Stress Testing Market Report

Risk-On, Risk-Off, Risk Up

Risk Settings to Highlight Periods of Heightened Volatility and Correlation

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Introduction

The risk-on, risk-off (RORO) behavior of markets relates to the fluctuating appetite of investors for risky assets. There are periods with optimism in the markets and higher willingness to take risk – this is risk-on. Then after a change in risk perception, risk-aversion increases, and there is a flight-to-safety; risky assets decline in price and investors buy safe-haven investments – this is risk-off.

Taken together, these two effects produce a binary picture of markets, with investors either in flight away from risky assets to safe ones, or the opposite. When this RORO behavior is prevalent, there is little discrimination within risky or safe assets, just the flow from one broad category to the other. As a result, market volatilities, and especially correlations, increase relative to so-called normal markets.

It is interesting to look back historically and attempt to identify periods where the RORO effect was strong. More relevant for risk management is to look ahead, posing the questions of how forecasts of portfolio risk might change if RORO were to take hold, and which particular positions would be most sensitive to this effect. This bears a strong relation to the stress calibration of risk models, a practice recently reaffirmed by the Basel Committee on Banking Supervision in their *Fundamental Review of the Trading Book*.[1]

In this paper, we present a way to calculate stressed standard deviation and expected shortfall for RORO periods. We develop a case study in RiskManager where we quantify the RORO effect on risk levels for a multi-asset class portfolio. Within this case study, we demonstrate how to identify the instruments that are more sensitive to the risk-on, risk-off effect.

[1] See www.bis.org, as well as the comments and references in Finger (2012). Reviewing the FRTB: Commentary on the Basel Committee's Fundamental Review of the Trading Book. MSCI Research Insight.

Historical Risk-On, Risk-Off Periods

Stressed risk levels should be estimated based on historical RORO risk environments. Past RORO days reveal the market behavior and risk characteristics during RORO times.

Since it is not specified whether a particular day in the past was a RORO day, we use statistical techniques to identify the historical RORO days. As volatilities and correlations deviate from their normal levels during RORO, we select the days when volatilities and correlations are different from "normal."

We apply a time series model[2] that assumes there are two possible states of the market: a neutral state and a RORO state. The covariance matrices of the market factor changes are different in the two states, but their means are identical. The market switches between the two states randomly, according to a fixed set of probabilities. The switching probabilities are also estimated. Based on this model, we can assign an ex-post probability that a given day was a RORO day. We consider a day to be a RORO day if this probability is greater than fifty percent.

This approach is similar to the setup we used in a previous paper[3] to select the hectic days of the market. Both models assume two regimes with different covariance matrices. In the earlier paper, the likelihood of being in the hectic state on one day was assumed to be independent of the state of the market on the prior day. The method applied in this paper, however, embeds stickiness by fixing the probabilities of the regime *change*. Therefore, the consecutive states are linked in our current study.

In another Stress Testing Market Report paper,[4] we used the sticky version of the regime switching model to discover the behavior of the Barra factors during risk-on, risk-off periods. In the Barra analysis, a three-state model was estimated to separate neutral, risk-on, and risk-off days. The distinction of the risk-on and risk-off days was necessary in order to quantify the directional changes during risk-on and risk-off. In this paper, we are focusing on changes in *risk* and not in *valuations*. The two-state model applied here captures the common risk characteristics of risk-on and risk-off.

Based on the daily factor changes of twelve selected factors[5] between April 2003 and September 2012, we label each day as 'RORO' or 'non-RORO' with the two-state sticky model.

The RORO days are shown in Figure 1. The bars highlight the RORO days with high volatilities and high correlations and, consequently, with high market risk.

This methodology selects many days from the period of the subprime crisis (see Figure 1). This is understandable, since this was a volatile period and this is the period when the term risk-on, risk-off became widespread in the market. Figure 1 shows clearly that the risk-on, risk-off phenomenon was typical during the subprime crisis; however, RORO days were also observable before the crisis and have occurred intermittently since.

