PGIM QUANTITATIVE SOLUTIONS

FLEXIBLE RISK ANALYTICS PLATFORMS

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ABOUT PGIM QUANTITATIVE SOLUTIONS

As the quantitative equity and multi-asset solutions specialist of PGIM, we seek to help solve complex investment problems with custom systematic solutions across the risk/return spectrum. We can customize down to the stock level for portfolio considerations, with product offerings that range from core solutions and systematic macro to multi-asset portfolios and overlays. We manage portfolios for a global client base with $116.4 billion in assets under management as of 12/31/2021.

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Overview

Measuring and interpreting the inherent risk of a portfolio is challenging. Since the COVID-driven market disruption of early 2020, we have witnessed periods of rising equity-bond correlation and elevated volatility in the Energy sector. More recently, market volatility climbed amid rising concerns about ongoing supply chain disruptions and rising inflation.

Developing risk platforms that are flexible enough to aid in ascertaining the evolving market risk landscape has become critical and essential. In fact, the 2008 Global Financial Crisis served as a catalyst for tighter regulatory control following a change in the perception of risk from an investment perspective. Risk functions can no longer be check-the-box exercises but rather must align with investment decisions to ensure accurate compliance with risk-control mandates.

Research shows that a comprehensive and valuable risk analytics platform must:

Be Flexible

- To assess market and investment strategy, risk analytics platforms must integrate with other investment platforms and provide dynamic what-if analysis for allocation decisions.
- Integrating risk analytics on a common platform provides enterprise-wide aggregation of risk and facilitates dialogue between investment professionals.

Include Stress Tests

- Stress tests are more transparent and intuitive than risk estimates and are therefore essential complements to risk model analysis.
- Stress tests overcome the shortcomings of risk models by estimating the impact of adverse market movements on a portfolio, capturing volatility jumps and changing correlation structures, and incorporating liquidity shifts.

Incorporate What-if Analysis

- What-if analysis includes multiple risk statistics under one framework, aggregating bottom-up holdings to the account and portfolio levels to provide a more accurate exposure measure than a time-series approach.
- Portfolio managers can then have a view into how risk statistics dynamically change as allocation weights are altered or an overlay position is added under various scenarios.

Flexible Risk Analytics Platforms

Effective Asset Risk Management

Measuring and interpreting the inherent risk of a portfolio is challenging. Since the COVID-driven market disruption of early 2020, we have witnessed periods of increasing equity-bond correlation and elevated volatility in the Energy sector. More recently, market volatility climbed amid heightened concerns about ongoing supply chain disruptions and rising inflation, which have been further exacerbated by Russia's invasion of Ukraine and the resultant disruption in commodity and energy production.

Developing risk platforms that are flexible enough to aid in ascertaining the evolving market risk landscape has become critical and essential. In fact, the 2008 Global Financial Crisis (GFC) served as a catalyst for tighter regulatory control following a change in the perception of risk from an investment perspective. Risk functions can no longer be check-the-box exercises but rather must align with investment decisions to ensure accurate compliance with risk-control mandates.

Desired Features of a Common Risk Platform

In order to compute and explain risk across different asset classes, risk platforms need to incorporate multiple views of risk. Stress tests, which can help detect edge events representing unwanted risk, are also crucial components for risk analysis. Multiple risk views include different settings for volatility and correlation estimates, and both granular and factor-based lenses for examining risk. In addition, appropriate risk methodologies such as parametric or Monte Carlo simulations are required for different portfolio payoff profiles. It should be noted that technology gains over the last decade, such as on-demand cloud-based architectures, have increased computational power to allow risk platforms to incorporate multiple views of risk.

Risk analytics should operate on a *common* platform in order to compare different risk views and facilitate dialogue between risk managers and portfolio managers. Ownership of multiple platforms for fixed income, equities, and commodities is problematic, whereas a common platform would help translate information from one market to another and provide enterprise-wide aggregations of risk. In addition, integration (preferably with Application Programming Interfaces, or APIs) to other investment platforms and internal data is important to streamline workflows.

Finally, stress tests should be a key component of a risk platform. Stress tests can include historical events and factor risk scenarios that propagate to all other relevant factors via a risk model. These scenarios are complementary to risk models, which typically do not incorporate extreme market shocks.

