A More Complete View of Equity Portfolio Risk:

Exposing Vulnerabilities with a Multi-Asset Class Risk System

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Introduction

Best practice in quantitative analysis of equity portfolios advocates matching the target portfolio with the representative risk model, i.e., a single country model for a single country portfolio, a regional model for a regional portfolio, and a global model for a global portfolio. According to the theory, restricting the model to the appropriate region and asset class should provide a better fit to the assets in the portfolio and limit the amount of specification error, compared with a model built on a much wider range of assets. But are we letting the wish be the father of the thought, and is this one of those times when breaking the rules — or at least bending them a little — can actually have positive consequences?

Many factors go into the investment thesis behind any equity portfolio. Some of these factors may have had an asset allocation component formed by certain views on the direction of asset classes other than equity. Some factors may be formed by an outlook on commodities, the future direction of interest rates, currencies, or even volatility regimes, all or any of which may impact equities' future fortunes. Augmenting the portfolio analysis to include its sensitivity to other asset classes would not only ensure that the portfolio is in line with all the aspects of the investment thesis, but may also provide valuable information to the

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manager about unintended cross-asset class bets he or she may not have identified through a pure equity model analysis. Even in the absence of macro views, understanding the portfolio's vulnerabilities to macro shocks can be quite informative.

This paper looks at ways the analysis of a global equity portfolio can be enhanced through the use of a multi-asset class risk solution, to deliver additional insights on the portfolio's sensitivities to certain macroeconomic factors and co-movements with other asset classes. Specifically, the question we are addressing here is whether we can complement the analysis from our equity fundamental factor models by looking at our portfolio through the lens of a multi-asset class system not bounded by equity-only factors to identify areas of misalignment with the manager's views on other asset classes.

The first part of this paper examines the sensitivities of a broad benchmark, such as the FTSE All-World Index. We began by running a series of transitive stress tests[2], shifting key underlying market and macroeconomic factors of interest to most equity portfolio managers, to simulate the effect of these changes on our portfolio's value. The question that this kind of stress test answers is: "What would happen to the value of my asset(s) or portfolio if the level of a given risk factor (or risk factors) went up or down by X-amount?" We first applied a set of equity factor shocks to the portfolio —these are shocks on portions of the coverage[3] of a standard global equity factor risk model, such as United States, European, Japanese, or Emerging equity markets, volatility, as well as major currencies. Next we applied a set of non-equity factor shocks to the portfolio. These include exogenous asset classes not part of a standard global equity model, such as commodities, interest rates, credit, and alternatives. A detailed list of the specific independent factors used for this analysis can be found in Appendix 1.

In the second part of this paper, we looked at the same results on two actively managed portfolios. Both active strategies have a predicted level of active risk to the FTSE All-World index of 3%. The "Value" portfolio targeted a value style tilt, controlling other styles in the portfolio but no other factors, such as industry, country, or currency, explicitly. The "Momentum" portfolio has the same settings but targets a momentum tilt.

Finally, we ran the active portfolios through a sample set of historical scenarios involving shocks on independent factors from multiple asset classes, simultaneously, to identify the sensitivity of the portfolio's profit and loss to various types of events. How well or poorly would our portfolio fare if there was another event like the European debt crisis, Brexit, a U.S. equity market crash such as 9/11, an Asian crisis, or a debt market crash such as the Russian Crisis and the Long-Term Capital Management crisis (LTCM)? A detailed description of each scenario, as well as the full list of independent factors shocked and their magnitude can be found in Appendix 2.

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[2] A transitive stress test is designed to shock a single independent variable to see the effect on each position and the whole portfolio. We shock each of the independent factors named in this paper and revalue the current present value of all assets in line with the correlation structure observed during the look-back period selected (two and five years). See "Stress Test in Axioma Risk" in the Axioma Risk documentation library for more details or contact your Axioma representative for more information

[3] Equity managers with access to a global equity fundamental factor model can perform factor shocks on Country, Market, Sector, and Style factors. We use a granular method with full repricing at the individual stock holdings level to replicate these linear factor tests with the Axioma Risk platform.

For this analysis, we used the Axioma World Wide Fundamental Factor model (medium-horizon variant) and the Axioma Portfolio Optimizer to construct the two active strategies and the Axioma Risk multi-asset class platform to perform the transitive stress tests and historical scenarios. To make comparison across factors easier, we used a symmetrical +/-20% shock on all factors with the exception of Yield on government bonds, where we used a 100 basis point increase in the 2Y, 5Y, and 10Y bond yields as a proxy for rising interest rate expectations. Catastrophe bonds were the other exception, where we simulated a 2% drop in the bond's price (the worst historical case we could find was -3.8%). All results are shown from an unhedged U.S. dollar perspective. The unhedged nature of the analysis means that the beta of each asset to the various shocks applied has two components, namely an asset class component, as well as a currency component. To identify which of the two sources is the main driver of change in the portfolio's present value, a decomposition of the beta is necessary.

A side note on stress testing: the choice of factors, look-back periods and magnitudes of shocks are somewhat subjective. In practice, modellers should experiment with multiple settings. We wanted to simulate the impact of a tightening U.S. monetary policy on our portfolios and first elected to use the 2-year, 5-year, and 10-year zero coupon government bonds and subject them to a shock of 100 bps. What we found in the process of using both two years and five years of return history for these bonds and equities to estimate the correlations was that bond yields, having been kept artificially low by the various QE programs, showed no correlation to equities, whereas one might have expected the two return series to be negatively correlated. Therefore, those test results showed hardly any impact (we only displayed the 10-year bond results here). Given that monetary policy has been the primary driver of (low) stock volatility for the past eight years, these results did not make sense to us. We then considered ways for investors to display their reactions to changes in monetary policy in financial markets, where bond prices are kept artificially still. We then went back to find when the word "tapering" was first heard — May 2013 — and elected to use a 20% fall in the FTSE Emerging Market Index as our proxy for the impact of a change in U.S. monetary policy on our portfolio. This example simply makes the point that, sometimes, the factor you are trying to stress isn't the one you should test, for a number of reasons, and finding a good proxy is vital to getting some intuition from this exercise.

Some Major Test Findings on Benchmark Risk

- In the past two years U.K. equities were more positively correlated with U.S. equities than Japanese equities (unhedged).
- Emerging markets as a whole were more positively correlated to their developed counterparts than either the United Kingdom or Japan.
- Global equities are more sensitive to movements in the yen than the euro (both against the dollar).
- Gold and Catastrophe bonds have been negatively correlated with global equities.
- REITs have a big impact: a negative 20% shock on Global REITs resulted in losses of over 14% for the index. They have a bigger impact on continental Europe and Australia, less in the United States, United Kingdom, and Japan.
- The U.S. component of the global index is more sensitive to movements in Oil, Gold, and United States and Japanese corporate credit spreads, while Japan does not seem to be too affected by commodity shocks.
- The United Kingdom is sensitive to commodities and oil, but not to Gold or corporate spreads.
- Australia seems to have a high sensitivity to Japanese corporate spreads and Catastrophe bonds.

Transitive Stress Tests on FTSE All-World Index

As of January 31, 2017, (the analysis date used in this report), U.S. equities represented 58% of the FTSE All-World index. Next came Japan with 9.4%, followed by the United Kingdom, France, and Germany with 6.6%, 3.5%, and 3.4%, respectively. Given this country allocation, we would expect that shocking the U.S. market would have the biggest impact on the index portfolio, followed by a pan-European market shock, and then a Japan market shock.

To confirm our assumption, we configured three separate equity market transitive factor shocks, simulating 20% drops in the values of the S&P 500, the FTSE Developed Europe, and the Nikkei 225 indices. We then determined their individual impact on the FTSE All-World Index by computing the correlation between the holdings of each index pair using two years of weekly return history with a flat weighting scheme, and used these sensitivities to measure how shifting one independent factor would affect the present value of our portfolio in an instantaneous shock.

Simulating a 20% drop in the value of U.S. equities resulted in a 19.6% drop in the value of the FTSE All-World Index. A total of 11.7% (or 60% of our total drop in PV) came from our U.S. country allocation in the index. The United Kingdom, despite having a lower weight in the index than Japan, was the next biggest contributor at -1.6%. In third place was Japan at -1.1% (see the table in Figure 1 for the full details). While the result of this simple stress test may come as no surprise to most experienced global equity portfolio managers, the test did deliver the first insight, namely that **the United Kingdom was more positively correlated with the United States than Japan** in the last two years (on an unhedged basis).

A 20% drop in the FTSE Developed Europe and the Nikkei 225 indices resulted in a 12.1% and 10.5% decline in our portfolio's present value, respectively, confirming our initial assumption on the influence ranking of various equity market shocks, based on the country allocation of the FTSE All-World Index at the time of this analysis. But what about equity markets outside the coverage of the index?

A 20% fall in the FTSE All-World Emerging Markets index resulted in a 12.6% decline in its developed counterpart. The U.S. component was responsible for 6.8% (or 53% of total), followed again by the United Kingdom and Japan at -1.1% and -0.9%, respectively. This ranking was similar to our first series of stress tests and, again, altogether not all that surprising. That said, we did get a second insight from these results in that they indicate that emerging markets as a whole, using the last two years as guide, **are more positively correlated to the FTSE All World Index than are either the United Kingdom or Japan (both members of the index) — by themselves**[4].

What about other elements of global equity portfolio management, such as currencies and volatility?

We simulated two individual currency shocks against the U.S. dollar; a 20% fall in the euro and a 20% rise in the value of the Japanese yen. We then measured the impact of changing exchange rates on the index portfolio using the same method highlighted in the above equity market shock section. A 20% fall in the euro, representing a strengthening dollar, resulted in a 2.1% increase in the present value of the FTSE

All-World Index. Conversely, a 20% strengthening of the yen against the dollar resulted in an almost 9% fall in the present value of the index. The fact that **global equities are more sensitive to movements in the yen than the euro against the dollar**, and by a large margin, is the third insight from this analysis. Global equity portfolio managers will certainly benefit from incorporating their views on the USD/JPY exchange rate into their portfolio construction process, even if their portfolios are currency-hedged.

Next we focused on the volatility regime and its potential influence on the index. We simulated a 20% rise in each of the most popular volatility measures for the U.S., Europe, and Japanese equity markets: the Vix, the vStoxx, and the JNIV. Those shocks resulted in a decline in the present value of the FTSE All-World Index of 1.7%, 1.8%, and 1.3%, respectively. Despite the U.S. market's (much) larger weight in the index over Europe (in aggregate), a rise in the volatility of the European market was more impactful. This clearly reflects the much higher volatility levels in Europe over the U.S. market these past two years, as a 20% rise from a higher base has a bigger impact. If the Vix climbed from 10% to 12%, who would notice? A 20% rise in volatility from the current historically low levels, as commented upon in a previous **applied research note**[5], is probably too low to be meaningful and readers are urged to either use a bigger shock or repeat this transitive test using a historical period of higher volatility for correlation estimates.

[4] The causation of this correlation is beyond the scope of this paper but, historically, falling developed markets have driven emerging ones lower, not the other way around.