A similar analysis on the non-overlapping five-day factor changes gives the RORO days in Figure 2. Though the risk-on, risk-off periods occur mostly during the subprime crisis, the five-day results confirm

[2] We fitted a two-state Gaussian regime switching model on the factor changes with zero autocorrelation. The movement across states was specified by a first-order Markov chain. The estimation procedure is described in: James D. Hamilton (1990): Analysis of Time Series Subject to Changes in Regime. Journal of Econometrics (5), p39-70.

[3] C Finger, Z Marossy: Updated Stress Testing Features in RiskMetrics RiskManager. MSCI Product Insight, September 2011.

[4] A Costabile, Z Marossy: Risk-On, Risk-Off in a Multifactor World. MSCI Stress Testing Market Report, August 2012.

[5] The factor list with descriptions can be found in Appendix A.

that the risk-on, risk-off behavior was not limited to the days of the subprime crisis. The RORO periods here differ somewhat from those in the daily analysis. This is due to the smoothing effect caused by the weekly factor changes being the sums of the daily changes. A single risky day during the week may not have a significant effect on the weekly return; therefore, the whole week may not qualify as RORO.

Based on the identification of historical RORO days, we proceed to examine portfolio risk under this effect. In the following case study, the calculation of stressed risk for RORO periods is based on the market movement of the historical RORO days. This approach gives a risk estimate that is specific to risk-on, risk-off periods.

Figure 1: Risk-On, Risk-Off Periods for One-Day Return Horizon.

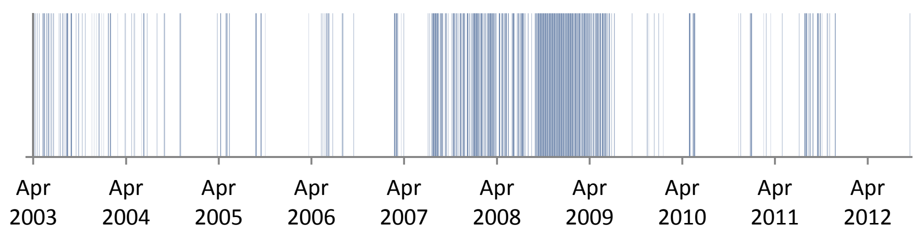
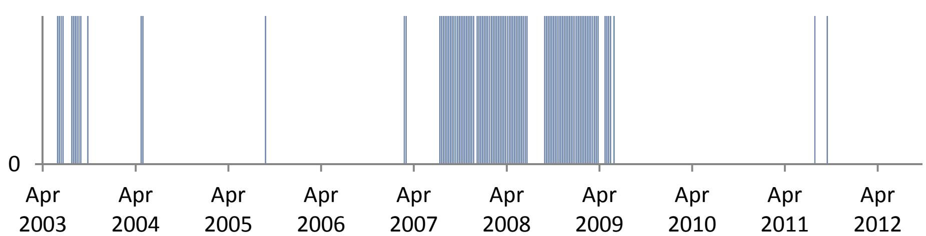


Figure 2: Risk-on, Risk-Off Periods for Five-Day Return Horizon.



Case Study with Stressed Risk Settings

We analyze the risk of a portfolio consisting of a blend of 40 percent equities modeled with the MSCI World Index, 20 percent US treasury bonds proxied with the CITI USBIG Treasury Index, 20 percent US corporate bonds represented with the CITI USBIG Corporate Index, and 20 percent emerging market bonds added as the JP Morgan EMBIG Index. All risk analyses are performed on the constituent positions of these indices.

We calculate the standard deviations and expected shortfalls of the blended portfolio and the asset class index portfolios. The risks are modeled based on the risk factors of the index constituents. The confidence level of the expected shortfall is 95 percent. The analysis date is October 1, 2012. We use historical and Monte Carlo methodologies to estimate risks.

We calculate one-day and five-day risk forecasts for three different regimes. For the first regime, we calculate the risk numbers based on factor behavior of the recent three years. The resulting risk numbers can be considered the baseline or unstressed levels of risk. The second risk setting works with factor changes on the RORO periods. In this case, the risk can be interpreted as stressed risk as the calculated risks mirror the market environment of RORO. The third risk setting is a stressed risk to reflect non-RORO periods. The Appendix shows details how the RORO and non-RORO risk settings were implemented in RiskManager.

