Exploratory Data Analysis in Finance Using PerformanceAnalytics

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UseR! International User and Developer Conference, Ames, Iowa, 8-10 Aug 2007
Outline

Visualization

Methods

Summary

Appendix: Set Up PerformanceAnalytics
Overview

- Exploratory data analysis with finance data often starts with visual examination to:
  - examine properties of asset returns
  - compare an asset to other similar assets
  - compare an asset to one or more benchmarks

- Application of performance and risk measures can build a set of statistics for comparing possible investments

- Examples are developed using data for six (hypothetical) managers, a peer index, and an asset class index

- Hypothetical manager data was developed from real manager timeseries using *accuracy* and *perturb* packages to disguise the data while maintaining some of the statistical properties of the original data.
Draw a Performance Summary Chart.

> charts.PerformanceSummary(managers[,c(manager.col,indexes.cols)],
+ colorset=rich6equal, lwd=2, ylog=TRUE)
Show Calendar Performance.

```r
> t(table.CalendarReturns( managers[,c(manager.col,indexes.cols)]) )

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
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<td>-2.1</td>
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<tr>
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<td>6.6</td>
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<td>Dec</td>
<td>1.8</td>
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<td>2.6</td>
<td>1.1</td>
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<td>20.4</td>
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<td>16.1</td>
<td>17.7</td>
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<td>21.4</td>
<td>14.6</td>
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<td>-6.4</td>
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<td>SP500 TR</td>
<td>23.0</td>
<td>33.4</td>
<td>28.6</td>
<td>21.0</td>
<td>-9.1</td>
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<td>-22.1</td>
<td>28.7</td>
<td>10.9</td>
<td>4.9</td>
<td>15.8</td>
</tr>
</tbody>
</table>
```
Calculate Statistics.

```r
> table.Stats(managers[,c(manager.col,peers.cols)])

<table>
<thead>
<tr>
<th></th>
<th>HAM1</th>
<th>HAM2</th>
<th>HAM3</th>
<th>HAM4</th>
<th>HAM5</th>
<th>HAM6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
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<td>125.0000</td>
<td>132.0000</td>
<td>132.0000</td>
<td>77.0000</td>
<td>64.0000</td>
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<tr>
<td>NAs</td>
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<td>7.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>55.0000</td>
<td>68.0000</td>
</tr>
<tr>
<td>Minimum</td>
<td>-0.0944</td>
<td>-0.0371</td>
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<tr>
<td>Quartile 1</td>
<td>0.0000</td>
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<td>-0.0198</td>
<td>-0.0164</td>
<td>-0.0016</td>
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<tr>
<td>Median</td>
<td>0.0112</td>
<td>0.0082</td>
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<td>0.0038</td>
<td>0.0128</td>
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<tr>
<td>Arithmetic Mean</td>
<td>0.0111</td>
<td>0.0141</td>
<td>0.0124</td>
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<td>0.0041</td>
<td>0.0111</td>
</tr>
<tr>
<td>Geometric Mean</td>
<td>0.0108</td>
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<td>0.0118</td>
<td>0.0096</td>
<td>0.0031</td>
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<tr>
<td>Quartile 3</td>
<td>0.0248</td>
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<td>0.0460</td>
<td>0.0309</td>
<td>0.0255</td>
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<td>Maximum</td>
<td>0.0692</td>
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<td>0.1508</td>
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<tr>
<td>SE Mean</td>
<td>0.0022</td>
<td>0.0033</td>
<td>0.0032</td>
<td>0.0046</td>
<td>0.0052</td>
<td>0.0030</td>
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<tr>
<td>LCL Mean (0.95)</td>
<td>0.0067</td>
<td>0.0076</td>
<td>0.0062</td>
<td>0.0019</td>
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<tr>
<td>UCL Mean (0.95)</td>
<td>0.0155</td>
<td>0.0206</td>
<td>0.0187</td>
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<tr>
<td>Variance</td>
<td>0.0007</td>
<td>0.0013</td>
<td>0.0013</td>
<td>0.0028</td>
<td>0.0021</td>
<td>0.0006</td>
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<tr>
<td>Stdev</td>
<td>0.0256</td>
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<td>0.0365</td>
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<td>0.0457</td>
<td>0.0238</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.6588</td>
<td>1.4580</td>
<td>0.7908</td>
<td>-0.4311</td>
<td>0.0738</td>
<td>-0.2800</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.3616</td>
<td>2.3794</td>
<td>2.6829</td>
<td>0.8632</td>
<td>2.3143</td>
<td>-0.3489</td>
</tr>
</tbody>
</table>
```
Compare Distributions.