[5] See research paper No. 84 "Is Risk Really As Low As You Think" on the Axioma website: http://research.axioma.com/is-risk-really-as-low-as-you-think

Figure 1. Detailed Equity Stress-Test Results, FTSE All-World Index

Two Year Look-Back

Country	% of PV	% of Risk	SPX -20%	FTSE EU -20%	N225 -20%	FTSE EM -20%	Euro -20%	JPY +20%	VIX +20%	VSTOXX +20%	JNI\ +20%
Totals	100.00%	100.00%	-19.57%	-12.13%	-10.49%	-12.57%	2.09%	-8.93%	-1.69%	-1.84%	-1.31%
US	57.87%	55.76%	-11.69%	-6.73%	-5.78%	-6.76%	2.93%	-5.89%	-1.01%	-1.02%	-0.75%
JP	9.36%	7.43%	-1.13%	-0.75%	-1.22%	-0.87%	0.37%	-0.61%	-0.09%	-0.13%	-0.13%
GB	6.64%	9.55%	-1.59%	-1.12%	-0.79%	-1.11%	-0.26%	-0.68%	-0.15%	-0.15%	-0.09%
FR	3.48%	3.86%	-0.74%	-0.55%	-0.37%	-0.51%	-0.21%	-0.29%	-0.07%	-0.09%	-0.04%
DE	3.38%	3.43%	-0.69%	-0.55%	-0.35%	-0.47%	-0.12%	-0.26%	-0.06%	-0.08%	-0.04%
CA	3.25%	3.49%	-0.66%	-0.38%	-0.33%	-0.50%	-0.02%	-0.18%	-0.06%	-0.05%	-0.04%
CH	3.23%	2.96%	-0.53%	-0.34%	-0.24%	-0.35%	-0.19%	-0.13%	-0.05%	-0.05%	-0.03%
AU	2.79%	3.34%	-0.60%	-0.35%	-0.40%	-0.51%	-0.03%	-0.20%	-0.05%	-0.05%	-0.05%
KR	1.75%	1.65%	-0.30%	-0.18%	-0.15%	-0.28%	-0.07%	-0.04%	-0.03%	-0.03%	-0.02%
HK	1.25%	0.67%	-0.22%	-0.14%	-0.13%	-0.19%	0.08%	-0.11%	-0.02%	-0.02%	-0.01%
ES	1.12%	1.39%	-0.25%	-0.19%	-0.15%	-0.19%	-0.14%	-0.10%	-0.02%	-0.03%	-0.02%
NL	1.09%	1.21%	-0.22%	-0.17%	-0.11%	-0.15%	-0.02%	-0.09%	-0.02%	-0.03%	-0.01%
SE	1.06%	1.24%	-0.23%	-0.17%	-0.12%	-0.16%	-0.05%	-0.09%	-0.02%	-0.02%	-0.01%
IT	0.77%	1.12%	-0.18%	-0.14%	-0.09%	-0.12%	-0.06%	-0.08%	-0.02%	-0.02%	-0.01%
DK	0.60%	0.58%	-0.10%	-0.07%	-0.05%	-0.07%	-0.02%	-0.04%	-0.01%	-0.01%	-0.01%
SG	0.49%	0.36%	-0.08%	-0.04%	-0.04%	-0.07%	-0.04%	-0.01%	-0.01%	-0.01%	-0.01%
BE	0.44%	0.44%	-0.08%	-0.06%	-0.04%	-0.06%	-0.02%	-0.03%	-0.01%	-0.01%	-0.01%
FI	0.37%	0.44%	-0.08%	-0.05%	-0.03%	-0.05%	-0.02%	-0.02%	-0.01%	-0.01%	-0.01%
IL	0.26%	0.24%	-0.04%	-0.02%	-0.02%	-0.02%	0.00%	-0.02%	-0.00%	-0.00%	-0.00%
NO	0.24%	0.27%	-0.05%	-0.04%	-0.03%	-0.04%	-0.02%	-0.02%	-0.00%	-0.01%	-0.00%
IE	0.17%	0.20%	-0.04%	-0.03%	-0.02%	-0.02%	-0.01%	-0.02%	-0.00%	-0.00%	-0.00%
CN	0.14%	0.10%	-0.02%	-0.01%	-0.01%	-0.02%	0.01%	-0.01%	-0.00%	-0.00%	-0.00%

Source: FTSE Russell, Standard and Poor's, Axioma Risk

We repeated the above exercise using five years of weekly return history instead of two for the correlation estimates, to see if the above results represented a departure from, or a continuation of, a longer-term trend. For the sake of space, aggregate results only are displayed in Figure 2 below.

The results of this second batch of stress tests were almost identical to the first, with one notable exception. Using five years of weekly returns to estimate correlations between the dollar/euro exchange rate and the FTSE All-World Index reversed the impact of the transitive stress test on the euro weakening

by 20%. In this variant, the value of the index fell by 2.0% versus a rise of 2.1%, when using two years of history to estimate correlations. The disturbance in the currency market caused by Brexit in July 2016 is probably to blame for this difference . This example highlights the need to include variations of the settings used in a transitive stress test in order to test the robustness of the results to the various inputs, and not to rely on a single scenario.

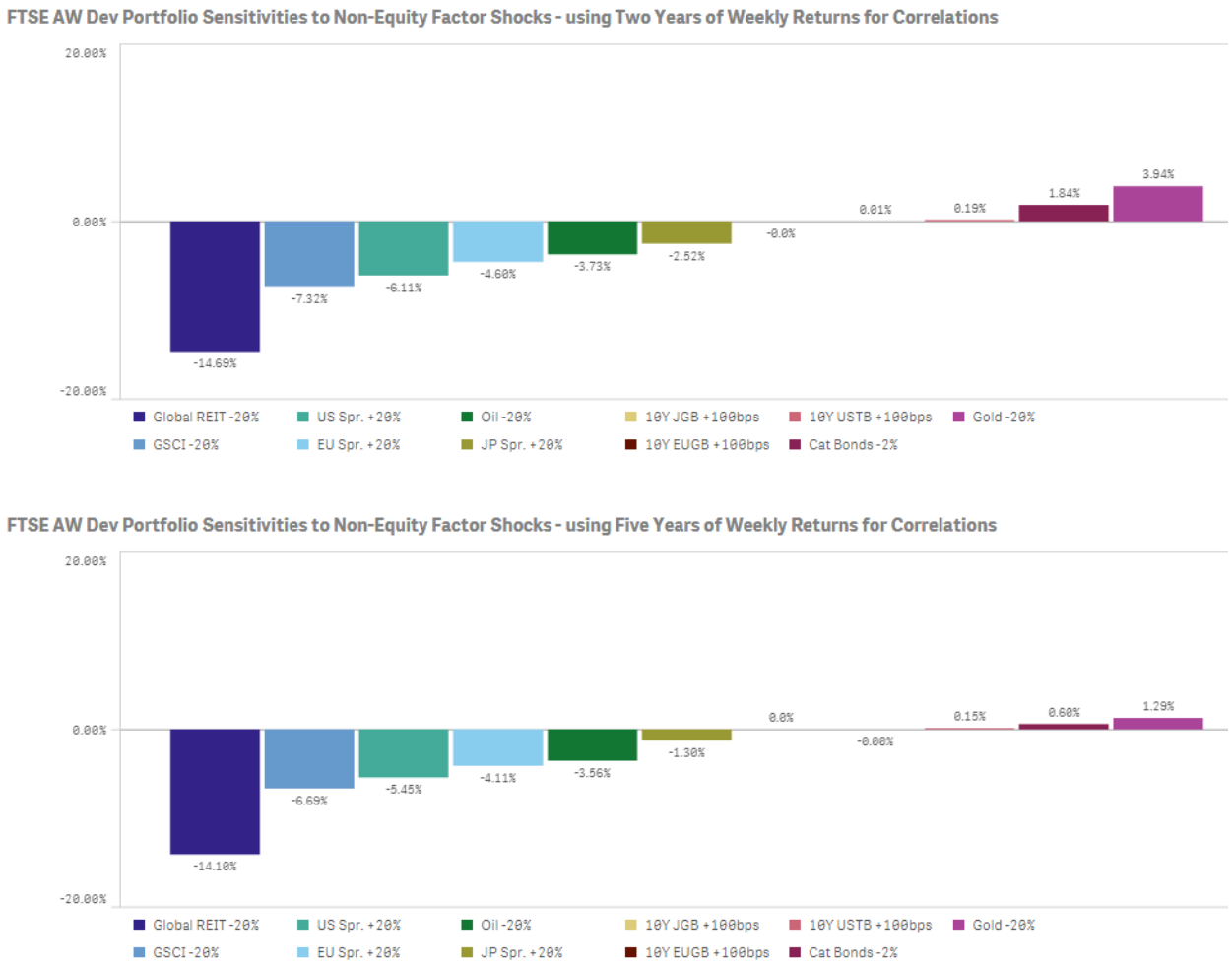
Figure 2. Aggregate Equity Stress-Test Results, FTSE All-World Index

Source: FTSE Russell, Standard and Poor's, Axioma Risk

[6] To confirm if this transitory impact is indeed the cause and if its impact has now reverted to the mean (of the last five years), a post-Brexit test using the last 90 days of daily return to estimate betas could be used.

We can use the rich content and flexibility of the Axioma Risk platform to perform individual stress tests on our index portfolio using exogenous factors to the equity asset class from the commodity, fixed interest, credit, and real estate markets. Using the Goldman Sachs Commodity Index (GSCI) series, we shocked the broad index, as well as its Oil and Gold subindices, by -20% to represent our commodity market shocks. We raised the yield on zero-coupon spot rates of two-year, five-year, and 10-year US Treasuries (USTB), European Government Bonds (EUGB), and Japanese government bonds (JGB), by 100 basis points each. We simulated a widening of credit spreads by 20% on US, European, and Japanese corporate bonds using various iTraxx series. Finally, we included two proxies for alternative assets we have increasingly seen in institutional investors' portfolios in recent years: Catastrophe bonds and Real Estate Investment Trusts. The former was stressed by simulating a 2% drop (in absolute terms) in the price of Swiss Re Cat bonds (the maximum drawdown in our recorded history was 3.8%). For the latter, we used the S&P Global REIT Index and simulated a 20% drop in the value of that asset class. The aggregate results are displayed in Figure 3 below.

Figure 3. Aggregate Non-Equity Stress-Test Results, FTSE All-World Index



Source: FTSE Russell, Axioma Risk

Several insights were revealed by this analysis. First, both **Gold and Catastrophe bonds have been negatively correlated with global equities** — increasingly so in the last two years — and represent a good source of diversification in a multi-asset class portfolio dominated by equities. Second, **commodities in general and oil in particular, have been positively correlated with global equities** for the last five years and this relationship seems fairly stable. Finally, in both the two and five-year look-back tests, **the -20% shock on Global REITs resulted in losses of over 14% for the index.**

Figures 4 and 5 (below) drill down to those non-equity shock results at both the country and sector levels. Cells highlighted in red indicate countries or sectors where the contribution to loss/gain from the factor shock was greater than their % contribution to portfolio risk would suggest, meaning that they were disproportionally affected by this particular factor over other components of the index. The highlights in the "% of Risk" column highlight the fact that most European countries' risk is currently higher than their weight in the index would suggest.