To accomplish these desired objectives, it should be noted that risk platforms require integration of holdings data, broker/custodian market values, risk factor market data, and a risk analytics engine capable of generating the desired risk statistics.

Table 1 lists the key features of a risk platform.

Table 1: Risk Platform Key Features

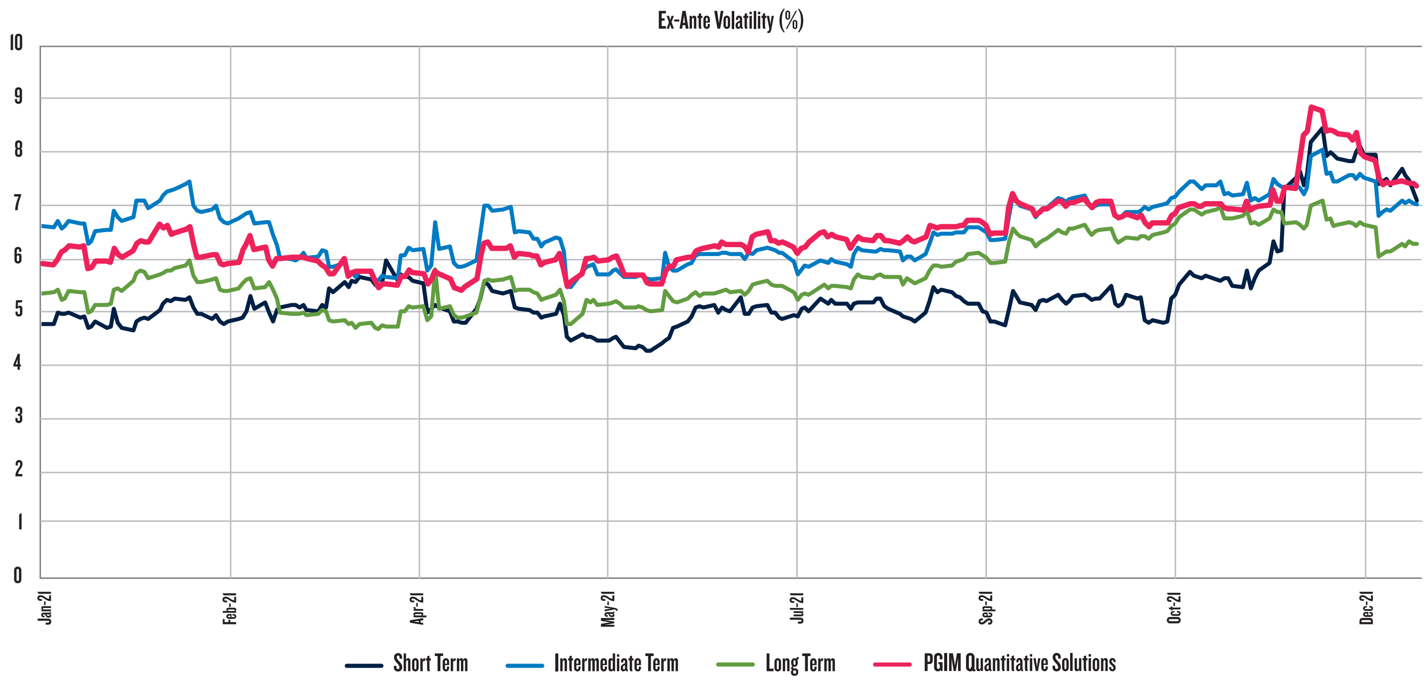
Flexible settings and model selection to generate multiple risk views
Stress testing module including historical and predictive (correlated) scenarios
APIs for ad-hoc risk analysis and to streamline workflows
Integration with other investment platforms and internal data
Enterprise-wide snapshot of risk
Dynamic analysis via what-if scenarios

Source: Author Calculations.

Multiple Risk Views

As part of PGIM Quantitative Solutions' risk model governance for Global Tactical Asset Allocation funds, we compare our internal proprietary risk model against Axioma's Global Multi-Asset Class Model under different decay settings (all within the same platform). Inputs for our internal risk model are adjusted under anticipated market volatility. Our portfolio managers anticipate elevated risk and modify risk inputs during volatile periods. In order to compare our internal model using different risk views, we adjust decay factors to produce models that provide upper and lower bounds to ex-ante risk estimates. Figure 1 depicts the different risk models that "sandwich" our internal risk model estimates.

