

Risk Model Testing, or Horses for Courses

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Custom Risk Models : Advantages and . . .

- Deliberately constructed to reflect a fund manager's investment process, which, in turn, reflects the way the manager thinks about the opportunity set
 - Custom Style factor definitions
 - Custom Industry Classifications
 - Custom Regional and Country factors
 - Custom treatment of Currency Risk
 - Custom parameters, periodicity, horizon, time-weighting, etc.
- A Custom Risk Model enables a manager to explicitly identify and quantify the deliberate bets in the portfolio, and to check whether there are any significant unintended bets that need to be minimised or hedged

Custom Risk Models : . . . Disadvantages

- Only really feasible for firms that have a well-defined investment process (typically Quant managers)
- Not very suitable for fundamental managers who rely more on qualitative judgement than quantitative analysis
- Analogous to Optimisation
 - Easy if you have Expected Returns for each stock
 - Bit more tricky if you just have views on the relative attractiveness of different stocks
- And, of course, Custom models cost more than Standard models

Standard Risk Models - Three Types

- Most investment firms use a Standard risk model
- Three basic types of multi-factor risk models :
 - Statistical (using principal component analysis)
 - Cross-sectional (usually with dummy variables)
 - Time Series (estimating stock betas against factor returns)
- Northfield pioneered the idea of Hybrid risk models, which capture the main advantages of each method
 - Statistical (ensures no systematic risk left in residuals)
 - Cross-sectional (necessary when stock betas change quickly)
 - Time Series (to distinguish between weight & exposure)

Standard Risk Models - Factor Variation

- Even within each type of defined standard risk model, there can be a lot of variation in the factors used
- Many standard risk models include Market factors
- Most also include either Industry or Sector factors
- These factors usually account for most stock risk
- Some models have Style factors, like Value or Growth
- International risk models usually (but not always!) have Currency factors to quantify Currency risk
- Models based on the Arbitrage Pricing Theory model developed by Chen, Roll & Ross use Macro-Economic factors

Horses for Courses

- All models work better for some stocks than for others
- Stock R-Squareds will vary considerably (e.g. XRD US)
 - Average 36% for top 3,000 by MktCap (max = 84% min = 0%)
 - Average 40% for top 1,000, and 42% for top 500 largest stocks
 - Average 20% overall for around 9,000 stocks
- Models in which the Market and Industry factors are market-capitalisation–weighted tend to work best on cap-weighted portfolios of large stocks
- We have built risk models which have different sets of Industry factors for Large Cap and Small Cap stocks

“Like, and Yet Unlike”

(Gimli, on Wizards)

- Most risk models are designed either with the needs of a particular set of fund managers in mind, or for looking at portfolio risk characteristics in a particular way
- During normal market conditions, most sensible risk models give reasonable estimates of portfolio risk or tracking error, a portfolio's beta to its benchmark and its split between factor risk and stock specific risk
- The main differences between them will lie in the factor decomposition they provide for risk managers
- However, in turbulent market conditions such as the Global Financial Crisis, they usually perform less well

How Not To Test Risk Models

- Portfolio managers using risk models sometimes complain that their *ex post* portfolio risk is different (usually higher) from the risk model's *ex ante* forecast
- However, this is comparing apples and oranges
- The *ex ante* forecast is based on a fixed set of weights
- The *ex post* result reflects varying weights over time
- In order to do an accurate test, we need to hold the portfolio weights constant over the testing period

How to Test Risk Models - 1

- First we construct a large set of test portfolios, and in each case, we select a portfolio and a benchmark
- We ran four kinds of test over 10 years, beginning in Dec 2004 and running to June 2015, on portfolios with fixed weights
- **The Risk Model Validation test :**
 - How well does the model forecast the **portfolio risk**, the **benchmark risk** and the **tracking error**?
- **The Portfolio beta to Benchmark test :**
 - How well does the risk model forecast the **beta** of the portfolio to the benchmark?

How to Test Risk Models - 2

- **The Bias Ratio test :**

- This first creates standardised returns by dividing the return over each period by the risk forecast at the start of the period
- If the risk model is unbiased the cumulative mean of the standardised returns should asymptotically tend to 0, and the standard deviation of the standardised returns should asymptotically tend to 1
- We set a 95% confidence interval and determine whether the results to each point in time are biased up, biased down, or unbiased
- We can then determine what percentage of the time the risk model is biased up, biased down, or unbiased

- **The Cross-Sectional Distribution test :**

- How well each model distinguishes between high and low risk portfolios

The Risk Models to be Tested

- We looked at three different US risk models
 - The Northfield US Fundamental risk model
 - The Northfield US Macro-Economic hybrid risk model (APT-based)
 - The Northfield US XRD hybrid risk model
- The first two are based on 60 calendar month returns (a 5 year look-back)
- The XRD (Cross Reference Day) model averages the values of four SRD (Single Reference Day) risk models, each based on a set of 80 4-weekly returns (just over 6 years), and staggered one week apart

Test Portfolios and Benchmarks

- One constraint is that stocks must have complete return histories to be used in the portfolios or benchmarks over the whole period
- Screening for stocks common to all three risk models with continuous return histories from December 2004 gave us a universe of around 2,500 stocks
- We generated random sets of 100 stocks to form sets of 50 equal-weighted and 50 Sqrt(mktcap)-weighted portfolios
- We created a capitalisation-weighted market benchmark from the 326 stocks in the S&P500 that existed from Dec 2004 to June 2015

Risk Model Testing Results

- The next nine slides give examples of the results in one particular case, the EquWtd1 portfolio against the Market Proxy benchmark
- We show the Risk Model Validation test, the Beta to Benchmark test and the Bias Ratio test for the Fundamental risk model, the Macro-Economic risk model and the XRD risk model
- The next three slides show the ability of each risk model to discriminate cross-sectionally between high risk and low risk portfolios, and between high and low tracking errors

Example : Risk Model Validation Test

| EqualWt1 | Portfolio | | |
|--------------------------|------------|-----|-----------|
| MktProxy | Benchmark | | |
| Fundamental | Risk Model | | |
| Valid for Portfolio Risk | Rejected | 54% | Validated |
| Valid for Benchmark Risk | Rejected | 43% | Validated |
| Valid for Relative Risk | Rejected | 91% | Validated |

Example : Risk Model Validation Test

| | | | |
|--------------------------|------------|-----|-----------|
| EqualWt1 | Portfolio | | |
| MktProxy | Benchmark | | |
| Macro Economic | Risk Model | | |
| Valid for Portfolio Risk | Rejected | 66% | Validated |
| Valid for Benchmark Risk | Rejected | 66% | Validated |
| Valid for Relative Risk | Rejected | 85% | Validated |

