Machine Learning Trading Strategy Development in Python, using ***zipline*** and ***pyfolio***

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Disclaimer

Overview

1. Intro: Who is Quantopian?
   - Provide quants and programmers free tools like ***zipline*** and ***pyfolio***, along with free market data for developing trading algorithms
   - Crowd-sourced quantitative investment manager
     - We make allocations to qualified algorithms, and we share a percentage of profits with the author.

2. Python in Quant Finance

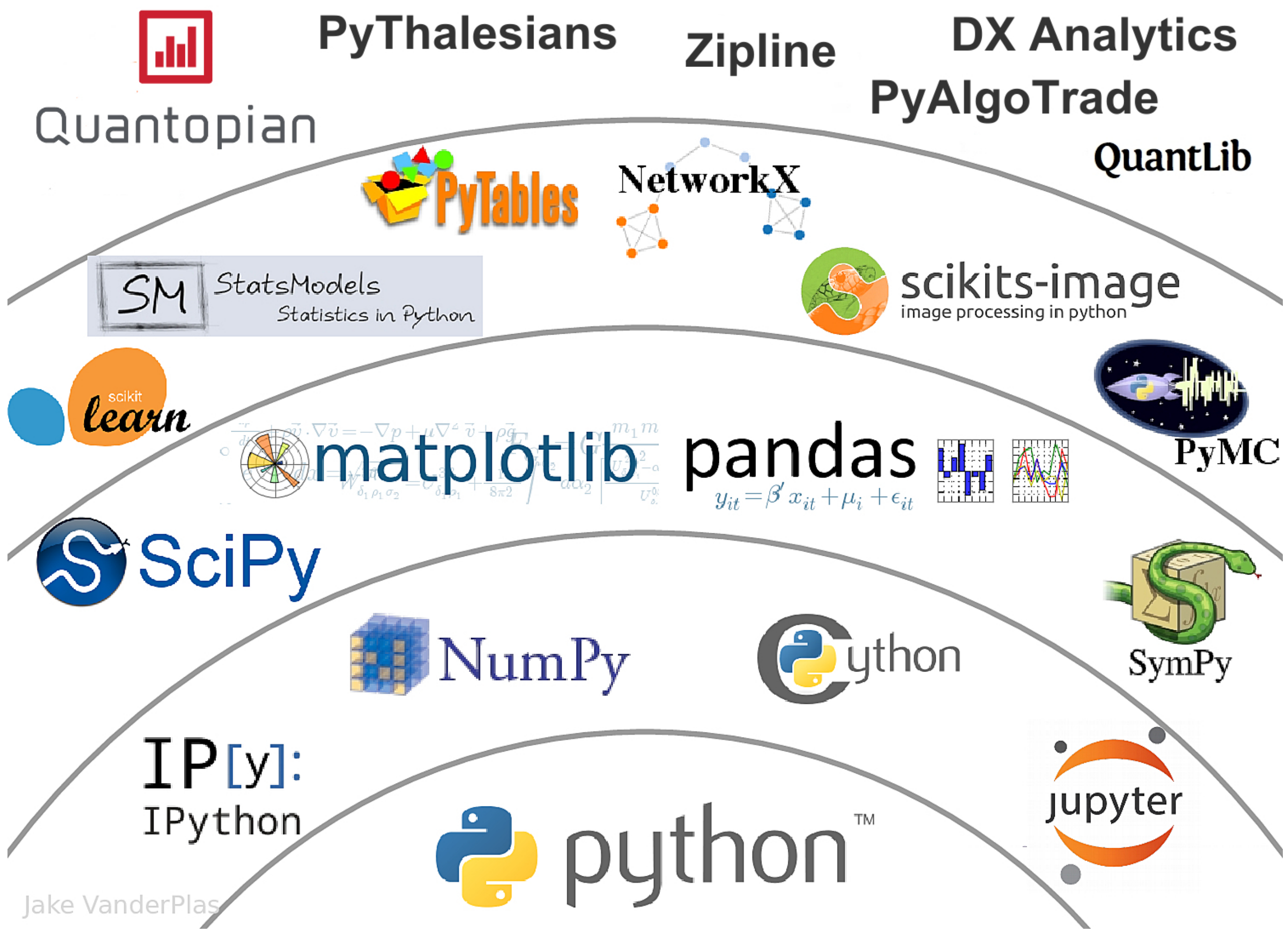
3. What are zipline & pyfolio?
   - Backtester and Portfolio Risk Analysis tools
   - Zipline
     - Open source and free: Apache v2 license
     - https://github.com/quantopian/zipline
     - Tutorial/Docs: http://www.zipline.io/index.html
   - Pyfolio
     - Open source and free: Apache v2 license
     - http://github.com/quantopian/pyfolio
     - Tutorial/Docs: http://quantopian.github.io/pyfolio/

- Will make these slides available on our public github repo:
  - https://github.com/quantopian/research_public/workshops

Why use Python for Quant Finance?

- Python is a general purpose language
- No hodge-podge of perl, bash, R, matlab, fortran, Excel
- Gives us access to a vibrant, rapidly expanding ecosystem of tools…
- *Very easy to learn*

The Quant Finance PyData Stack



- Source: [Jake VanderPlas: State of the Tools]
  - (https://www.youtube.com/watch?v=5GlNDD7qbP4)

Zipline + pyfolio

- ***Zipline***: open-source backtester by Quantopian
- Powers Quantopian.com
  - Various models for transaction costs and slippage.
  - Web based IDE for creating and deploying trading algorithms
- Hosted ipython notebook research server
  - Ad-hoc data analysis. We provide market data.
  - Pull in strategy backtest results from the Web IDE and use ***pyfolio***

Using zipline & pyfolio stand-alone

- Installation
- Use Anaconda to get a full PyData ecosystem.
- Then you can conda install the ***zipline*** package which includes ***pyfolio***.
  - *conda install -c Quantopian zipline*
  - More info: https://conda.anaconda.org/quantopian
- Just want ***pyfolio***? *pip install pyfolio*
  - No dependency on zipline, can simply use pyfolio with portfolio returns contained in a CSV file

- Import / Usage (typical)
  - Zipline: import *TradingAlgorithm* class, and individual zipline specific API functions (based on specific usecase)

```
from zipline import TradingAlgorithm
from zipline.api import order_target, record, symbol, history, add_history, order_target_percent
from zipline.api import schedule_function, date_rules, time_rules, order, get_open_orders, get_datetime
from zipline.api import set_slippage, set_commission
from zipline.api import slippage
from zipline.api import commission

from zipline.utils import tradingcalendar
```

  - Pyfolio

```
import pyfolio as pf
```

What is zipline?

Zipline Examples

- Simple Example
  - ipython notebook, running locally
  - “Hello World” algorithm: 50-day MA/200-day MA crossover

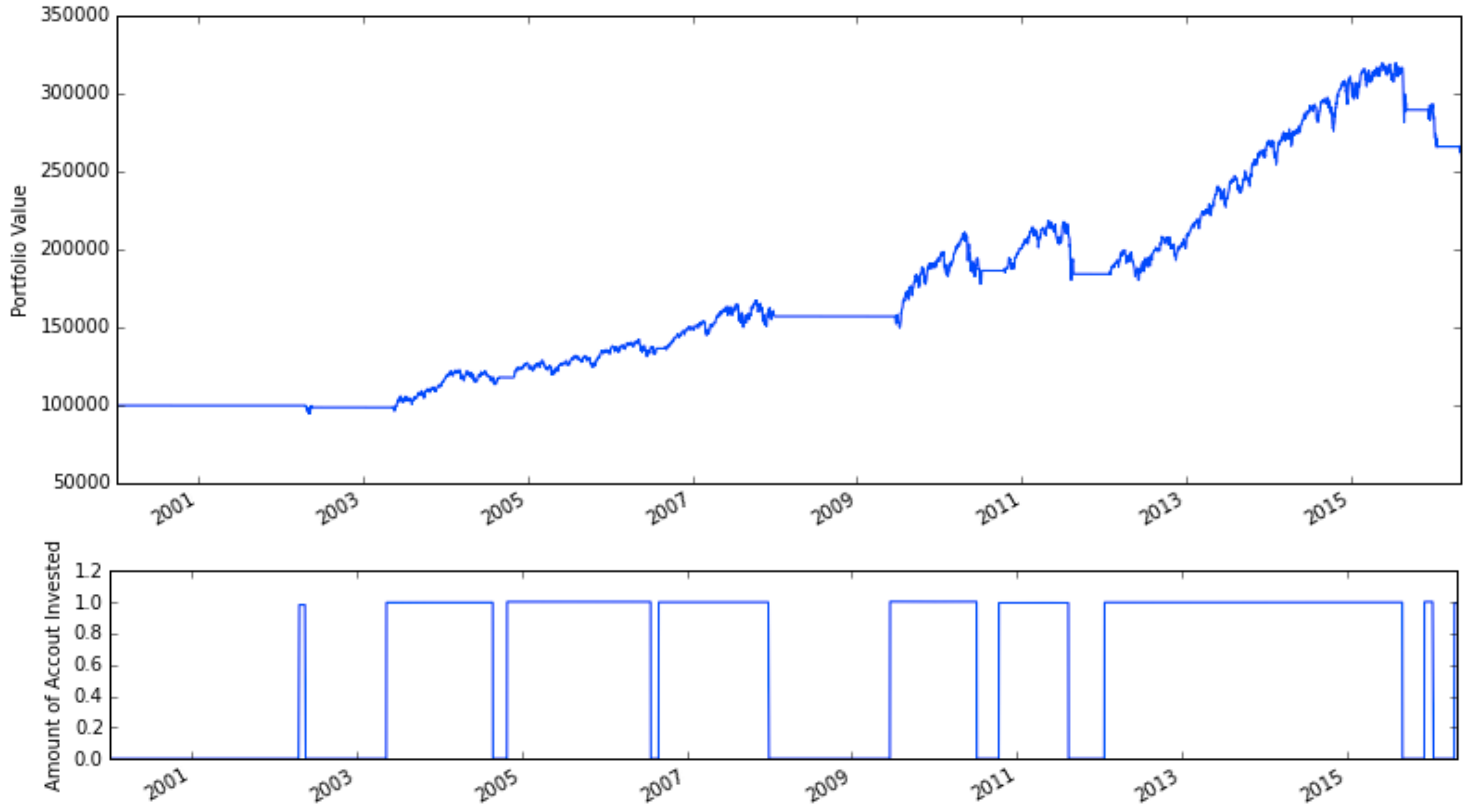
- Machine Learning Example
  - Quantopian IDE + *pyfolio* in Quantopian’s hosted ipython notebook server
  - Inspired by algorithm shared in the Quantopian community forum
    - https://www.quantopian.com/posts/machine-learning-support-vector-regression

- If we have time...
  - Visualize sensitivity of a strategy to variation in input parameter values
    - Pair trading example using Gold and Oil ETF’s
      - https://www.quantopian.com/posts/sensitivity-analysis-aka-parameter-optimization-of-pair-trade-input-parameters

  - Zipline + TensorFlow
    - Dr. Erk Subasi, QuantCon 2016 Talk:
      - "Honey, I Deep-Shrunk the Sample Covariance Matrix!”
    - https://github.com/erksubasi/AutoencoderCovShrinkage/blob/master/QuantCon2016.ipynb

Zipline: Simple Example

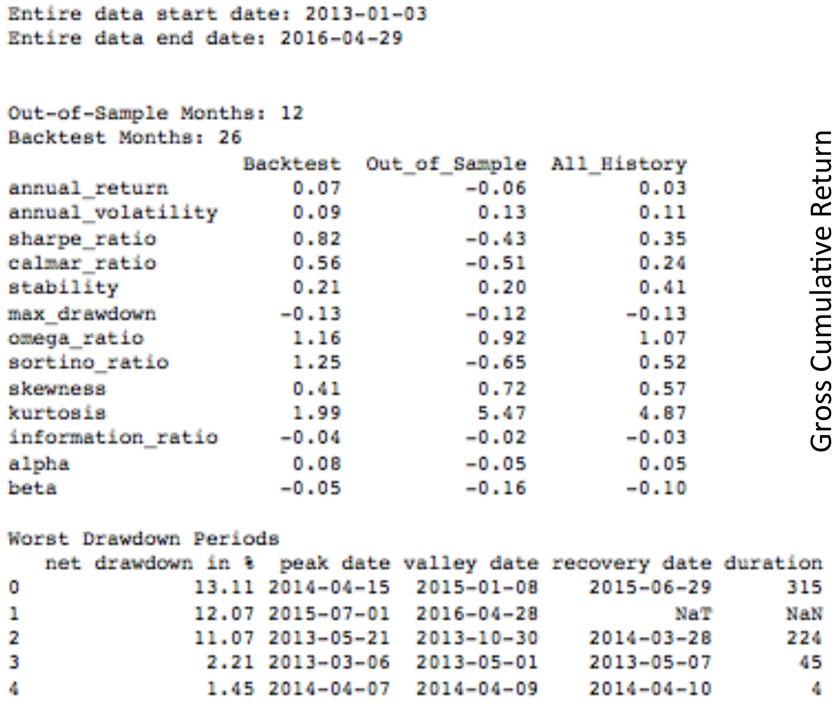
- From the Zipline Tutorial: http://www.zipline.io/beginner-tutorial.html#ipython-notebook
- The Hello World of trading strategies
  - Buy a stock when its 50-day moving average crosses above its 200-day moving average
  - Sell the stock when its 50-day MA falls back below its 200-day MA