Figure 1: Multiple Risk Views – Comparison of Internal vs. External Risk Models



Source: PGIM Quantitative Solutions, Qontigo/Axioma. Data as of 12/31/2021.

Moreover, not only do the risk models provide bounds, they move in the same direction over this period. When deviations do occur, we dig further into the risk models by examining asset volatility inputs and risk contributions by sub-strategies to gain further insight.

A key outcome of examining different risk model estimates side-by-side on the same platform is that it facilitates a more detailed discussion for portfolio managers around the results from our internal risk model, leading to a better understanding of the underlying risk. In contrast, using separate risk platforms for investment groups and risk functions is problematic. This stems from different groups using various risk methodologies (with little communication) in which distinctions may be difficult to reconcile and becomes problematic in strategies which involve risk limits such as volatilities or risk contributions. The volatility measures from a risk team might be greater than the front office estimates and trigger a risk limit, which could force portfolio rebalancing and erosion of alpha.

Risk Modeling and Stress Testing

In the previous section, we utilized risk models with decay factors that were in line with tactical allocation time horizons. This illustrates that selecting the appropriate risk models and pricing functions that capture the risk of investment strategies is important. For instance, an equity strategy comprised of a blend of growth and value stocks should utilize a fundamental risk model, which contains style factors such as growth and value. Moreover, pricing functions should be included for strategies involving asymmetric payoffs. In this case, risk statistics such as VaR (value at risk) or CVaR (conditional VaR), which include these pricing functions, should be implemented under Monte Carlo simulations. We will provide an example of VaR later in this section.

Why stress tests?

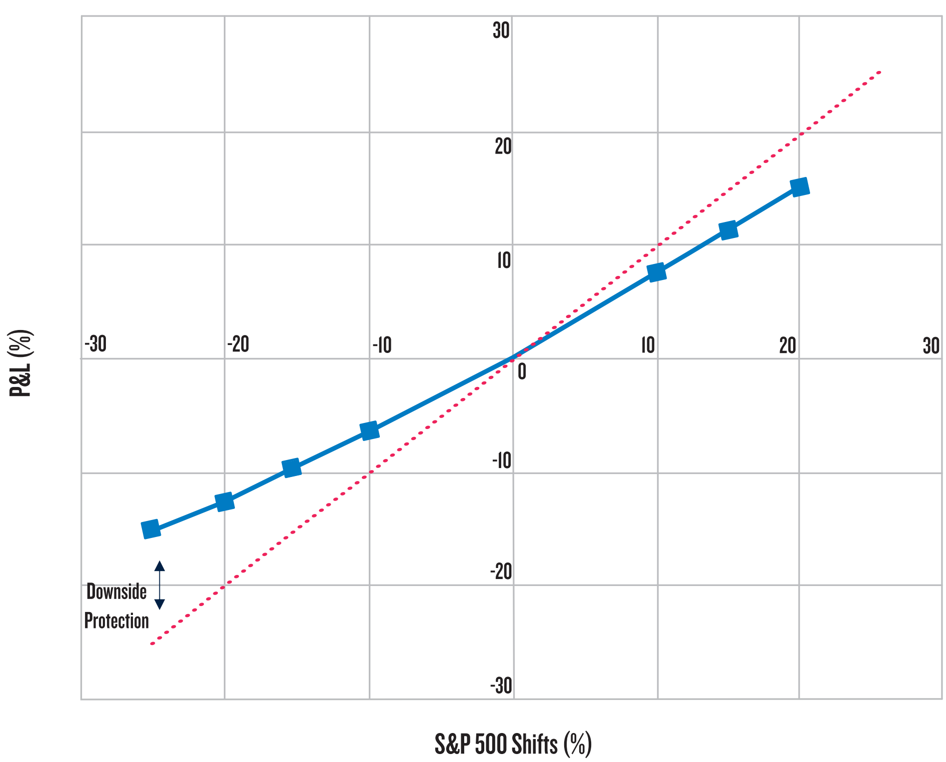
In building a robust risk platform, stress tests are indispensable complements to risk models because they overcome the shortcomings of statistical or fundamental models. In fact, most risk models do not adequately capture volatility jumps or changing correlation structures and perform poorly when liquidity dries up, as occurred in 2008 when Lehman Brothers collapsed, precipitating the GFC. A key component in designing a stress test is the selection of scenarios, which typically requires a subjective projection of risk factors. Thus, practitioners describe stress testing as both an art and science.