Results

Risk Numbers Increase During Risk-On, Risk-Off Periods

The risk forecasts are summarized in Table 1 for the one-day analysis horizon and in Table 2 for the five-day analysis horizon. The risk numbers are presented for both the blended portfolio and the asset class portfolios as a percent of the present value. Risk numbers suggest the following conclusions:

1. **The RORO-based stressed risk is higher than baseline risk.**

The baseline historical standard deviation of the blended portfolio is 0.43 percent for the one-day horizon according to Table 1. The stressed value of this historical standard deviation is 0.80 percent on RORO days and 0.32 percent on non-RORO days. This indicates that the one-day standard deviation increases for the blended portfolio under the RORO risk scenario compared to baseline risk.

Based on Table 1 and Table 2, we can confirm that RORO periods have higher risk compared to the risk calculated on the recent three years since each portfolio has higher standard deviation and expected shortfall during the RORO periods for both analysis horizons and both risk methodologies.

2. **The strength of the RORO effect on portfolio risk can vary depending on the recent risk levels.**

After a long quiet non-RORO period, a jump to RORO would have significant effects on risk. Following a hectic period, the RORO effect is limited since the original risk level is high. Therefore, comparing stressed risk numbers to recent risk can provide insight about the nature of the recent periods and the magnitude of potential risk shocks on the portfolio.

For instance, the US Treasury bond portfolio has one-day RORO and non-RORO historical expected shortfalls of 0.87 percent and 0.50 percent, respectively. The baseline risk of 0.56 percent is closer to the non-RORO level of 0.50 percent. Moving to the RORO risk regime would cause a significant change in the risk of the US Treasury bond portfolio.

Independent of the applied statistic, risk methodology, portfolio, or analysis horizon, the risk numbers based on the recent three years are closer to the non-RORO risks in Table 1 and 2, so the effect of the RORO shock is strong currently.

3. **Assets have different sensitivity to the RORO stress.**

In moving from the baseline to RORO, the risk numbers increase for each asset class. The risk multiplier, however, is larger for equities, emerging market bonds, and the blended portfolio, since it is smaller for US treasury and corporate bonds. For example, the one-day historical expected shortfall increases by approximately 50 percent for the US corporate bond index portfolio from 0.74 percent to 1.13 percent. The one-day historical expected shortfall of the emerging market bond index portfolio almost doubles to reach the level of 1.65.

The analysis of stressed risk can reveal opportunities to decrease the effect of the risk-on, risk-off phenomenon on the portfolio. As the US bond portfolios are less sensitive to the RORO shock, a portfolio with higher allocation to these portfolios has less risk increase under RORO.

4. The risk of heavy tails is higher for some asset classes during RORO periods.
Though the one-day historical and Monte Carlo standard deviations are close for equities in the RORO regime (1.94 percent and 2.01 percent, respectively), the historical expected shortfall (4.79 percent) is larger than the Monte Carlo expected shortfall (4.01 percent). As the Monte Carlo methodology works with the assumption that the factor changes have Gaussian distribution, this result suggests that equity factors have heavier tails compared to Gaussian distribution during RORO. The risk of large losses on the equity portfolio is high.

We can make the same observation for the emerging market bond portfolio and the blended portfolio, at both the one- and five-day horizons.

Table 1: One-Day Risk Statistics (percent).

