Momentum Strategies *using MATLAB*

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About Me

- Researcher at IBM T. J. Watson Lab in machine learning (‘94-’97).
- Quantitative researcher/trader for Morgan Stanley, Credit Suisse, and various hedge funds (‘97-’05).
- Principal of QTS Capital Management which manages a hedge fund as well as client accounts.
- Author:
  – *Quantitative Trading: How to Build Your Own Algorithmic Trading Business* (Wiley 2009).
  – *Algorithmic Trading: Winning Strategies and Their Rationale* (Wiley 2013).
- Blogger: epchan.blogspot.com

About You

- What's your name?
- Do you already trade algorithmically?
- Do you trade stocks, futures, or currencies?
- Do you program in MATLAB already?

What Cause Momentum?

- Futures: Persistence of roll returns.
- Slow diffusion, analysis and acceptance of new information. E.g. PEAD
- Forced sales or purchases of assets by index/mutual/hedge/exchange-traded funds.
  - Contagion due to
    - Risk management
    - Investors redemption/subscription
  - Index composition changes
  - Levered ETFs: Forced rebalancing at market close.

HFT and "Momentum Ignition"

- HFT: Market manipulation ignites momentum.
  - Quote matching
  - Flipping
  - Stop hunting
  - Front-running order flow
- We will examine trading strategies exploiting each cause of momentum.

MATLAB tutorial

- MATLAB is a software development platform that allows you to:
  - Backtest a trading strategy with very few lines of codes (because it is an *array processing* language).
  - Utilize ready-made toolboxes for specialized computation such as cointegration tests, optimization, volatility prediction (GARCH), etc.
  - Automate trading by receiving real-time market data, generating and submitting orders to brokerage, and monitoring positions and P&L.

Why MATLAB?

- You can tap into a large community of MATLAB users, programmers and free software for support.

- Why not use R?
  - Very similar to MATLAB, and it is free!
  - Mathworks, Inc. offers better customer support.
  - MATLAB toolboxes quality better assured.
  - R's debugger (R-Studio) is not very polished.
  - R is slower. (Rf. github.com/probml/pmtk3/wiki/WhyMatlab)
  - Hard to connect to .Net execution platform.
  - Cannot be compiled to C/C++.

Why MATLAB?

- Why not use Python?
  - Python is also free!
  - Python is not fully vectorized. Need for-loops often.
    - numpy and scipy are vectorized version of Python
  - Python has step-by-step debugger.
    - spyder
    - Can also use Visual Studio
  - Pandas extension: library built for data reading and analysis.
    - Can call R library.
  - Can be compiled to C/C++ for fast execution.

- MATLAB, R, Python can all connect to brokerages and used as execution platforms.
  - Latency is about 60ms vs <1ms for C++.
  - Matlab code can be complied into C/C++ to remove latency.
  - Matlab is fastest: economics.sas.upenn.edu/~jesusfv/comparison_languages.pdf

Arrays

- MATLAB has similar syntax as Basic.
- E.g. to initialize an array A, type

```
A=NaN(1, 3)
A(1)=0.1
A(2)=0.2
```

- To stop printing content of array, just add ;

```
A;
```

Arrays

- To add a comment, use %

```
A(3)=0.3; % we are adding a third element to A
% everything after the % is ignored
```

- Concatenate 2 arrays

```
X=[1 3 4]
Y=[6 8 9]
Z=[X Y] % concatenate by columns
W=[X; Y] % guess what this is?
```

Value assignment

- You can assign a common value to a large number of array elements.

```
U=0.8*ones(1, 3) % an array with dimension 1x3, i.e. a
  row vector
V=zeros(4,2) % an array with dim 4x2
X=false(3) % a 3x3 logical array
```

Value assignment

- You can construct an array by an explicit list

```
X=[4 5 6] % a row vector
Y=[7, 8, 9] % also a row vector
Z=[-1; -2; -5] % a column vector
```

Cell arrays

- Can have a cell array of strings

```
Y={'IBM', 'MSFT', 'GOOG'} % a cell array (row vector)
Z={'A'; 'C'; 'F'} % a column vector of strings
```

- Useful for sending orders.
- Useful for parsing and analyzing news.