In Figure 4, the country breakdown table, we see that **the U.S. component of the global index is more sensitive to movements in Oil, Gold, and U.S. and Japanese corporate credit spreads**. Conversely, **Japan does not seem to be that affected by commodity shocks**, but is sensitive to changes in domestic corporate spreads and Catastrophe bonds. **The United Kingdom is sensitive to commodities and oil, but not to Gold or corporate spreads in general. Global REITs seem to be a big deal for continental Europe and Australia**, reflecting the allocation of this asset class in these investors' portfolios, **but not so much for the United States, United Kingdom, and Japan. Australia seems to have a high sensitivity to Japanese corporate spreads and Catastrophe bonds,** too.

Figure 4. Country-Level Drill Down for Selected Non-Equity Factor Shocks

Country Code	% of PV	% of Risk	Global REIT -20%	% of Shock	GSCI -20%	% of Shock	Oil -20%	% of Shock	Gold -20%	% of Shock	US Spr. +20%	% of Shock	EU Spr. +20%	% of Shock	JP Spr. +20%	% of Shock	Cat Bonds -2%	% of Shock
Total	**100%**	**100%**	**-14.7%**	**100%**	**-7.3%**	**100%**	**-3.7%**	**100%**	**3.9%**	**100%**	**-6.1%**	**100%**	**-4.6%**	**100%**	**-2.5%**	**100%**	**1.8%**	**100%**
US	57.9%	55.8%	-8.2%	55.7%	-4.0%	54.5%	-2.1%	55.9%	3.4%	85.4%	-3.5%	57.2%	-2.4%	52.8%	-1.5%	57.9%	0.9%	50.2%
JP	9.4%	7.4%	-0.9%	6.3%	-0.4%	5.7%	-0.2%	4.9%	0.2%	5.2%	-0.3%	5.5%	-0.3%	6.6%	-0.3%	12.5%	0.2%	9.2%
GB	6.6%	9.5%	-1.2%	8.5%	-0.7%	9.9%	-0.4%	10.0%	0.2%	4.4%	-0.5%	8.5%	-0.4%	9.4%	-0.1%	5.6%	0.2%	9.2%
FR	3.5%	3.9%	-0.6%	4.2%	-0.3%	4.1%	-0.1%	3.9%	0.1%	2.1%	-0.2%	4.0%	-0.2%	4.8%	-0.1%	2.8%	0.1%	5.2%
DE	3.4%	3.4%	-0.6%	3.9%	-0.2%	3.3%	-0.1%	3.2%	0.1%	3.1%	-0.2%	3.8%	-0.2%	4.6%	-0.1%	2.7%	0.1%	5.3%
CA	3.2%	3.5%	-0.5%	3.4%	-0.4%	5.4%	-0.2%	5.6%	-0.1%	-2.2%	-0.2%	4.0%	-0.1%	3.1%	-0.1%	3.2%	0.0%	1.1%
CH	3.2%	3.0%	-0.5%	3.1%	-0.2%	2.7%	-0.1%	2.6%	0.0%	0.0%	-0.2%	2.8%	-0.1%	3.0%	0.0%	1.9%	0.1%	2.8%
AU	2.8%	3.3%	-0.6%	3.8%	-0.2%	3.4%	-0.1%	3.0%	0.0%	-0.7%	-0.2%	3.5%	-0.2%	3.3%	-0.1%	4.5%	0.1%	4.7%
KR	1.8%	1.6%	-0.3%	1.9%	-0.1%	1.9%	-0.1%	1.9%	-0.1%	-1.5%	-0.1%	1.7%	-0.1%	1.7%	-0.1%	2.1%	0.0%	2.3%
HK	1.2%	0.7%	-0.1%	1.0%	-0.1%	1.1%	0.0%	1.1%	0.0%	0.8%	-0.1%	1.2%	-0.1%	1.2%	0.0%	1.3%	0.0%	1.8%
ES	1.1%	1.4%	-0.2%	1.5%	-0.1%	1.6%	-0.1%	1.5%	0.0%	0.0%	-0.1%	1.5%	-0.1%	1.9%	0.0%	1.2%	0.0%	1.0%
NL	1.1%	1.2%	-0.2%	1.2%	-0.1%	1.1%	0.0%	1.1%	0.0%	1.0%	-0.1%	1.2%	-0.1%	1.4%	0.0%	0.9%	0.0%	1.4%
SE	1.1%	1.2%	-0.2%	1.2%	-0.1%	1.3%	0.0%	1.2%	0.0%	0.9%	-0.1%	1.2%	-0.1%	1.5%	0.0%	0.6%	0.0%	2.0%
IT	0.8%	1.1%	-0.2%	1.1%	-0.1%	1.1%	0.0%	1.1%	0.0%	0.9%	-0.1%	1.1%	-0.1%	1.3%	0.0%	0.7%	0.0%	1.0%
DK	0.6%	0.6%	-0.1%	0.7%	0.0%	0.4%	0.0%	0.4%	0.0%	0.2%	0.0%	0.5%	0.0%	0.7%	0.0%	0.3%	0.0%	0.5%
SG	0.5%	0.4%	-0.1%	0.4%	0.0%	0.5%	0.0%	0.5%	0.0%	-0.6%	0.0%	0.5%	0.0%	0.4%	0.0%	0.5%	0.0%	0.8%
BE	0.4%	0.4%	-0.1%	0.5%	0.0%	0.4%	0.0%	0.4%	0.0%	0.3%	0.0%	0.4%	0.0%	0.5%	0.0%	0.3%	0.0%	0.3%
FI	0.4%	0.4%	-0.1%	0.5%	0.0%	0.4%	0.0%	0.4%	0.0%	0.3%	0.0%	0.4%	0.0%	0.5%	0.0%	0.2%	0.0%	0.4%
IL	0.3%	0.2%	0.0%	0.2%	0.0%	0.1%	0.0%	0.1%	0.0%	0.3%	0.0%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	0.2%
NO	0.2%	0.3%	0.0%	0.3%	0.0%	0.4%	0.0%	0.4%	0.0%	-0.1%	0.0%	0.3%	0.0%	0.3%	0.0%	0.2%	0.0%	0.3%
IE	0.2%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	0.2%	0.0%	0.1%	0.0%	0.2%
CN	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%
NZ	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	-0.1%
AT	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%
PT	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	-0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
RU	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: FTSE Russell, Axioma Risk

In figure 5, the sector level table, we see that financials are not only the largest component of the index, but also the riskiest, more than their weight would suggest. As sensitivities go, financials are very sensitive to movements in the price of gold, long bond yield, corporate spreads and catastrophe bonds. The shock on Global REITs saw seven out of the 11 sectors contribute a higher percentage to portfolio loss than their contribution to the original portfolio risk. The 10Y USTB, US credit spreads, and Catastrophe bond shocks also contributed more to expected losses in five sectors each than their contribution to the original portfolio's risk, indicating that these five sectors were quite sensitive to those shocks. The shock on commodities and oil was the least impactful (in terms of number of sectors whose contribution to portfolio loss was greater than their contribution to risk), with only Energy and Materials reacting strongly to shocks in those asset classes.

No matter your investment style, top-down or bottom-up, mapping the sensitivities of your investment universe to other asset classes can provide valuable insights about the impact various macroeconomic events may have on your investments. Knowing that movements in the price of gold will disproportionately affect your U.S. and Financials holdings can help you better protect your portfolio for news and events that may disrupt that asset class. Managers can also ensure their allocation is in line with their firm's views on this asset class, or simply be made aware of unwanted sensitivities. The most affected sectors in the gold shock was not Materials, but Financials, IT, Consumer Discretionary, and Health Care. A simple sector allocation from an equity-only risk decomposition would not make the link between these two asset classes. A manager with an underweight in Materials, and Gold Mining in particular, could still be very exposed to Gold via these other sectors. Only a cross-asset class analysis would reveal that.

Figure 5. Sector-Level Drill Down for Selected Non-Equity Factor Shocks

GICS Sector	% of PV	% of Risk	Global REIT -20%	% of Shock	GSCI -20%	% of Shock	Oil -20%	% of Shock	Gold -20%	% of Shock	US Spr. +20%	% of Shock	EU Spr. +20%	% of Shock	JP Spr. +20%	% of Shock	Cat Bonds -2%	% of Shock
Totals	**100%**	**100%**	**-14.7%**	**100%**	**-7.3%**	**100%**	**-3.7%**	**100%**	**3.9%**	**100%**	**-6.1%**	**100%**	**-4.6%**	**100%**	**-2.5%**	**100%**	**1.8%**	**100%**
Financials	18.2%	21.5%	-2.4%	16.4%	-1.5%	21.2%	-0.8%	21.3%	1.8%	46.9%	-1.3%	21.5%	-1.1%	23.4%	-0.7%	26.2%	0.5%	27.2%
Info. Tech.	15.4%	15.2%	-2.4%	16.2%	-1.1%	14.9%	-0.6%	14.8%	1.0%	26.5%	-1.0%	17.0%	-0.7%	15.5%	-0.5%	18.4%	0.4%	21.8%
Consumer Disc.	12.5%	12.3%	-1.9%	13.2%	-0.9%	11.8%	-0.4%	11.7%	0.7%	16.8%	-0.8%	12.9%	-0.6%	13.9%	-0.3%	13.7%	0.3%	14.7%
Health Care	11.7%	10.3%	-1.6%	11.2%	-0.5%	6.6%	-0.2%	6.6%	0.6%	14.4%	-0.5%	8.9%	-0.5%	10.2%	-0.2%	8.2%	0.3%	14.2%
Industrials	11.4%	10.9%	-1.5%	10.5%	-0.8%	10.6%	-0.4%	10.3%	0.3%	7.8%	-0.7%	11.0%	-0.5%	10.8%	-0.3%	10.0%	0.1%	7.8%
Consumer Stap.	9.7%	7.8%	-1.4%	9.3%	-0.4%	6.0%	-0.2%	5.7%	-0.2%	-4.5%	-0.4%	6.2%	-0.3%	6.6%	-0.1%	5.2%	0.0%	1.6%
Energy	6.7%	8.4%	-1.0%	7.1%	-1.1%	15.7%	-0.6%	17.2%	0.1%	2.4%	-0.6%	9.3%	-0.3%	7.2%	-0.2%	6.7%	0.1%	7.5%
Materials	5.3%	5.7%	-0.9%	6.0%	-0.6%	8.1%	-0.3%	7.9%	-0.1%	-1.9%	-0.4%	7.2%	-0.3%	6.5%	-0.1%	5.5%	0.1%	6.0%
Telecomm.	3.1%	3.0%	-0.4%	2.9%	-0.2%	2.5%	-0.1%	2.2%	-0.1%	-1.9%	-0.1%	2.3%	-0.1%	2.3%	-0.1%	2.2%	0.0%	1.4%
Utilities	3.1%	2.4%	-0.5%	3.3%	-0.1%	1.1%	0.0%	0.8%	-0.2%	-4.6%	-0.1%	1.5%	-0.1%	1.4%	0.0%	1.3%	0.0%	-2.1%
Real Estate	3.0%	2.6%	-0.6%	3.9%	-0.1%	1.6%	-0.1%	1.4%	-0.1%	-1.9%	-0.1%	2.2%	-0.1%	2.2%	-0.1%	2.4%	0.0%	-0.3%

Source: FTSE Russell, Axioma Risk

Transitive Stress Tests on Active Portfolios

As previously mentioned, many factors, external to the equity market, may have contributed to the choice of alpha signal. The manager's views on the direction of interest rates or commodity prices may have helped shape the decision to target a specific investment style for outperformance. We used the same set

of transitive factor stress tests described above to analyze whether an actively managed portfolio's active returns are sensitive to shocks in other asset classes and if they are aligned with the macroeconomic beliefs that drove their equity style decision. This analysis is also relevant to Quant managers, who may have developed their investment strategies based solely on factor performance, without regard to the macro environment. Knowing their macro sensitivities could be quite helpful to understanding, and explaining, performance both ex-ante and ex-post.