Zipline: Machine Learning Example

- Inspired by algorithm shared in the Quantopian community forum
  - https://www.quantopian.com/posts/machine-learning-support-vector-regression
- Train SVM on 5 simple price/volume features (open/high/low/close/volume)
  - Train using trailing 21-day (1-month) window, and predict whether the stock will be up or down the next day
    - Go Long or Short based on the prediction
  - Risk Management: If trade loses more than 1%, exit the trade.
    - Since we're using SPY (the SP500 ETF) in this example, a 1% move is somewhat sizeable

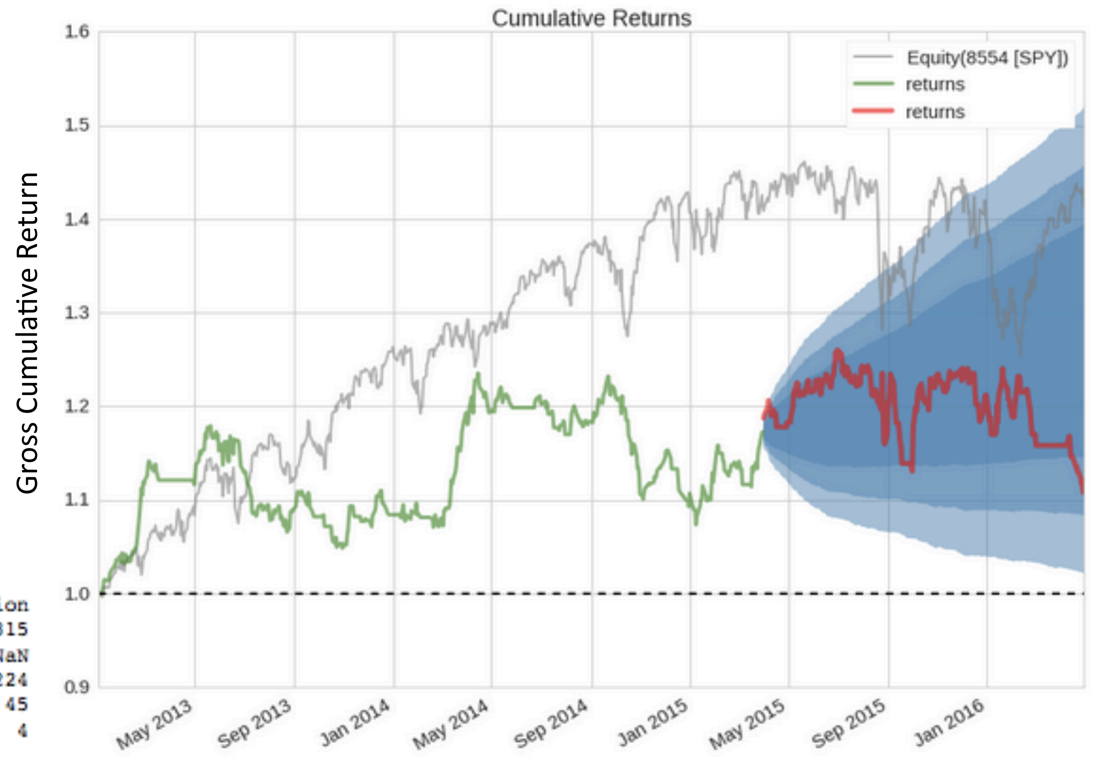
– ***Pyfolio*** analysis: For example purposes, I set the out-of-sample date to be right after the forum post was made



```
Entire data start date: 2013-01-03
Entire data end date: 2016-04-29


Out-of-Sample Months: 12
Backtest Months: 26
                   Backtest  Out_of_Sample  All_History
annual_return          0.07          -0.06         0.03
annual_volatility      0.09           0.13         0.11
sharpe_ratio           0.82          -0.43         0.35
calmar_ratio           0.56          -0.51         0.24
stability              0.21           0.20         0.41
max_drawdown          -0.13          -0.12        -0.13
omega_ratio            1.16           0.92         1.07
sortino_ratio          1.25          -0.65         0.52
skewness               0.41           0.72         0.57
kurtosis               1.99           5.47         4.87
information_ratio     -0.04          -0.02        -0.03
alpha                  0.08          -0.05         0.05
beta                  -0.05          -0.16        -0.10

Worst Drawdown Periods
   net drawdown in %  peak date valley date recovery date duration
0              13.11 2014-04-15  2015-01-08    2015-06-29      315
1              12.07 2015-07-01  2016-04-28           NaT      NaN
2              11.07 2013-05-21  2013-10-30    2014-03-28      224
3               2.21 2013-03-06  2013-05-01    2013-05-07       45
4               1.45 2014-04-07  2014-04-09    2014-04-10        4
```



The gross cumulative returns presented are gross of fees and do not reflect the deduction of any fees or expenses.

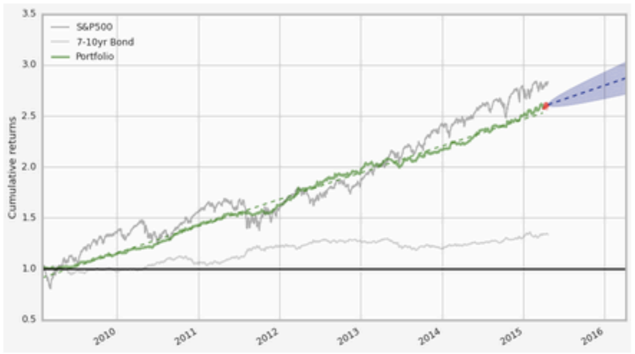
More details about ***pyfolio***

“Tearsheets”

- Collection of tables and plots.

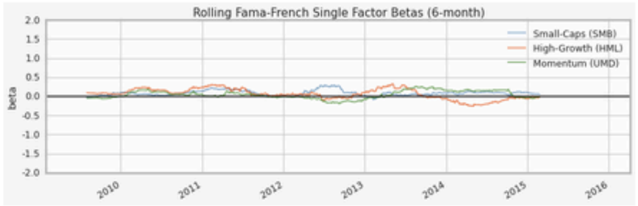
Visualizations

- Daily returns of a stock, or trading strategy
- Positions
- Transactions
- Periods of market stress
- *Bayesian risk analyses



Rolling Portfolio Beta to SP500
6-mo
12-mo
beta

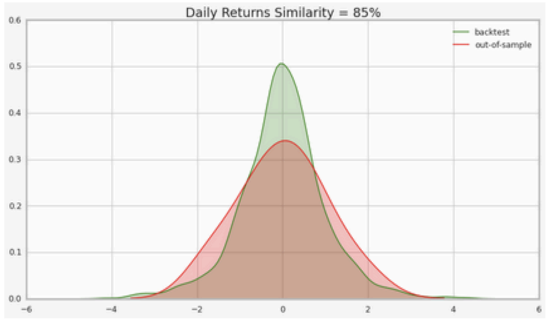
Rolling Sharpe ratio (6-month)
Sharpe ratio

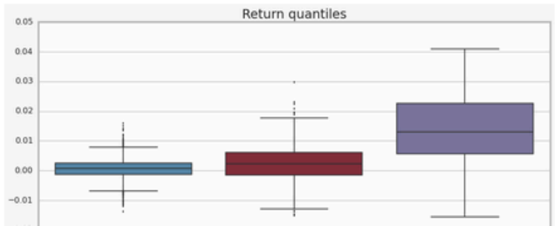


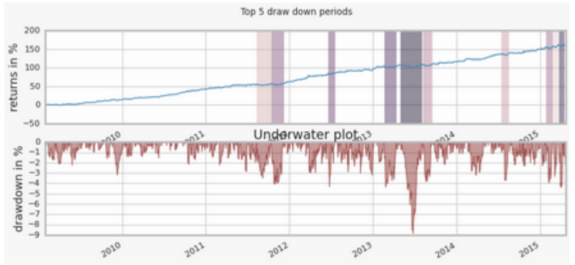
Multi-factor Alpha (vs. Factors: Small-Cap, High-Growth, Momentum)
alpha

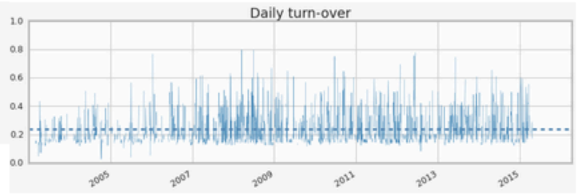
Monthly Returns (%)

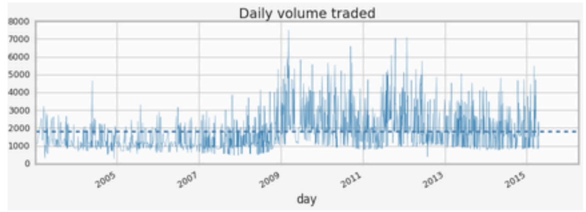
mean
Annual Returns (%)