Example : Risk Model Validation Test

| | | | |
|--------------------------|------------|-----|-----------|
| EqualWt1 | Portfolio | | |
| MktProxy | Benchmark | | |
| XRD US v2.19.9 | Risk Model | | |
| Valid for Portfolio Risk | Rejected | 69% | Validated |
| Valid for Benchmark Risk | Rejected | 43% | Validated |
| Valid for Relative Risk | Rejected | 90% | Validated |

Example : Beta of Portfolio to Benchmark Test

| EqualWt1 | Portfolio | | |
|-----------------------------|------------|--------|---------|
| MktProxy | Benchmark | | |
| Fundamental | Risk Model | | |
| | Minimum | Mean | Maximum |
| Ex Ante Beta to Benchmark | 0.759 | 1.063 | 1.179 |
| Ex Post Beta to Benchmark | 0.523 | 1.123 | 1.782 |
| S. E. of Ex Post Beta (12m) | 0.081 | 0.198 | 0.427 |
| Ex Ante Beta - Ex Post Beta | -0.802 | -0.055 | 0.597 |

Example : Beta of Portfolio to Benchmark Test

| | | | |
|-----------------------------|------------|--------|---------|
| EqualWt1 | Portfolio | | |
| MktProxy | Benchmark | | |
| Macro Economic | Risk Model | | |
| | Minimum | Mean | Maximum |
| Ex Ante Beta to Benchmark | 0.454 | 0.996 | 1.257 |
| Ex Post Beta to Benchmark | 0.523 | 1.123 | 1.782 |
| S. E. of Ex Post Beta (12m) | 0.081 | 0.198 | 0.427 |
| Ex Ante Beta - Ex Post Beta | -1.012 | -0.125 | 0.310 |

Example : Beta of Portfolio to Benchmark Test

| | | | |
|-----------------------------|------------|-------|---------|
| EqualWt1 | Portfolio | | |
| MktProxy | Benchmark | | |
| XRD US v2.19.9 | Risk Model | | |
| | Minimum | Mean | Maximum |
| Ex Ante Beta to Benchmark | 1.036 | 1.168 | 1.315 |
| Ex Post Beta to Benchmark | 0.496 | 1.152 | 1.509 |
| S. E. of Ex Post Beta (12m) | 0.060 | 0.186 | 0.384 |
| Ex Ante Beta - Ex Post Beta | -0.354 | 0.025 | 0.775 |

Example : Bias Ratio Test

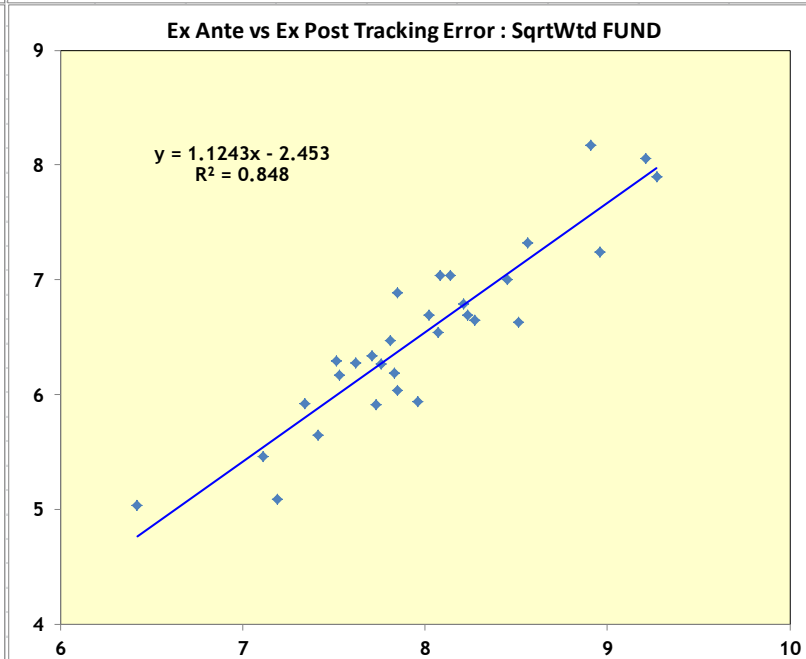
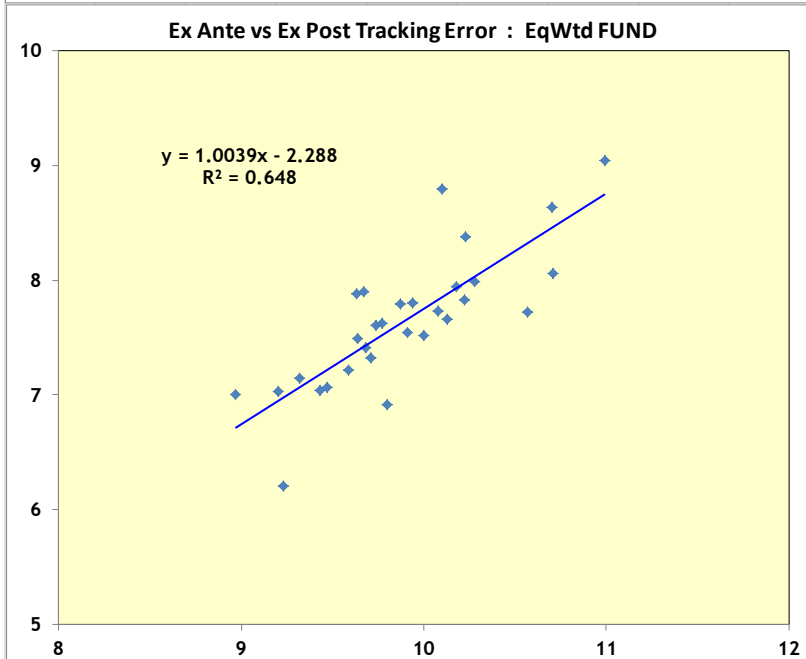
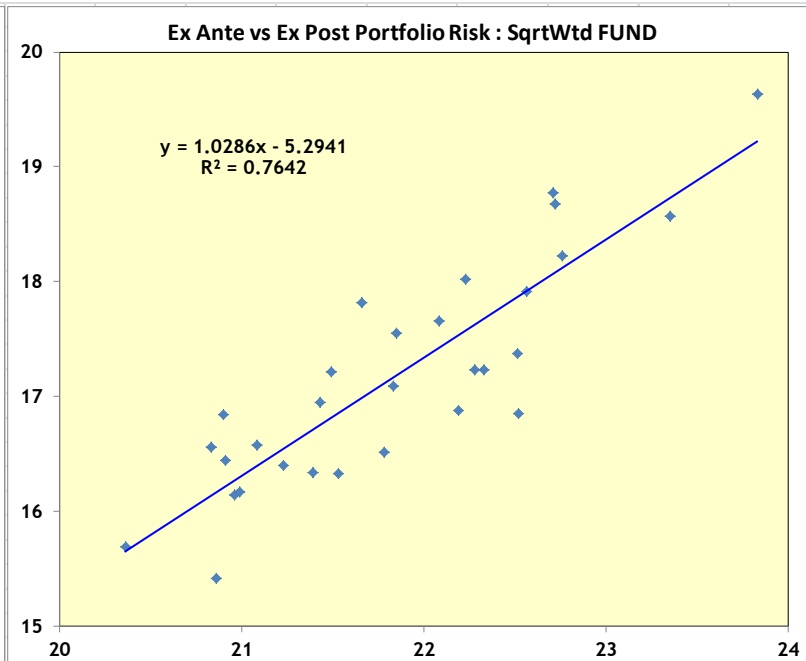
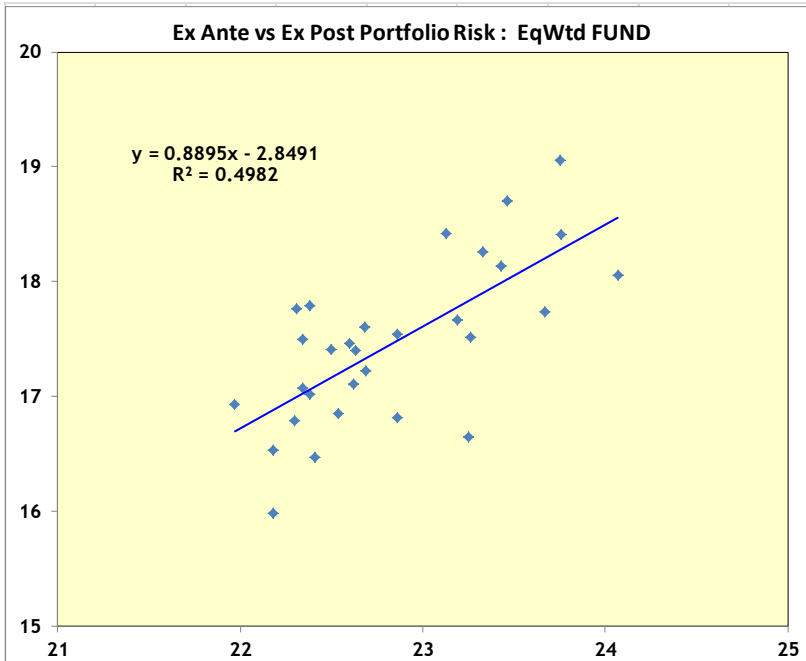
| | | | |
|----------------------------------|--------------------|----------------|------------------|
| EqualWt1 | Portfolio | | |
| MktProxy | Benchmark | | |
| Fundamental | Risk Model | | |
| Bias Ratio Test Results | biased down | no bias | biased up |
| Portfolio bias ratio test | 0% | 79% | 21% |
| Benchmark bias ratio test | 37% | 63% | 0% |
| Relative bias ratio test | 46% | 54% | 0% |