Stress tests need not reflect correlations under normal periods and are designed by specifying directional shocks to parsimonious or granular risk factors. Since stress test results are represented as P&Ls, they are more transparent and intuitive than risk estimates such as portfolio volatility or VaR. In addition, they can suggest better hedges so that managers can mitigate unacceptable levels of risk.

After stress scenarios have been selected, positions in a portfolio need to be repriced. As mentioned earlier, full repricing should be applied to securities that exhibit nonlinear and asymmetric payoffs. A large negative equity return may have little effect on a call, for example, but a large positive return may significantly increase its value. Moreover, if investment managers can quantify the difference between full repricing and delta approximations, they can better analyze tail risks and actively add hedges under what-if scenarios.

To illustrate, consider our Market Participation Strategy (MPS), which employs options to mitigate extreme downside losses. Figure 2 depicts the equity profile from applying a predictive stress test to the S&P 500 Index. Under a predictive stress test, a set of core factors is explicitly selected and shifted, while the remaining peripheral risk factor shifts are implied from the covariance of factor returns. In this case, the core factor is the S&P 500 and the peripheral factors include factors such as interest rates and implied volatilities. From Figure 2, we observe that the equity option strategies mitigate extreme downside losses while participating in the upside. Note that a full nonlinear model is required to capture the asymmetric payoff. A linear delta approximation (represented as a dotted line) would overstate the losses from large negative equity returns. And the difference between the dotted line and the payoff represents the amount of downside protection.

Figure 2: Nonlinear P&L Profile for MPS



Source: Qontigo/Axioma. Data as of 12/31/2021.

Also, Table 2 lists a side-by-side VaR comparison under the different risk methodologies. The Monte Carlo VaR includes full repricing of options, while parametric VaR does not. Since full pricing captures the downside protection, we observe that the Monte Carlo VaR is less than the parametric VaR.

Table 2: VaR Comparison for MPS – VaR is Computed at the 95th Percentile

Asset Class	Risk Type	Factor Type	Parametric VaR95	MCVaR95
Total			**13.89**	**13.59**
Equity			**0.83**	**0.63**
	Risk Type: Equity		0.83	0.63
		Country	0.33	0.28
		Industry	0.00	0.02
		Market	0.52	0.31
		Specific Risk	0.00	0.01
		Stock		
		Style	-0.03	0.02
Index Option			**13.08**	**12.74**
	Risk Type: Equity		16.01	12.41
		Country	6.10	5.16
		Equity Index		
		Industry	0.04	0.35
		Market	9.80	5.84
		Specific Risk	0.57	0.79
		Style	-0.50	0.29
	Risk Type: Interest Rate		-0.05	-0.26
	Risk Type: Vega		-2.88	0.56
Bond			**0.00**	**0.08**
	Risk Type: Interest Rate		0.00	0.08
	Risk Type: Issuer Credit			
Bond Future			**-0.01**	**0.14**
	Risk Type: Interest Rate		-0.01	0.14