Arithmetics

- Adding 2 vectors, the old-fashsioned (Basic) way

```
x=[1 2 3];
y=[4 5 6];
z=NaN(1, 3);
for i=1:3 % 1:3 is [1 2 3]
    z(i)=x(i)+y(i)
end
```

Arithmetics

- But you can also use the MATLAB way

```
z=x+y
```

- Array multiplication and division

```
z=x.*y % . Indicates element-by-element operation
z=x./y
```

- Matrix multiplication

```
x=randn(3)
y=randn(3)
x*y % Guess what this is?
x/y % Guess what this is?
```

Arithmetics

- Transpose of a matrix

```
A'
```

- Inverse of a matrix

```
inv(A)
eye(size(A,1))/A
```

Subarrays

```
y=[0.1 0.2 0.3 0.4 0.5]
y([1 3]) % select 1st and 3rd elements
y([1:3 5]) % 1:3 means 1st to 3rd elements
y([3:end]) % 3:end means 3rd to last
  elements
y([end:-1:1]) % what do you think this is?
  % end:-1:1 means starts from last element
  and moves up to 1
y([end:-2:1]) % what do you think this is?
  % starts from last element and moves up 2
  at a time
```

Subarrays

- Selecting entire rows or columns

```
x=[1 2 3; 4 5 6; 7 8 9]
xr=x(1, :) % entire first row selected
xc=x(:, 2) % entire second column selected
```

Exercise

- Create an array as follows:

```
data=[20100917 13.45; ...
      20100916 14.00; ...
      20100915 14.23]
```

- This could represent a price array with dates, in reverse chronological order.
- Question: How do you re-fashion the array so that it is in chronological order?

Answer

- `data=data(end:-1:1, :)`
- Alternatively:

```
data=flipud(data);
```

Or:

```
data=sortrows(data, 1);
```

Subarrays

- Selecting a subarray by logical values:

```
x=[1.3 -2 4 5]
xlogical=x>2 % what are the values of xlogical?
[0 0 1 1 ]
x(xlogical) % what do you think this is?
[4 5]
```

- Short-hand for logical selection

```
x(x>2)
```

Subarrays

- **Find**ing the indices of a subarray that fits some criterion

```
v=[3 7 9]
idx=find(v>5) % what do you think this is
idx=[2 3]
```

- Can of course use this index array to select subarray too

```
v(idx)
```

Subarrays

- Adding subarrays

```
x=[1 2 3]
y=[0.1 0.2 0.3 0.4 0.5]
x([1 3]) + y([4 2]) % Guess what this is?
```

- Deleting subarrays

```
x([1 3])=[]
```

- Deleting entire rows or columns

```
x=[1 2 3; 4 5 6; 7 8 9]
x(1, :)=[] % entire 1st row deleted
x(:, 2)=[] % entire 2nd column deleted
```

Exercise

- Create this random array:

```
data=rand(10, 2)
```

- How do you delete a row that has a number smaller than 0.5 in the second column?

Answer

- `data(data(:, 2) < 0.5, :)=[]`

Functions on arrays

- Beauty of MATLAB: all built-in functions work on arrays.

```
x=[3 4 5]
log(x) % what do you think this gives?
```

- Lots of built-in functions

```
sum, cumsum, diag, max, min, mean, std, corrcoef,
  repmat, reshape, squeeze, sort, sortrow,
rand, size, length, eigs,  fix, round, floor, ceil,
  mod, factorial, setdiff, union, intersect,
ismember, unique, any, all, eval, eye, ones,
  strmatch, regexp, regexprep, plot, hist, bar,
scatter, try, catch, circshift, datestr, datenum,
  isempty, isfinite, isnan, islogical, randperm, …
```

Functions

- Lots of functions from toolboxes:

`fft, qz, svd, chol, ode45, pdepe, fminsearch, optimset, quad, airy, besselh, beta, ellipj, erf, gamma, legendre, …`

- Useful native toolboxes:

  Datafeed, trading, **statistics**, financial, financial instruments, fixed-income, econometrics (including GARCH), optimization, global optimization, **neural networks**, wavelets

- Freeware: spatial-econometrics.com

Exercise

- Build a user-defined function mybackshift(lag, x)
  - This function will lag an array by one period (e.g. 1 day).

```
cls=[11 12 13 14]' % Column vector
prevCls=mybackshift(1, cls) % prevCls=[NaN 11 12 13]'
```

  - Extremely useful for time series data, e.g. calculate daily returns

```
dailyret=(cls-mybackshift(1, cls))./mybackshift(1, cls)
```

Exercise

- Construct the mybackshift function by File->New->Function and save your file in C:/PairsWS/mybackshift.m
- Make sure that

  cls=[11 12 13 14]’ and

  mybackshift(1, cls) is [NaN 11 12 13]’

Answer

```
function y=mybackshift(lag,x)
% y=mybackshift(lag,x)
y=[NaN(lag,size(x,2)); x(1:end-lag,:)];
```

Exercise

- Build a moving average function: mymovingAvg(x, lookback)

```
x=[ 1 2 -3;
    3 4  0;
    0 6  20;
    5 8  -10];
```

- Make sure that the output of mymovingAvg(x, 2) is

```
[NaN NaN NaN;
 2   3   -1.5;
 1.5 5   10;
 2.5 7   5];
```

Answer

```
function [mvavg] = movingAvg(x, lookback)
   mvavg=zeros(size(x));
   for i=0:lookback-1
          mvavg=mvavg+backshift(i, x);
   end
   mvavg=mvavg / lookback;
```

Exercise

- Think of something you often do with price or position arrays in Excel or other programs, and figure out how you can do that in MATLAB.

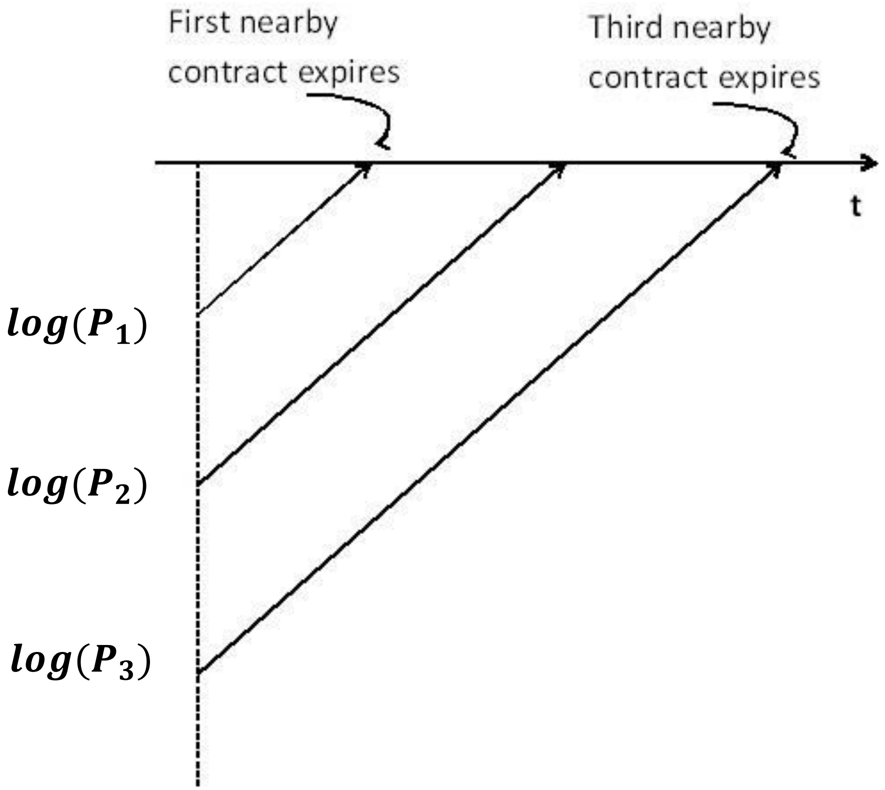
More on MATLAB

- Things I have not covered in details:
  - String processing: regular expressions. (Useful for scrapping website for information.)
  - Plotting, animation.
  - GUI development.
- Additional learning materials:
  - www.mathworks.com/moler/
  - cseweb.ucsd.edu/~datorres/docs/MatlabTip.pdf
  - en.wikibooks.org/wiki/MATLAB_Programming