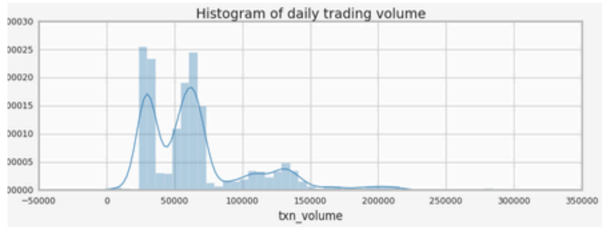




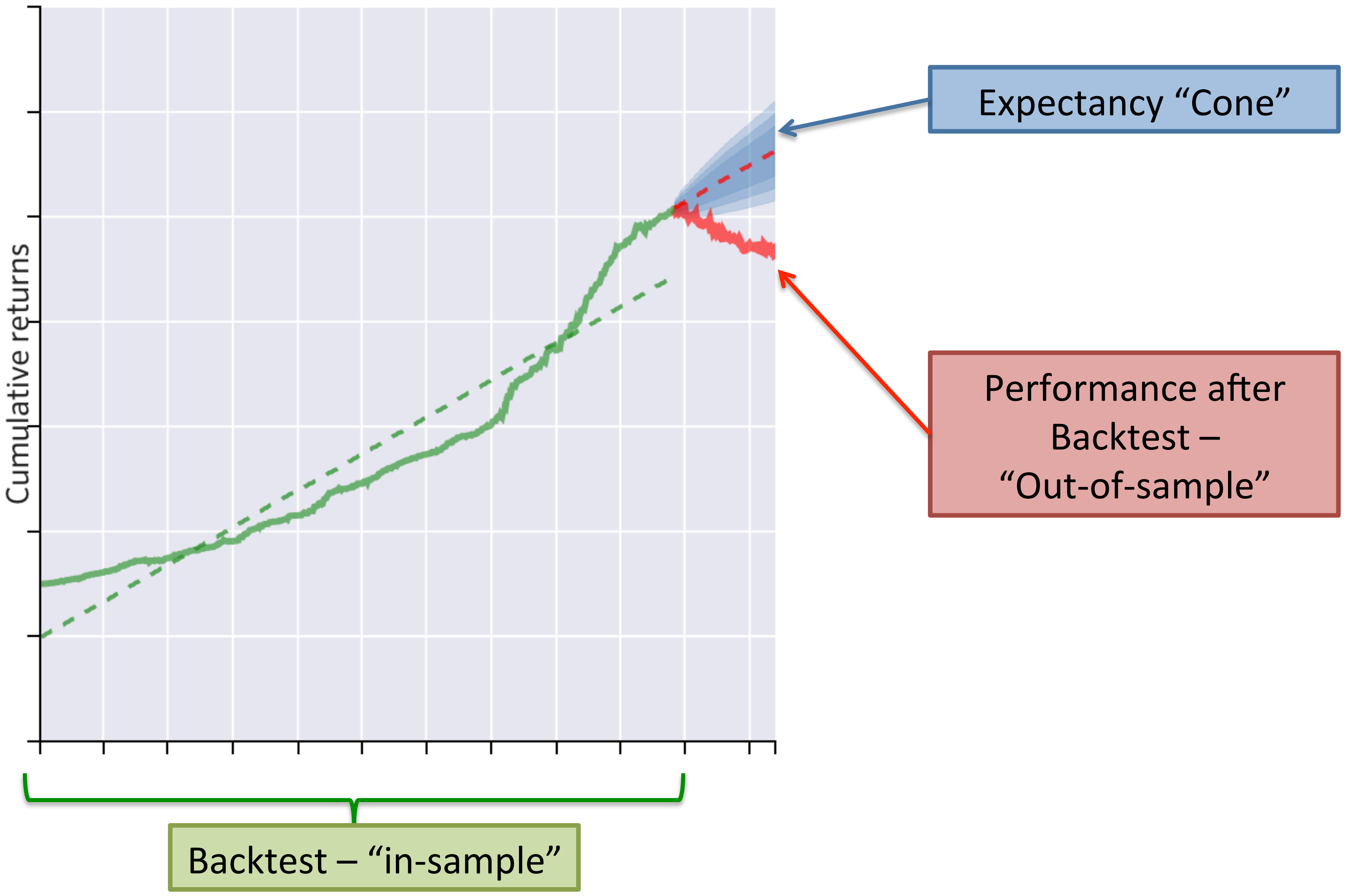








Backtest vs. Out-of-Sample Analysis



What is the Cone?

"Cone":
Projected expectations and "Risk bands" based on the backtest in-sample performance of the strategy

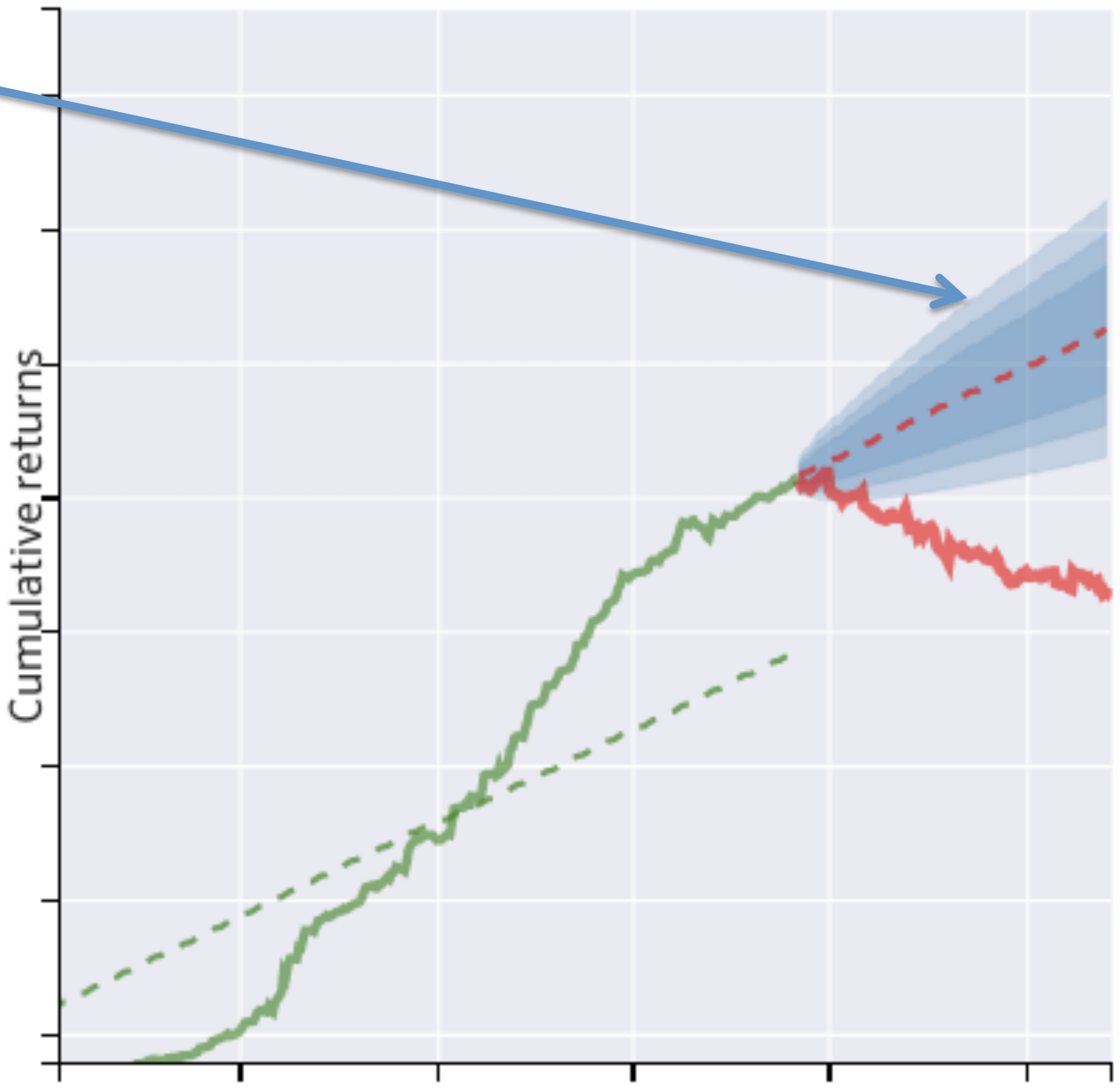
Green = Backtest, in-sample

Red = Live Trading, out-of-sample

Blue cone = volatility bands

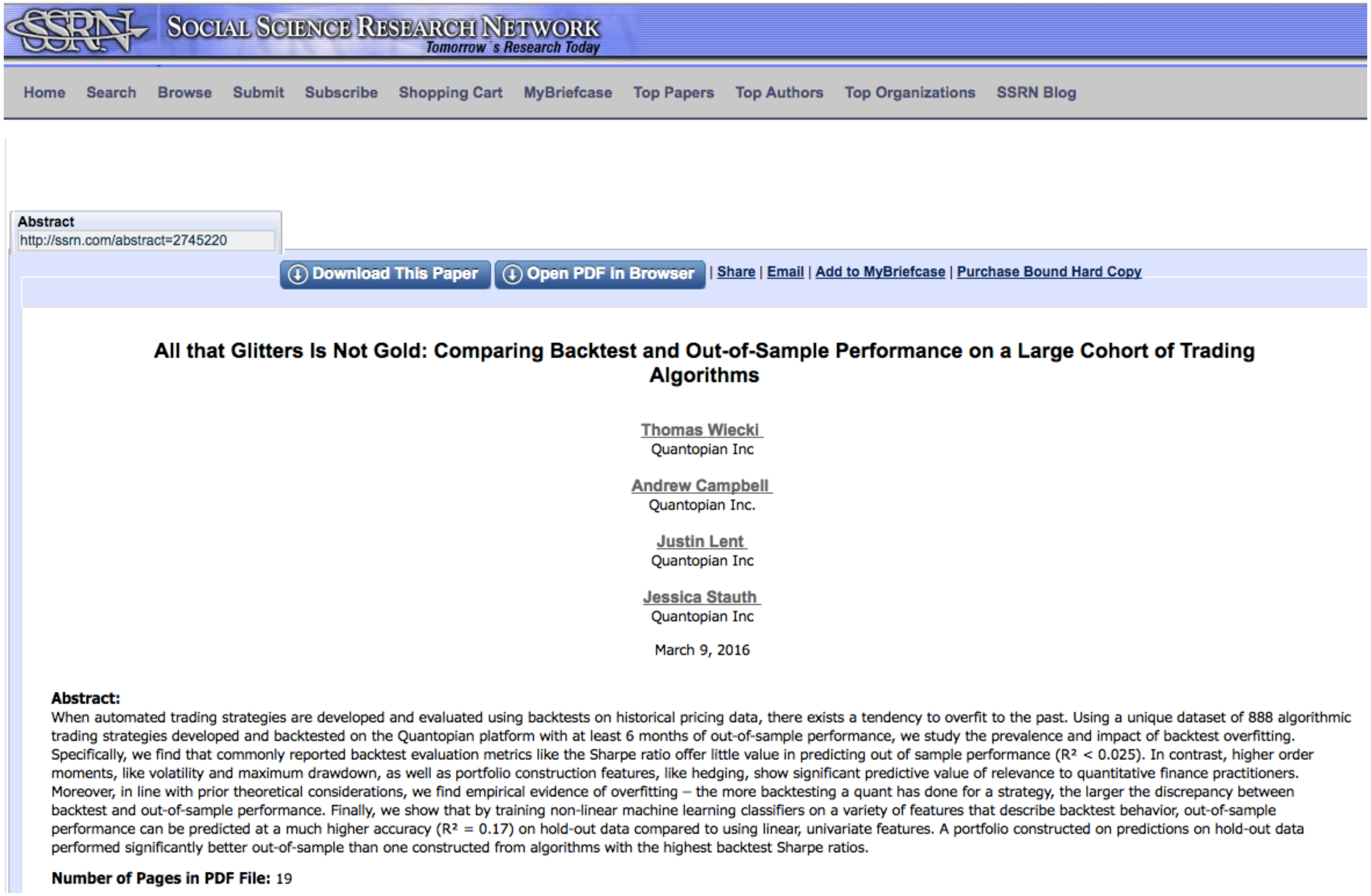
- 1.0, 1.5, 2.0 stdevs

Consider exiting trading strategy if it starts trading outside of the -2.0 stdev region of the cone



Recent paper

http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2745220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All that Glitters Is Not Gold: Comparing Backtest and Out-of-Sample Performance on a Large Cohort of Trading Algorithms

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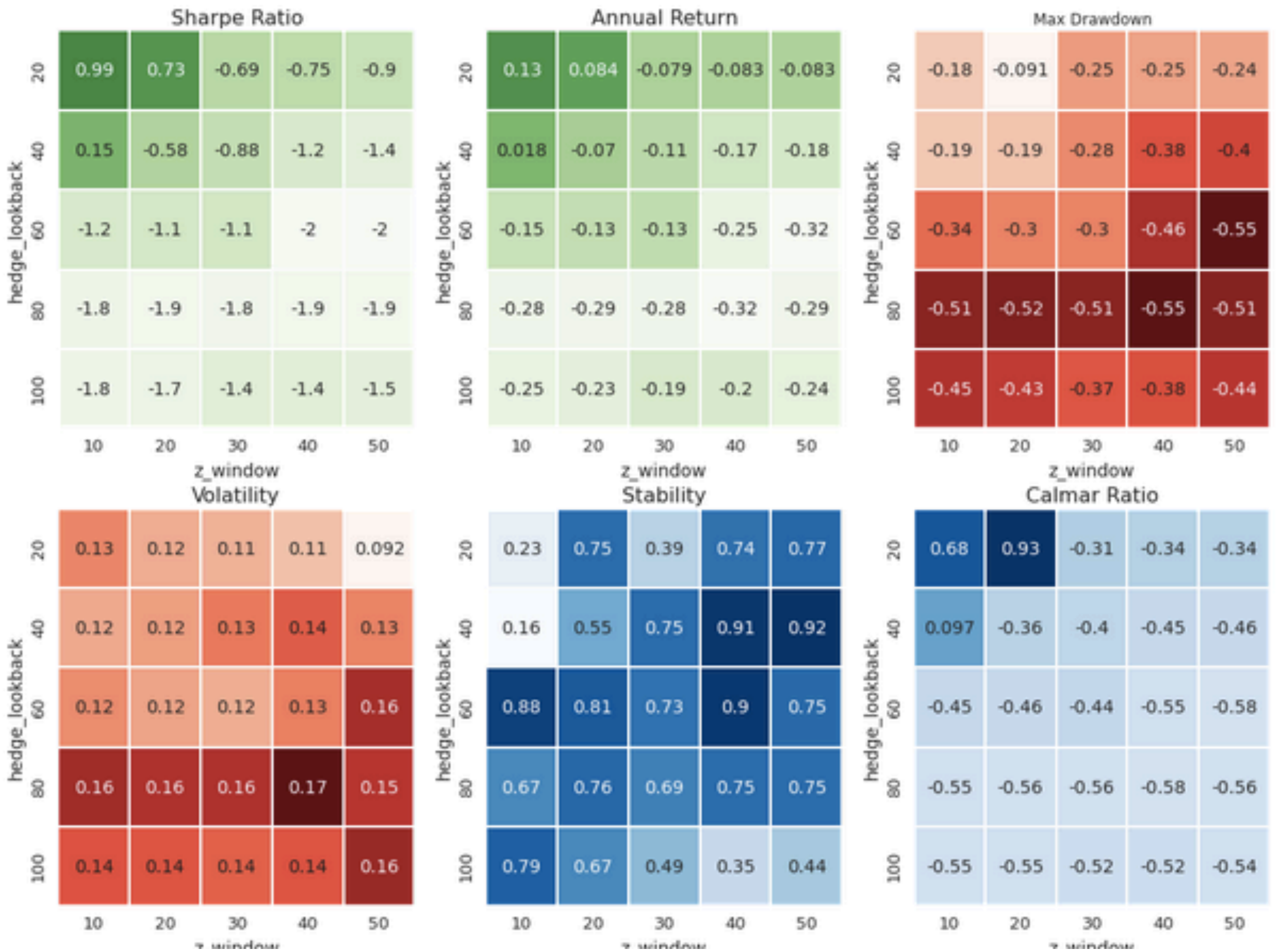
March 9, 2016