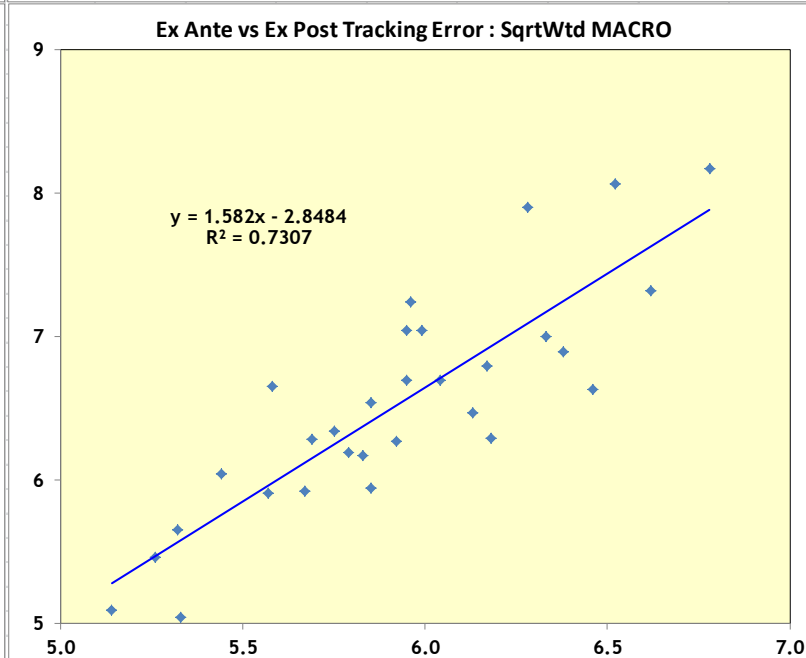
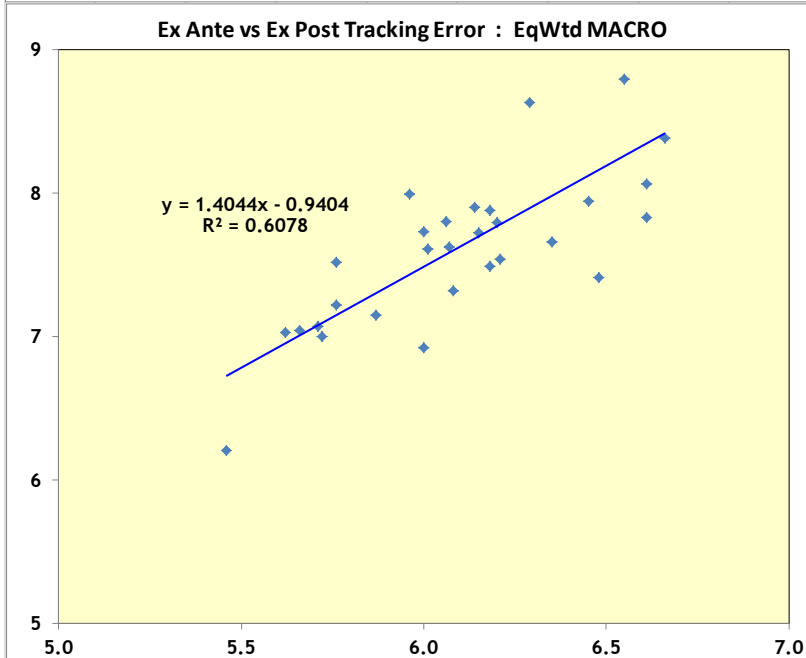
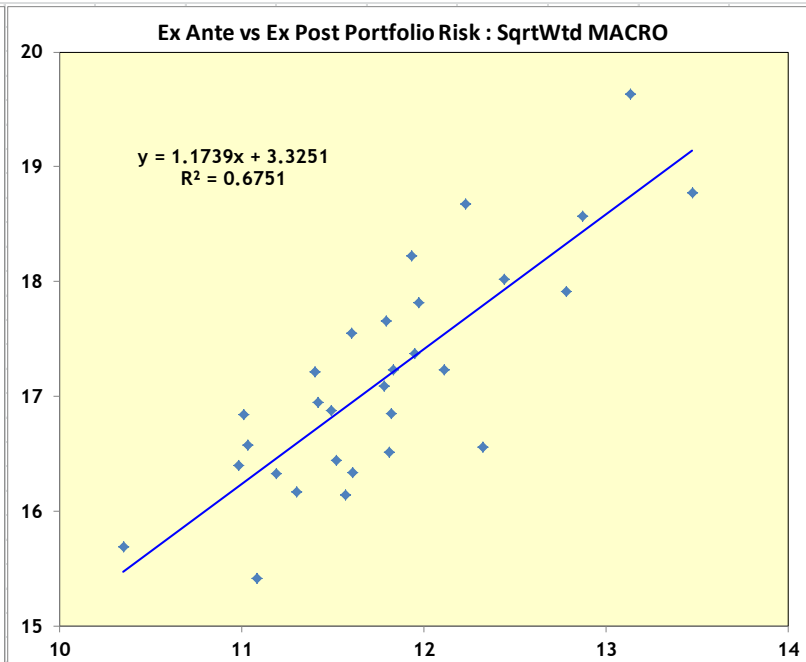
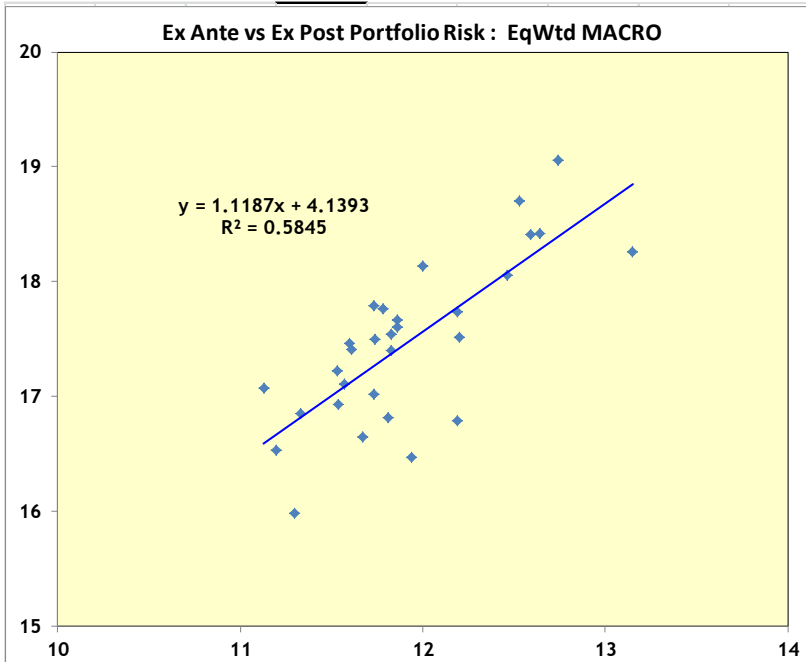
Example : Bias Ratio Test