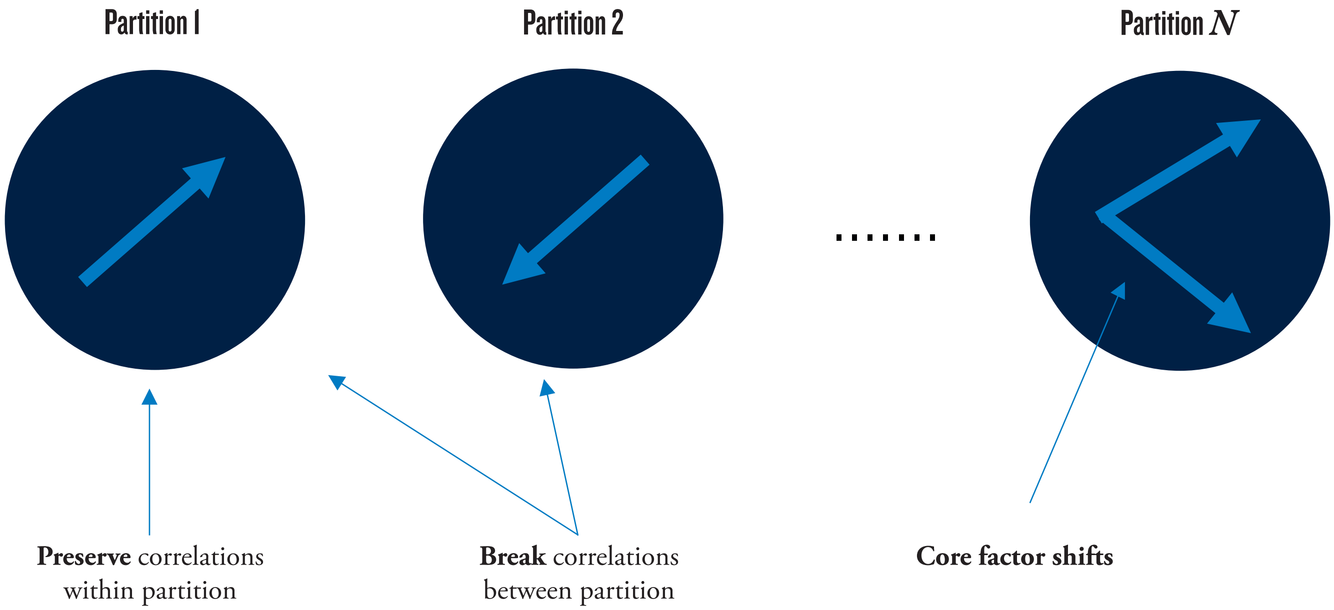
Source: Qontigo/Axioma. Data as of 12/31/2021.

Flexible Stress Tests – Partitioned Stress Tests

In this section, we specify how stress tests can be designed under changing correlation regimes and provide a simple example of an inflation-based stress test for one of our GTAA sub-strategies.

Partitioned stress tests are composite-predictive stress tests that are applied to a portfolio (we used predictive stress tests to depict the Nonlinear P&L Profile for MPS in Figure 2). We can partition a portfolio across dimensions such as asset class or country. For each partition, we apply separate localized predictive stress tests, and then sum the results to the portfolio level.

Figure 3: Partitioned Stress Tests



Source: Author calculation.

This allows us to *preserve* correlations within partitions, while shifting core factors across different partitions in arbitrary ways, which may even break correlations between core factors. See Figure 3 for a depiction.

It is not uncommon to observe changing risk factor correlations in the markets. For example, the US dollar and S&P 500 were positively correlated before the COVID-19 pandemic, and then became negatively correlated in March 2020 as the US dollar became a safe haven for global investors. Under a partitioned stress test, we can partition asset classes such as US equities and currency, and apply localized S&P 500 and US dollar shocks to the equity and currency positions, respectively. Just as the actual correlation of the S&P 500 and US dollar changed, we can design a partitioned stress test where we shift the S&P 500 and US dollar returns in the same or opposite direction while preserving the equity and currency correlations within the asset class blocks.

Example: Inflation-based scenario

As an illustrative example, we apply a partitioned stress test to our developed market currency sub-strategy. Consider an inflation-based stress test over concerns about soaring consumer prices and the cost of energy and raw materials. We (subjectively) select the core factors:

- US Dollar Index (DXY) +5%
- Crude Oil +10%

Under this scenario, as inflation surges, the US dollar becomes a safe haven, while oil prices spike.

Applying each of these stress tests separately (albeit, still useful) gives the scenario results listed in the top portion of Table 3.

Table 3 : Univariate and Partitioned Stress Tests for Developed Market Currency Sub-strategy

Univaried Scenario	P&L
Dollar Index DXY +5%	-0.64%
Crude Oil +10%	+0.12%
Partitioned Scenario	**P&L**
Total	+0.10%
Partition 1: Commodity Currency	+0.20%
Partition 2: Non-Commodity Currency	-0.10%

Source: Qontigo/Axioma. Data as of 12/31/2021.

Since all of the betas over the estimation period are negative to the US dollar, all long (short) currency positions will decline (rise) in value for a positive shock to the DXY Index. Here we observe a P&L contribution of -64bps to the full portfolio. For the oil shock, we observe a P&L of +12bps, which is mainly driven by the higher-beta commodity currencies.