We created two active portfolios representing strategies that bet on value and momentum, respectively, with a maximum of 3% of active risk against our benchmark, the FTSE All-World Index, used in the above analysis. Each strategy represents an investment thesis that the targeted style will outperform the benchmark, and the portfolio construction process uses a global equity factor model, as well as an optimizer. The definitions of the "alpha" signal correspond to the Value and Medium-Term Momentum factors in the Axioma Worldwide Medium Horizon (AXWW-MH) risk model so as to eliminate misalignment risk from using definitions that differ from the risk model's factor definition for these styles. Each portfolio is constructed with an explicit constraint on all non-targeted style factors, but no constraints on country, industry, or market risk factors. The resulting active portfolios have an active exposure to the target factor (1.51 for Value and 1.22 for Medium-Term Momentum) and no active exposure to all other style factors in the model. Both portfolios have a predicted active risk of exactly 3% and more than half of their active risk comes from style risk, with 100% of that risk coming from the active exposure to the target factor (see Figure 6 below).

Figure 6. Summary Characteristics of Active Momentum and Active Value Portfolios

Portfolio Summary	Momentum	% of Risk
No. of Names	137	
Predicted Beta (WW-MH)	1.01	
Risk Summary		
Active Risk	**3.00%**	**100%**
Active Specific Risk	1.86%	38.3%
Active Factor Risk	2.36%	61.7%
Risk Decomposition	**Risk**	
Style	**2.93%**	**58%**
Exchange Rate Sensitivity	0.00%	0.00%
Growth	0.00%	0.00%
Leverage	0.00%	0.00%
Liquidity	0.00%	0.00%
Medium-Term Momentum	**2.93%**	**57.65%**
Short-Term Momentum	0.00%	0.00%
Size	0.00%	0.00%
Value	0.00%	0.00%
Volatility	0.00%	0.00%
Country	**0.63%**	**1.97%**
Industry	**1.52%**	**2.09%**
Currency	**0.58%**	**0.03%**

Portfolio Summary	Value	% of Risk
No. of Names	103	
Predicted Beta (WW-MH)	1.04	
Risk Summary		
Active Risk	**3.00%**	**100%**
Active Specific Risk	2.03%	46.0%
Active Factor Risk	2.20%	54.0%
Risk Decomposition	**Risk**	
Style	**2.73%**	**56%**
Exchange Rate Sensitivity	0.00%	0.00%
Growth	0.00%	0.00%
Leverage	0.00%	0.00%
Liquidity	0.00%	0.00%
Medium-Term Momentum	0.00%	0.00%
Short-Term Momentum	0.00%	0.00%
Size	0.00%	0.00%
Value	**2.73%**	**56.11%**
Volatility	0.00%	0.00%
Country	**0.79%**	**-1.10%**
Industry	**1.18%**	**-4.50%**
Currency	**0.61%**	**3.49%**

Source: FTSE Russell, Axioma Portfolio

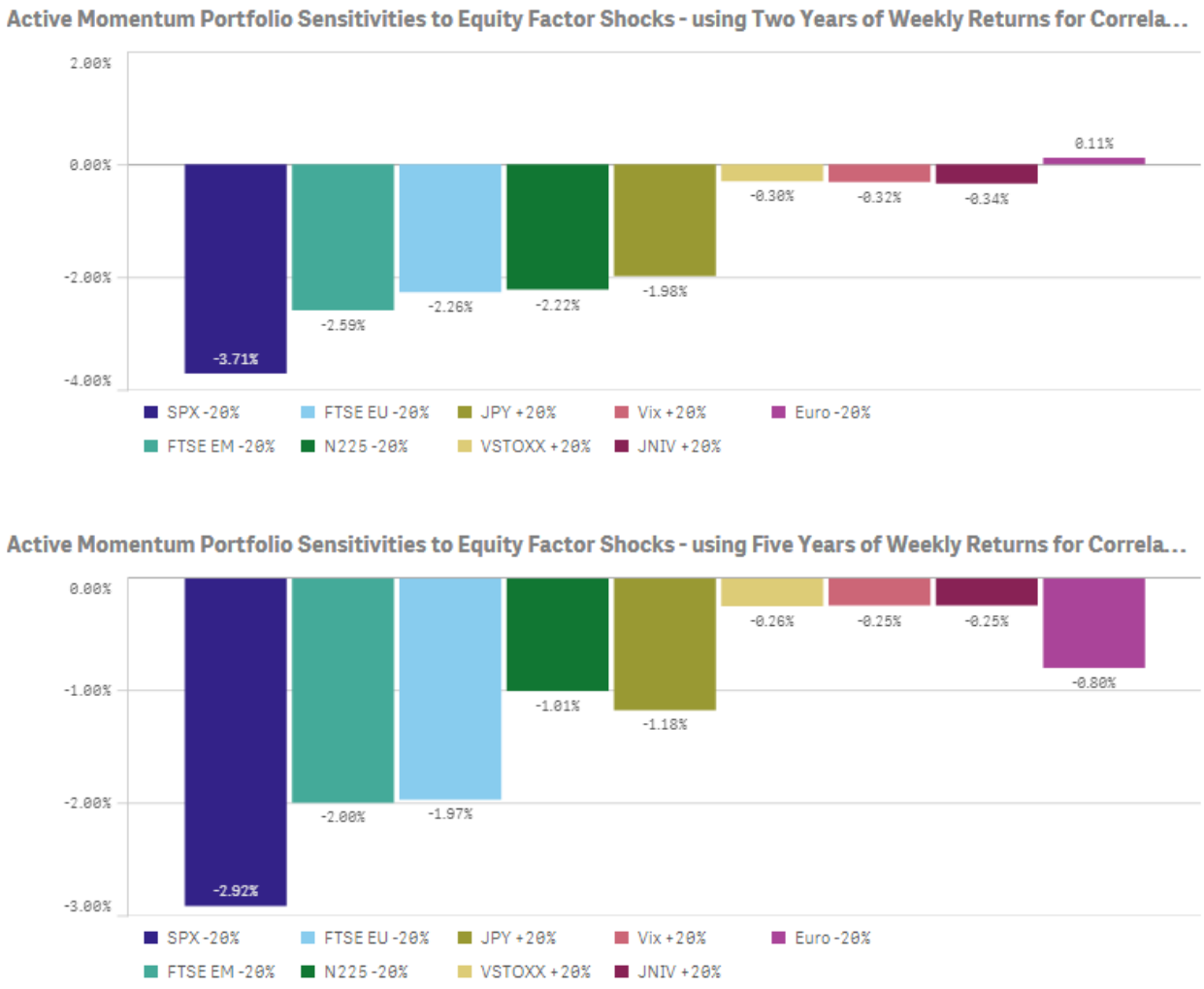
Active Momentum Strategy

Figure 7 displays the portfolio-level results from our equity factor shocks as a percentage change in active present value for the Active Momentum strategy, using both two and five years of weekly returns to estimate the correlation between each holding in the portfolio and the factor being shocked. We can quickly see that this style strategy would strongly underperform under almost all equity-related factor shocks, even though the predicted beta by the equity risk model in Figure 6 shows a beta of 1.0 for this portfolio versus the benchmark. We can also see that this underperformance has increased in the recent past as the correlation between our active positions and those factors were stronger in the last two years than they were over the past five years. The negative impact from an appreciating Japanese yen in particular has doubled in the two-year test versus the five-year test. It would therefore seem from these results that momentum as an investment style is falling further out of favor in times of equity market stress and that the high volatility of the USD/JPY exchange rate has investors on edge. As we have already stated, global equity managers should have a view on this factor given its influence. In contrast, the gains from a weakening euro that we saw in the index portfolio in the two-year test have all but disappeared here.

Our sample Momentum Portfolio was quite sensitive to changes in equity factors, as well as to a number of macro factors. These results were country- and asset-specific, so vulnerabilities could differ widely for other portfolios.

Even if the momentum strategy is in line with the firm's outlook on the equity and currency factors above, the analysis is still valuable as it informs the manager of the size of the potential downside if their views are wrong. Active managers need to deliver risk-adjusted returns to their clients and understanding the nature of the downside of the ledger is therefore beneficial in explaining performance. How does the predicted upside of this portfolio compare with the potential downside these scenarios highlight? Is there a plan for adjusting the positions in the event of one of those scenarios? Which assets in the portfolio are most affected and should be on a "factor watch list" for potential rebalancing?

Figure 7. Aggregate Equity Stress-Test Results, Active Momentum Portfolio



Source: FTSE Russell, Axioma Risk

Figure 8 shows the results of the non-equity factor shocks discussed earlier and applied to our active Momentum portfolio. Contrary to the results on the broad index, the shock applied to Global REITs had a much smaller negative impact on active returns than the shocks applied to commodities, U.S. corporate spreads, and oil, indicating that the Momentum strategy has a bullish view on these factors (since our stress tests reflect a fall in these asset classes). Did the manager know that his equity portfolio was in fact "long" Oil, commodities, credit spreads, and global REITs? Are these implied views in line with the firm's macroeconomic outlook?

Figure 8. Aggregate Non-Equity Stress-Test Results, Active Momentum Portfolio

Source: FTSE Russell, Axioma Risk

The country breakdown reveals that the sensitivity from a fall in Global REITs has some offsetting qualities. The contribution to active loss from the overweights in France, Australia, the United Kingdom, and Canada, could be offset by trading into the underweight positions in Switzerland, Japan, Sweden, and Hong Kong. As for Gold, the overweight in the U.S. market contributed almost all (83%) of the active losses projected from a 20% fall in that asset class and there do not seem to be enough offsetting positions to rebalance the portfolio for a complete hedge. The manager is therefore exposed to this asset class without the means to hedge its negative impact. Was this intentional?