Abstract:
When automated trading strategies are developed and evaluated using backtests on historical pricing data, there exists a tendency to overfit to the past. Using a unique dataset of 888 algorithmic trading strategies developed and backtested on the Quantopian platform with at least 6 months of out-of-sample performance, we study the prevalence and impact of backtest overfitting. Specifically, we find that commonly reported backtest evaluation metrics like the Sharpe ratio offer little value in predicting out of sample performance ($R^2 < 0.025$). In contrast, higher order moments, like volatility and maximum drawdown, as well as portfolio construction features, like hedging, show significant predictive value of relevance to quantitative finance practitioners. Moreover, in line with prior theoretical considerations, we find empirical evidence of overfitting – the more backtesting a quant has done for a strategy, the larger the discrepancy between backtest and out-of-sample performance. Finally, we show that by training non-linear machine learning classifiers on a variety of features that describe backtest behavior, out-of-sample performance can be predicted at a much higher accuracy ($R^2 = 0.17$) on hold-out data compared to using linear, univariate features. A portfolio constructed on predictions on hold-out data performed significantly better out-of-sample than one constructed from algorithms with the highest backtest Sharpe ratios.

Number of Pages in PDF File: 19

Model Sensitivity to Input Parameter Values

- Pair trading example using Gold and Oil ETF's
  https://www.quantopian.com/posts/sensitivity-analysis-aka-parameter-optimization-of-pair-trade-input-parameters



Sharpe Ratio

hedge_lookback \ z_window	10	20	30	40	50
20	0.99	0.73	-0.69	-0.75	-0.9
40	0.15	-0.58	-0.88	-1.2	-1.4
60	-1.2	-1.1	-1.1	-2	-2
80	-1.8	-1.9	-1.8	-1.9	-1.9
100	-1.8	-1.7	-1.4	-1.4	-1.5

Annual Return

hedge_lookback \ z_window	10	20	30	40	50
20	0.13	0.084	-0.079	-0.083	-0.083
40	0.018	-0.07	-0.11	-0.17	-0.18
60	-0.15	-0.13	-0.13	-0.25	-0.32
80	-0.28	-0.29	-0.28	-0.32	-0.29
100	-0.25	-0.23	-0.19	-0.2	-0.24

Max Drawdown

hedge_lookback \ z_window	10	20	30	40	50
20	-0.18	-0.091	-0.25	-0.25	-0.24
40	-0.19	-0.19	-0.28	-0.38	-0.4
60	-0.34	-0.3	-0.3	-0.46	-0.55
80	-0.51	-0.52	-0.51	-0.55	-0.51
100	-0.45	-0.43	-0.37	-0.38	-0.44

Volatility

hedge_lookback \ z_window	10	20	30	40	50
20	0.13	0.12	0.11	0.11	0.092
40	0.12	0.12	0.13	0.14	0.13
60	0.12	0.12	0.12	0.13	0.16
80	0.16	0.16	0.16	0.17	0.15
100	0.14	0.14	0.14	0.14	0.16

Stability

hedge_lookback \ z_window	10	20	30	40	50
20	0.23	0.75	0.39	0.74	0.77
40	0.16	0.55	0.75	0.91	0.92
60	0.88	0.81	0.73	0.9	0.75
80	0.67	0.76	0.69	0.75	0.75
100	0.79	0.67	0.49	0.35	0.44

Calmar Ratio

hedge_lookback \ z_window	10	20	30	40	50
20	0.68	0.93	-0.31	-0.34	-0.34
40	0.097	-0.36	-0.4	-0.45	-0.46
60	-0.45	-0.46	-0.44	-0.55	-0.58
80	-0.55	-0.56	-0.56	-0.58	-0.56
100	-0.55	-0.55	-0.52	-0.52	-0.54

Summary

- ***Zipline*** backtester can be used standalone or in the Quantopian IDE
  - Support for testing and trading futures contracts is coming

- ***pyfolio*** bundles various useful portfolio analyses tools and includes Bayesian modeling functionality beyond what was presented today
  - Can be used with Zipline/Quantopian developed strategies or simply on a CSV file of daily returns

- Quantopian's Jess Stauth, PhD. "Using pyfolio" webinar: https://www.youtube.com/watch?v=-VmZAlBWUko

- ***pyfolio*** is still young -- please contribute: https://github.com/quantopian/pyfolio/labels/help%20wanted

Thank you.
Questions?

justin@quantopian.com

These slides and the example Zipline algo ipython notebook will be made available here:

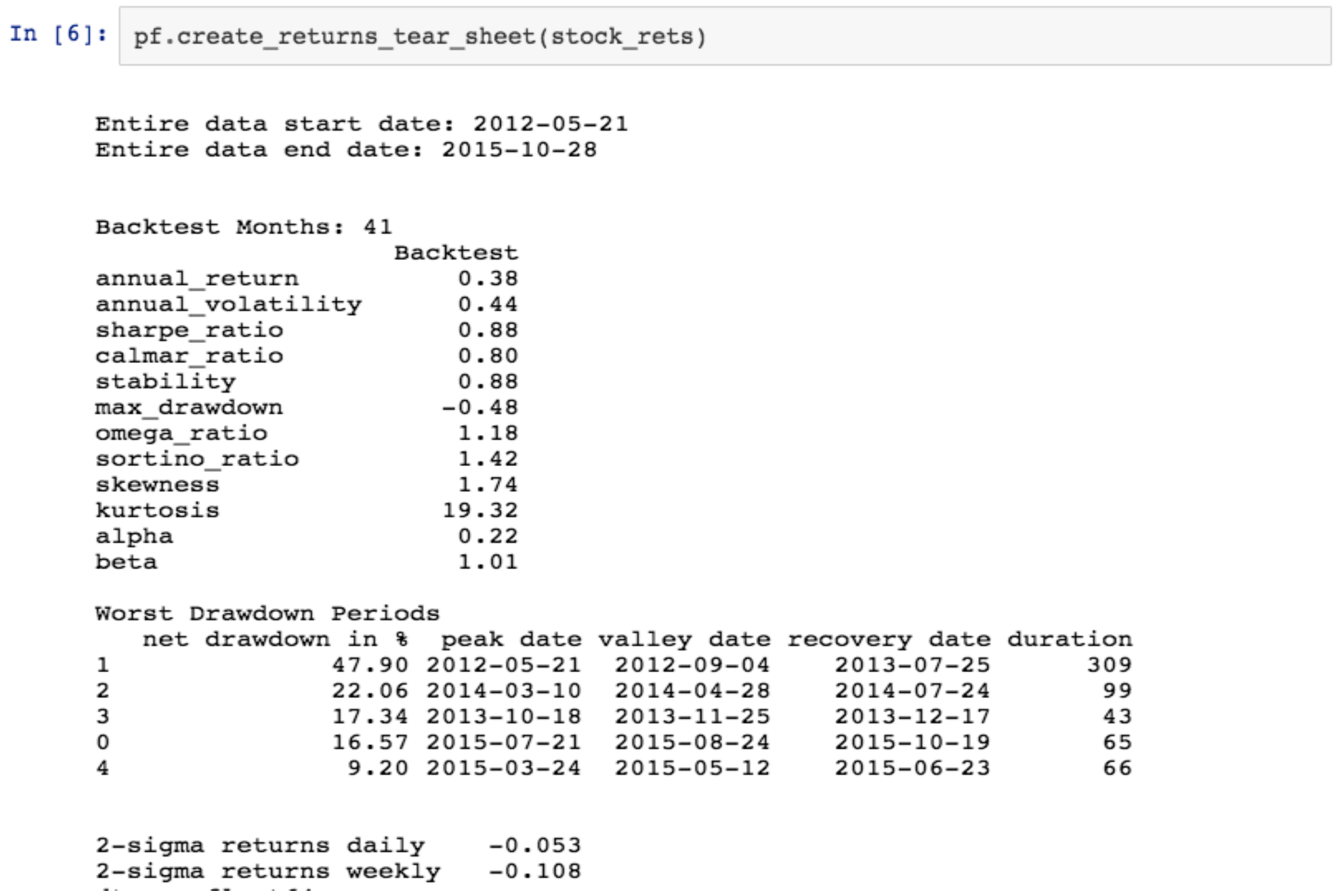
https://github.com/quantopian/research_public/