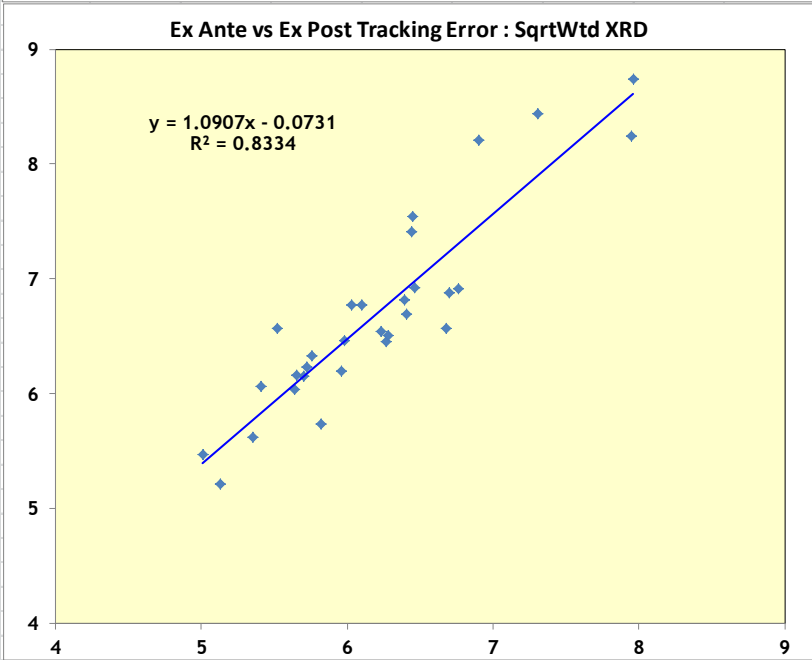
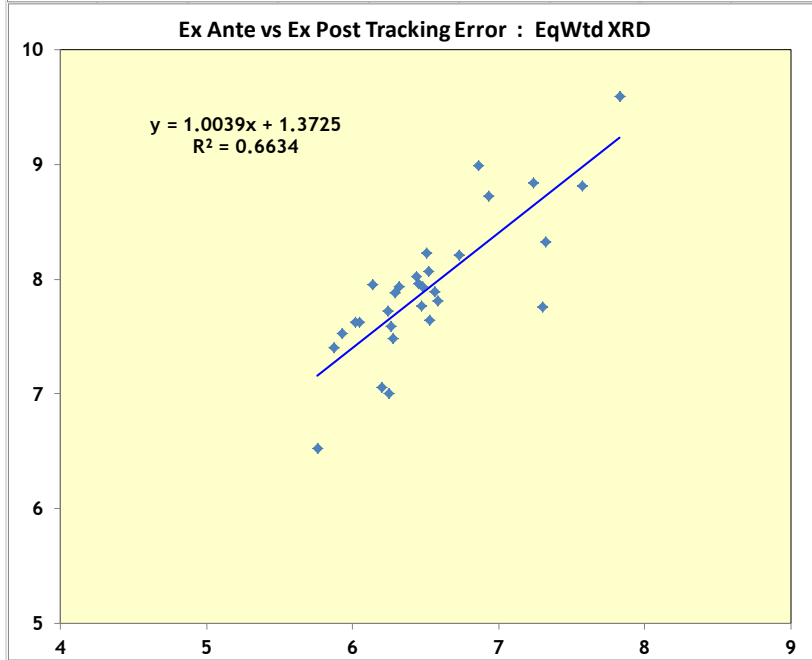
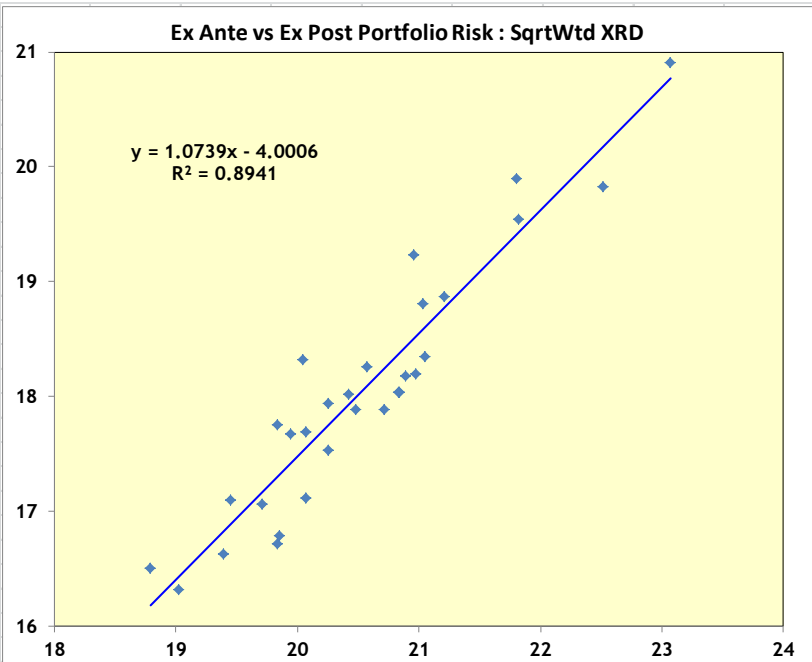
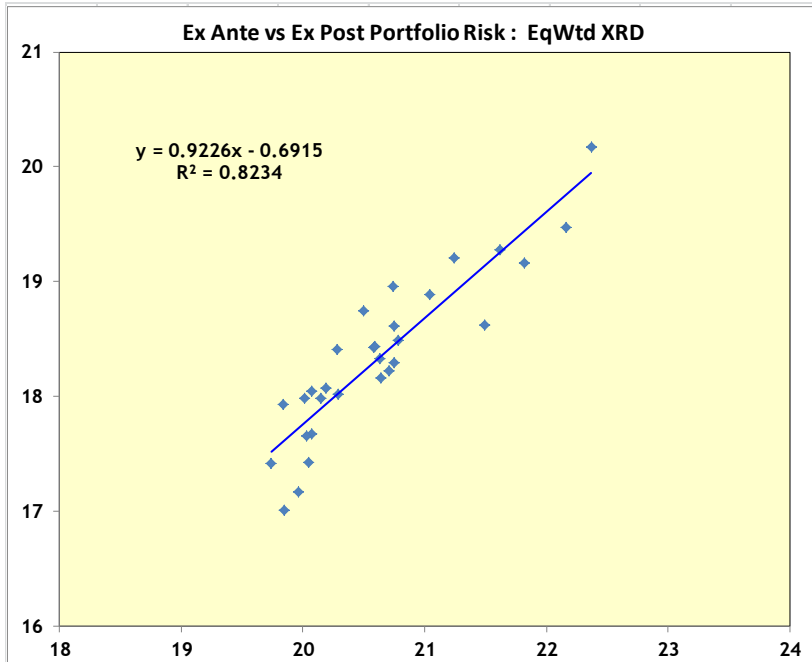
| | | | |
|----------------------------------|--------------------|----------------|------------------|
| EqualWt1 | Portfolio | | |
| MktProxy | Benchmark | | |
| Macro Economic | Risk Model | | |
| Bias Ratio Test Results | biased down | no bias | biased up |
| Portfolio bias ratio test | 97% | 3% | 0% |
| Benchmark bias ratio test | 0% | 4% | 96% |
| Relative bias ratio test | 0% | 22% | 78% |