Figure 9 Country-Level Drill Down for Non-Equity Factor Shocks for Active Momentum

Country	% of PV	% of Risk	Global REIT -20%	% of Shock	GSCI - 20%	% of Shock	Oil -20%	% of Shock	Gold - 20%	% of Shock	US Spr. +20%	% of Shock	EU Spr. +20%	% of Shock	JP Spr. +20%	% of Shock	Cat Bonds - 2%	% of Shock
Total	**0%**	**100%**	**-1.8%**	**100%**	**-3.4%**	**100%**	**-1.9%**	**100%**	**1.7%**	**100%**	**-2.2%**	**100%**	**-1.2%**	**100%**	**-1.0%**	**100%**	**0.2%**	**100%**
FR	3.4%	9.4%	-0.9%	51.4%	-0.6%	18.0%	-0.3%	15.7%	0.3%	17.6%	-0.6%	25.4%	-0.4%	35.9%	-0.2%	24.7%	0.2%	116.8%
AU	2.2%	5.6%	-0.7%	38.1%	-0.5%	13.6%	-0.2%	12.7%	0.1%	5.7%	-0.4%	17.5%	-0.2%	18.6%	-0.2%	24.7%	0.1%	67.7%
DE	2.0%	7.3%	-0.3%	15.0%	-0.2%	4.8%	-0.1%	4.1%	0.0%	-2.0%	-0.1%	5.6%	-0.1%	7.5%	0.0%	2.7%	0.0%	-24.0%
GB	2.0%	9.5%	-0.6%	32.5%	-0.7%	19.4%	-0.3%	17.5%	0.0%	-0.3%	-0.5%	21.2%	-0.3%	23.9%	-0.1%	11.2%	0.2%	124.7%
CA	0.9%	2.2%	-0.1%	6.8%	-0.3%	7.5%	-0.1%	7.3%	0.0%	0.6%	-0.2%	7.8%	-0.1%	6.5%	-0.1%	9.0%	0.0%	10.1%
US	0.6%	54.9%	-0.5%	30.0%	-1.8%	51.6%	-1.0%	53.9%	1.4%	83.2%	-0.9%	43.0%	-0.5%	42.6%	-0.5%	48.4%	-0.1%	-70.5%
IT	0.6%	1.7%	0.0%	1.1%	0.0%	0.7%	0.0%	0.7%	0.0%	-0.1%	0.0%	0.5%	0.0%	-0.1%	0.0%	1.5%	0.0%	-1.8%
DK	0.0%	0.7%	0.0%	0.4%	0.0%	0.0%	0.0%	0.1%	0.1%	5.1%	0.0%	0.5%	0.0%	1.4%	0.0%	0.6%	0.0%	13.8%
PE	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
IL	0.0%	0.3%	0.0%	2.1%	0.0%	0.7%	0.0%	0.8%	0.0%	-0.1%	0.0%	0.8%	0.0%	0.8%	0.0%	0.3%	0.0%	3.1%
RU	0.0%	0.0%	0.0%	-0.4%	0.0%	-0.1%	0.0%	-0.1%	0.0%	0.1%	0.0%	-0.1%	0.0%	-0.1%	0.0%	-0.1%	0.0%	-0.5%
PT	-0.1%	0.0%	0.0%	-0.7%	0.0%	-0.2%	0.0%	-0.2%	0.0%	0.1%	0.0%	-0.2%	0.0%	-0.3%	0.0%	-0.1%	0.0%	-0.3%
AT	-0.1%	0.0%	0.0%	-0.7%	0.0%	-0.2%	0.0%	-0.2%	0.0%	-0.2%	0.0%	-0.3%	0.0%	-0.5%	0.0%	-0.2%	0.0%	-1.1%
NZ	-0.1%	0.0%	0.0%	-0.7%	0.0%	-0.1%	0.0%	-0.1%	0.0%	0.3%	0.0%	-0.2%	0.0%	-0.2%	0.0%	-0.2%	0.0%	0.7%
CN	-0.1%	0.0%	0.0%	-0.7%	0.0%	-0.3%	0.0%	-0.2%	0.0%	-0.1%	0.0%	-0.3%	0.0%	-0.4%	0.0%	-0.2%	0.0%	-1.3%
IE	-0.2%	0.0%	0.0%	-1.7%	0.0%	-0.4%	0.0%	-0.4%	0.0%	-0.5%	0.0%	-0.5%	0.0%	-0.9%	0.0%	-0.4%	0.0%	-2.2%
ES	-0.2%	0.6%	0.0%	-1.6%	0.0%	0.3%	0.0%	0.2%	0.0%	1.5%	0.0%	0.4%	0.0%	0.3%	0.0%	1.2%	0.0%	6.7%
NO	-0.2%	-0.1%	0.0%	-2.3%	0.0%	-0.9%	0.0%	-0.8%	0.0%	0.1%	0.0%	-0.9%	0.0%	-1.2%	0.0%	-0.4%	0.0%	-3.2%
FI	-0.4%	-0.1%	0.1%	-3.8%	0.0%	-0.8%	0.0%	-0.7%	0.0%	-0.6%	0.0%	-1.2%	0.0%	-1.8%	0.0%	-0.6%	0.0%	-3.6%
NL	-0.4%	0.4%	0.1%	-3.8%	0.0%	0.0%	0.0%	0.2%	0.0%	2.6%	0.0%	0.0%	0.0%	-0.7%	0.0%	0.5%	0.0%	-7.2%
BE	-0.4%	0.0%	0.1%	-4.1%	0.0%	-0.9%	0.0%	-0.8%	0.0%	-0.7%	0.0%	-1.1%	0.0%	-2.0%	0.0%	-0.7%	0.0%	-3.3%
SG	-0.5%	0.1%	0.1%	-3.5%	0.0%	-1.1%	0.0%	-1.0%	0.0%	1.4%	0.0%	-1.3%	0.0%	-1.6%	0.0%	-1.2%	0.0%	-7.3%
KR	-0.5%	0.9%	0.1%	-4.2%	0.0%	-0.8%	0.0%	-0.5%	0.0%	1.2%	0.0%	-0.9%	0.0%	-1.4%	0.0%	-1.5%	0.0%	-6.1%
HK	-0.9%	0.3%	0.1%	-5.3%	0.1%	-1.7%	0.0%	-1.5%	0.0%	-2.0%	0.0%	-2.1%	0.0%	-3.5%	0.0%	-2.3%	0.0%	-14.2%
SE	-1.1%	-0.2%	0.2%	-9.9%	0.1%	-2.8%	0.0%	-2.4%	0.0%	-2.1%	0.1%	-3.4%	0.1%	-5.8%	0.0%	-1.7%	0.0%	-19.2%
CH	-2.4%	0.6%	0.3%	-19.0%	0.1%	-3.8%	0.1%	-3.2%	0.0%	0.3%	0.1%	-5.5%	0.1%	-8.1%	0.0%	-3.4%	0.0%	-19.7%
JP	-4.1%	6.0%	0.3%	-15.1%	0.1%	-2.3%	0.0%	-1.0%	-0.2%	-11.3%	0.1%	-4.6%	0.1%	-9.0%	0.1%	-11.9%	-0.1%	-58.1%

Source: FTSE Russell, Axioma Risk

The Sector breakdown in Figure 10 highlights the exposure to widening credit spreads in the United Kingdom, Europe, and Japan from the overweighs in Financials, Energy and Materials sectors. Again, the underweight positions in Consumer Staples, Consumer Discretionary, and Health Care can provide some hedge but not nearly enough to completely neutralize the exposure. What are the manager's views on the direction of corporate credit spreads in these countries, and are they in line with the views of the fixed income managers or the views communicated to clients by the economic strategy documentation?

Figure 10. Sector-Level Drill-Down for Non-Equity Factor Shocks for Active Momentum

GICS L1	% of PV	% of Risk	Global REIT -20%	% of Shock	GSCI - 20%	% of Shock	Oil -20%	% of Shock	Gold - 20%	% of Shock	US Spr. +20%	% of Shock	EU Spr. +20%	% of Shock	JP Spr. +20%	% of Shock	Cat Bonds - 2%	% of Shock
Totals	**0%**	**100%**	**-1.8%**	**100%**	**-3.4%**	**100%**	**-1.9%**	**100%**	**1.7%**	**100%**	**-2.2%**	**100%**	**-1.2%**	**100%**	**-1.0%**	**100%**	**0.2%**	**100%**
Financials	10.0%	15.6%	-1.7%	94.2%	-1.3%	39.6%	-0.7%	36.5%	1.3%	79.4%	-1.1%	47.8%	-0.8%	64.4%	-0.5%	48.8%	0.4%	190.0%
Energy	5.1%	27.0%	-1.6%	86.7%	-1.6%	47.1%	-1.0%	49.3%	0.1%	4.8%	-0.9%	41.8%	-0.5%	39.1%	-0.3%	34.4%	-0.1%	-61.7%
Materials	4.1%	18.9%	-1.4%	76.6%	-1.0%	29.6%	-0.5%	26.9%	-0.1%	-3.8%	-0.8%	37.4%	-0.5%	44.7%	-0.3%	28.9%	0.2%	114.3%
Info. Tech.	2.3%	11.9%	-0.3%	17.1%	-0.3%	8.2%	-0.1%	7.6%	0.4%	23.9%	-0.3%	11.9%	-0.1%	12.0%	-0.1%	13.5%	0.0%	-8.9%
Industrials	2.0%	7.4%	-0.4%	21.2%	-0.2%	7.0%	-0.1%	6.6%	0.0%	0.5%	-0.2%	8.2%	-0.2%	12.9%	0.0%	3.9%	0.0%	-3.1%
Telecomm.	-0.6%	4.5%	0.0%	-2.4%	0.0%	0.8%	0.0%	1.2%	0.1%	3.2%	-0.1%	2.4%	0.0%	0.8%	-0.1%	8.6%	0.0%	-4.6%
Real Estate	-2.3%	0.7%	0.5%	-25.1%	0.1%	-2.4%	0.0%	-1.9%	0.1%	3.6%	0.1%	-4.5%	0.1%	-6.1%	0.0%	-4.4%	0.0%	2.8%
Utilities	-2.5%	1.1%	0.4%	-20.9%	0.0%	-1.0%	0.0%	-0.2%	0.2%	10.7%	0.1%	-2.3%	0.0%	-3.8%	0.0%	-2.0%	0.0%	15.5%
Health Care	-4.4%	5.2%	0.7%	-35.9%	0.2%	-5.5%	0.1%	-5.2%	-0.3%	-18.8%	0.2%	-10.9%	0.2%	-17.0%	0.1%	-7.7%	-0.1%	-60.4%
Consumer Disc.	-4.9%	6.1%	0.8%	-41.4%	0.4%	-11.5%	0.2%	-10.4%	-0.2%	-11.9%	0.3%	-15.6%	0.3%	-23.2%	0.1%	-11.3%	-0.1%	-64.0%
Consumer Stap.	-8.9%	1.7%	1.3%	-70.2%	0.4%	-12.0%	0.2%	-10.2%	0.1%	8.4%	0.4%	-16.2%	0.3%	-23.9%	0.1%	-12.8%	0.0%	-19.8%

Source: FTSE Russell, Axioma Risk

Of course, as noted, the portfolio contains a fair amount of specific risk, so we can look at the results on an asset level to identify a mismatch between the manager's asset selection model and the firm's macro analysis. For example, the holding the most damaged (-1.75%) by a fall in the GSCI index is Oneok, Inc. in

the Energy Sector, in which the manager has a 5.2% overweight position! The size of the overweight here is probably responsible for the bulk of the sensitivity rather than anything specific to Oneok, Inc., but these results raise questions as to the downside risk associated with the manager's very strong conviction on this position. Is the downside risk really worth it? The second most damaged (-0.39%) position is Glencore plc in the Materials sector, which is 1.3% overweight in the portfolio (see Figure 11 below). The six biggest contributors to active loss are all high-conviction positions with over 1% active weight in the portfolio. Given these results from our stress tests, and the firm's macro views on commodities, could the manager have built a better momentum portfolio reflecting all of the available research from other asset classes, perhaps by adding other constraints on industries or countries?