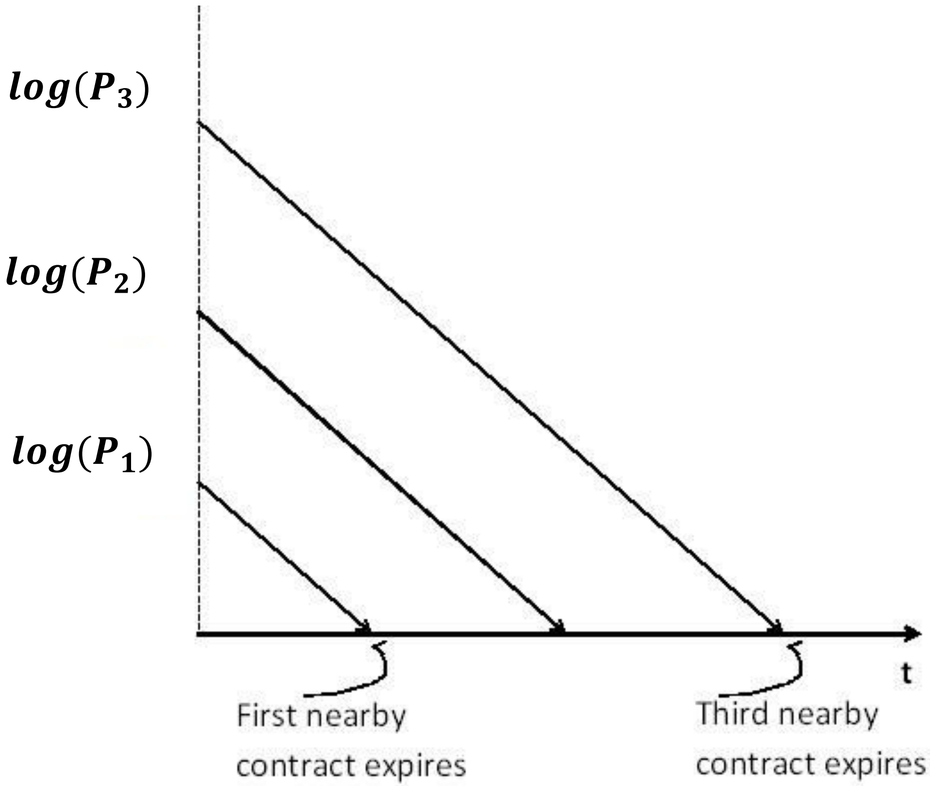
Roll Returns As Driver of Futures Momentum

- Total returns in futures = returns of spot price+roll returns.
  - Even if spot price is unchanged, futures price can still change.
  - If roll return is positive: (normal) backwardation.
  - If roll return is negative: contango.

Backwardation



Contango



$log(P_3)$
$log(P_2)$
$log(P_1)$
t
First nearby contract expires
Third nearby contract expires

Forward Curves

- “Forward curve” of futures = plots of futures prices against time-to-maturity at a fixed time in history.
  - As opposed to our plots of prices evolving in time.
- Also called “term structure” of futures.
- *Exercise:* Sketch the forward curves of futures in backwardation and contango, respectively.