Example : Bias Ratio Test

| | | | |
|----------------------------------|--------------------|----------------|------------------|
| EqualWt1 | Portfolio | | |
| MktProxy | Benchmark | | |
| XRD US v2.19.9 | Risk Model | | |
| Bias Ratio Test Results | biased down | no bias | biased up |
| Portfolio bias ratio test | 40% | 52% | 8% |
| Benchmark bias ratio test | 11% | 69% | 19% |
| Relative bias ratio test | 0% | 29% | 71% |







Overall Summary Results - 1

| Ex Post values calculated over 1 year | AVERAGES | | AVERAGES | | AVERAGES | | AVERAGES | | AVERAGES | |
|--|----------|----------|----------|---------|----------|---------|------------|------------|----------|---------|
| | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd |
| | XRD | XRD | FUND | FUND | MACRO | MACRO | MACRO F&NR | MACRO F&NR | | |
| RETURNS | 4-weekly | 4-weekly | Monthly | Monthly | Monthly | Monthly | Monthly | Monthly | Monthly | Monthly |
| Portfolio Returns | 0.83 | 0.69 | 0.94 | 0.85 | 0.94 | 0.85 | 0.68 | 0.77 | | |
| Relative Returns | 0.34 | 0.19 | 0.24 | 0.16 | 0.24 | 0.16 | -0.01 | 0.08 | | |
| PORTFOLIO BETA to BENCHMARK | | | | | | | | | | |
| Ex Ante Forecast Beta to Benchmark | 1.119 | 1.116 | 1.012 | 1.000 | 0.973 | 0.948 | 0.864 | 0.829 | | |
| Ex Post Beta to Benchmark | 1.098 | 1.132 | 1.102 | 1.116 | 1.102 | 1.116 | 1.072 | 1.045 | | |
| Standard Error of Ex Post Beta | 0.184 | 0.146 | 0.193 | 0.158 | 0.193 | 0.158 | 0.206 | 0.226 | | |
| Correlation of Ex Ante to Ex Post Beta | 0.711 | 0.872 | 0.418 | 0.677 | 0.346 | 0.630 | 0.824 | 0.851 | | |
| Ex Ante Beta - Ex Post Beta | 0.024 | -0.014 | -0.089 | -0.115 | -0.129 | -0.175 | -0.219 | -0.219 | | |
| BIAS RATIO TEST | | | | | | | | | | |
| Portfolio Risk (biased down) | 35% | 36% | | 1% | 99% | 98% | 83% | 97% | | |
| Portfolio Risk (no bias) | 61% | 60% | 83% | 83% | 1% | 2% | 17% | 3% | | |
| Portfolio Risk (biased up) | 4% | 4% | 17% | 16% | | | | | | |
| Relative Risk (biased down) | | | 45% | 25% | | | | | | |
| Relative Risk (no bias) | 34% | 56% | 55% | 75% | 16% | 43% | 29% | 43% | | |
| Relative Risk (biased up) | 66% | 44% | | | 84% | 57% | 71% | 57% | | |