Figure 11. Holdings Level Change in % of Active Present Value from Non-Equity Factors

Two Year Look-Back

Country	Stock Name	% of PV	% of Risk	GSCI -20%	Oil -20%	Gold -20%	10Y USTB +100bps	10Y EUGB +100bps	US Spr. +20%	EU Spr. +20%	JP Spr. +20%	Cat Bonds -2%	Global REIT -20%
Totals		-0.00%	100.00%	-3.39%	-1.94%	1.69%	0.11%	0.02%	-2.21%	-1.22%	-0.97%	0.19%	-1.81%
US	ONEOK INC NEW	5.21%	18.77%	-1.20%	-0.69%	-0.07%	0.01%	-0.00%	-0.62%	-0.31%	-0.19%	-0.10%	-1.22%
GB	GLENCORE PLC	1.34%	4.19%	-0.39%	-0.21%	-0.10%	0.01%	0.00%	-0.29%	-0.19%	-0.05%	0.10%	-0.51%
US	WILLIAMS COS INC DEL	1.27%	3.45%	-0.38%	-0.24%	0.22%	0.01%	0.00%	-0.24%	-0.16%	-0.07%	0.01%	-0.41%
FR	ARCELORMITTAL	1.54%	4.69%	-0.35%	-0.17%	-0.06%	0.01%	0.00%	-0.29%	-0.19%	-0.11%	0.12%	-0.50%
DE	DEUTSCHE POST AG	2.99%	2.91%	-0.25%	-0.12%	0.05%	0.01%	-0.00%	-0.21%	-0.21%	-0.05%	0.04%	-0.54%
CA	BANK OF NOVA SCOTIA	1.57%	1.03%	-0.22%	-0.12%	-0.04%	0.00%	0.00%	-0.15%	-0.08%	-0.06%	0.02%	-0.25%
AU	WORLEYPARSONS LTD	0.68%	1.96%	-0.19%	-0.10%	-0.05%	0.00%	0.00%	-0.12%	-0.06%	-0.08%	0.02%	-0.21%
US	CHEVRON CORP NEW	1.27%	0.84%	-0.19%	-0.11%	0.03%	0.00%	0.00%	-0.08%	-0.05%	-0.03%	0.01%	-0.17%
CA	ENCANA CORP	0.50%	1.31%	-0.18%	-0.11%	-0.04%	0.00%	0.00%	-0.10%	-0.05%	-0.04%	0.00%	-0.11%
US	MORGAN STANLEY	1.54%	1.42%	-0.18%	-0.10%	0.35%	0.01%	0.00%	-0.16%	-0.12%	-0.08%	0.04%	-0.20%
GB	ANGLO AMERICAN	0.57%	1.46%	-0.17%	-0.08%	-0.13%	0.00%	0.00%	-0.11%	-0.06%	-0.03%	0.01%	-0.16%
US	COMERICA INC	1.15%	1.48%	-0.16%	-0.09%	0.21%	0.01%	0.00%	-0.11%	-0.08%	-0.06%	0.05%	-0.12%
GB	3I GROUP	1.38%	1.52%	-0.16%	-0.08%	0.11%	0.00%	0.00%	-0.13%	-0.12%	-0.05%	0.08%	-0.30%
FR	ARKEMA	1.30%	1.81%	-0.16%	-0.08%	0.08%	0.00%	0.00%	-0.14%	-0.12%	-0.04%	0.03%	-0.30%
GB	HSBC HOLDINGS PLC	1.44%	1.26%	-0.15%	-0.07%	0.13%	0.01%	0.00%	-0.11%	-0.10%	-0.05%	0.07%	-0.21%
US	HEWLETT PACKARD ENTERPRISE C	1.85%	2.72%	-0.15%	-0.08%	0.15%	0.00%	0.00%	-0.15%	-0.11%	-0.09%	0.03%	-0.30%
US	APPLIED MATLS INC	1.58%	2.68%	-0.14%	-0.08%	0.18%	0.01%	-0.00%	-0.15%	-0.10%	-0.06%	0.01%	-0.25%
AU	MACQUARIE GP LTD	1.24%	0.62%	-0.14%	-0.07%	0.18%	0.00%	0.00%	-0.13%	-0.10%	-0.07%	0.06%	-0.30%
US	INTERNATIONAL BUSINESS MACHINES	1.90%	1.16%	-0.13%	-0.06%	0.10%	0.00%	0.00%	-0.12%	-0.07%	-0.06%	0.02%	-0.29%

Source: FTSE Russell, Axioma Risk

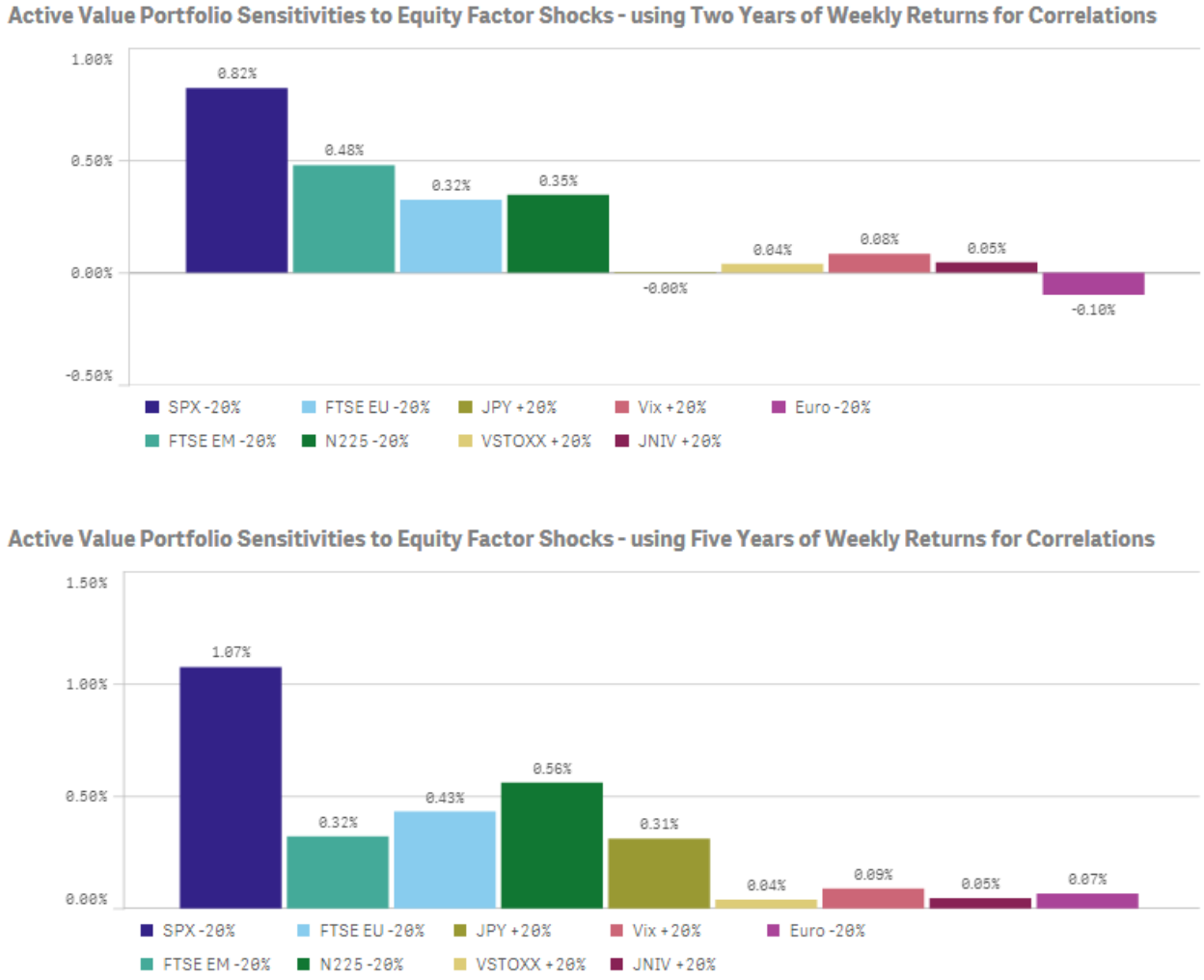
Active Value Strategy

Figures 12 and 13 display the portfolio-level results for the equity and non-equity factor stress tests on the Active Value strategy. This is clearly a defensive strategy, as it would outperform in times of equity market stress, although the magnitude of this outperformance is marginal[7]. In terms of country allocation, the Value strategy only shares an underweight in Japan and Australia with the Momentum strategy. In contrast, it has a sharp overweight position of 6.3% in Hong Kong, while the Momentum strategy is underweight by 0.9%

[7] Note to self: It would be informative to conduct the same factor stress tests in reverse, assuming a 20% rise in equity markets, to see if this defensive quality comes at high underperformance costs during a bull market.

in that market. The Value portfolio seems to have successfully neutralized all equity-related factor shocks, despite some areas of concentration at the country, sector, and industry group level. Its underweight in the United States means that it would benefit the most from a fall in that asset class, but did the manager know that the portfolio would outperform in a scenario that sees emerging markets fall by 20%?

Figure 12. Aggregate Equity Stress-Test Results, Active Value Portfolio



Source: FTSE Russell, Axioma Risk

Interestingly, the Value portfolio is overweight the Real Estate sector (its biggest active exposure in fact), yet Figure 13 shows that it would outperform under a scenario of falling Global REITs prices. Drilling down to the Sector level in Figure 14 decomposes that outperformance for this portfolio. The contribution to active loss from the overweight position in Real Estate and Utilities is more than offset by positive contributions coming from the underweight position in Industrials, Materials, Energy, and Consumer Staples. If the manager intended on being “long” real estate, why are the stress test results showing an outperformance from a fall in that asset class?

Our sample Value portfolio was less sensitive to non-equity shocks, as losses in one country or sector tended to be offset by gains in others. In other words, risks were better-hedged than in the Momentum portfolio.

In order to square that circle we need to dig deeper into the Real Estate sector's -0.92% contribution to the portfolio's +0.8% active gains from a 20% fall in the Global REITs. The active losses predicted from the Real Estate sector come from a -0.91% in Hong Kong and a -0.44% in the United Kingdom, offset mainly by a +0.27% in the United States. So it would seem that both the Hong Kong and United Kingdom overweight positions are in line with the manager's intent on being "long" real estate (since they would drop with a fall in Global REITS prices), but the underweight in the United States is not. Within the U.S. Real Estate sub-portfolio, only one holding, VEREIT, Inc., in which the manager is overweight by 0.3%, shows a negative contribution to active return (-0.07%). All other holdings in that sub-portfolio show positive contributions, especially Simon PPTY Group and American Tower Corp. (both underweight) in case of a fall in Global REITs. So only the manager's overweight in VEREIT, Inc. is in line with his position on real estate and there may be a mismatch with the asset selection model for the United States in that sector. If the underweight in the U.S. market is a critical part of the strategy, then given this information, the manager might consider rebalancing the portfolio to achieve it via means that do not contradict his views on real estate.

Figure 13. Aggregate Non-Equity Stress-Test Results, Active Value Portfolio

Source: FTSE Russell, Axioma Risk

The only other impactful factor of note for this portfolio is the commodities market. Its losses from overweight positions in Real Estate and Utilities, though, are more than offset by gains from its underweight positions in Materials, Industrials, and Energy to deliver an aggregate positive impact of 0.39% from a 20% fall in the GSCI index. Is the manager bearish on commodities?