- Look in folder: /workshops/StartupML_05_12_2016

Disclaimer

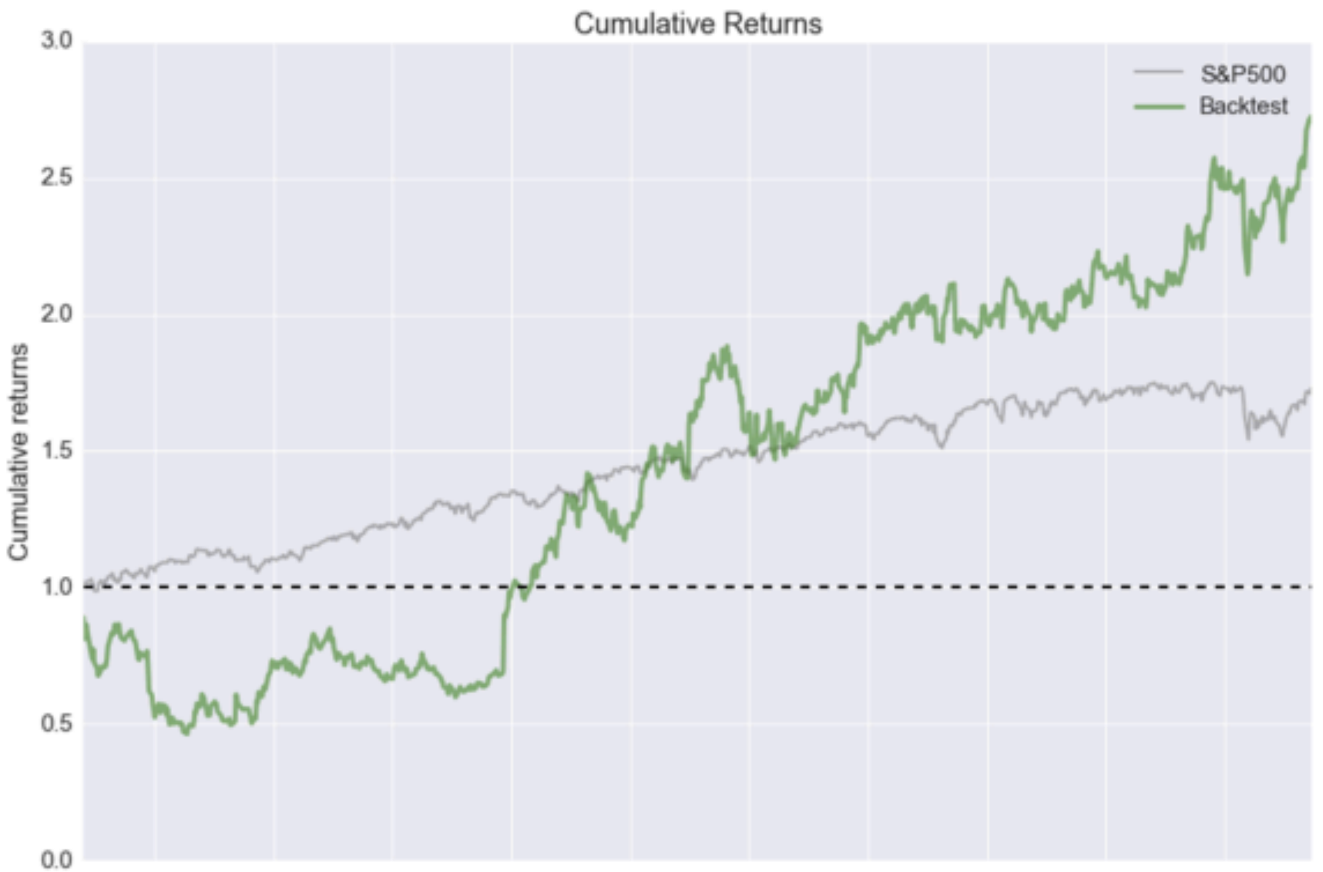
Appendix

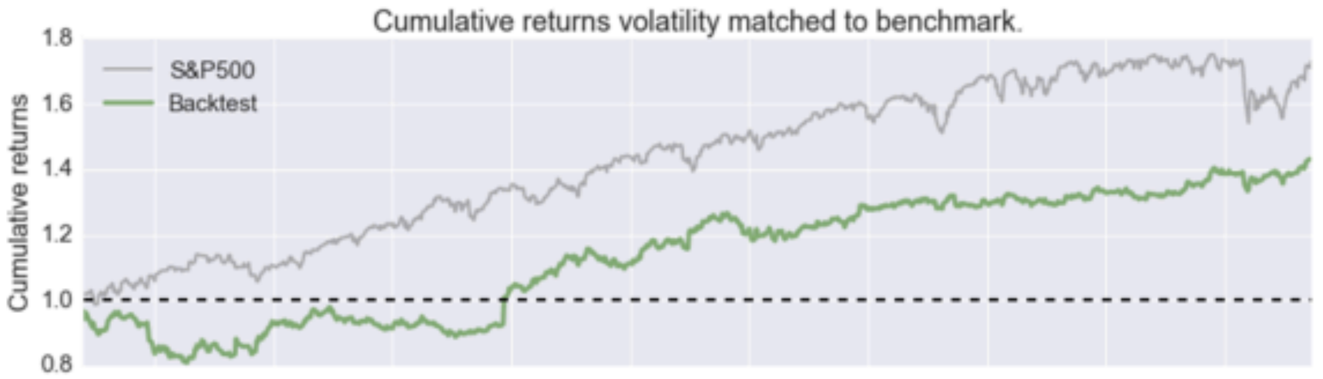
Pyfolio Tearsheet Components

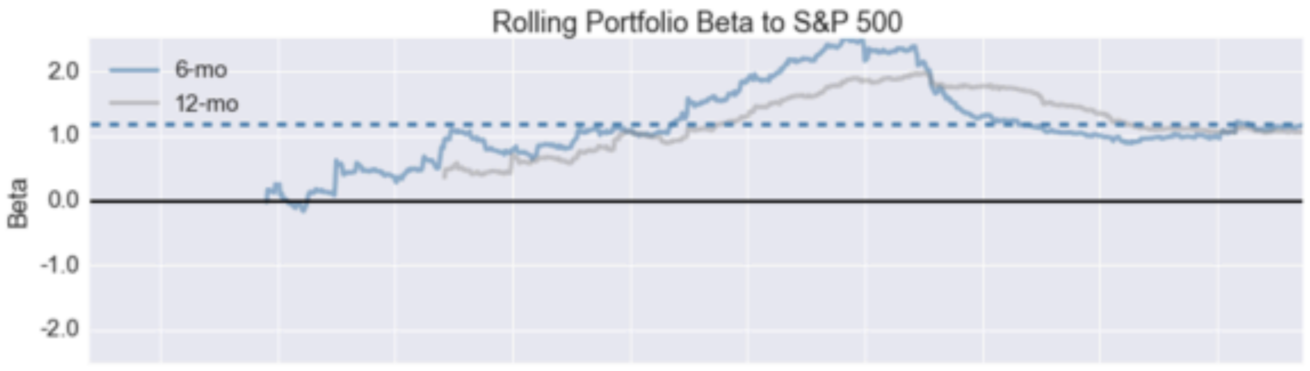


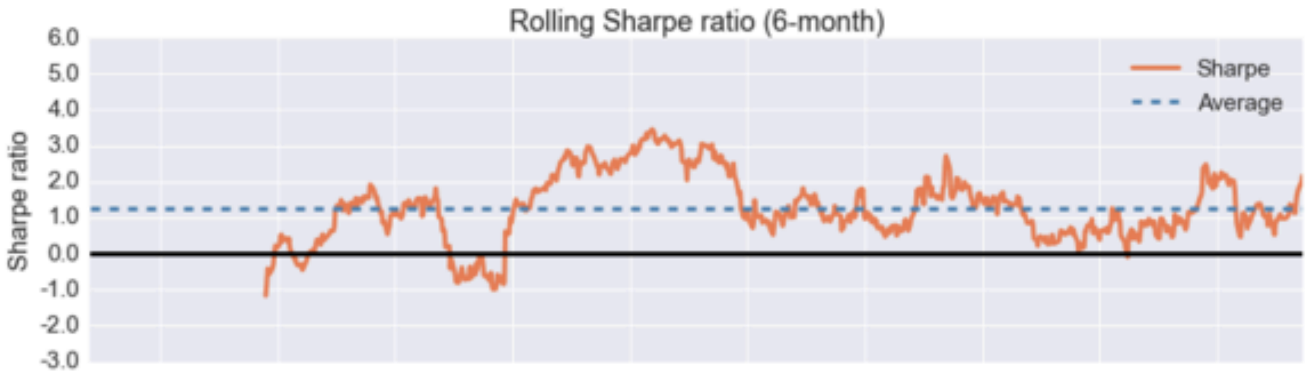
```
In [6]: pf.create_returns_tear_sheet(stock_rets)
```

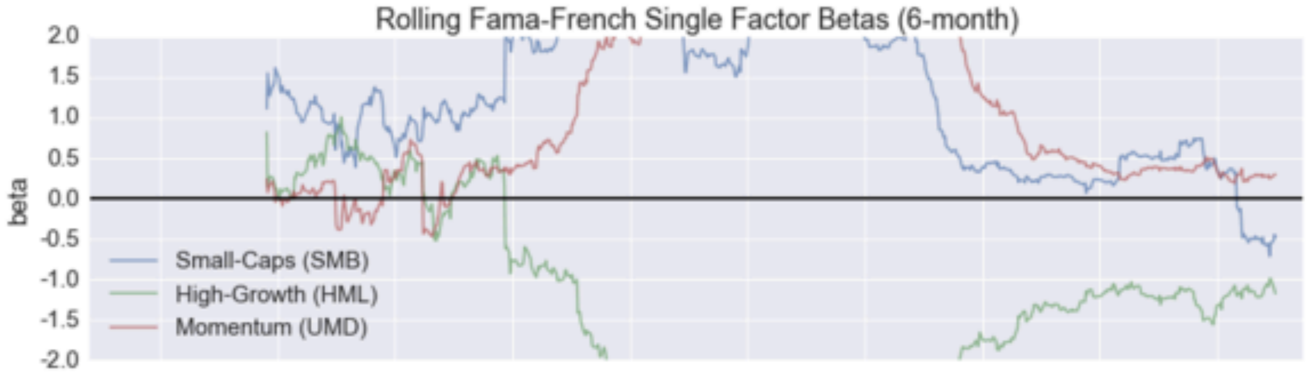
```
Entire data start date: 2012-05-21
Entire data end date: 2015-10-28


Backtest Months: 41
                   Backtest
annual_return          0.38
annual_volatility      0.44
sharpe_ratio           0.88
calmar_ratio           0.80
stability              0.88
max_drawdown          -0.48
omega_ratio            1.18
sortino_ratio          1.42
skewness               1.74
kurtosis              19.32
alpha                  0.22
beta                   1.01

Worst Drawdown Periods
   net drawdown in %  peak date valley date recovery date duration
1              47.90 2012-05-21  2012-09-04    2013-07-25      309
2              22.06 2014-03-10  2014-04-28    2014-07-24       99
3              17.34 2013-10-18  2013-11-25    2013-12-17       43
0              16.57 2015-07-21  2015-08-24    2015-10-19       65
4               9.20 2015-03-24  2015-05-12    2015-06-23       66


2-sigma returns daily    -0.053
2-sigma returns weekly   -0.108
```


Cumulative Returns
Cumulative returns
3.0
2.5
2.0
1.5
1.0
0.5
0.0
S&P500
Backtest


Cumulative returns volatility matched to benchmark.
Cumulative returns
1.8
1.6
1.4
1.2
1.0
0.8
S&P500
Backtest

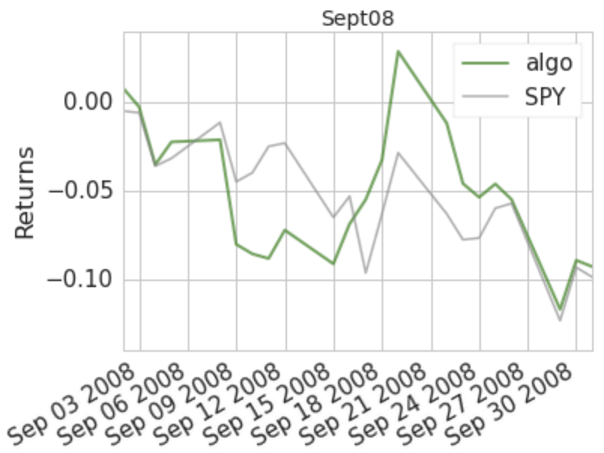

Rolling Portfolio Beta to S&P 500
6-mo
12-mo
Beta
2.0
1.0
0.0
-1.0
-2.0

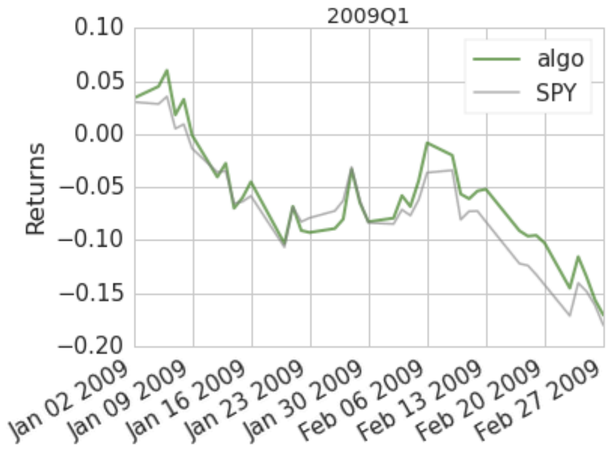

Rolling Sharpe ratio (6-month)
Sharpe
Average
Sharpe ratio
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0

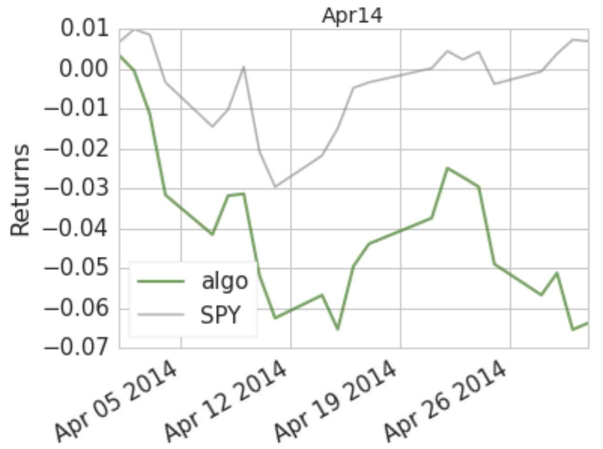

Rolling Fama-French Single Factor Betas (6-month)
Small-Caps (SMB)
High-Growth (HML)
Momentum (UMD)
beta
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