Overall Summary Results - 2

| | AVERAGES | | AVERAGES | | AVERAGES | | AVERAGES | |
|---|----------|---------|----------|---------|----------|---------|------------|------------|
| Ex Post values calculated over 1 year | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd |
| | XRD | XRD | FUND | FUND | MACRO | MACRO | MACRO F&NR | MACRO F&NR |
| FORECAST RISKS | | | | | | | | |
| Ex Ante Portfolio Risk (p.a.) | 20.63 | 20.52 | 22.84 | 21.84 | 11.91 | 11.79 | 12.78 | 12.72 |
| Ex Ante Tracking Error (p.a.) | 6.53 | 6.20 | 9.89 | 7.98 | 6.11 | 5.92 | 8.11 | 8.23 |
| Ex Post Portfolio Risk | 18.34 | 18.04 | 17.46 | 17.17 | 17.46 | 17.17 | 18.67 | 18.11 |
| Ex Post Tracking Error | 7.93 | 6.69 | 7.64 | 6.52 | 7.64 | 6.52 | 9.00 | 9.10 |
| Correlation Ex Ante to Ex Post Portfolio Risk | 0.907 | 0.946 | 0.706 | 0.874 | 0.765 | 0.822 | 0.891 | 0.909 |
| Correlation Ex Ante to Ex Post Tracking Error | 0.815 | 0.913 | 0.805 | 0.921 | 0.780 | 0.855 | 0.719 | 0.712 |
| Ex Ante - Ex Post Portfolio Risk | 2.29 | 2.49 | 5.37 | 4.67 | -5.55 | -5.38 | -5.89 | -5.39 |
| Ex Ante - Ex Post Relative Risk | -1.40 | -0.49 | 2.25 | 1.46 | -1.53 | -0.60 | -0.89 | -0.87 |
| RISK MODEL VALIDATION TESTS | | | | | | | | |
| Risk Model Valid for Portfolio | 66% | 62% | 59% | 60% | 60% | 60% | 68% | 62% |
| Risk Model Valid for Relative | 83% | 84% | 83% | 81% | 74% | 82% | 73% | 75% |

Overall Summary Results - Comments 1

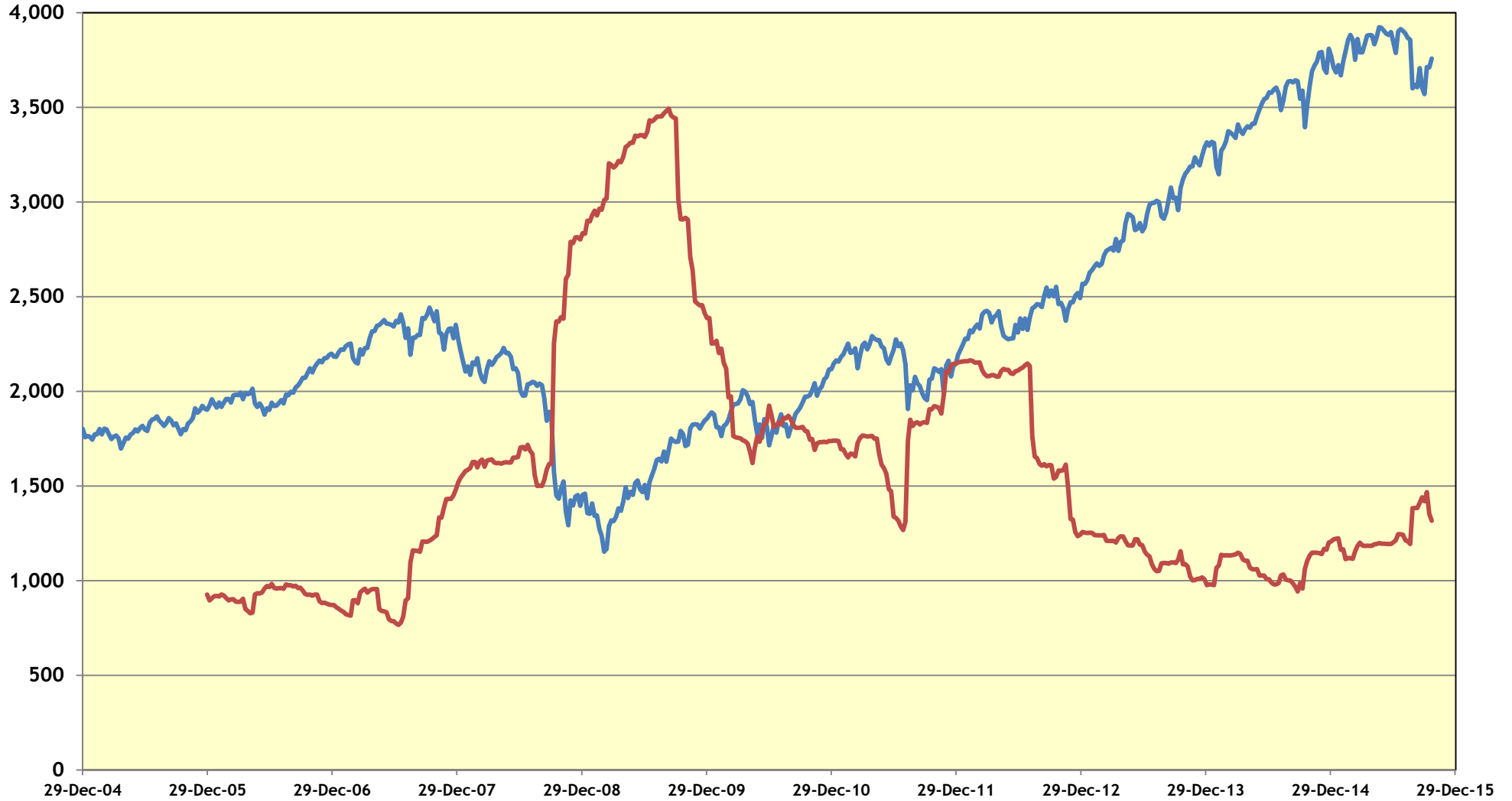
- Returns
 - Over this whole period, most portfolios had positive returns
 - A cap-weighted benchmark gave us positive relative returns
- Beta to Benchmark
 - The XRD model was closest on average
 - The MACRO model had higher correlations for Financial and Natural Resource portfolios, but bigger differences
- Bias Ratio Test
 - The FUNDAMENTAL model was best on Portfolio and Relative risk

Overall Summary Results - Comments 2

- Forecast Risks
 - The XRD model did slightly better most of the time, but the FUNDAMENTAL model was almost as good on Tracking Error
- Risk Model Validation Test
 - We have a very similar story here, with the XRD model being slightly better than the FUNDAMENTAL model, and the MACRO model being usually not quite as good

Interesting Sub-Periods - 1

— S&P 500 (TR) — Rolling StdDev



Interesting Sub-Periods - 2

- We divided the 10.5 year period into 4 Sub-Periods
 - Low Volatility Bull Market January 2005 to July 2007
 - The GFC Crash August 2007 to March 2009
 - The Recovery April 2009 to December 2012
 - The New Normal January 2013 to June 2015