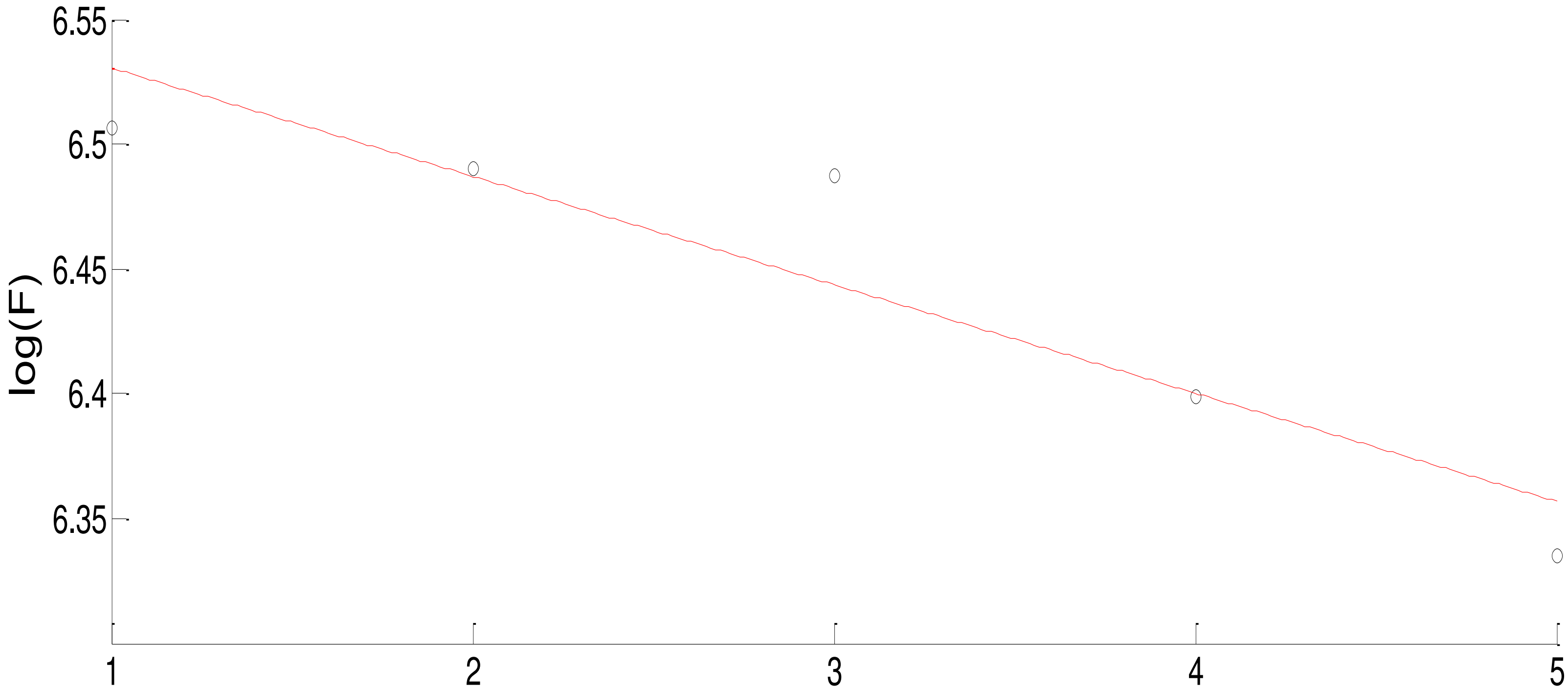
Exercise: Estimating Spot and Roll Returns

- Assume both spot and roll returns are constant over time:
  - $F(t,T) = c\ e^{\alpha t} exp(\gamma(t-T))$ where t is current date, T is expiration date, c, α (spot return), and γ (roll return) are constants.
- Input: Corn futures closing price data in a $\mathcal{T}$xM array *cl*, where $\mathcal{T}$ is the number of trading days, and M is the number of contracts.
  - epchan.com/book2/inputDataDaily_C2_20120813.mat (userid/pw=kelly).
  - Contract ending in 0000$ is spot price.