Under the partitioned stress test, we apply the oil and dollar shocks to two different partitions. The first partition contains the commodity currencies (such as AUD and NOK) while the second partition contains the remaining developed currencies. We apply the oil shock of 10% to the first partition and a DXY shock of 5% to the second partition. In this scenario we see a positive P&L of +20bp. This result is not surprising, and more accurate than the univariate stress tests, as commodity currencies provide a natural hedge to commodity shocks.

What-if Analysis – Putting it All Together

Up to now we have focused on risk statistics such as portfolio volatility, VaR, and stress testing. In addition, exposure-based statistics such as betas and style factor exposures are extremely helpful in identifying portfolio tilts and are typically consistent with other risk statistics. For instance, a large style factor exposure to growth implies a significant risk contribution to the growth risk factor (under a fundamental risk model). Thus, including exposure-based statistics along with portfolio risk measures and stress tests provides a more complete picture of risk.

Under a what-if analysis, we include all the statistics mentioned above and see how they dynamically change as allocation weights are altered under various scenarios. Note that a bottom-up holdings aggregation for all risk statistics is applied to the account and portfolio levels. This holdings-based approach provides a more accurate exposure measure than a time-series approach. For our Global Multi-Asset Solutions business, our portfolio managers adjust allocations across different styles in sub-accounts and sleeves. Moreover, managers can analyze the impact of what-if trades within the overlay or liquidity sleeves to the portfolio.

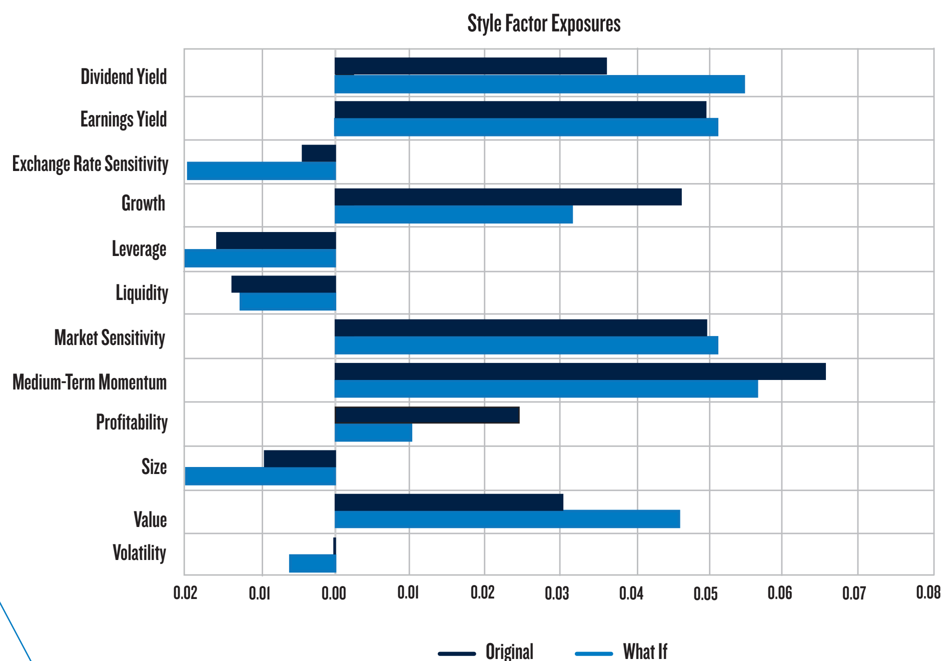
Figure 4 depicts a what-if analysis where an allocation to a value fund is increased. The risk analytics platform revaluates the portfolio style exposures and allows our portfolio managers to quantitatively measure the impact. Here we clearly observe that the value exposure has increased.

Figure 5 provides another what-if analysis where overlay positions are adjusted and the impact at the portfolio level is dynamically computed. In this example, exposure to the Russell 2000 Growth Index is increased and the impact is displayed on the right-hand side of Figure 4. As expected, an increase in the exposure to the growth factor is displayed. We also observe an increase in total portfolio and active risk. As in the previous example, this is a bottoms-up holding calculation were the individual factor exposures of the Russell 2000 Growth Index constituents are aggregated to the rest of the portfolio.

