponding set of "Concentration Adjusted Notional Limits" for each segment, assuming no change to the rest of the portfolio. Users can specify the Sector Risk Contribution Weight Limits to be the same or different across segments, e.g. automotive segment's allocation of or contribution to portfolio risk (loss or earnings volatility) should not exceed 20% of Portfolio Risk. In addition to the GCorr industry and country segmentations, PortfolioStudio allows for up to four user-defined segmentations for segment-level reporting, what-if analysis, stress testing, optimization, and limit setting.

Figure 9 Limit setting using Risk vs. Notional Curves for sectors in an example portfolio.

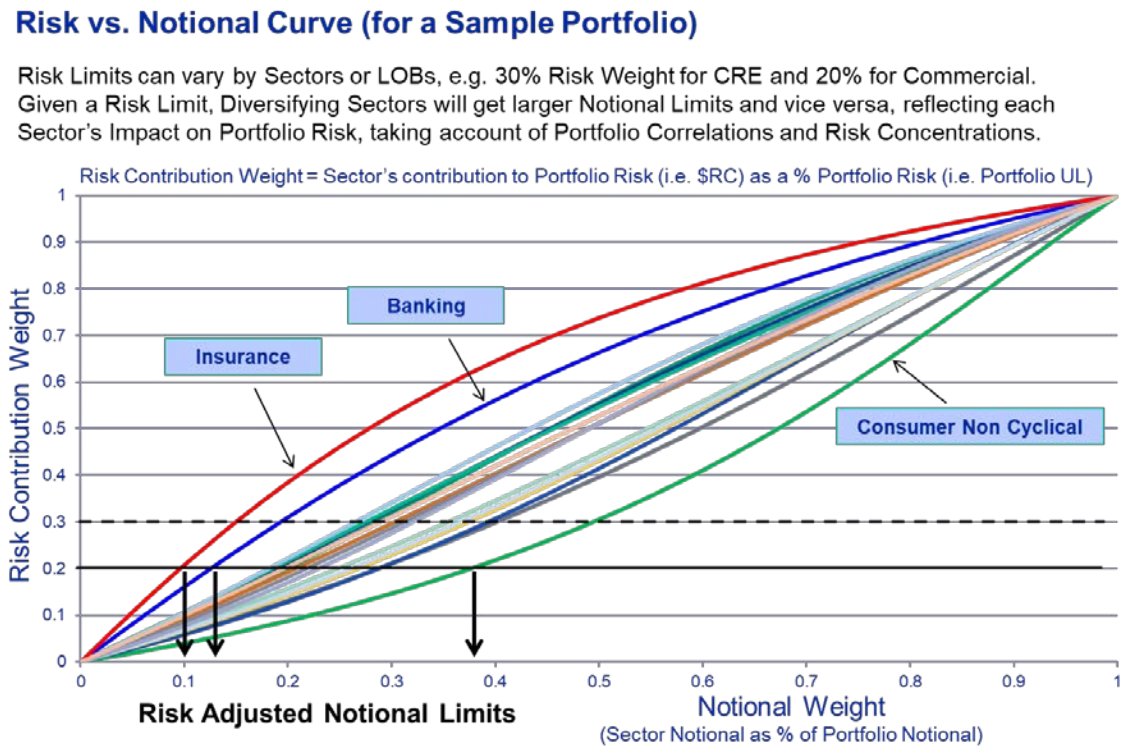


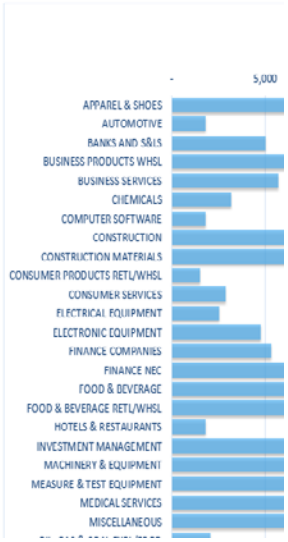
Figure 10 Limit setting via PortfolioStudio.

Risk Contribution Limits

Group Names	Notional ($)	Risk Contribution Weights (%)	Correlation with Portfolio (%)	Risk Contribution Limits (0-100%)	Notional Limits ($)	Weight Limits
APPAREL & SHOES	1,563,135	0.48%	16.71%	10.00%	15,042,685	23.04%
AUTOMOTIVE	291,942	0.94%	23.01%	10.00%	1,826,807	3.42%
BANKS AND S&LS	4,799,908	9.45%	48.31%	10.00%	5,010,825	9.63%
BUSINESS PRODUCTS WHSL	1,697,490	0.18%	8.80%	10.00%	25,449,689	33.67%
BUSINESS SERVICES	1,555,601	1.82%	26.55%	10.00%	5,718,987	10.21%
CHEMICALS	2,841,540	8.49%	37.37%	10.00%	3,185,339	6.11%
COMPUTER SOFTWARE	2,376,424	14.47%	45.65%	10.00%	1,833,363	3.58%
CONSTRUCTION	3,143,736	4.28%	34.07%	10.00%	5,995,676	10.97%
CONSTRUCTION MATERIALS	505,437	0.16%	5.97%	10.00%	6,113,954	10.65%
CONSUMER PRODUCTS RETL/WHSL	1,407,682	8.92%	34.99%	10.00%	1,515,061	2.92%
CONSUMER SERVICES	1,994,950	5.89%	32.75%	10.00%	2,881,193	5.47%
ELECTRICAL EQUIPMENT	1,797,960	6.19%	35.04%	10.00%	2,530,658	4.83%
ELECTRONIC EQUIPMENT	713,151	0.92%	24.49%	10.00%	4,740,148	8.49%
FINANCE COMPANIES	1,543,834	1.35%	15.43%	10.00%	5,318,181	9.57%
FINANCE NEC	1,322,315	1.43%	31.12%	10.00%	6,653,838	11.64%
FOOD & BEVERAGE	3,003,492	2.27%	24.02%	10.00%	8,544,782	14.90%
FOOD & BEVERAGE RETL/WHSL	1,442,066	0.70%	16.60%	10.00%	9,573,506	15.97%
HOTELS & RESTAURANTS	1,345,933	6.45%	32.27%	10.00%	1,806,057	3.45%
INVESTMENT MANAGEMENT	640,325	0.26%	8.43%	10.00%	6,496,732	11.26%
MACHINERY & EQUIPMENT	811,776	0.37%	19.82%	10.00%	11,357,474	18.21%
MEASURE & TEST EQUIPMENT	1,354,744	0.38%	15.49%	10.00%	15,313,935	23.28%
MEDICAL SERVICES	1,563,447	1.18%	18.27%	10.00%	6,822,787	11.95%
MISCELLANEOUS	686,578	0.39%	24.64%	10.00%	10,751,891	17.37%
OIL, GAS & COAL EXPL/PROD	2,042,306	9.82%	38.96%	10.00%	2,068,279	3.99%
PAPER	1,595,906	5.54%	28.93%	10.00%	2,334,510	4.44%
PHARMACEUTICALS	369,501	0.31%	12.92%	10.00%	4,411,050	7.90%
PUBLISHING	1,023,330	0.27%	8.26%	10.00%	9,588,906	15.88%
REAL ESTATE	1,025,567	1.25%	26.11%	10.00%	5,295,996	9.44%
REAL ESTATE INVESTMENT TRUSTS	1,733,533	1.35%	19.47%	10.00%	6,974,125	12.22%
STEEL & METAL PRODUCTS	1,803,016	1.18%	17.08%	10.00%	7,519,003	13.07%
TELEPHONE	881,813	1.34%	16.65%	10.00%	3,223,701	5.95%
TRANSPORTATION	1,191,793	0.93%	16.04%	10.00%	5,929,023	10.48%
TRUCKING	479,997	0.04%	7.95%	10.00%	28,431,282	35.64%
UTILITIES, ELECTRIC	1,274,524	0.98%	13.42%	10.00%	5,336,027	9.55%