Figure 14. Sector-Level Drill Down for Non-Equity Factor Shocks for Active Value

GICS L1	% of PV	% of Risk	Global REIT -20%	% of Shock	GSCI - 20%	% of Shock	Oil -20%	% of Shock	Gold - 20%	% of Shock	US Spr. +20%	% of Shock	EU Spr. +20%	% of Shock	JP Spr. +20%	% of Shock	Cat Bonds - 2%	% of Shock
Totals	**0.0%**	**100.0%**	**0.8%**	**100.0%**	**0.4%**	**100.0%**	**0.2%**	**100.0%**	**0.3%**	**100.0%**	**-0.1%**	**100.0%**	**0.0%**	**100.0%**	**0.0%**	**100.0%**	**0.0%**	**100.0%**
Real Estate	7.1%	15.4%	-0.9%	-112.2%	-0.6%	-149.5%	-0.3%	-177.9%	0.1%	25.9%	-0.5%	480.0%	-0.4%	2432.5%	-0.2%	513.9%	0.1%	-2152.5%
Utilities	6.6%	18.0%	-1.0%	-118.5%	-0.3%	-81.3%	-0.1%	-80.3%	-0.3%	-109.0%	-0.3%	314.3%	-0.2%	1431.7%	-0.1%	268.6%	-0.1%	837.4%
Info. Tech.	3.6%	19.8%	-0.1%	-15.6%	-0.1%	-26.9%	-0.1%	-36.6%	0.3%	123.3%	-0.1%	136.4%	-0.1%	342.6%	0.0%	28.8%	-0.1%	823.2%
Telecomm.	2.9%	5.2%	-0.3%	-41.7%	-0.2%	-44.3%	-0.1%	-50.4%	0.1%	37.3%	-0.1%	128.0%	-0.1%	696.7%	-0.1%	133.5%	0.0%	-422.7%
Health Care	0.0%	9.1%	0.1%	11.8%	0.0%	5.0%	0.0%	13.8%	-0.1%	-45.4%	0.0%	16.3%	0.0%	41.0%	0.0%	-62.6%	0.0%	-559.0%
Financials	-0.3%	11.7%	0.4%	46.0%	0.1%	22.9%	0.0%	10.3%	0.2%	88.4%	0.1%	-57.9%	0.1%	-698.1%	0.0%	16.8%	-0.1%	1108.0%
Consumer Disc.	-1.0%	23.3%	0.0%	3.6%	-0.1%	-30.8%	-0.1%	-35.5%	-0.2%	-79.6%	-0.2%	197.2%	-0.1%	707.3%	0.0%	-52.4%	0.2%	-3124.0%
Consumer Stap.	-2.3%	2.8%	0.4%	51.2%	0.2%	39.1%	0.1%	48.2%	0.1%	34.2%	0.1%	-110.3%	0.1%	-682.0%	0.0%	-43.8%	0.0%	456.5%
Energy	-2.5%	-0.3%	0.3%	34.2%	0.3%	79.3%	0.2%	98.1%	0.0%	-1.3%	0.1%	-150.1%	0.1%	-349.5%	0.0%	-82.1%	0.0%	71.2%
Materials	-5.3%	-3.9%	0.9%	107.2%	0.6%	151.8%	0.3%	168.0%	0.1%	27.1%	0.4%	-444.5%	0.3%	-1876.1%	0.1%	-316.2%	-0.1%	1763.7%
Industrials	-8.7%	-1.0%	1.1%	133.9%	0.5%	134.7%	0.2%	142.1%	0.0%	-1.1%	0.4%	-409.4%	0.3%	-1946.1%	0.1%	-304.4%	-0.1%	1298.3%

Source: FTSE Russell, Axioma Risk

In summary, the active momentum portfolio seems to have achieved its desired style exposure by also taking on some large non-equity asset class risks. The manager needs to ensure these are aligned with the firm's views on other asset classes. In contrast, the active value portfolio seems to have done a good job isolating and hedging almost all of the non-equity asset class risks while still achieving a similar level of target factor purity during its portfolio construction process. Of course, these are only examples, but they illustrate how important this type of analysis can be in helping any kind of active portfolio manager — quantitative or fundamental — avoid unnecessary drawdowns from contradictions between their portfolio holdings and their views on other asset classes.

Historical Scenarios

In this last section, we examine how well our two active portfolios would perform if held during various historic scenarios, such as Brexit or the China Crash of 2015, by reproducing the market environment across multiple asset classes during those periods. The full details of the replicated shock factors from each historical crisis can be found in Appendix 2[8].

As we saw in the previous section, the Active Momentum portfolio is overweight the United States, United Kingdom, France, and Germany. It is therefore not that surprising to see the Lehman Collapse, Black Monday, 9/11, and Brexit scenarios causing the most underperformance versus the FTSE All- World Index. The Lehman Collapse, however, is by far the worst-case scenario for this portfolio, causing a 13.5% and 9.8% underperformance in the two and five-year tests, respectively (see Figure 15). Most of that comes from the U.S. allocation, as expected, but while the United States is only overweight by 0.6%, it represents over 50% of the active loss by itself. Digging into the sector allocation for the U.S. sub-portfolio we see that the Active Momentum portfolio is overweight Energy by 5.2% and Financials by 5%. Those two sectors contribute -3.8% and -3.5% respectively to the United States' -6.8% in total active loss. Digging deeper still,

[8] Note that the independent factors selected and the magnitudes of the shocks are subjective decisions made by the author for the purpose of this report. In practice, parallel scenarios with multiple parameter settings and look-back periods should be conducted to qualify the robustness of those results.

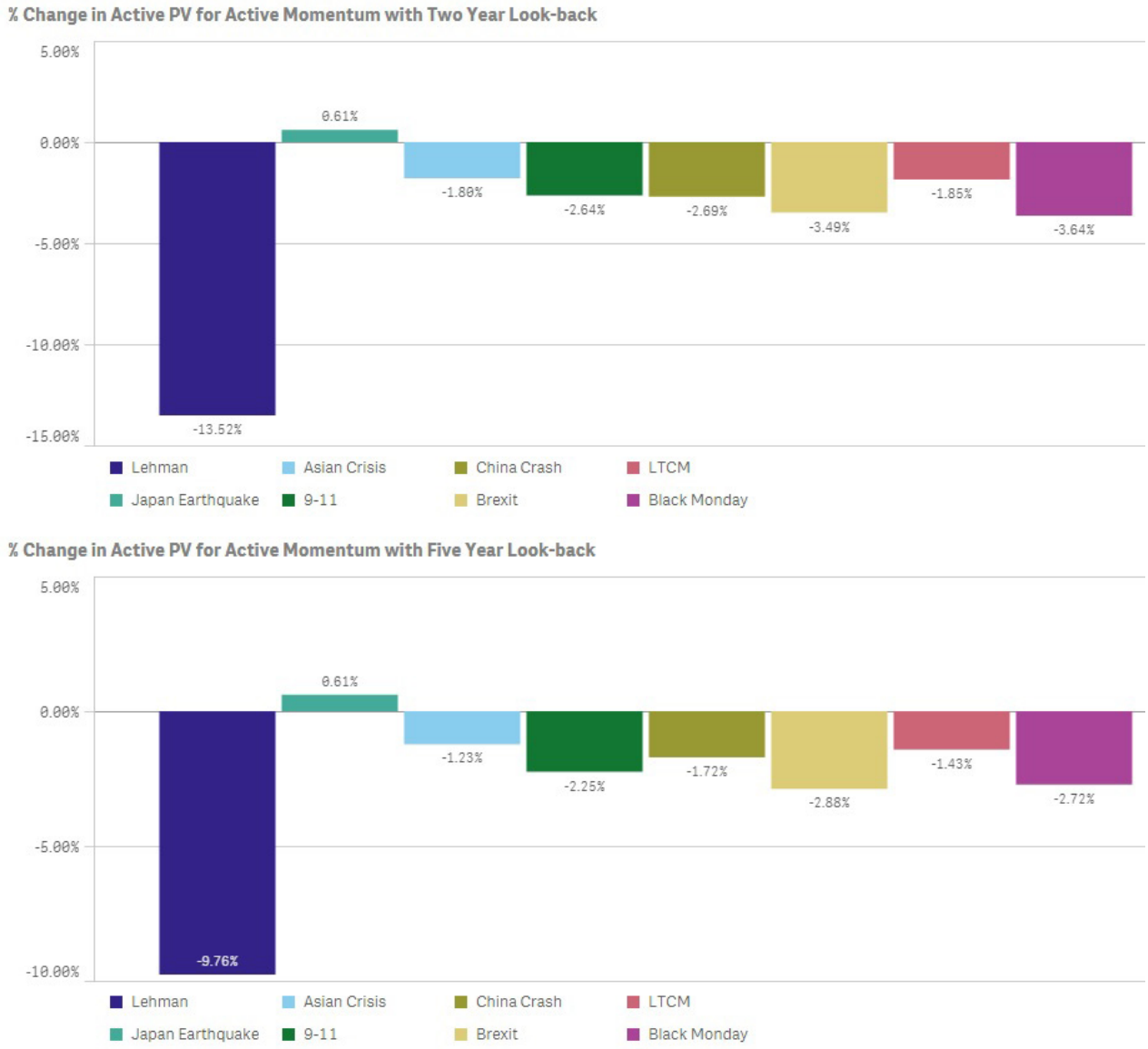
we find our old friend in the Energy sector, Oneok, Inc., with a 5.2% overweight contributing a whopping -3.5% loss by itself, more than the next six overweight positions combined. That level of loss contribution should require a special kind of conviction by the manager.

Among the Financials, the reasons for the underperformance are equally concentrated as in the Energy sector, and the top three overweight positions of Morgan Stanley, Charles Schwab, and Berkshire Hathaway contribute -1.1%, -0.7%, and -0.6%, respectively, to the active loss. On the other side of the ledger, the underweights in Goldman Sachs, State Street, Blackrock, BNY Mellon, and Capital One all contributed positively in this scenario. Given this analysis, and an expectation of — or a desire to protect the portfolio against — another Lehman-like event, the manager now has information about which stocks in the Financial sector to overweight in order to both maintain the desired sector allocation and simultaneously limit downside risk.

The drill-down analysis on the Black Monday and 9/11 scenarios produces identical results for those names. Armed with this quantitative information, the manager should require a higher risk-premium from his analysts on Morgan Stanley, Charles Schwab, Berkshire Hathaway, and TD Ameritrade, than on Goldman Sachs, Blackrock, State Street, or Capital One.

The only bright spot for the Active Momentum strategy was its 4.1% underweight in Japan, which allowed it to outperform marginally in the Japan Earthquake scenario; the only scenario with a positive ending for that portfolio.