Figure 4: Style Factor What-if Analysis

Account Allocations

Account	Original	What-If
Strategy 1	9.67%	4.67%
Strategy 2	17.25%	17.25%
Strategy 3	3.18%	3.18%
Strategy 4	11.74%	11.74%
Strategy 5	0.33%	0.33%
Strategy 6	18.39%	18.39%
Strategy 7	2.18%	2.18%
Strategy 8	0.80%	0.80%
Strategy 9	0.00%	0.00%
Strategy 10 - Value	1.59%	6.59%
Strategy 11	0.00%	0.00%
Strategy 12	0.57%	0.57%
Strategy 13	14.43%	14.43%
Strategy 14	4.99%	4.99%
Strategy 15	2.53%	2.53%
Strategy 16	4.11%	4.11%
Strategy 17	0.56%	0.56%
Strategy 18	1.89%	1.89%
Strategy 19	0.39%	0.39%
Strategy 20	4.71%	4.71%
Strategy 21	0.68%	0.68%
	100%	**100%**

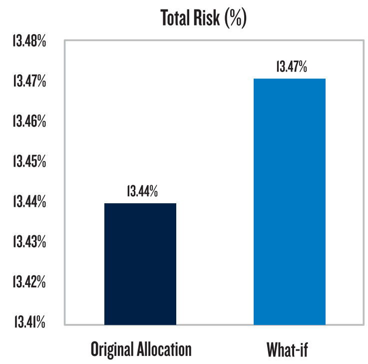


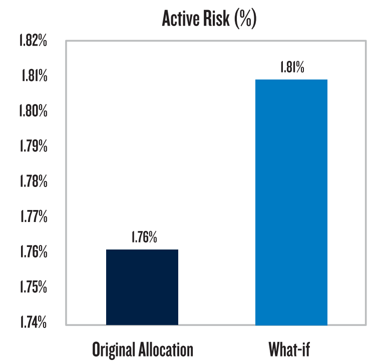
Increase allocation to Value

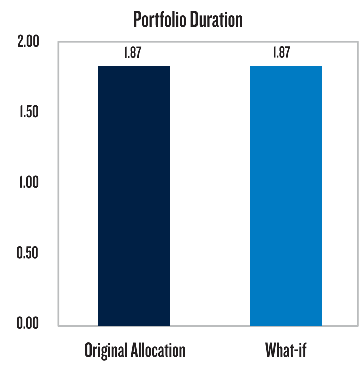
Source: Qontigo/Axioma. Data as of 12/31/2021. For illustrative purposes only.

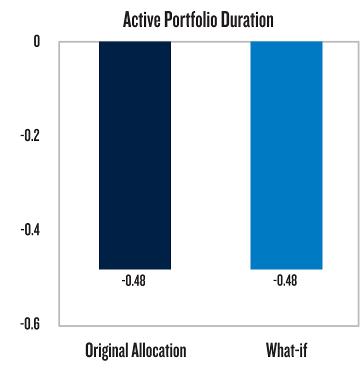
Figure 5: What-if Analysis by Adjusting Overlay Positions