> chart.Boxplot(managers[ trailing36.rows, c(manager.col, peers.cols, + indexes.cols)], main = "Trailing 36-Month Returns")
Compare Distributions.

```r
> layout(rbind(c(1,2),c(3,4)))
> chart.Histogram(managers[,1,drop=F], main = "Plain", methods = NULL)
> chart.Histogram(managers[,1,drop=F], main = "Density", breaks=40,
+ methods = c("add.density", "add.normal"))
> chart.Histogram(managers[,1,drop=F], main = "Skew and Kurt", methods = c
+ ("add.centered", "add.rug"))
> chart.Histogram(managers[,1,drop=F], main = "Risk Measures", methods = c
+ ("add.risk"))
```
Show Relative Return and Risk.

```r
> chart.RiskReturnScatter(managers[trailing36.rows,1:8], Rf=.03/12, main = "+ Trailing 36-Month Performance", colorset=c("red", rep("black",5), "orange", + "green"))
```

![Trailing 36-Month Performance](image)
Examine Performance Consistency.

```r
> charts.RollingPerformance(managers[, c(manager.col, peers.cols, + indexes.cols)], Rf=.03/12, colorset = c("red", rep("darkgray",5), "orange", + "green"), lwd = 2)
```

![Rolling 12 month Performance](image)
Display Relative Performance.

```r
> chart.RelativePerformance(managers[, manager.col, drop = FALSE],
+   managers[, c(peers.cols, 7)], colorset = tim8equal[-1], lwd = 2, legend.loc
+   = "topleft")
```

![Relative Performance Chart](image)
Compare to a Benchmark.

```r
> chart.RelativePerformance(managers[, c(manager.col, peers.cols) ],
+ managers[, 8, drop=F], colorset = rainbow8equal, lwd = 2, legend.loc =
+ "topleft")
```

![Relative Performance Chart](attachment:image.png)
Compare to a Benchmark.

```r
> table.CAPM(managers[trailing36.rows, c(manager.col, peers.cols)],
+ managers[ trailing36.rows, 8, drop=FALSE], Rf = managers[ trailing36.rows,
+ Rf.col, drop=F ])

<table>
<thead>
<tr>
<th></th>
<th>HAM1 to SP500 TR</th>
<th>HAM2 to SP500 TR</th>
<th>HAM3 to SP500 TR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>0.0051</td>
<td>0.0020</td>
<td>0.0020</td>
</tr>
<tr>
<td>Beta</td>
<td>0.6267</td>
<td>0.3223</td>
<td>0.6320</td>
</tr>
<tr>
<td>Beta+</td>
<td>0.8227</td>
<td>0.4176</td>
<td>0.8240</td>
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<tr>
<td>Beta-</td>
<td>1.1218</td>
<td>-0.0483</td>
<td>0.8291</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.3829</td>
<td>0.1073</td>
<td>0.4812</td>
</tr>
<tr>
<td>Annualized Alpha</td>
<td>0.0631</td>
<td>0.0247</td>
<td>0.0243</td>
</tr>
<tr>
<td>Correlation</td>
<td>0.6188</td>
<td>0.3276</td>
<td>0.6937</td>
</tr>
<tr>
<td>Correlation p-value</td>
<td>0.0001</td>
<td>0.0511</td>
<td>0.0000</td>
</tr>
<tr>
<td>Tracking Error</td>
<td>0.0604</td>
<td>0.0790</td>
<td>0.0517</td>
</tr>
<tr>
<td>Active Premium</td>
<td>0.0384</td>
<td>-0.0260</td>
<td>-0.0022</td>
</tr>
<tr>
<td>Information Ratio</td>
<td>0.6363</td>
<td>-0.3295</td>
<td>-0.0428</td>
</tr>
<tr>
<td>Treynor Ratio</td>
<td>0.1741</td>
<td>0.1437</td>
<td>0.1101</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>HAM4 to SP500 TR</th>
<th>HAM5 to SP500 TR</th>
<th>HAM6 to SP500 TR</th>
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<tbody>
<tr>
<td>Alpha</td>
<td>0.0009</td>
<td>0.0002</td>
<td>0.0022</td>
</tr>
<tr>
<td>Beta</td>
<td>1.1282</td>
<td>0.8755</td>
<td>0.8150</td>
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<tr>
<td>Beta+</td>
<td>1.8430</td>
<td>1.0985</td>
<td>0.9993</td>
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<tr>
<td>Beta-</td>
<td>1.2223</td>
<td>0.5283</td>
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<tr>
<td>R-squared</td>
<td>0.3444</td>
<td>0.5209</td>
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<tr>
<td>Annualized Alpha</td>
<td>0.0109</td>
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<tr>
<td>Correlation</td>
<td>0.5868</td>
<td>0.7218</td>
<td>0.6897</td>
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<tr>
<td>Correlation p-value</td>
<td>0.0002</td>
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<td>Tracking Error</td>
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<td>0.0601</td>
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<td>Active Premium</td>
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<td>0.0138</td>
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<tr>
<td>Information Ratio</td>
<td>0.1433</td>
<td>-0.1319</td>
<td>0.2296</td>
</tr>
<tr>
<td>Treynor Ratio</td>
<td>0.0768</td>
<td>0.0734</td>
<td>0.1045</td>
</tr>
</tbody>
</table>
```
Calculate Returns.