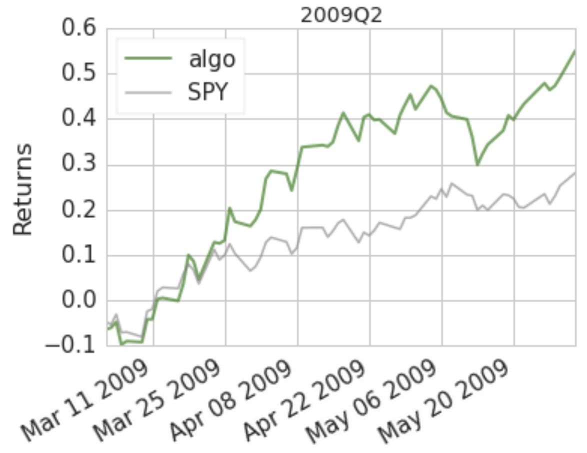
Performance during Market Stress Events

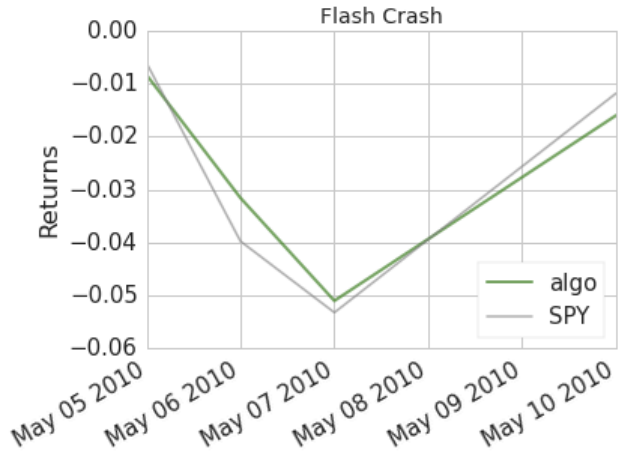
Pyfolio contains 15-20 pre-defined market stress periods so you can easily see how well your strategy performs during crisis events