Portfolio	Risk Setting	Historical Standard Deviation	Monte Carlo Standard Deviation	95% Historical Expected Shortfall	95% Monte Carlo Expected Shortfall
Blended portfolio	baseline	0.43	0.42	0.95	0.87
	RORO (high risk)	0.80	0.81	1.92	1.64
	Non-RORO (low risk)	0.32	0.31	0.66	0.66
MSCI World Index	baseline	1.09	1.06	2.58	2.19
	RORO (high risk)	1.94	2.01	4.79	4.01
	Non-RORO (low risk)	0.72	0.70	1.57	1.47
CITI - USBIG Treasury Index	baseline	0.27	0.26	0.56	0.53
	RORO (high risk)	0.43	0.44	0.87	0.87
	Non-RORO (low risk)	0.24	0.24	0.50	0.49
CITI - USBIG Corporate Index	baseline	0.32	0.31	0.74	0.68
	RORO (high risk)	0.53	0.52	1.13	1.11
	Non-RORO (low risk)	0.30	0.30	0.66	0.63
JP Morgan EMBIG Index	baseline	0.36	0.36	0.84	0.74
	RORO (high risk)	0.66	0.65	1.65	1.35
	Non-RORO (low risk)	0.33	0.34	0.71	0.71

Table 2: Five-Day Risk Statistics (percent).

Portfolio	Risk Setting	Historical Standard Deviation	Monte Carlo Standard Deviation	95% Historical Expected Shortfall	95% Monte Carlo Expected Shortfall
Blended portfolio	baseline	1.06	1.06	2.36	2.06
	RORO (high risk)	2.03	1.98	4.81	3.82
	Non-RORO (low risk)	0.81	0.81	1.65	1.58
MSCI World Index	baseline	2.70	2.73	5.83	5.30
	RORO (high risk)	4.43	4.35	10.79	8.21
	Non-RORO (low risk)	1.89	1.91	3.99	3.66
CITI - USBIG Treasury Index	baseline	0.57	0.56	1.25	1.18
	RORO (high risk)	0.85	0.84	1.65	1.70
	Non-RORO (low risk)	0.53	0.54	1.15	1.13
CITI - USBIG Corporate Index	baseline	0.63	0.62	1.45	1.33
	RORO (high risk)	0.95	0.94	2.17	1.91
	Non-RORO (low risk)	0.63	0.65	1.37	1.33
JP Morgan EMBIG Index	baseline	0.83	0.82	1.87	1.72
	RORO (high risk)	1.72	1.68	5.27	3.49
	Non-RORO (low risk)	0.79	0.78	1.68	1.60

The Diversification Effect is Weaker During Risk-On, Risk-Off Periods

The diversification benefit is an indicator of the decrease in risk due to diversification. For the analysis here, we define undiversified risk as the sum of the constituent-level risks. We then define the diversification benefit as the difference between the undiversified and actual portfolio risk, normalized by the undiversified risk.

Besides the constituent-level diversification effect within each asset class index portfolio, we also examine the cross-asset class diversification within the blended portfolio. In this case, the diversification benefit is the difference between the sum of the asset class risks and the actual blended portfolio risk, again normalized by the undiversified risk.

The results are listed in Table 3 and 4. The main findings are the following:

1. **The impact of RORO on the diversification benefit is asset-specific.**

As we move from the baseline to the RORO setting, the diversification effect decreases for equities, emerging market bonds and the blended portfolio. For example, the relative diversification benefit decreases the one-day historical standard deviation of the blended portfolio by 31.5 percent under the baseline risk environment. The same diversification benefit is 27.6 percent under the RORO regime. The decrease in the diversification benefit can be attributed to the increased correlations among the constituents of the equity and the emerging market portfolios and across the asset classes.

The diversification effect becomes stronger for the US treasury portfolio during RORO. The diversification benefit for the one-day historical standard deviation increases from the baseline 8.8 percent to 10.3 percent. A detailed drilldown of risk shows that long-term bonds are less sensitive to the

RORO phenomenon, and the risk change is low in reaction to the RORO stress. As a result, long-term treasury bonds act as diversifying assets in the era of increased risk, so the diversification effect increases.

2. **Diversification benefit analysis gives information about the tweaks in recent correlations.** The baseline diversification within the equity portfolio (34.8 percent for the one-day historical expected shortfall) is very close to the RORO diversification (33.9 percent for the same risk measure). For this portfolio, therefore, correlations based on the last three years are close to the stressed correlation levels. On the other hand, recent cross-asset class correlations are closer to the non-RORO levels since the diversification effect based on the last three years are comparable to the non-RORO diversification level. See, for example, the one-day historical expected shortfall of the blended portfolio where the diversification benefit is 34.7 percent now, 33.7 percent under non-RORO and 27.4 percent under RORO.