- Unsurprisingly, we get different results between the sub-periods

Low Vol Bull Market - 1

| | LOW VOL BULL MARKET : 05-JAN-05 to 18-JUL-07 | | | | | |
|---|--|-----------------|------------------|------------------|-------------------|-------------------|
| Risk Model | XRD AVERAGES | XRD AVERAGES | FUND AVERAGES | FUND AVERAGES | MACRO AVERAGES | MACRO AVERAGES |
| RETURNS | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd |
| Portfolio Returns | 1.31 | 1.25 | 1.15 | 1.12 | 1.15 | 1.12 |
| Relative Returns | 0.51 | 0.45 | 0.37 | 0.34 | 0.36 | 0.34 |
| PORTFOLIO BETA to BENCHMARK | | | | | | |
| Forecast Beta to Benchmark | 1.12 | 1.08 | 0.93 | 0.93 | 0.74 | 0.63 |
| Ex Post Beta to Benchmark (1 year) | 1.14 | 1.19 | 1.23 | 1.21 | 1.23 | 1.21 |
| Standard Error of Ex Post Beta (1 year) | 0.24 | 0.19 | 0.30 | 0.24 | 0.30 | 0.24 |
| Ex Ante Beta - Ex Post Beta (1 year) | -0.02 | -0.11 | -0.30 | -0.28 | -0.49 | -0.58 |
| BIAS RATIO TEST | | | | | | |
| Portfolio Risk (biased down) | 0% | 0% | 0% | 0% | 93% | 89% |
| Portfolio Risk (no bias) | 79% | 76% | 70% | 63% | 7% | 11% |
| Portfolio Risk (biased up) | 21% | 24% | 30% | 37% | 0% | 0% |
| Relative Risk (biased down) | 0% | 0% | 4% | 1% | 0% | 0% |
| Relative Risk (no bias) | 99% | 100% | 96% | 99% | 66% | 100% |
| Relative Risk (biased up) | 1% | 0% | 0% | 0% | 34% | 0% |

Low Vol Bull Market - 2

| | LOW VOL BULL MARKET : 05-JAN-05 to 18-JUL-07 | | | | | |
|--|--|-------|-------|-------|-------|-------|
| FORECAST RISKS | | | | | | |
| Ex Ante Portfolio Risk (p.a.) | 16.22 | 15.47 | 18.01 | 16.77 | 6.81 | 6.19 |
| Ex Ante Tracking Error (p.a.) | 6.51 | 5.56 | 9.63 | 7.02 | 5.98 | 5.69 |
| Ex Post Portfolio Risk (1 year) | 13.30 | 12.95 | 11.59 | 10.72 | 11.59 | 10.72 |
| Ex Post Tracking Error (1 year) | 7.07 | 5.86 | 7.29 | 5.88 | 7.29 | 5.88 |
| Ex Ante Portfolio Risk - Ex Post Portfolio Risk (1 year) | 2.92 | 2.52 | 6.42 | 6.05 | -4.78 | -4.53 |
| Ex Ante Relative Risk - Ex Post Relative Risk (1 year) | -0.56 | -0.30 | 2.34 | 1.14 | -1.31 | -0.19 |
| RISK MODEL VALIDATION TESTS | | | | | | |
| Risk Model Valid for Portfolio (1 year) | 88% | 86% | 80% | 79% | 24% | 27% |
| Risk Model Valid for Relative (1 year) | 95% | 95% | 96% | 98% | 82% | 96% |
| | | | | | | |

GFC Crash - 1

| | GFC CRASH : 15-AUG-07 to 25-MAR-09 | | | | | |
|---|------------------------------------|----------|----------|----------|----------|----------|
| Risk Model | XRD | XRD | FUND | FUND | MACRO | MACRO |
| | AVERAGES | AVERAGES | AVERAGES | AVERAGES | AVERAGES | AVERAGES |
| RETURNS | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd |
| Portfolio Returns | -2.60 | -2.68 | -2.65 | -2.61 | -2.65 | -2.61 |
| Relative Returns | 0.05 | -0.03 | -0.01 | 0.03 | -0.01 | 0.03 |
| PORTFOLIO BETA to BENCHMARK | | | | | | |
| Forecast Beta to Benchmark | 1.17 | 1.16 | 1.03 | 1.01 | 1.07 | 0.99 |
| Ex Post Beta to Benchmark (1 year) | 1.16 | 1.15 | 1.05 | 1.07 | 1.05 | 1.07 |
| Standard Error of Ex Post Beta (1 year) | 0.12 | 0.11 | 0.13 | 0.12 | 0.13 | 0.12 |
| Ex Ante Beta - Ex Post Beta (1 year) | 0.01 | 0.01 | -0.02 | -0.06 | 0.02 | -0.09 |
| BIAS RATIO TEST | | | | | | |
| Portfolio Risk (biased down) | 31% | 32% | 0% | 0% | 100% | 100% |
| Portfolio Risk (no bias) | 69% | 68% | 56% | 51% | 0% | 0% |
| Portfolio Risk (biased up) | 0% | 0% | 44% | 49% | 0% | 0% |
| Relative Risk (biased down) | 0% | 0% | 15% | 0% | 0% | 0% |
| Relative Risk (no bias) | 68% | 71% | 85% | 100% | 28% | 70% |
| Relative Risk (biased up) | 32% | 29% | 0% | 0% | 73% | 30% |

GFC Crash - 2

| | GFC CRASH : 15-AUG-07 to 25-MAR-09 | | | | | |
|--|------------------------------------|--------|--------|--------|--------|--------|
| FORECAST RISKS | | | | | | |
| Ex Ante Portfolio Risk (p.a.) | 18.28 | 18.07 | 19.25 | 18.41 | 9.82 | 9.29 |
| Ex Ante Tracking Error (p.a.) | 6.73 | 6.30 | 10.08 | 8.90 | 5.64 | 5.35 |
| Ex Post Portfolio Risk (1 year) | 32.82 | 32.28 | 31.23 | 31.43 | 31.23 | 31.43 |
| Ex Post Tracking Error (1 year) | 11.95 | 10.92 | 11.19 | 10.47 | 11.19 | 10.47 |
| Ex Ante Portfolio Risk - Ex Post Portfolio Risk (1 year) | -14.53 | -14.21 | -11.98 | -13.02 | -21.41 | -22.14 |
| Ex Ante Relative Risk - Ex Post Relative Risk (1 year) | -5.22 | -4.61 | -1.11 | -1.57 | -5.55 | -5.12 |
| RISK MODEL VALIDATION TESTS | | | | | | |
| Risk Model Valid for Portfolio (1 year) | 39% | 38% | 41% | 40% | 3% | 33% |
| Risk Model Valid for Relative (1 year) | 33% | 35% | 82% | 65% | 22% | 94% |