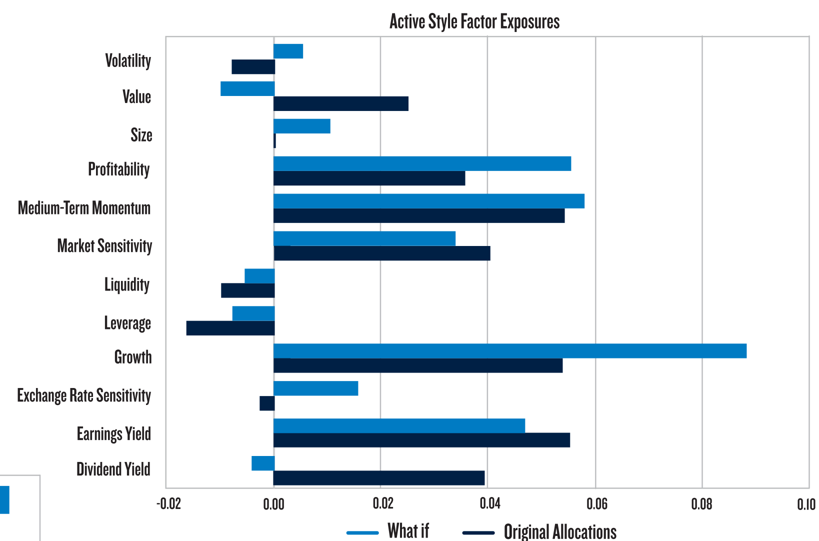
	Exposure Wt (%)	What-If
Total Exposure (Ex-Cash)	**100.00%**	**100.00%**
CME E-Mini Russell 2000 Index Future December 2021	1.15%	1.15%
Financial Select Sector SPDR Fund	0.88%	0.88%
Materials Select Sector SPDR Fund	0.27%	0.27%
MSCI EAFE Mini Future December 2021	8.09%	8.09%
NASDAQ 100 (E-Mini) Future December 2021	1.47%	1.47%
S&P 500 (E-Mini) Future December 2021	73.28%	23.28%
T-Notes (10 Years) Future December 2021	2.22%	2.22%
T-Notes (2 Years) Future December 2021	3.63%	3.63%
T-Notes (5 Years) Future December 2021	7.10%	7.10%
US T-Bonds Future December 2021	2.34%	2.34%
US Treasury Bill 12-09-2021	4.64%	4.64%
British Pounds	0.00%	0.00%
US Dollars	94.75%	94.75%
Energy SPDR		0.00%
Financials SPDR		0.00%
Materials SPDR		0.00%
MSCI EAFE		0.00%
MSCI EM		0.00%
MSCI Europe		0.00%
MSCI Japan		0.00%
NASDAQ 100		0.00%
Russell 1000 Growth		**50.00%**
Russell 1000 Value		0.00%
Russell 2000 Index		0.00%
S&P 500 Index		0.00%

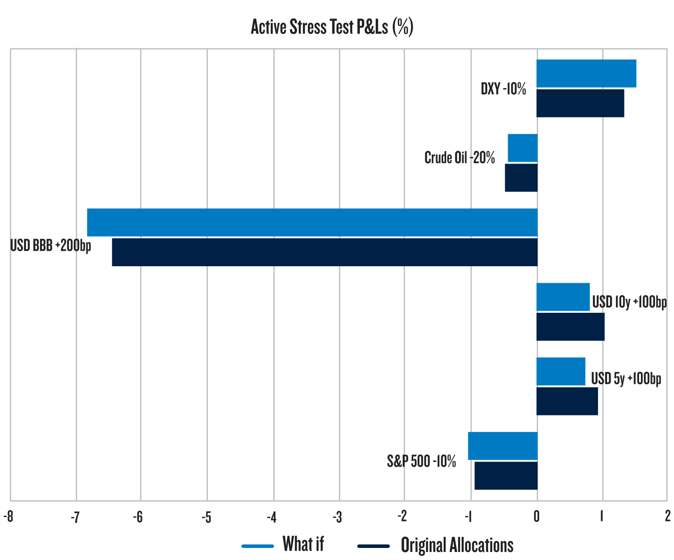












Source: Qontigo/Axioma. Data as of 12/31/2021. For illustrative purposes only.

Conclusion

To appropriately analyze the risk of evolving market landscapes and different investment strategies, portfolio managers require flexible risk platforms that can integrate with other investment platforms and provide dynamic what-if analysis for allocation decisions. Adjustable risk settings (such as decay factors and risk model selection) can be fine-tuned to provide a more accurate picture of risk and multiple risk views with different settings can be compared side-by-side to gain further insight into tail risk. Integrating risk analytics on a common platform provides enterprise-wide aggregation of risk and facilitates dialogue between investment professionals.

Stress tests are essential components of risk platforms that provide complementary analysis to risk models. Stress tests are more transparent and intuitive than risk estimates and overcome the shortcomings of risk models, which do not adequately capture volatility jumps or changing correlation structures and perform poorly when liquidity dries up. Designed to estimate the impact of adverse market movements on a portfolio, stress test scenarios can be extreme, but should always be plausible.

Finally, interactive visualization in the form of what-if analysis is important. Here we can combine multiple risk statistics such as risk contributions, stress tests, and exposure-based statistics such as betas and style factor exposures all under one framework. Portfolio managers can then have a view into how the statistics dynamically change as allocation weights are altered or an overlay position is added under various scenarios. All risk statistics are then recomputed in real time and displayed so that portfolio managers can quantify the impact of allocation decisions.

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