Figure 15. Historical Scenarios Summary, Active Momentum Portfolio

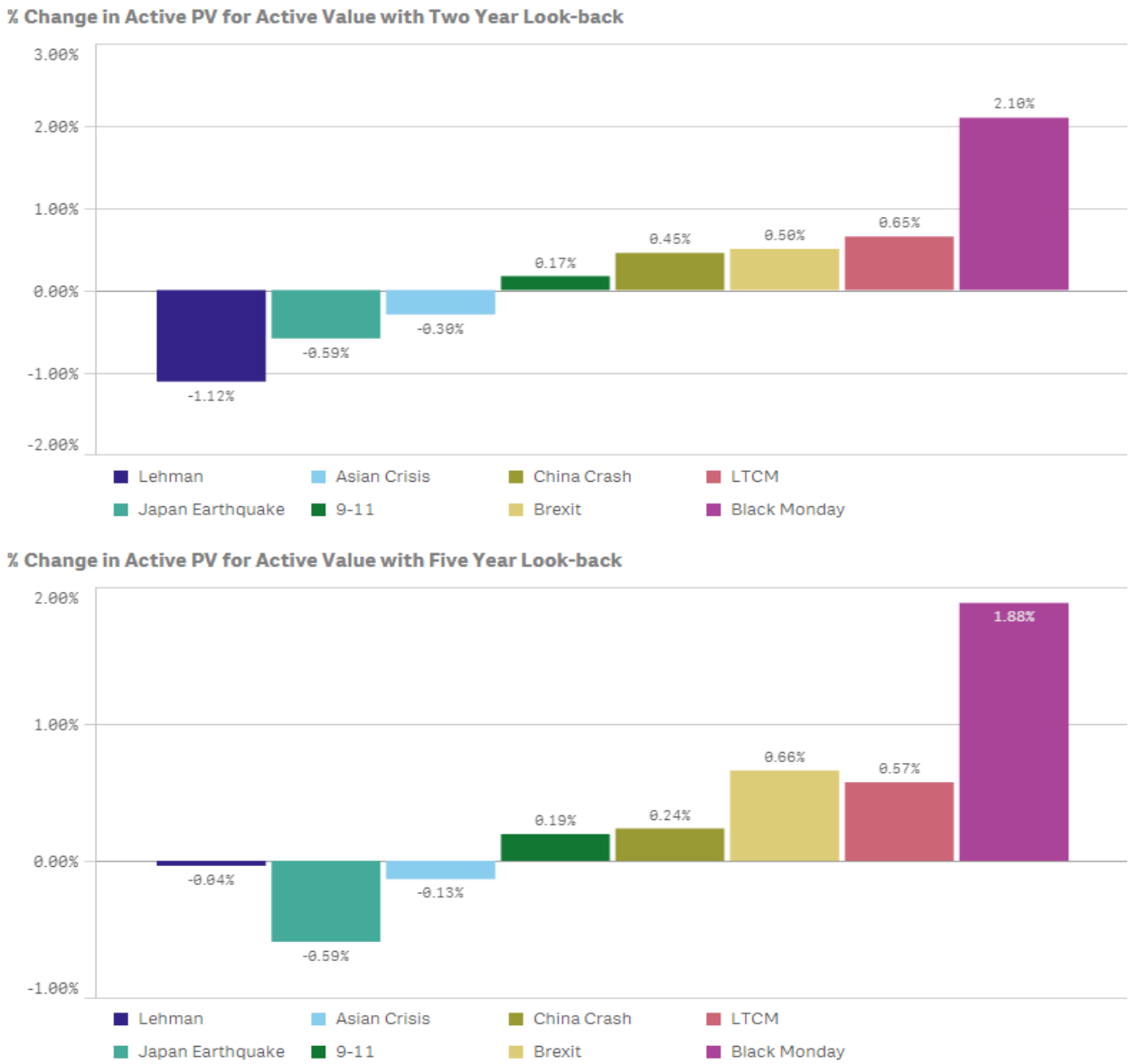


Source: FTSE Russell, Axioma Risk

As with our single-factor stress tests, the Active Value portfolio performs much better than its Active Momentum counterpart against our historical scenarios (see Figure 16). The same set of historical scenarios produced positive active returns in five out of eight results. Interestingly, the Lehman Collapse and Black Monday — both crises having their genesis in the financial sector — had opposite results for this portfolio, even more so when using the last two years to estimate correlations compared with the last five. In the two-year test, the former produced a -1.1% underperformance, while the latter produced an outperformance of 2.1%. In the five-year test, the results were -0.04% and 1.9%, respectively.

A look at the country breakdown shows that the overweight in Germany, Hong Kong, and South Korea delivered losses in both scenarios, but the underweight in the United States only delivered active gains under the Black Monday scenario. Historical scenarios involve multiple simultaneous shocks across a number of factors. Managers should investigate the factors that contributed to gains and losses in each of the scenarios to identify the differences in their nature and build a hedging plan for each in their risk management framework. Did the same countries, sectors, industries, and individual stock holdings behave the same in each of the two scenarios? At what levels did the differences exist and what drove those dislocations between the two scenarios, thought to be very similar in nature? The answers to these questions can provide the manager with valuable insights about the systemic nature of their exposures and potentially highlight any biases their stock-selection model may have toward certain types of crises.

Figure 16. Historical Scenarios Summary, Active Value Portfolio



Source: FTSE Russell, Axioma Risk

Conclusion

Active equity managers face two new competitive pressures. The first is the surge in popularity of Smart Beta products, which has squeezed the pure active space. The second is the trend towards multi-asset class solutions adopted by most liability-driven investors who are unable to get any yield in a decade-long period of near-zero interest rates. This has created an environment where alpha is harder to obtain, and the lines between asset classes are blurred.

In this tougher environment, equity managers cannot ignore information provided by other asset classes about their active bets. They must ensure consistency between their stock selection model and views on “macro” factors through a portfolio construction process that leverages multi-asset class relationships in a systematic manner. The challenge comes in translating cross-asset class correlations into actionable insights.

This paper proposed the use of a multi-asset class risk platform to build a three-dimensional process, for evaluating active decisions made in a single asset class portfolio against “macro” factors exogenous to that asset class. Only by examining these relationships across multiple time horizons, analysis levels and macro factors can managers get a complete and reliable assessment of the consistency between their portfolio and views on other asset classes. The value of this process can only be enhanced through continuous innovation in the selection of the “macro” factors, and the flexibility of the risk systems used to test them. The former helps the user avoid the trap of interpreting correlation as causation; the latter helps to overcome a reliance on the past as prologue.

Appendix 1: Description of factors used for the transitive stress tests

Factor Shock Name	Factor Used
Equity Factors	
Markets	
SPX -20%	S&P 500 Index
FTSE EU -20%	FTSE Europe 100 Index
N225 -20%	Nikkei 225 Index
FTSE EM -20%	FTSE All World Emerging Index
FX	
Euro -20%	USD/Euro FX Spot Rate
JPY +20%	USD/JPY FX Spot Rate
Volatility	
VIX +20%	CBOE Vix Index
VSTOXX +20%	VSTOXX Volatility Index
JNIV +20%	Implied Volatility Surface for Nikkei 225 (delta 0.5 30-Day)
Non-Equity Factors	
Commodities	
GSCI -20%	GSCI Index Excess return
Gold -20%	GSCI Gold Index Excess return
Oil -20%	GSCI Crude Oil Index Excess return
Interest Rates	
10Y USTB +100bps	US USD 10-Year Government Zero Coupon Spot Rate
10Y EUGB +100bps	FR EUR 10-Year Government Zero Coupon Spot Rate
10Y JGB +100bps	JP JPY 10-Year Government Zero Coupon Spot Rate
Credit Spreads	
US Spr. +20%	MarkIT: CDX-NAHYS27V1-7Y
EU Spr. +20%	MarkIT: ITRAXX-EUROPES26V1-7Y
JP Spr. +20%	MarkIT: ITRAXX-JAPANS22V1-5Y
Alternatives	
CAT Bonds -2%	Swiss RE Catastrophe Bond Price history from TR
Global REIT -20%	S&P Global REIT Index

Source: FTSE Russell, Axioma Risk

Appendix 2: Description of Historical Scenarios

Scenario Name	Description	Scenario Name	Description
Brexit	FTSE 350 Index -25%	**LTCM Crisis**	S&P 500 −12.03%
	DAX Index -24%		DAX −10.80%
	CAC 40 Index -21%		FTSE 100 −8.58%
	S&P500 Index -16%		NIKKEI 225 −4.67%
			US Govt yields 3 months −6.99%
China Crash	S&P500 Index -7.6%		US Govt yields 2 years −6.99%
	ASX 200 Index -6.7%		US Govt yields 10 years −6.99%
	nikkei225 Index -9.9%		US Swap 6 months −4.72%
	HangSeng Index -22.7%		US Swap 5 years −4.72%
	FTSE Index -11.9%		US Swap 20 years −4.72%
	Stoxx 600 -9.2%		Great Britain Govt yield 3 months −4.48%
	HangSeng China Enterprises Index -32.6%		Great Britain Govt yield 2 years −4.48%
	EUR/USD +1.2%		Great Britain Govt yield 10 years −4.48%
	GBP/USD -0.2%		Germany Govt yield 3 months −1.68%
	JPY/USD +3.4%		Germany Govt yield 2 years −1.68%
	AUD/USD -8.4%		Germany Govt yield 10 years −1.68%
	USD.Gvt.1Y +6.2bps		CAD (Canada) −1.17%
	EUR.Gvt.1Y -3.8bps		GBP (Great Britain) +2.38%
	JPY.Gvt.1Y +1.2bps		JPY (Japan) +3.18%
	USD BBB Spread Curve +39.7bps		VIX (Volatility Index) 39.25%
Asian Crisis	S&P 500 −8.23%	**Lehman Collapse**	EUR.Gvt.1Y -193.5bps
	DAX −13.82%		JPY.Gvt.1Y -12.4bps
	FTSE 100 −9.00%		GBP.Gvt.1Y -241bps
	NIKKEI 225 −5.21%		USD.Gvt.1Y -117bps
	KOSPI -12.70%		USD BBB Spread Curve +395bps
	STI -15.47%		JPY/USD +12.9%
	US Govt yields 3 months −5.90%		GBP/USD -17.3%
	US Govt yields 2 years −5.90%		EUR/USD -11.6%
	US Govt yields 10 years −5.90%		russell1000 Index -41.0%
	JPY Govt yields 3 months −5.34%		ASX 200 Index -31.6%
	JPY Govt yields 2 years −5.34%		Nikkei225 Index -36.9%
	JPY Govt yields 10 years −5.34%		FTSE Emerging Index -46.7%
	EUR Govt yield 3 months −5.34%		HangSeng Index -36.5%
	EUR Govt yield 2 years −5.34%		FTSE 100 Index -28.5%
	EUR Govt yield 10 years −5.34%		
	THB (Thailand) −1.69%	**Black Monday**	S&P 500 −27.18%
	GBP (Great Britain) +1.82%		DAX −13.20%
	JPY (Japan) -0.72%		FTSE 100 −23.34%
	VIX (Volatility Index) 59.87%		NIKKEI 225 −17.01%
			US Govt yields 3 months −8.29%
9/11	USD.Gvt.1Y -58bps		US Govt yields 2 years −8.29%
	EUR.Gvt.1Y -45bps		US Govt yields 10 years −8.29%
	S&P500 Index -11.7%		GBP (Great Britain) +0.64%
	HangSeng Index -13.8%		JPY (Japan) -0.10%
	ASX 200 Index -9.3%		
	JPY/USD +3.7%	**Japan Earthquake**	Historical movement of stock prices
	EUR/USD +1.7%		between Mar 10-15 applied

Source: FTSE Russell, Axioma Risk

Contact us to learn more about how Axioma can bring more information and insights to your investment process.

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