▶ The single-period arithmetic return, or simple return, can be calculated as

$$ R_t = \frac{P_t}{P_{t-1}} - 1 = \frac{P_t - P_{t-1}}{P_{t-1}} $$

(1)

▶ Simple returns, cannot be added together. A multiple-period simple return is calculated as:

$$ R_t = \frac{P_t}{P_{t-k}} - 1 = \frac{P_t - P_{t-k}}{P_{t-k}} $$

(2)

▶ The natural logarithm of the simple return of an asset is referred to as the continuously compounded return, or *log return*:

$$ r_t = \ln(1 + R_t) = \ln \frac{P_t}{P_{t-1}} = p_t - p_{t-1} $$

(3)

▶ Calculating log returns from simple gross return, or vice versa:

$$ r_t = \ln(1 + R_t), \quad R_t = \exp(r_t) - 1. $$

(4)

▶ *Return.calculate* or *CalculateReturns* (now deprecated) may be used to compute discrete and continuously compounded returns for data containing asset prices.
Return.annualized — Annualized return using

\[
prod(1 + R_a)^{scale/n} - 1 = \sqrt[n]{\prod(1 + R_a)^{scale}} - 1
\]  

(5)

TreynorRatio — ratio of asset’s Excess Return to Beta \( \beta \) of the benchmark

\[
\frac{(R_a - R_f)}{\beta_{a,b}}
\]  

(6)

ActivePremium — investment’s annualized return minus the benchmark’s annualized return

Tracking Error — A measure of the unexplained portion of performance relative to a benchmark, given by

\[
TrackingError = \sqrt{\sum \frac{(R_a - R_b)^2}{\text{len}(R_a) \sqrt{scale}}}
\]  

(7)

InformationRatio — ActivePremium/TrackingError
Compare to a Benchmark.

```r
> charts.RollingRegression(managers[, c(manager.col, peers.cols), drop = + FALSE], managers[, 8, drop = FALSE], Rf = .03/12, colorset = redfocus, lwd = + 2)
```