Recovery - 1

| | RECOVERY 22-APR-09 to 26-DEC-12 | | | | | |
|---|---------------------------------|-----------------|------------------|------------------|-------------------|-------------------|
| Risk Model | XRD AVERAGES | XRD AVERAGES | FUND AVERAGES | FUND AVERAGES | MACRO AVERAGES | MACRO AVERAGES |
| RETURNS | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd |
| Portfolio Returns | 1.76 | 1.53 | 2.06 | 1.90 | 2.06 | 1.90 |
| Relative Returns | 0.51 | 0.28 | 0.43 | 0.27 | 0.43 | 0.27 |
| PORTFOLIO BETA to BENCHMARK | | | | | | |
| Forecast Beta to Benchmark | 1.11 | 1.12 | 1.04 | 1.03 | 1.07 | 1.09 |
| Ex Post Beta to Benchmark (1 year) | 1.05 | 1.09 | 1.10 | 1.12 | 1.10 | 1.12 |
| Standard Error of Ex Post Beta (1 year) | 0.15 | 0.12 | 0.13 | 0.11 | 0.13 | 0.11 |
| Ex Ante Beta - Ex Post Beta (1 year) | 0.06 | 0.03 | -0.06 | -0.09 | -0.03 | -0.03 |
| BIAS RATIO TEST | | | | | | |
| Portfolio Risk (biased down) | 73% | 74% | 0% | 2% | 100% | 100% |
| Portfolio Risk (no bias) | 27% | 26% | 100% | 98% | 0% | 0% |
| Portfolio Risk (biased up) | 0% | 0% | 0% | 0% | 0% | 0% |
| Relative Risk (biased down) | 0% | 0% | 43% | 18% | 0% | 0% |
| Relative Risk (no bias) | 8% | 32% | 57% | 82% | 0% | 13% |
| Relative Risk (biased up) | 92% | 68% | 0% | 0% | 100% | 87% |

Recovery - 2

| | RECOVERY 22-APR-09 to 26-DEC-12 | | | | | |
|--|---------------------------------|-------|-------|-------|-------|-------|
| FORECAST RISKS | | | | | | |
| Ex Ante Portfolio Risk (p.a.) | 26.07 | 26.31 | 28.88 | 27.97 | 16.89 | 16.96 |
| Ex Ante Tracking Error (p.a.) | 7.10 | 7.13 | 10.87 | 9.15 | 6.99 | 6.76 |
| Ex Post Portfolio Risk (1 year) | 18.06 | 18.07 | 18.07 | 17.96 | 18.07 | 17.96 |
| Ex Post Tracking Error (1 year) | 7.04 | 5.84 | 6.60 | 5.66 | 6.60 | 5.66 |
| Ex Ante Portfolio Risk - Ex Post Portfolio Risk (1 year) | 8.01 | 8.25 | 10.82 | 10.01 | -1.18 | -1.00 |
| Ex Ante Relative Risk - Ex Post Relative Risk (1 year) | 0.06 | 1.29 | 4.27 | 3.49 | 0.39 | 1.09 |
| RISK MODEL VALIDATION TESTS | | | | | | |
| Risk Model Valid for Portfolio (1 year) | 63% | 60% | 66% | 68% | 93% | 91% |
| Risk Model Valid for Relative (1 year) | 97% | 91% | 71% | 69% | 93% | 91% |

New Normal - 1

| | NEW NORMAL : 23-JAN-13 to 10-JUN-15 | | | | | |
|---|-------------------------------------|-----------------|------------------|------------------|-------------------|-------------------|
| Risk Model | XRD AVERAGES | XRD AVERAGES | FUND AVERAGES | FUND AVERAGES | MACRO AVERAGES | MACRO AVERAGES |
| RETURNS | EqWtd | SqrtWtd | EqWtd | SqrtWtd | EqWtd | SqrtWtd |
| Portfolio Returns | 1.28 | 1.15 | -0.45 | 1.31 | 1.42 | 1.31 |
| Relative Returns | 0.07 | -0.06 | 1.86 | -0.10 | 0.01 | -0.10 |
| PORTFOLIO BETA to BENCHMARK | | | | | | |
| Forecast Beta to Benchmark | 1.09 | 1.11 | 1.01 | 1.03 | 1.01 | 1.06 |
| Ex Post Beta to Benchmark (1 year) | 1.08 | 1.10 | 0.94 | 1.01 | 0.94 | 1.01 |
| Standard Error of Ex Post Beta (1 year) | 0.26 | 0.19 | 0.23 | 0.18 | 0.23 | 0.18 |
| Ex Ante Beta - Ex Post Beta (1 year) | 0.02 | 0.01 | 0.12 | 0.03 | 0.08 | 0.06 |
| BIAS RATIO TEST | | | | | | |
| Portfolio Risk (biased down) | 3% | 4% | 0% | 0% | 100% | 100% |
| Portfolio Risk (no bias) | 97% | 96% | 84% | 95% | 0% | 0% |
| Portfolio Risk (biased up) | 0% | 0% | 16% | 5% | 0% | 0% |
| Relative Risk (biased down) | 0% | 0% | 96% | 66% | 0% | 0% |
| Relative Risk (no bias) | 7% | 54% | 4% | 34% | 0% | 33% |
| Relative Risk (biased up) | 93% | 46% | 0% | 0% | 100% | 67% |

New Normal - 2

| | NEW NORMAL : 23-JAN-13 to 10-JUN-15 | | | | | |
|--|-------------------------------------|-------|-------|-------|-------|-------|
| FORECAST RISKS | | | | | | |
| Ex Ante Portfolio Risk (p.a.) | 18.60 | 18.70 | 21.26 | 20.27 | 11.27 | 11.69 |
| Ex Ante Tracking Error (p.a.) | 5.55 | 5.37 | 8.45 | 6.58 | 5.25 | 5.29 |
| Ex Post Portfolio Risk (1 year) | 11.43 | 10.69 | 11.12 | 10.81 | 11.12 | 10.81 |
| Ex Post Tracking Error (1 year) | 7.09 | 5.48 | 6.97 | 5.46 | 6.97 | 5.46 |
| Ex Ante Portfolio Risk - Ex Post Portfolio Risk (1 year) | 7.17 | 8.01 | 10.14 | 9.45 | 0.14 | 0.87 |
| Ex Ante Relative Risk - Ex Post Relative Risk (1 year) | -1.55 | -0.11 | 1.47 | 1.12 | -1.72 | -0.17 |
| RISK MODEL VALIDATION TESTS | | | | | | |
| Risk Model Valid for Portfolio (1 year) | 64% | 52% | 28% | 30% | 100% | 100% |
| Risk Model Valid for Relative (1 year) | 82% | 99% | 94% | 96% | 73% | 94% |

Conclusion

- Over the different sub-periods, it is clear that different models perform more or less well
- We did not have enough time to go into the detail of the results of the MACRO model applied to Financial and Natural Resource portfolios, but, as expected, it does perform better on these kinds of concentrated portfolios, especially in extreme conditions
- The real moral of this story is that it is prudent to consider portfolio risk from more than one perspective; often they will agree, but when they do not, the portfolio merits closer attention