Evenly Assign Risk Contribution Limits (0-100) 10.00%

Calculate Risk-based Limits



Borrower Limits: What is the notional limit given a limit on each borrower's Risk Contribution?

Using a similar approach as that for limit setting for segments described above, PortfolioStudio can also calculate Concentration Adjusted Notional Limits for the top-20 borrowers ranked by $ Risk Contribution.

To review, this section describes how PortfolioStudio can be used to set Concentration Adjusted Notional Limits given a user-specified limit on segment's or borrower's contribution to portfolio risk. This quantitative risk sensitive limit setting can be performed periodically using PortfolioStudio to reflect changes to portfolio holdings and their risk characteristics, as well as changes to risk appetite. In the next section, we describe the next key step in increasing portfolio return/risk.

5. Increasing/Decreasing Credit Exposure to Increase Portfolio Return/Risk

Prior sections focused on risk, i.e., the denominator of return/risk ratio. In this section and the next, we describe how PortfolioStudio can be used to calculate and increase portfolio return/risk and stakeholder value. We also discuss relevant best practices and ways to overcome implementation challenges.

Asset Selection: Which exposures should be increased/decreased to increase portfolio return/risk?

We can show that exposure's standalone, expected return equals that exposure's marginal contribution to portfolio expected return, regardless of exposure notional and portfolio characteristics. Thus, an exposure's Sharpe Ratio, defined as "expected return / Risk Contribution," is a marginal measure quantifying exposure's incremental impact on portfolio return/risk and can be used to decide which exposures to increase/decrease in order to increase portfolio return/risk. Portfolio return/risk can be increased by increasing exposures with Sharpe Ratios higher than the portfolio Sharpe Ratio and decreasing exposures with Sharpe Ratios lower than portfolio Sharpe Ratio. Portfolio Sharpe Ratio changes with the portfolio, and can be used as a dynamic hurdle rate, without the need to compare exposure's Sharpe Ratio with an exogenously imposed hurdle rate, which often is static and not portfolio-sensitive, despite changes in portfolio. Furthermore, using an exogenously imposed hurdle rate is superfluous (relative to using portfolio Sharpe Ratio as the hurdle rate) and may lead to asset selection that can actually decrease portfolio Sharpe Ratio.[3]

PortfolioStudio calculates and reports each exposure's and segment's expected return (or credit earnings based on CECL or IFRS 9) and Sharpe Ratio, together with Risk Contribution, correlation with portfolio, and other risk measures discussed previously, and which can be used to selectively increase/decrease exposures and increase portfolio return/risk. If regulatory or capital structure requirements appear to constrain the said asset selection, the institution can overcome such apparent constraints by scaling up (increasing) or scaling down (decreasing) all current exposures in the portfolio, or by raising additional capital, and then unconstrainedly proceeding towards the relative direction (buy/sell) and amounts (asset weights) indicated by the aforementioned Sharpe Ratio-based asset selection and portfolio improvement.

Optimal Allocation to Segments: Which segments should be grown/reduced and by how much, in order to maximize portfolio return/risk (Sharpe Ratio)?

Consistent with the Sharpe Ratio-based asset selection discussed previously, and utilizing segment level results from Monte Carlo simulation, PortfolioStudio's Deal Allocation application quickly calculates segment level optimal investment amounts that maximize portfolio return/risk, given user specified investment budget and segment level buy/sell limits. Users can choose to optimize the portfolio via any of the four strategies:

- Mean-Variance: minimize portfolio return volatility while meeting a target expected return
- Minimum Volatility: minimize portfolio return volatility across all expected return levels
- Maximum Sharpe Ratio: maximize portfolio Sharpe Ratio, i.e., expected return / return volatility
- Risk Parity: to the extent possible, equalize each segment's $ Risk Contribution ($RC)

Each of these optimization strategies can be performed on the portfolio with or without new deals. Each strategy can also be performed under user-specified stress scenarios. If regulatory or capital structure requirements appear to constrain the said optimization, the institution can overcome such apparent constraints by scaling up (increasing) or scaling down (decreasing) all current exposures in portfolio, or by raising additional capital, and then unconstrainedly proceeding towards the optimal direction (buy/sell) and asset weights indicated by the aforementioned return/risk optimization.