Table 3: Relative Diversification Benefit for the One-Day Analysis Horizon (percent).

Portfolio	Risk Setting	Historical Standard Deviation	Monte Carlo Standard Deviation	95% Historical Expected Shortfall	95% Monte Carlo Expected Shortfall
Across asset classes	Baseline	31.5	31.7	34.7	31.6
	RORO (high risk)	27.6	27.8	27.4	27.9
	Non-RORO (low risk)	31.1	31.8	33.7	30.9
MSCI World Index	baseline	39.2	40.0	34.8	39.7
	RORO (high risk)	39.5	38.2	33.9	37.4
	Non-RORO (low risk)	55.0	55.9	53.9	54.3
CITI - USBIG Treasury Index	baseline	8.8	8.9	8.6	8.7
	RORO (high risk)	10.3	10.3	14.2	10.8
	Non-RORO (low risk)	7.9	8.1	9.7	8.5
CITI - USBIG Corporate Index	baseline	37.4	38.2	39.1	36.0
	RORO (high risk)	35.4	36.1	43.0	35.2
	Non-RORO (low risk)	39.4	38.4	45.9	39.1
JP Morgan EMBIG Index	baseline	40.0	40.1	40.1	40.5
	RORO (high risk)	30.5	31.7	31.8	31.6
	Non-RORO (low risk)	40.0	39.3	44.0	38.9

Table 4: Relative Diversification Benefit for the Five-Day Analysis Horizon (percent).

Portfolio	Risk Setting	Historical Standard Deviation	Monte Carlo Standard Deviation	95% Historical Expected Shortfall	95% Monte Carlo Expected Shortfall
Across asset classes	baseline	28.6	28.9	27.3	30.7
	RORO (high risk)	18.1	18.7	21.6	18.8
	Non-RORO (low risk)	29.0	29.9	32.2	30.7
MSCI World Index	baseline	32.1	31.7	32.9	31.7
	RORO (high risk)	33.2	34.0	30.2	33.4
	Non-RORO (low risk)	47.6	46.8	45.1	47.3
CITI - USBIG Treasury Index	baseline	8.3	8.2	10.6	5.8
	RORO (high risk)	9.6	9.9	11.9	10.1
	Non-RORO (low risk)	7.1	6.9	8.8	6.0
CITI - USBIG Corporate Index	baseline	36.0	35.8	37.8	34.8
	RORO (high risk)	39.5	39.1	43.6	41.3
	Non-RORO (low risk)	34.5	33.3	40.1	34.9
JP Morgan EMBIG Index	baseline	34.5	34.4	38.0	34.1
	RORO (high risk)	23.0	23.7	19.2	23.6
	Non-RORO (low risk)	34.0	35.1	37.5	34.7

Conclusion

In this paper, we introduced a framework to quantify the effect of risk-on, risk-off behavior on portfolio risk. We identified the historical risk-on, risk-off periods. In a case study, we calculated the stressed risk measures based on these risk-on, risk-off periods for different asset classes and a multi-asset class portfolio. We compared the results to the current risk levels that were calculated based on data from the recent three years.

We found that risk would increase for each asset class if risk-on, risk-off behavior were to appear in the market. We observed that the equity and the emerging market bond portfolios are more sensitive to this kind of shock, since the magnitude of the risk increase was higher and the risk of the tail events is more significant for these portfolios. Additionally, the diversification effect decreased during risk-on, risk-off in the case of the equity and the emerging market bond portfolios. Long-term US treasury bonds are less sensitive to a risk-on, risk-off stress and could serve as diversifying assets within the US Treasury bond portfolio.

Appendix A

List of Factors to Identify Risk Regimes

Table A.1 provides details about the factors that were used to identify risk-on, risk-off periods. To calculate the factor changes, we used absolute changes (change in the factor level) or relative changes (changes in the log factor level). Table A.1. shows the change type for each factor.