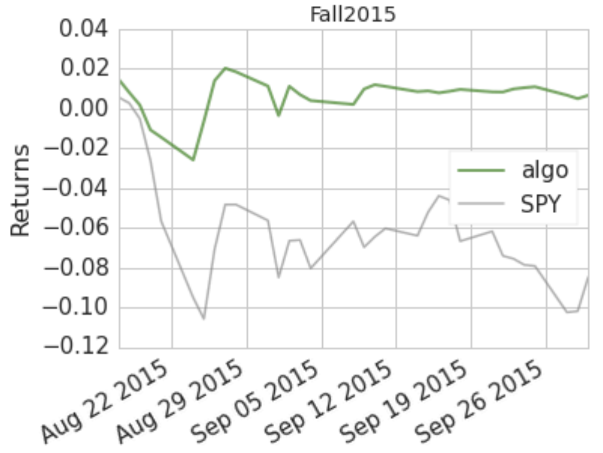


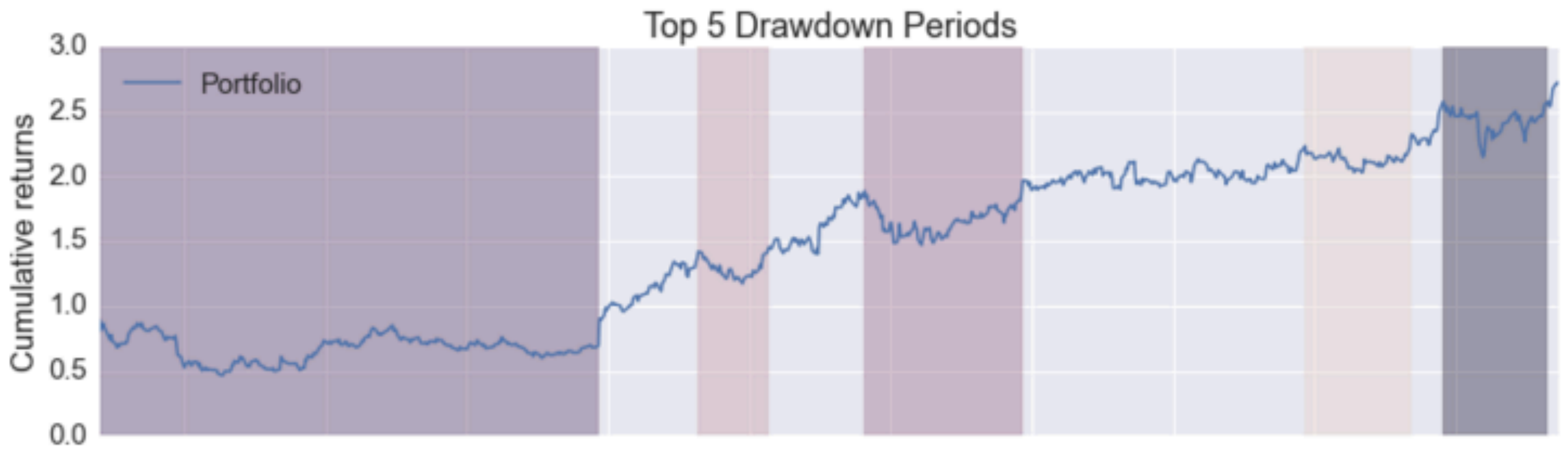


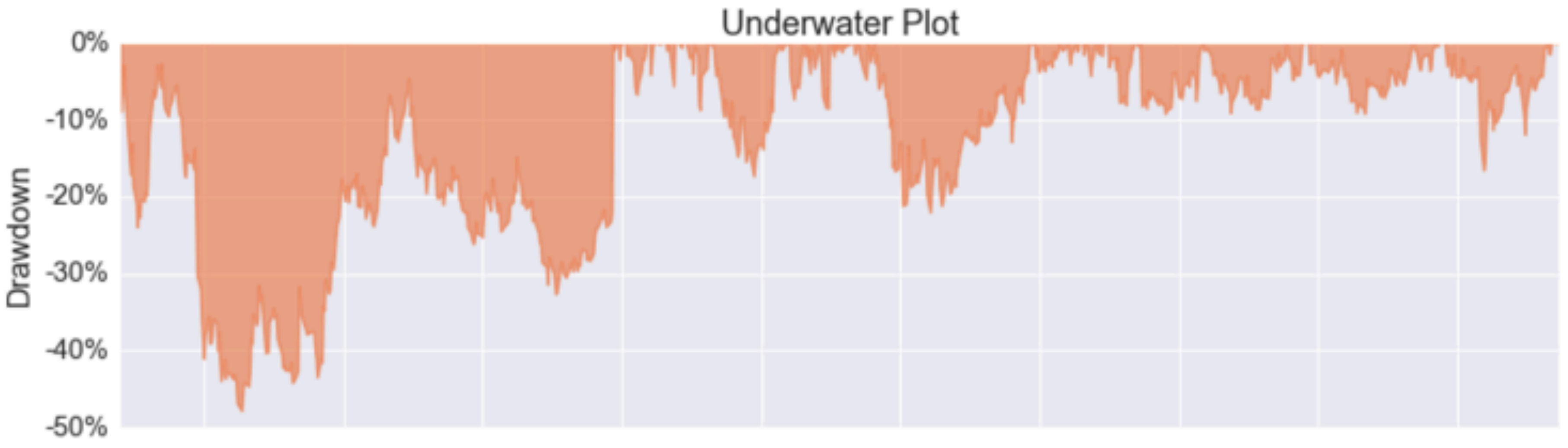


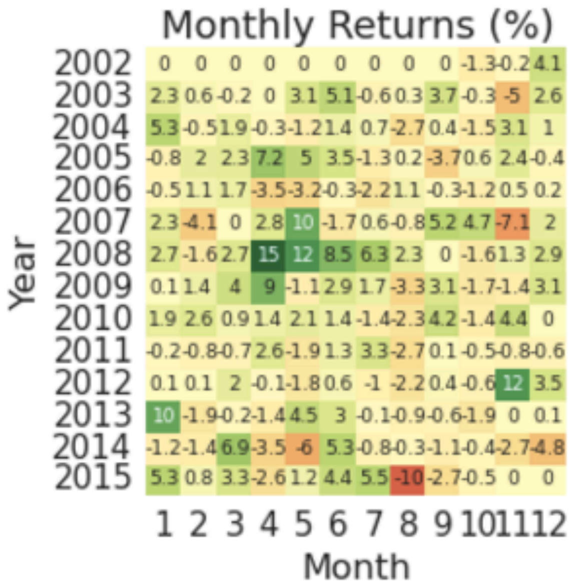




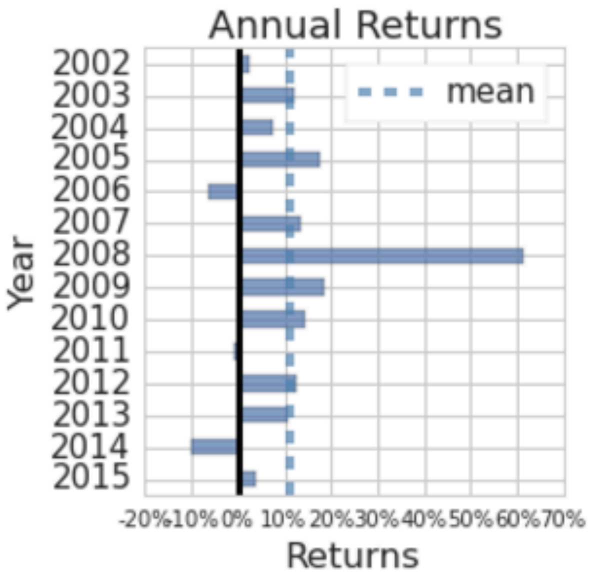


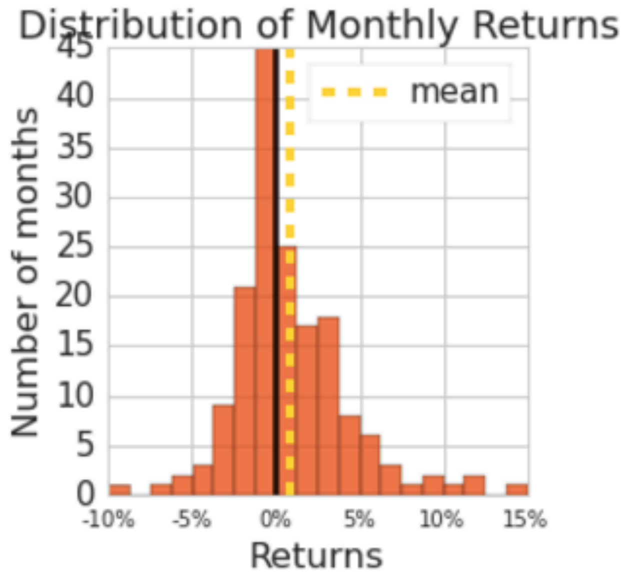

Top 5 Drawdown Periods
Portfolio
Cumulative returns
3.0
2.5
2.0
1.5
1.0
0.5
0.0

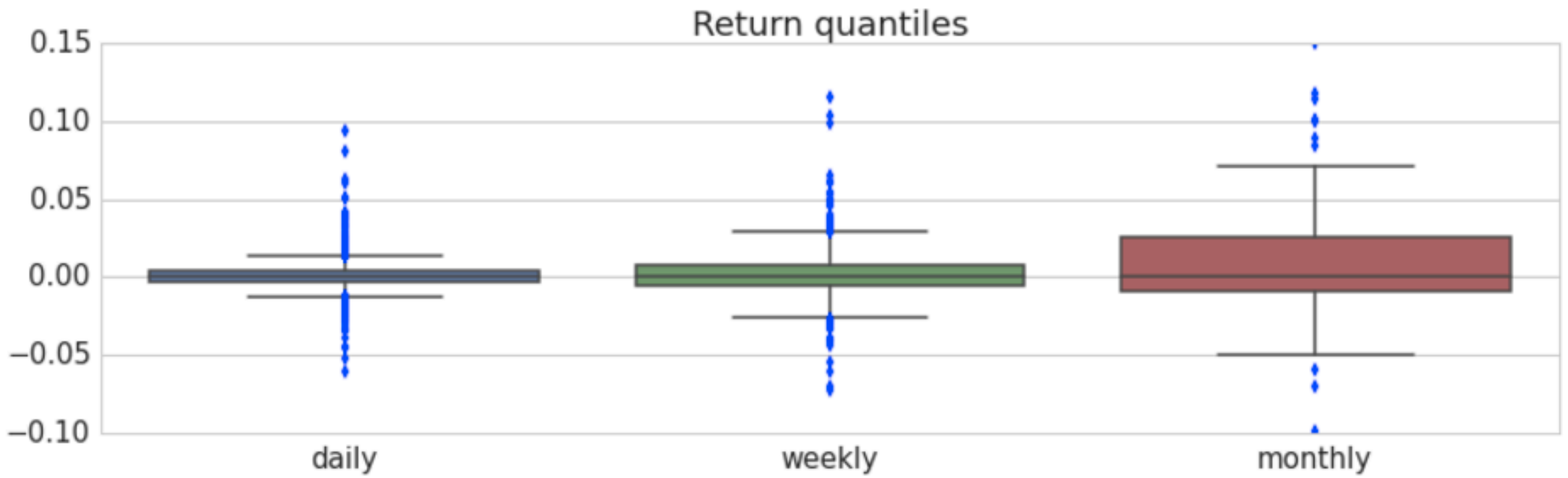

Underwater Plot
Drawdown
0%
-10%
-20%
-30%
-40%
-50%



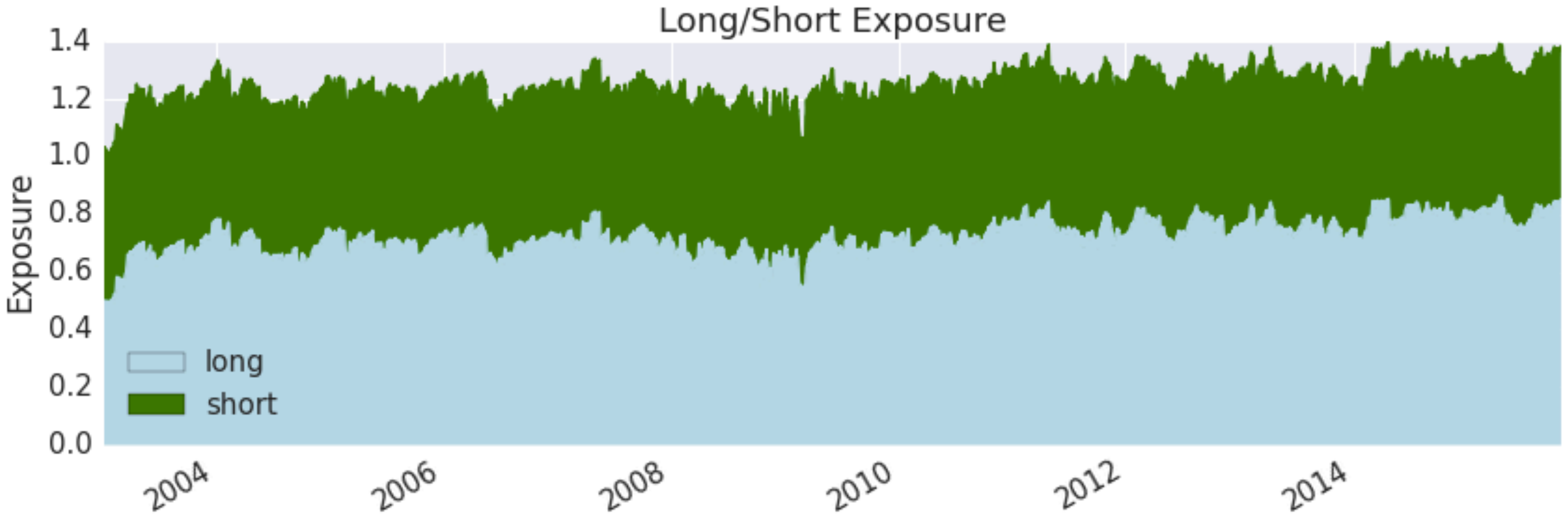
Year	1	2	3	4	5	6	7	8	9	10	11	12
2002	0	0	0	0	0	0	0	0	0	-1.3	-0.2	4.1
2003	2.3	0.6	-0.2	0	3.1	5.1	-0.6	0.3	3.7	-0.3	-5	2.6
2004	5.3	-0.5	1.9	-0.3	-1.2	1.4	0.7	-2.7	0.4	-1.5	3.1	1
2005	-0.8	2	2.3	7.2	5	3.5	-1.3	0.2	-3.7	0.6	2.4	-0.4
2006	-0.5	1.1	1.7	-3.5	-3.2	-0.3	-2.2	1.1	-0.3	-1.2	0.5	0.2
2007	2.3	-4.1	0	2.8	10	-1.7	0.6	-0.8	5.2	4.7	-7.1	2
2008	2.7	-1.6	2.7	15	12	8.5	6.3	2.3	0	-1.6	1.3	2.9
2009	0.1	1.4	4	9	-1.1	2.9	1.7	-3.3	3.1	-1.7	-1.4	3.1
2010	1.9	2.6	0.9	1.4	2.1	1.4	-1.4	-2.3	4.2	-1.4	4.4	0
2011	-0.2	-0.8	-0.7	2.6	-1.9	1.3	3.3	-2.7	0.1	-0.5	-0.8	-0.6
2012	0.1	0.1	2	-0.1	-1.8	0.6	-1	-2.2	0.4	-0.6	12	3.5
2013	10	-1.9	-0.2	-1.4	4.5	3	-0.1	-0.9	-0.6	-1.9	0	0.1
2014	-1.2	-1.4	6.9	-3.5	-6	5.3	-0.8	-0.3	-1.1	-0.4	-2.7	-4.8
2015	5.3	0.8	3.3	-2.6	1.2	4.4	5.5	-10	-2.7	-0.5	0	0