[3] For example, an exposure "i" with Sharpe Ratio (SR_i) greater than an exogenously imposed hurdle rate (HR) but less than portfolio Sharpe Ratio (SR_p), i.e. HR < SR_i < SR_p, will pass the hurdle but will actually decrease portfolio Sharpe Ratio. Similarly, an exposure "i" with Sharpe Ratio (SR_i) less than an exogenously imposed hurdle rate (HR) but greater than portfolio Sharpe Ratio (SR_p), i.e. HR > SR_i > SR_p, will fail the hurdle but will actually increase portfolio Sharpe Ratio.

Figure 11 Segment-level optimization and deal allocation via PortfolioStudio.

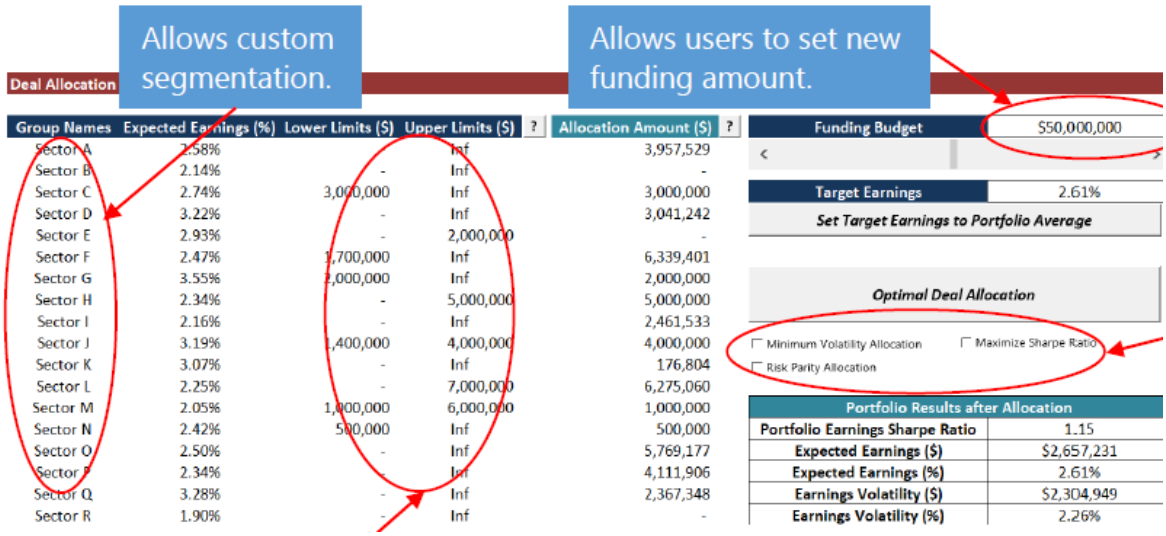


Figure 12 Increase in portfolio return/risk after performing deal allocation and portfolio optimization via PortfolioStudio.

	Before Optimization	After Optimization	Change
Holding Amount (Billion)	$50.434	$60.435	19.83%
Expected Return (ER)	1.73%	1.90%	9.58%
Unexpected Loss (UL)	1.90%	1.80%	-5.26%
Economic Capital (EC)	7.89%	8.21%	4.08%
Sharpe Ratio (ER/UL)	0.91	1.05	15.67%

PortfolioStudio also calculates and plots the efficient frontier, showing the full range of possible return and risk levels for the portfolio, including the point (shown as a red cross in Figure 16) corresponding to the maximum Sharpe Ratio.

Figure 13 Efficient frontier output from PortfolioStudio.

To review, this section describes how PortfolioStudio can be used to increase portfolio return/risk by Sharpe Ratio-based asset selection and segment-level portfolio optimization. The following section describes the next key step in increasing portfolio return/risk.

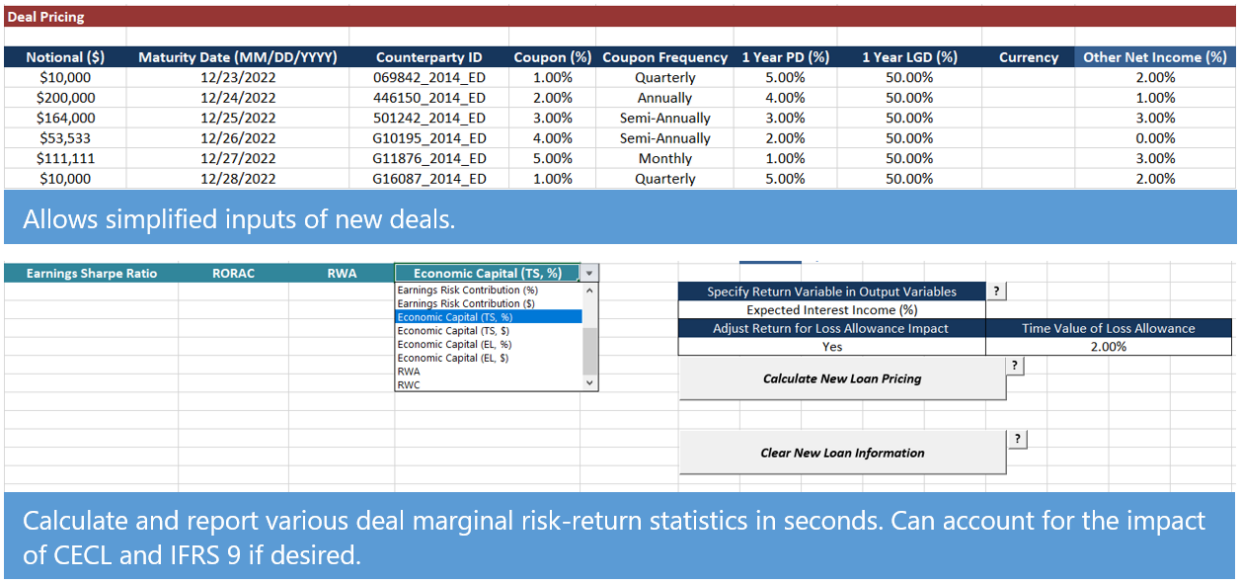
6. Pricing and Sizing New Deals to Increase Portfolio Return/Risk