Table A.1: Factors Used To Identify Risk-On, Risk-Off Periods.

Factors	Description	Change type
CDX NAIG S18	Five-year North American Investment Grade - Series 18 CDS Index Spread Level. For the current on-the-run series, this is equal to the top level spread, but for historical correlation and volatility calculations, we construct a theoretical top-level spread from the 125 index constituents, and add the historical observed index – constituent basis. This is done to extend a reasonable history before March 20, 2012, when Series 18 first started trading.	Relative
CDX NAHY S18	Five-year North American High Yield - Series 18 CDS Index Spread Level. For the current on-the-run series, this is equal to the top level spread, but for historical correlation and volatility calculations, we construct a theoretical top level spread from the 100 index constituents, and add the historical observed index – constituent basis. This is done to extend a reasonable history before May 15, 2012, when Series 18 first started trading.	Relative
EUR.USD	Euro/USD Foreign Exchange Rate.	Relative
Eurodollar Three-Month Volatility	Implied volatility time series of three months at-the-money options on Eurodollar interest rate futures.	Relative
Europe Two-year Government Bond	Euro Two-Year Zero Rate, constructed by MSCI from on-the-run German Treasury bonds.	Absolute
MSCI Emerging Market Index	Time series of MSCI Emerging Market Equity Index using end-of-day closing prices.	Relative
MSCI USA Index	Time series of MSCI USA equity index using end-of-day closing prices.	Relative
US Ten-year Government Bond	US Government 10-Year Zero Rate, constructed by MSCI from on-the-run US Treasury bonds.	Absolute
US Three-month LIBOR	Three-month USD Swap zero rate constructed by MSCI from Eurodollar futures market data.	Absolute
US Two-year Government Bond	US Government Two-Year Zero Rate, constructed by MSCI from on-the-run US Treasury bonds.	Absolute
VIX	Time series of the CBOE Market Volatility Index using end-of-day closing prices.	Relative
WTI One-Month Crude Oil	One-Month CME light sweet crude oil time series. One-Month tenor constructed as a Constant Maturity Future time series by interpolating the first two near-term CL futures contracts.	Relative

Appendix B

Implementing the RORO and Non-RORO Risk Settings in RiskManager

To calculate risk numbers based on the RORO days in RiskManager, users should apply a risk setting that specifies the RORO days that are then used for the calculations. We applied the multiple date ranges functionality of RiskManager where the RORO periods can be added as non-consecutive date ranges. For the one-day analysis horizon, each RORO day was included separately as the End Date of the date range. For the five-day analysis horizon, we inserted the last day of the five-day period as an End Date of the date range. The decay factor was set to one (1).

Non-RORO risk settings were created similarly.

The RORO and non-RORO risk settings are available in RiskManager 4. Table B.1 maps the names used in RiskManager to the risk settings defined in this paper.

Table B.1: RORO Risk Settings in RiskManager.

Risk Setting	Analysis Horizon	RiskManager Name
RORO (high risk)	1D	Risk-On, Risk-Off (high risk) 1D
non-RORO (low risk)	1D	Risk-On, Risk-Off (low risk) 1D
RORO (high risk)	5D	Risk-On, Risk-Off (high risk) 5D
non-RORO (low risk)	5D	Risk-On, Risk-Off (low risk) 5D

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"Stress Testing in RiskManager: Contemplating a Eurozone Breakup," February 2012.
http://www.msci.com/resources/research_papers/product_insight_-_stress-
testing_in_riskmanager_contemplating_a_eurozone_breakup_-_february_2012.html

"Hedging the Risk of $200 per Barrel," March 2012.
http://www.msci.com/resources/research_papers/multi-
asset_class_market_report_hedging_the_risk_of_200_per_barrel.html

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http://www.msci.com/resources/research_papers/multi-asset_class_market_report_-_stress-
testing_in_barraone_contemplating_a_eurozone_breakup_-_apri.html

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[1] *As of June 30, 2011, based on eVestment, Lipper and Bloomberg data.*