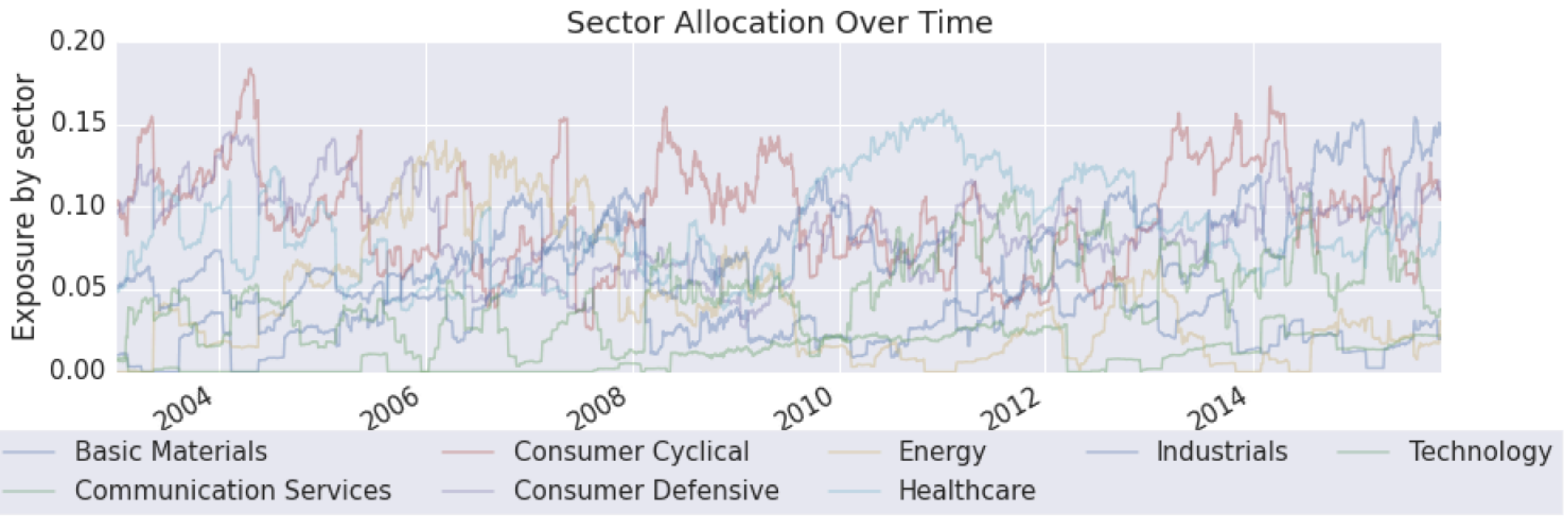


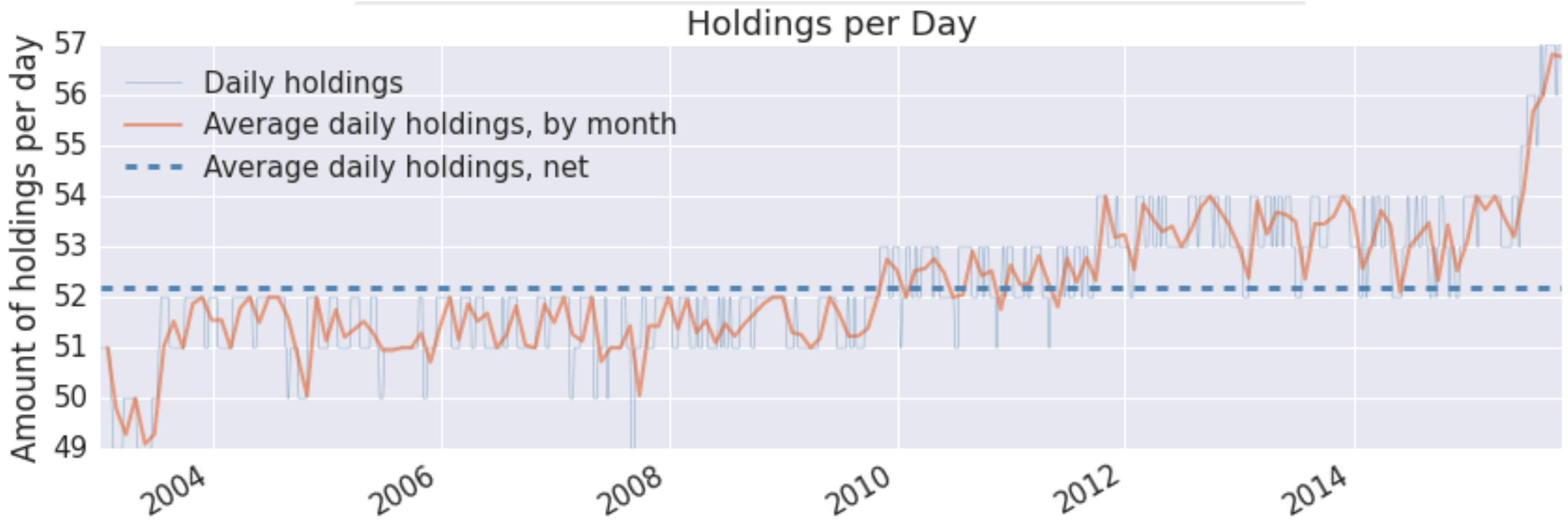


Long/Short Exposure over Time



Sector Exposure over Time



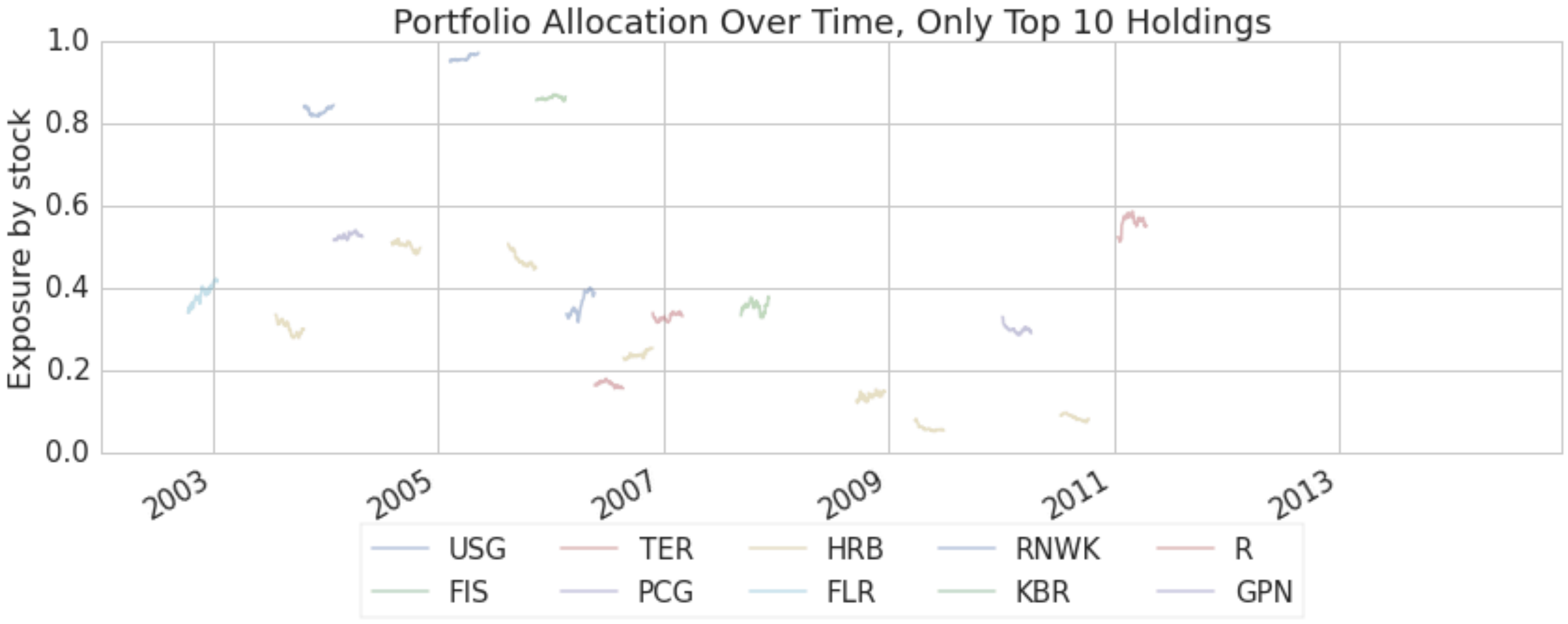


Single Stock Concentration

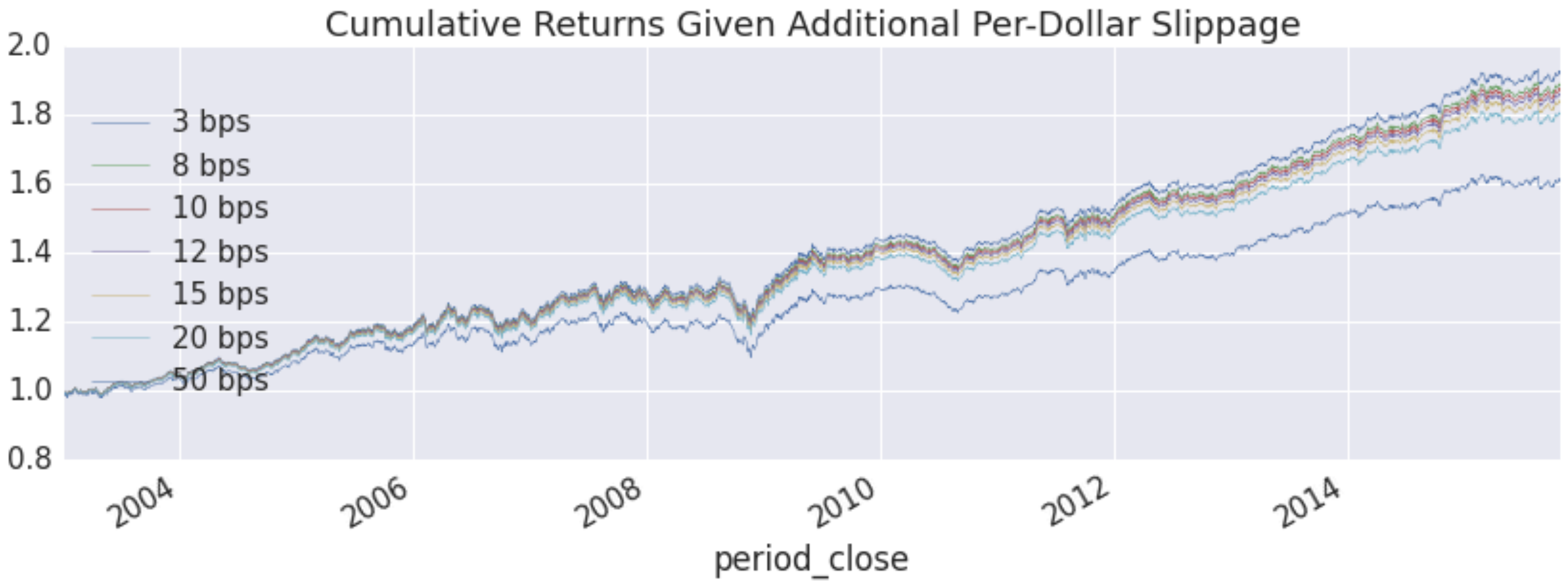
```
Top 10 long positions of all time (and max%)
[u'USG' u'FIS' u'TER' u'PCG' u'HRB' u'FLR' u'RNWK' u'KBR' u'R' u'GPN']
[ 0.972  0.87   0.586  0.54   0.52   0.423  0.401  0.379  0.343  0.33 ]
```

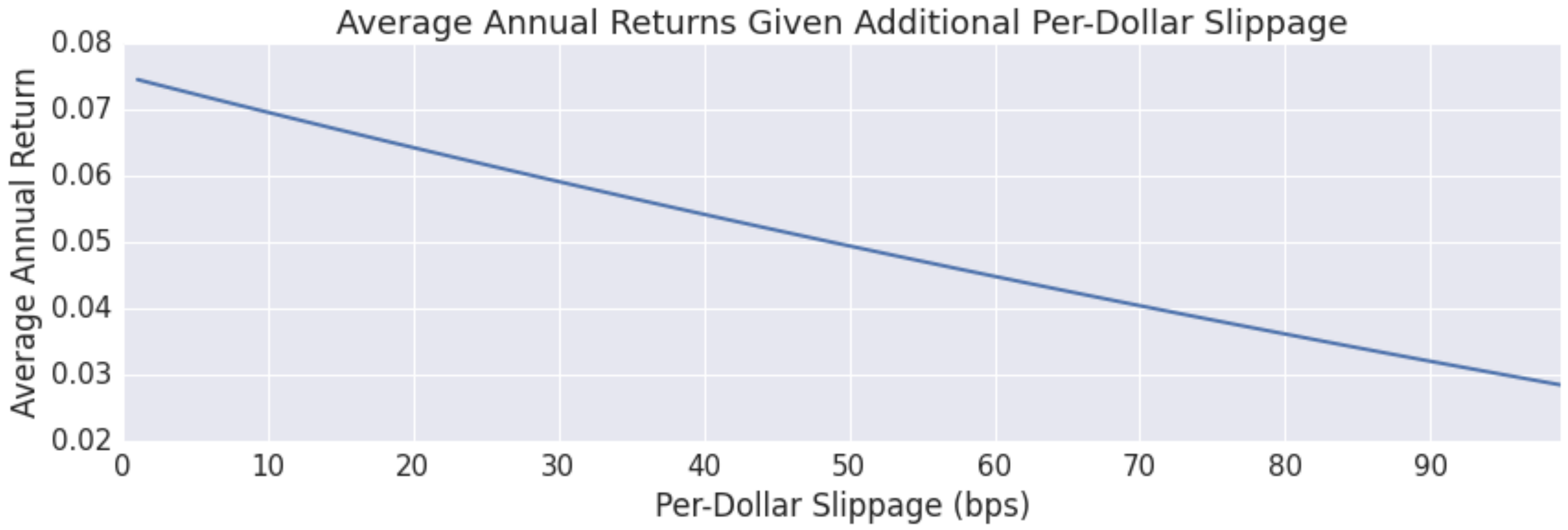
Red Flag, at 1 point, USG was 97% of the portfolio!

```
Top 10 short positions of all time (and max%)
[]
[]
```



Slippage and Transaction Cost Sensitivity

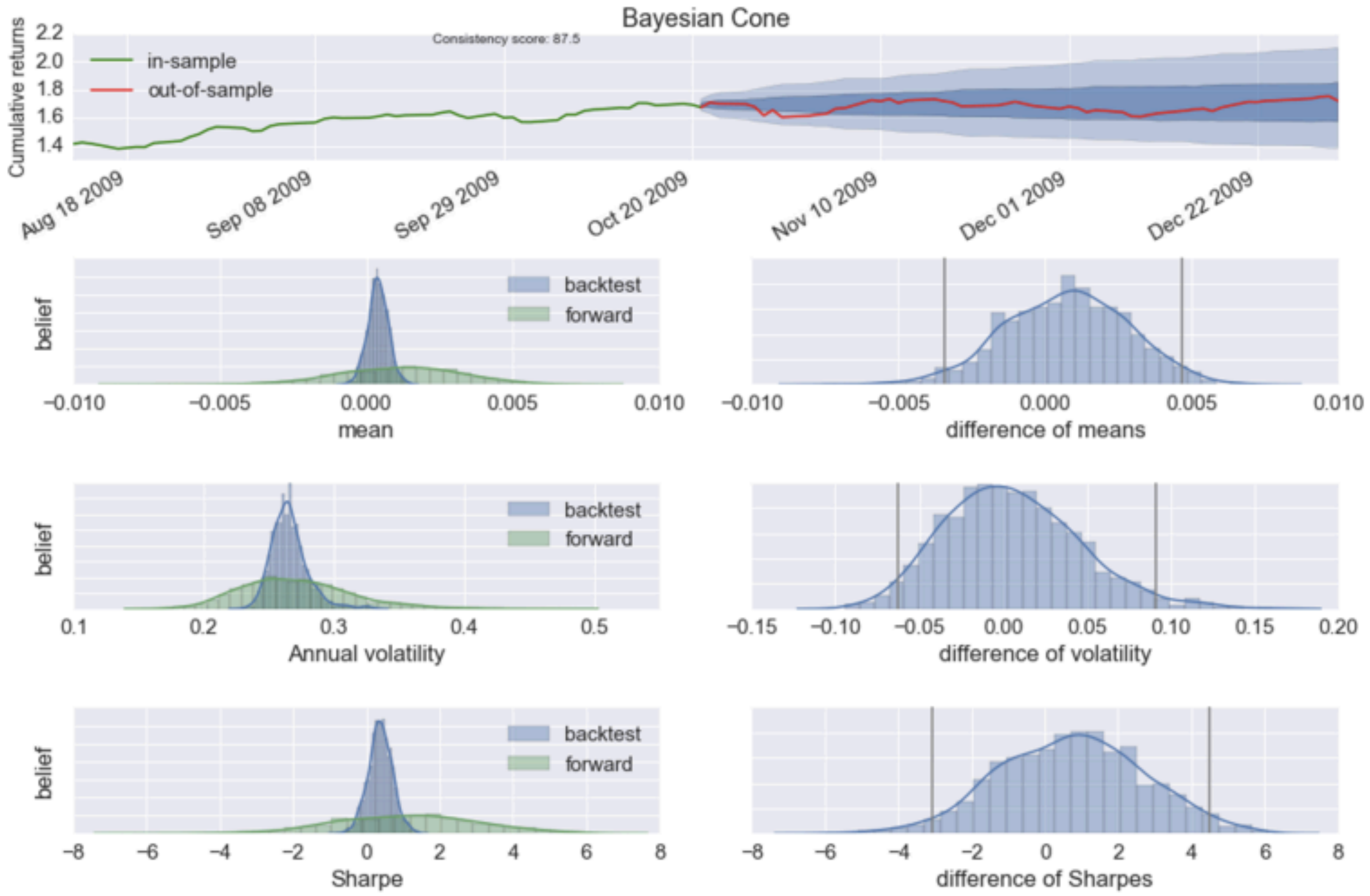




Bayesian analysis in pyfolio

- Sneak-peek into ongoing research.
- Primary focus is comparing backtest (in-sample) and forward-test (out-of-sample; OOS).
- Sophisticated statistical modeling takes *uncertainty* into account.
- Uses T-distribution to model returns (instead of normal).
  - Addresses ‘fat-tail’ nature of financial returns
- Relies on PyMC3.
  - Python module for Bayesian statistical modeling and model fitting which focuses on advanced Markov chain Monte Carlo fitting algorithms.

Modeling Trading Strategy Uncertainty with Bayesian Analysis



More Info on Bayesian Analysis

Accompanying blog post:
http://blog.quantopian.com/bayesian-cone/

Bayesian Methods for Hackers:
http://camdavidsonpilon.github.io/Probabilistic-Programming-and-Bayesian-Methods-for-Hackers/

Our Data Scientist's blog (Thomas Wiecki, PhD)

- twiecki.github.io
- Active developer of PyMC3: http://pymc-devs.github.io/pymc3

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