The prior section focused on how PortfolioStudio can be used to decide what to buy, sell, or hold to increase portfolio return/risk. What is equally important is to do so at the right price and with the correct size and terms. Sizing and structuring deals appropriately become even more important when the institution is a price-taker rather than a price-setter. PortfolioStudio's deal pricing module enables institutions to quickly calculate return and risk measures for a new deal or a basket of new deals, considering the deal's standalone risk (driven mostly by PD, LGD, and maturity), as well as portfolio correlation and risk concentrations. The module has an intuitive user interface that enables deal makers to conveniently specify borrower characteristics (e.g. notional, PD, LGD, etc.) and deal terms and conditions (e.g. coupon, maturity, etc.). Users can also choose to incorporate the impact of CECL and IFRS 9 provisions or macroeconomic/stress scenarios into deal pricing.

Risk-Based Pricing: What is the deal's Risk Contribution and Sharpe Ratio, i.e., deal's impact on portfolio return/risk, taking account of deal's notional, standalone risk, and correlation with portfolio?

Leveraging key metrics from the original portfolio analysis, PortfolioStudio can quickly (within seconds) calculate marginal return and risk statistics, including expected return (or credit earnings), Risk Contribution (RC), Sharpe Ratio, and incremental portfolio economic capital for new deals. Alternately, given RC for a deal, one can calculate the pricing required to meet or exceed portfolio Sharpe Ratio or any user specified hurdle rate. Users can also calculate return/risk measures by substituting PortfolioStudio's expected return (numerator) with a user specified expected return, which should be a marginal measure, in order to remain consistent with Risk Contribution (denominator), which is marginal.

Figure 14 Risk-based deal pricing via PortfolioStudio.



Notional ($)	Maturity Date (MM/DD/YYYY)	Counterparty ID	Coupon (%)	Coupon Frequency	1 Year PD (%)	1 Year LGD (%)	Currency	Other Net Income (%)
$10,000	12/23/2022	069842_2014_ED	1.00%	Quarterly	5.00%	50.00%		2.00%
$200,000	12/24/2022	446150_2014_ED	2.00%	Annually	4.00%	50.00%		1.00%
$164,000	12/25/2022	501242_2014_ED	3.00%	Semi-Annually	3.00%	50.00%		3.00%
$53,533	12/26/2022	G10195_2014_ED	4.00%	Semi-Annually	2.00%	50.00%		0.00%
$111,111	12/27/2022	G11876_2014_ED	5.00%	Monthly	1.00%	50.00%		3.00%
$10,000	12/28/2022	G16087_2014_ED	1.00%	Quarterly	5.00%	50.00%		2.00%

Sections 2–6 describe how PortfolioStudio can be used to efficiently perform the five key steps to increasing portfolio return/risk. Section 7 describes additional PortfolioStudio functionality.

7. PortfolioStudio: Additional Functionality

What-If Analysis

PortfolioStudio's what-if analysis application allows users to modify inputs, e.g. by scaling or shifting PDs, for certain or all segments in a portfolio and examine the impact on portfolio risk statistics. It provides a convenient way for users to perform sensitivity analysis without creating and loading new portfolios.

Figure 15 What-If analysis inputs.

What-if Analysis				
Variable Name	Scale	Shift	Segmentation Level	Segmentation Name
Notional		100000	Industry	AUTOMOTIVE
Coupon		0.01	Country	AUSTRALIA
PD Term Structure	1.10		User Defined Sector 1	A1
Maturity		1	All	

Figure 16 What-If analysis results.

	Previous Portfolio Results	Updated Portfolio Results
Holding Amount	$1,000,000,000	$2,000,000,000
Expected Earnings	3.2%	1.3%
Expected Interest Income - Default Loss	3.4%	8.8%
Expected Interest Income	4.0%	9.5%
Earnings Volatility	1.6%	2.7%
Earnings at Risk	6.8%	19.6%
Earnings Sharpe Ratio	2.1	3.2
Economic Capital (TS)	8.6%	21.5%
Economic Capital (EL)	9.7%	20.5%
Risk-Based Capital (RBC)	NA	NA
RORAC	0.4	0.1
Current Loss Allowance	NA	NA
Average Annualized PD to Maturity	1.0%	1.1%
Average LGD	50.0%	50.0%
Average Maturity	2.2	2.1
Average RSQ	22.7%	21.9%

Risk Dashboard

PortfolioStudio's Risk Dashboard provides an executive view of all relevant risk measures on one screen. Users can choose from pre-defined templates with ability to move, select, or remove items. Clicking any item on the Risk Dashboard launches detailed view or corresponding module, most of which have been described previously in this document.

Figure 17 Risk dashboard.

Portfolio Risk Breakdown

Segment	EAD ($bn)	EAD	Risk Contribution (RC) (% of Portfolio)	(Per $EAD)	PD	LGD
Corporate	6.287	55%	35.0%	1.51%	0.30%	57.9%
CRE	2.033	18%	18.0%	1.94%	0.50%	23.8%
Retail	2.097	18%	12.0%	1.31%	0.40%	20.7%
Structured	1.031	9%	35.0%	6.44%	1.70%	41.4%
Portfolio	**11.448**	**100%**	**100%**	**1.94%**	**0.50%**	**43.5%**

Top 20 Borrowers by Risk Contribution (RC)

Sector	EAD	Risk Contribution (RC) (% of Portfolio)	(Per $EAD)	Concentration Coefficient (CC)	PD	LGD	Maturity (Years)
Borrower1	1.8%	4.8%	7.51%	7.51%	0.30%	57.9%	3.3
Borrower2	2.2%	3.7%	4.94%	3.94%	0.50%	23.8%	5.1
Borrower3	1.8%	3.2%	5.31%	3.31%	0.40%	20.7%	2.2
Borrower4	1.5%	2.5%	5.00%	2.44%	1.70%	41.4%	2.8
Portfolio	**100%**	**100%**	**1.94%**	**1.94%**	**0.50%**	**43.5%**	**3.2**