![Rolling 12-month Regressions](image)
## Calculate Downside Risk

```r
> table.DownsideRisk(managers[,1:6], Rf=.03/12)

<table>
<thead>
<tr>
<th></th>
<th>HAM1</th>
<th>HAM2</th>
<th>HAM3</th>
<th>HAM4</th>
<th>HAM5</th>
<th>HAM6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi Deviation</td>
<td>0.0191</td>
<td>0.0201</td>
<td>0.0237</td>
<td>0.0395</td>
<td>0.0324</td>
<td>0.0175</td>
</tr>
<tr>
<td>Gain Deviation</td>
<td>0.0169</td>
<td>0.0347</td>
<td>0.0290</td>
<td>0.0311</td>
<td>0.0313</td>
<td>0.0149</td>
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<tr>
<td>Loss Deviation</td>
<td>0.0211</td>
<td>0.0107</td>
<td>0.0191</td>
<td>0.0365</td>
<td>0.0324</td>
<td>0.0128</td>
</tr>
<tr>
<td>Downside Deviation (MAR=10%)</td>
<td>0.0178</td>
<td>0.0164</td>
<td>0.0214</td>
<td>0.0381</td>
<td>0.0347</td>
<td>0.0161</td>
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<tr>
<td>Downside Deviation (Rf=3%)</td>
<td>0.0154</td>
<td>0.0129</td>
<td>0.0185</td>
<td>0.0353</td>
<td>0.0316</td>
<td>0.0133</td>
</tr>
<tr>
<td>Downside Deviation (0%)</td>
<td>0.0145</td>
<td>0.0116</td>
<td>0.0174</td>
<td>0.0341</td>
<td>0.0304</td>
<td>0.0121</td>
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<td>Maximum Drawdown</td>
<td>0.1518</td>
<td>0.2399</td>
<td>0.2894</td>
<td>0.2874</td>
<td>0.3405</td>
<td>0.0788</td>
</tr>
<tr>
<td>Historical VaR (95%)</td>
<td>-0.0258</td>
<td>-0.0294</td>
<td>-0.0425</td>
<td>-0.0799</td>
<td>-0.0733</td>
<td>-0.0341</td>
</tr>
<tr>
<td>Historical ES (95%)</td>
<td>-0.0513</td>
<td>-0.0331</td>
<td>-0.0555</td>
<td>-0.1122</td>
<td>-0.1023</td>
<td>-0.0392</td>
</tr>
<tr>
<td>Modified VaR (95%)</td>
<td>-0.0342</td>
<td>-0.0276</td>
<td>-0.0368</td>
<td>-0.0815</td>
<td>-0.0676</td>
<td>-0.0298</td>
</tr>
<tr>
<td>Modified ES (95%)</td>
<td>-0.0610</td>
<td>-0.0614</td>
<td>-0.0440</td>
<td>-0.1176</td>
<td>-0.0974</td>
<td>-0.0390</td>
</tr>
</tbody>
</table>
```
Semivariance and Downside Deviation

- Downside Deviation as proposed by Sharpe is a generalization of semivariance which calculates bases on the deviation below a Minimum Acceptable Return (MAR)

\[ \delta_{MAR} = \sqrt{\frac{\sum_{t=1}^{n} (R_t - MAR)^2}{n}} \]  \hspace{1cm} (8)

- Downside Deviation may be used to calculate semideviation by setting MAR=mean(R) or may also be used with MAR=0

- Downside Deviation (and its special cases semideviation and semivariance) is useful in several performance to risk ratios, and in several portfolio optimization problems.
Value at Risk

- Value at Risk (VaR) has become a required standard risk measure recognized by Basel II and MiFID
- Traditional mean-VaR may be derived historically, or estimated parametrically using

\[
z_c = q_p = qnorm(p) \tag{9}
\]

\[
VaR = \bar{R} - z_c \cdot \sqrt{\sigma} \tag{10}
\]

- Even with robust covariance matrix or Monte Carlo simulation, mean-VaR is not reliable for non-normal asset distributions
- For non-normal assets, VaR estimates calculated using GPD (as in VaR.GPD) or Cornish Fisher perform best
- Modified Cornish Fisher VaR takes higher moments of the distribution into account:

\[
z_{cf} = z_c + \frac{(z_c^2 - 1)S}{6} + \frac{(z_c^3 - 3z_c)K}{24} + \frac{(2z_c^3 - 5z_c)S^2}{36} \tag{11}
\]

\[
modVaR = \bar{R} - z_{cf} \sqrt{\sigma} \tag{12}
\]

- Modified VaR also meets the definition of a coherent risk measure per Artzner, et al. (1997)
Risk/Reward Ratios in *PerformanceAnalytics*

- **SharpeRatio** — return per unit of risk represented by variance, may also be annualized by

\[
\frac{n \cdot \text{prod}(1 + R_a)^{scale} - 1}{\sqrt{\text{scale}} \cdot \sqrt{\sigma}}
\]  

(13)

- **Sortino Ratio** — improvement on Sharpe Ratio utilizing downside deviation as the measure of risk

\[
\frac{(R_a - MAR)}{\delta_{MAR}}
\]

(14)

- **Calmar and Sterling Ratios** — ratio of annualized return (Eq. 1) over the absolute value of the maximum drawdown