Top 20 Sectors by Risk Contribution (RC)

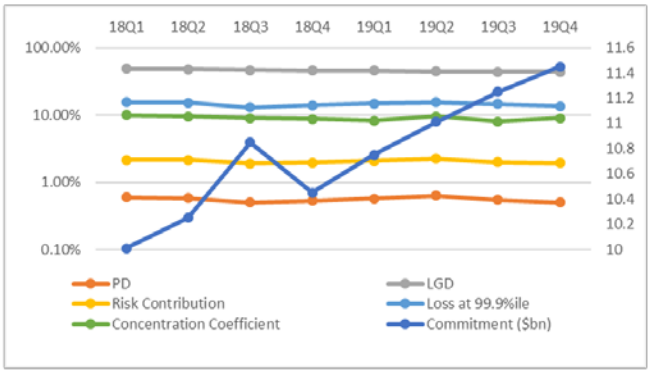
Country	EAD	Risk Contribution (RC) (% of Portfolio)	(Per $EAD)	Concentration Coefficient (CC)	PD	LGD	Maturity (Years)
Sector 1	10%	22.1%	5.51%	7.51%	0.30%	57.9%	3.3
Sector 2	15%	17.7%	2.94%	3.94%	0.50%	23.8%	5.1
Sector 3	10%	14.2%	3.31%	3.31%	0.40%	20.7%	2.2
Sector 4	8%	11.1%	3.00%	2.44%	1.70%	41.4%	2.8
Portfolio	**100%**	**100%**	**1.94%**	**1.94%**	**0.50%**	**43.5%**	**3.2**

Top 20 Countries by Risk Contribution (RC)

Country	EAD	Risk Contribution (RC) (% of Portfolio)	(Per $EAD)	Concentration Coefficient (CC)	PD	LGD	Maturity (Years)
Country 1	10%	22.1%	5.51%	7.51%	0.30%	57.9%	3.3
Country 2	15%	17.7%	2.94%	3.94%	0.50%	23.8%	5.1
Country 3	10%	14.2%	3.31%	3.31%	0.40%	20.7%	2.2
Country 4	8%	11.1%	3.00%	2.44%	1.70%	41.4%	2.8
Portfolio	**100%**	**100%**	**1.94%**	**1.94%**	**0.50%**	**43.5%**	**3.2**

Portfolio Risk Trend (last 8 quarters)

	18Q1	18Q2	18Q3	18Q4	19Q1	19Q2	19Q3	19Q4
EAD ($bn)	10.01	10.25	10.85	10.45	10.75	11.01	11.25	11.45
PD	0.60%	0.58%	0.50%	0.53%	0.57%	0.63%	0.55%	0.50%
LGD	48.5%	47.5%	46.5%	45.5%	45.5%	44.5%	44.0%	43.5%
Risk Contribution	2.14%	2.15%	1.89%	1.97%	2.09%	2.22%	1.99%	1.94%
Loss at 99.9%ile	15.5%	15.2%	13.0%	14.0%	14.9%	15.5%	14.5%	13.5%
Concentration Coefficient (CC)	9.9%	9.5%	9.0%	8.7%	8.2%	9.5%	8.0%	9.0%

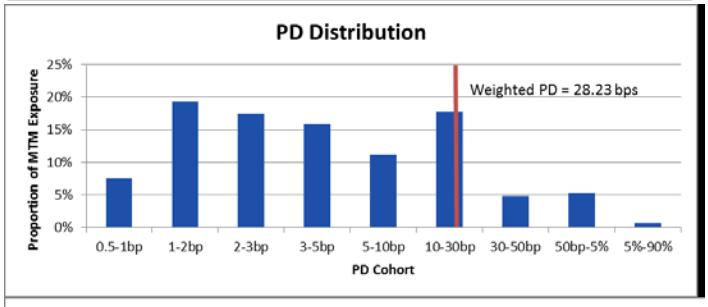


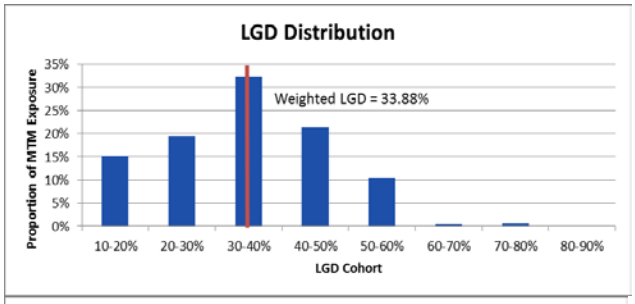
Concentration Limit Breaches:

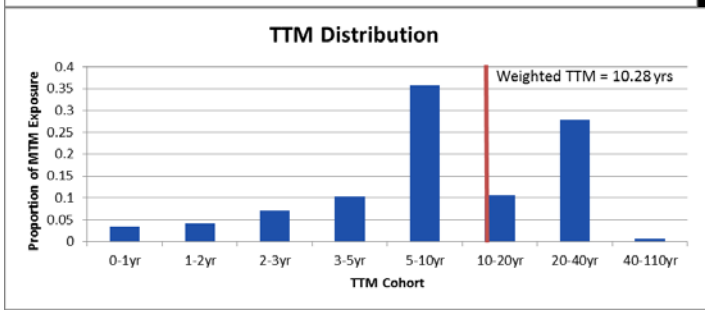
Sector Limit	•Breach: None •Watch: Sector1 EAD of 1.14B close to limit of 1.2B
Borrower Limit	•Breach: Borrower1 EAD of 220M exceeds limit of 200M

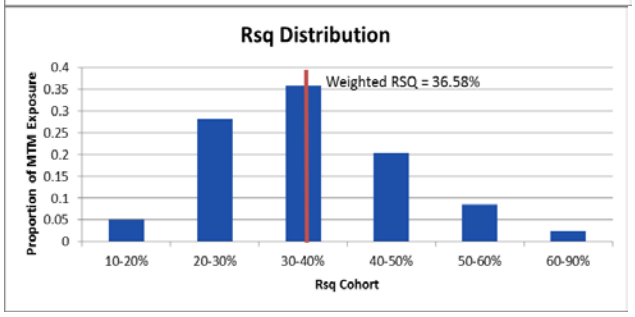
New Deals:

Xyz Inc.	•100M, 5-year Term Loan 3.75% maturing 12/31/2025 •Rating AA, PD 0.25%, LGD 50%, Expected Return: 5% •RegCap: 10M, EC: 11M, Sharpe Ratio: .5

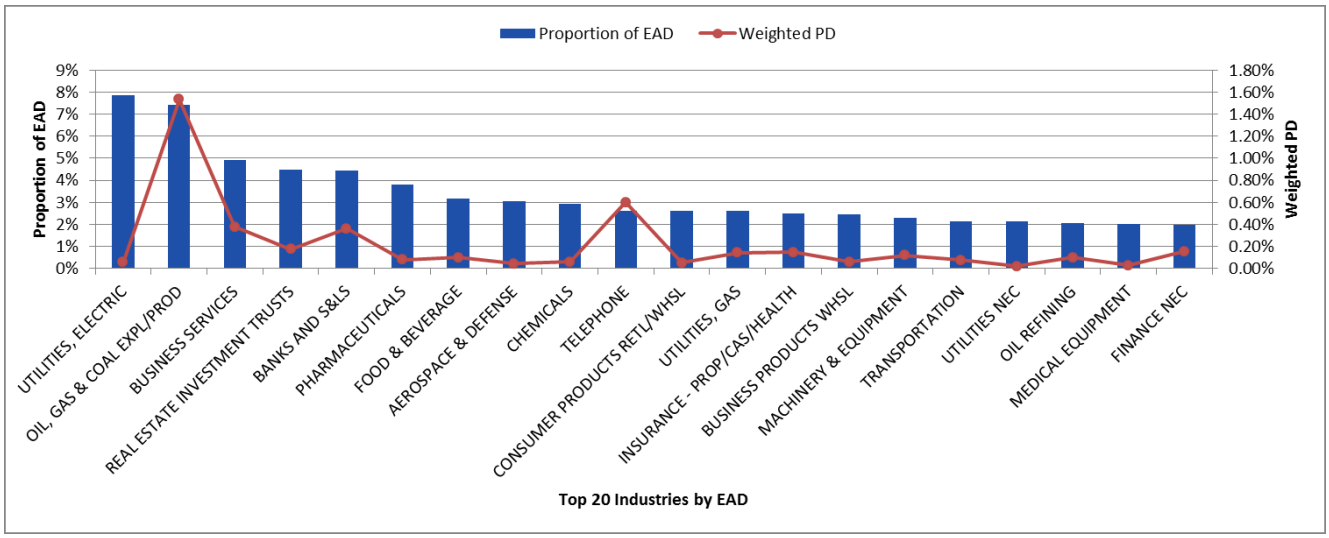


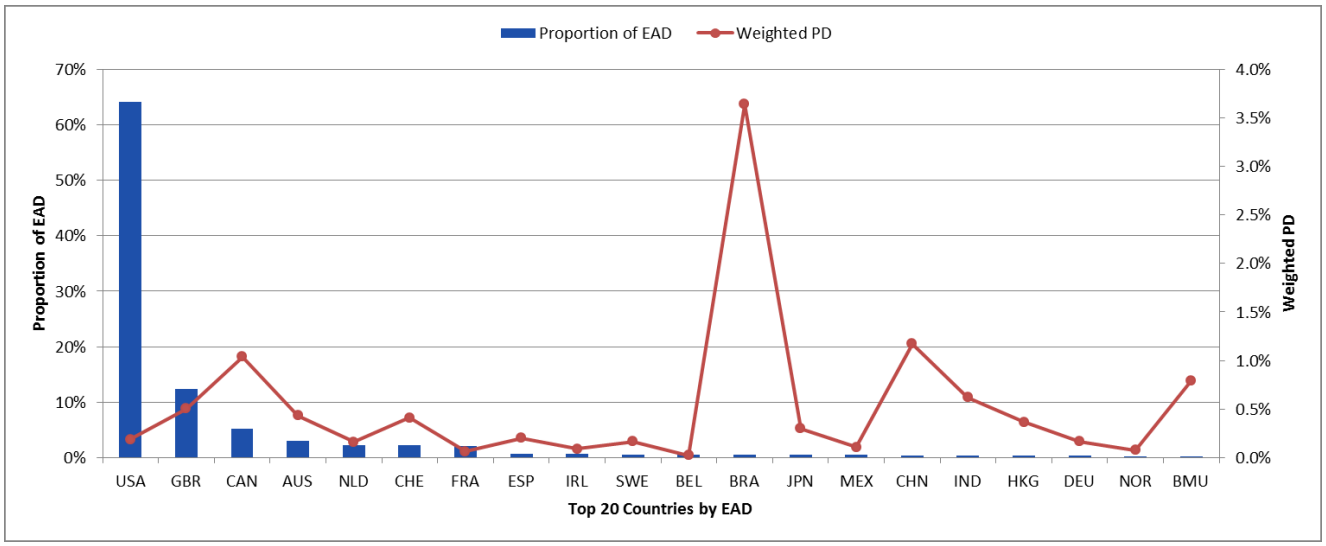




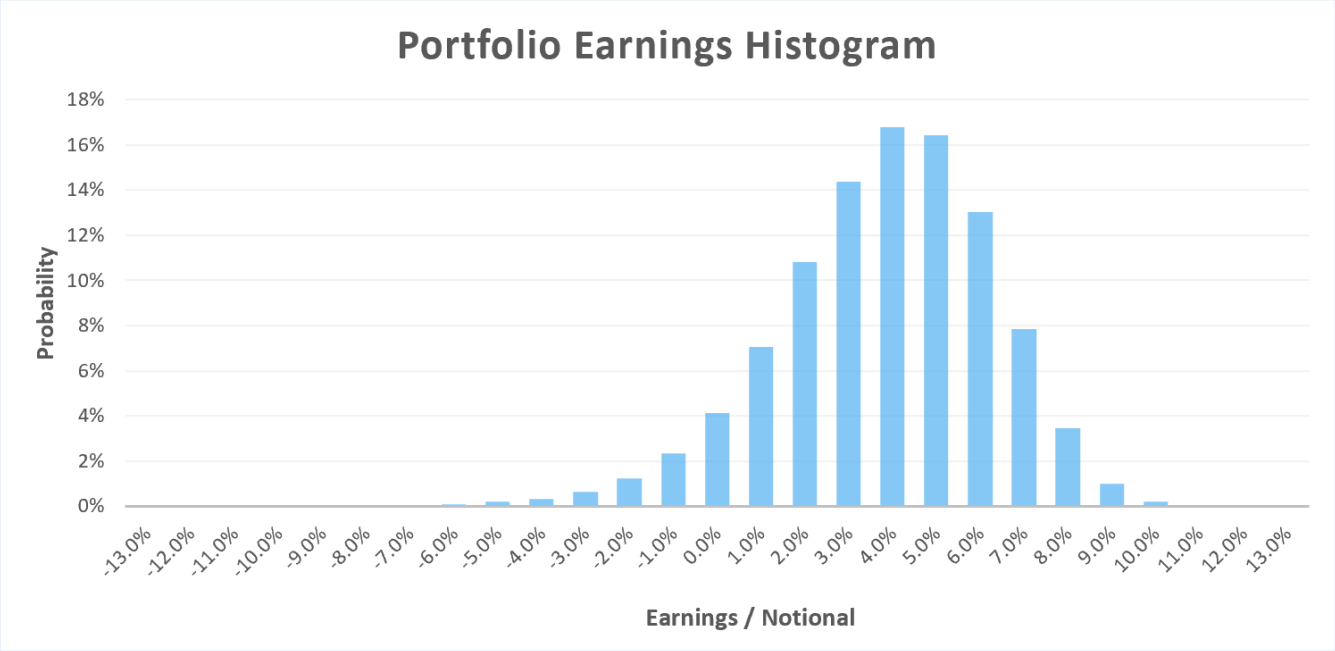


Risk Dashboard (continued)



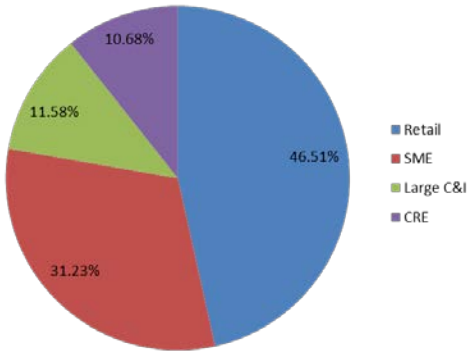


Risk Dashboard (continued)



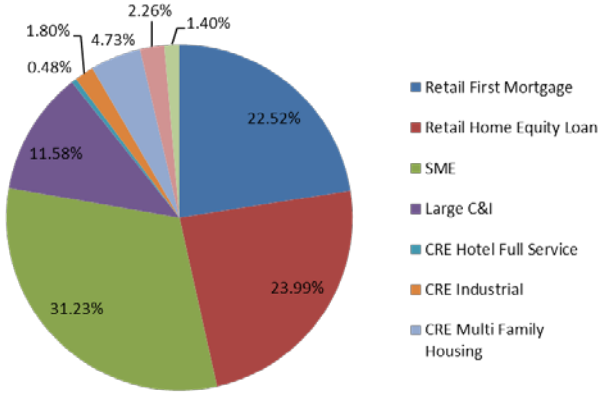
Risk Dashboard (continued)

Portfolio Composition (Notional)



Portfolio	Notional	Notional	# of Instruments
	(% of Portfolio)	($'000s)	
Retail	46.51%	12,650,838	407,922
SME	31.23%	8,494,168	61,789
Large C&I	11.58%	3,150,808	373
CRE	10.68%	2,905,110	2,225
Total Portfolio	**100.00%**	**27,200,924**	**472,309**

Sub-Portfolio Composition (Notional)



Portfolio	Notional	Notional
	(% of Portfolio)	($'000s)
Retail	46.51%	12,650,838
First Mortgage	22.52%	6,125,363
Home Equity Loan	23.99%	6,525,475
SME	31.23%	8,494,168
Large C&I	11.58%	3,150,808
CRE	10.68%	2,905,110
Hotel Full Service	0.48%	130,471
Industrial	1.80%	490,905
Multi Family Housing	4.73%	1,286,432
Office	2.26%	615,381
Retail Property	1.40%	381,921
Total Portfolio	**100.00%**	**27,200,924**

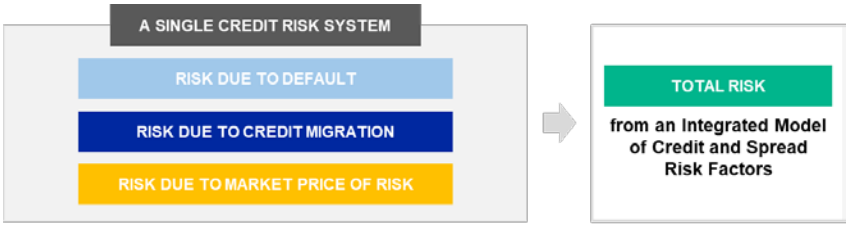
Sub-Portfolio	MTM	Risk Contribution	Correlation w/Portfolio	R-Squared	Stand Alone Risk	PD	LGD	Maturity
	(% of Portfolio)	(% of MTM)	(Correlation [VHi,VHp])	(Systematic Risk %)	(StdDev as % of MTM)			(Year)
Retail	47.02%	0.22%	5.65%	4.70%	2.91%	0.95%	35.38%	8.14
SME	31.12%	1.06%	11.19%	5.03%	8.06%	3.23%	40.19%	3.42
Large C&I	11.54%	0.84%	18.71%	33.19%	3.25%	1.60%	38.02%	3.47
CRE	10.32%	1.53%	20.76%	30.78%	6.58%	3.15%	48.16%	3.95
Total Portfolio	**100.00%**	**0.69%**	**10.44%**	**10.78%**	**4.93%**	**1.96%**	**38.50%**	**5.70**