- **Sortino’s Upside Potential Ratio** — upside semdiviation from MAR over downside deviation from MAR

\[
\frac{\sum_{t=1}^{n} (R_t - MAR)}{\delta_{MAR}}
\]

(15)

- **Favre’s modified Sharpe Ratio** — ratio of excess return over Cornish-Fisher VaR

\[
\frac{(R_a - R_f)}{\text{modVaR}_{R_a, p}}
\]

(16)
Summary

- Performance and risk analysis are greatly facilitated by the use of charts and tables.
- The display of your information is in many cases as important as the analysis.
- *PerformanceAnalytics* contains several tools for measuring and visualizing data that may be used to aid investment decision making.

Further Work

- Additional parameterization to make charts and tables more useful.
- Pertrac or Morningstar-style sample reports.
- Functions and graphics for more complicated topics such as factor analysis and optimization.
Install PerformanceAnalytics.

- As of version 0.9.4, PerformanceAnalytics is available in CRAN
- Version 0.9.5 was released at the beginning of July
- Install with:
  ```
  > install.packages("PerformanceAnalytics")
  ```
- Required packages include `Hmisc`, `zoo`, and `Rmetrics` packages such as `fExtremes`.
- Load the library into your active R session using:
  ```
  > library("PerformanceAnalytics").
  ```
Load and Review Data.

```r
> data(managers)
> head(managers)

<table>
<thead>
<tr>
<th>HAM1</th>
<th>HAM2</th>
<th>HAM3</th>
<th>HAM4</th>
<th>HAM5</th>
<th>HAM6</th>
<th>EDHEC</th>
<th>LS</th>
<th>EQ</th>
<th>SP500</th>
<th>TR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996-01-31</td>
<td>0.0074</td>
<td>NA</td>
<td>0.0349</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>0.0340</td>
<td></td>
</tr>
<tr>
<td>1996-02-29</td>
<td>0.0193</td>
<td>NA</td>
<td>0.0351</td>
<td>0.0195</td>
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<td>0.0093</td>
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</tr>
<tr>
<td>1996-03-31</td>
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<td>NA</td>
<td>0.0258</td>
<td>-0.0098</td>
<td>NA</td>
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<td></td>
<td>0.0096</td>
<td></td>
</tr>
<tr>
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<td>0.0236</td>
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<tr>
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<td>0.0353</td>
<td>0.0028</td>
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<td>0.0258</td>
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</tr>
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<td>-0.0303</td>
<td>-0.0019</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>0.0038</td>
<td></td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>US 10Y TR</th>
<th>US 3m TR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996-01-31</td>
<td>0.00380</td>
</tr>
<tr>
<td>1996-02-29</td>
<td>-0.03532</td>
</tr>
<tr>
<td>1996-03-31</td>
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</tr>
<tr>
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<td>-0.00543</td>
</tr>
<tr>
<td>1996-06-30</td>
<td>0.01507</td>
</tr>
</tbody>
</table>
```
Set Up Data for Analysis.

```r
> dim(managers)
[1] 132 10
> managers.length = dim(managers)[1]
> colnames(managers)
[1] "HAM1" "HAM2" "HAM3" "HAM4" "HAM5"
[6] "HAM6" "EDHEC LS EQ" "SP500 TR" "US 10Y TR" "US 3m TR"

> manager.col = 1
> peers.cols = c(2,3,4,5,6)
> indexes.cols = c(7,8)
> Rf.col = 10
> #factors.cols = NA
> trailing12.rows = ((managers.length - 11):managers.length)
> trailing12.rows
[1] 121 122 123 124 125 126 127 128 129 130 131 132

> trailing36.rows = ((managers.length - 35):managers.length)
> trailing60.rows = ((managers.length - 59):managers.length)
> #assume contiguous NAs - this may not be the way to do it na.contiguous()
> frInception.rows = (length(managers[,1]) -
+ length(managers[,1][!is.na(managers[,1])]) + 1):length(managers[,1])
```
Draw a Performance Summary Chart.

```r
> charts.PerformanceSummary(managers[,c(manager.col,indexes.cols)],
+ colorset=rich6equal, lwd=2, ylog=TRUE)
```

![Performance Summary Chart](image)

**HAM1 Performance**

- **Cumulative Return**
- **Monthly Return**
- **Drawdown**