Sub-Portfolio	MTM	Risk Contribution	Correlation w/Portfolio	R-Squared	Stand Alone Risk	PD	LGD	Maturity
	(% of Portfolio)	(% of MTM)	(Correlation [VHi,VHp])	(Systematic Risk %)	(StdDev as % of MTM)			(Year)
Retail	47.02%	0.22%	5.65%	4.70%	2.91%	0.95%	35.38%	8.14
First Mortgage	23.00%	0.14%	6.51%	6.35%	1.59%	1.26%	8.10%	8.28
Home Equity Loan	24.01%	0.30%	4.83%	3.12%	4.17%	0.65%	61.51%	8.00
SME	31.12%	1.06%	11.19%	5.03%	8.06%	3.23%	40.19%	3.42
Large C&I	11.54%	0.84%	18.71%	33.19%	3.25%	1.60%	38.02%	3.47
CRE	10.32%	1.53%	20.76%	30.78%	6.58%	3.15%	48.16%	3.95
Hotel Full Service	0.45%	2.39%	29.39%	49.02%	7.62%	5.10%	32.43%	4.14
Industrial	1.75%	1.36%	18.55%	31.26%	6.53%	4.09%	49.83%	3.36
Multi Family Housing	4.60%	1.58%	23.16%	31.27%	6.09%	2.29%	49.14%	4.04
Office	2.16%	1.48%	17.18%	27.27%	7.35%	3.50%	49.35%	4.35
Retail Property	1.35%	1.40%	18.31%	28.00%	6.73%	3.62%	46.04%	3.69
Total Portfolio	**100.00%**	**0.69%**	**10.44%**	**10.78%**	**4.93%**	**1.96%**	**38.50%**	**5.70**

Spread Risk

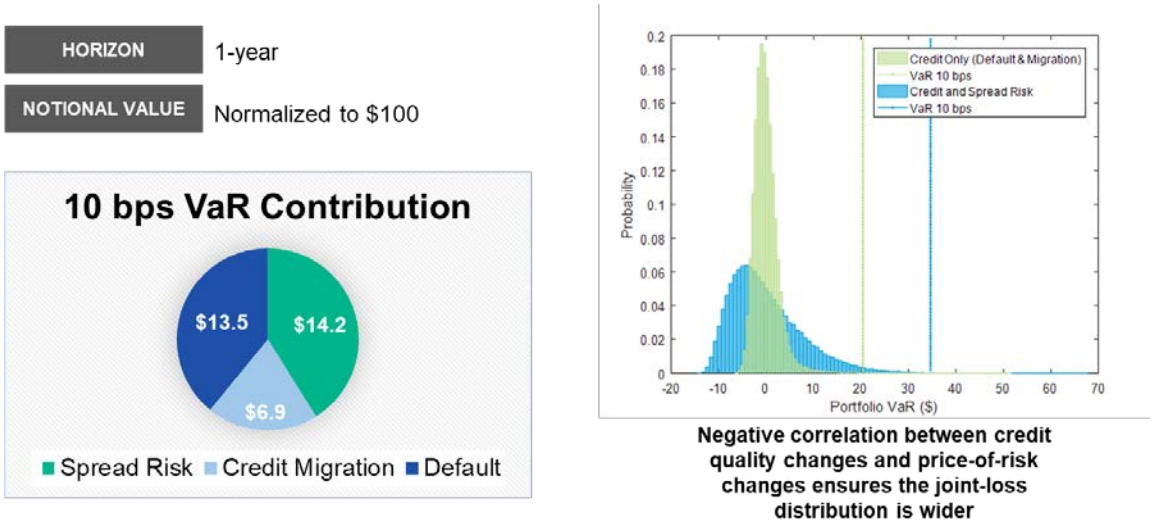
PortfolioStudio's spread-risk module allows for simultaneously modeling of credit risk and spread risk and facilitates spread-risk decomposition.

Figure 18 Benefits of joint modeling credit risk and spread risk.



- Ability to set more accurate and granular risk correlation parameters
- Straightforward risk decomposition
- Avoids double counting
- Improved operational efficiency

Figure 19 Spread risk decomposition.



Straightforward spread risk decomposition	Select Portfolio Run 1 Default Risk-Demo-5/2	vs	Select Portfolio Run 2 Default+Migration Risk	vs	Select Portfolio Run 3 Default+Migration+Spread Risk-
Number of Monte Carlo Simulations	100000	=	100000	=	100000
Target Probability	0.05%	=	0.05%	=	0.05%
Horizon (year)	1.00	=	1.00	=	1.00
Accounting Rule	Fair Value		Fair Value		Fair Value
Spread Valuation	Static Lambda		Static Lambda		Stochastic Lambda
Default/Non-Default Mode	TRUE		FALSE		FALSE
Holding Amount	$51,824,502	=	$51,824,502	=	$51,824,502
Expected Interest Income - Default Loss	2.18%	=	2.18%	=	2.18%
Earnings Volatility	1.26%	<	2.32%	<	4.39%
Economic Capital (TS)	4.51%	<	7.60%	<	14.84%
Economic Capital (EL)	6.82%	<	9.92%	<	17.39%
	Default Risk Only		Default + Migration Risk		Default + Migration + Spread Risk

8. Summary

Institutions holding credit portfolios can increase stakeholder value by increasing return/risk, while also ensuring capital adequacy and regulatory compliance. This requires five key steps:

1. Measuring portfolio risk and ensuring capital adequacy
2. Quantifying each exposure's incremental impact on portfolio risk
3. Setting limits to prevent excessive risk concentrations
4. Increasing/decreasing credit exposure to increase portfolio return/risk
5. Pricing and sizing new deals to increase portfolio return/risk

Designed with the business user in mind, and as described in this document, Moody's Analytics' PortfolioStudio is an agile efficient solution that helps institutions perform these five key steps and increase portfolio return/risk.

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