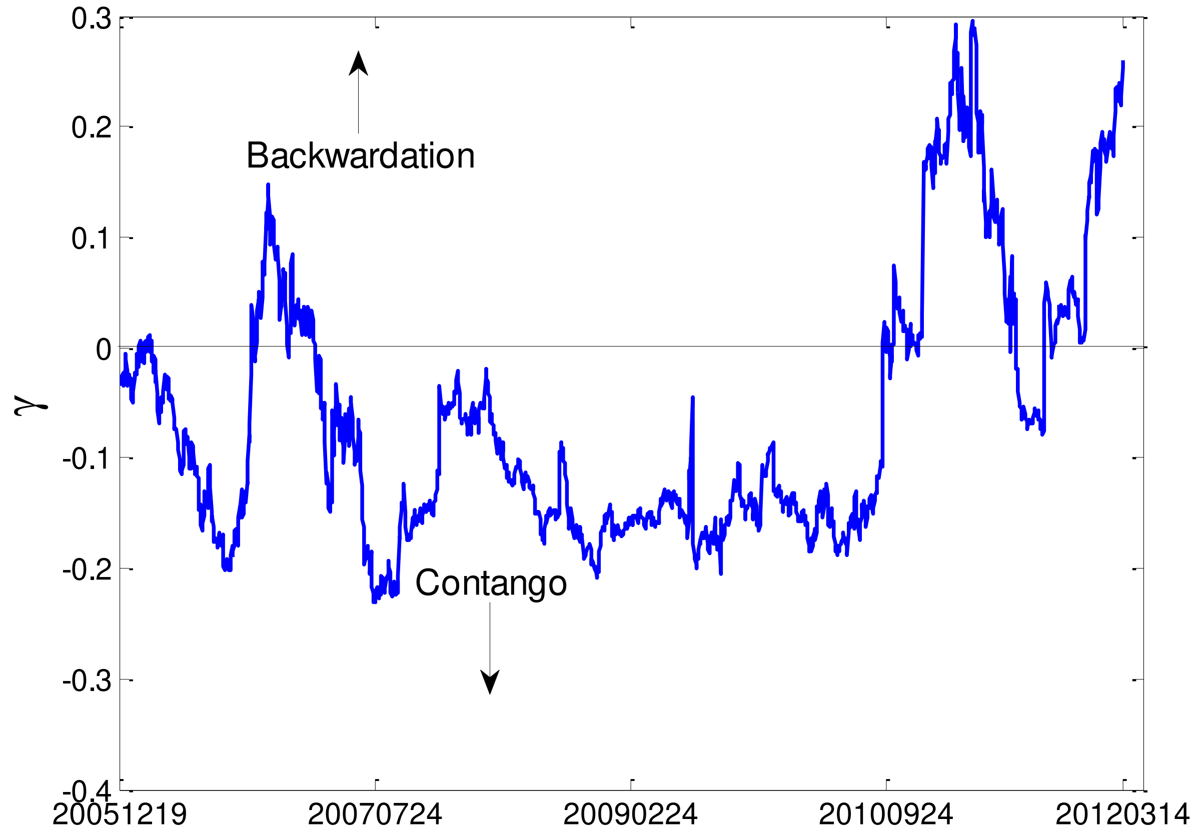
Exercise: Estimating Spot and Roll Returns

- Take the log of the cash and futures prices.
- Use linear regression (*ols* from spatial-econometrics.com) on the cash prices to find α.
- Pick an arbitrary date, select the 5 nearest contracts, and plot their prices against time-to-maturity.
  - Verify that the plot fits a straight line!
- For every date, again select the 5 nearest contracts, and use *ols* to find γ.
- Plot γ as a function of date.
  - Identify when backwardation and contango occurred.
- Solution program is *estimateFuturesReturns.m*

Futures prices vs Time-to-Maturity (Forward curve)



Roll returns as function of time



Spot vs Roll Returns

- α =slope of log cash prices vs time

  =2.8%
- γ =slope of forward curve (log futures prices vs time-to-maturity).
- Note during longer periods, $|\gamma| \gg \alpha$
  - Very favorable for momentum trading!

Types of Momentum

- Time series momentum:
  - Past returns of a price series are positively correlated with future returns.
  - E.g. A stock that went up will go higher.
- Cross-sectional momentum:
  - Past *relative* returns are positively correlated with future *relative* returns.
  - I.e. Past returns of an instrument that out(under)-performs another instrument will continue to do so.
  - E.g. AAPL outperformed BBRY last year, though both went up. AAPL will continue to outperform BBRY this year, even though we are in a bear market for tech stocks.

Roll Returns and Futures Momentum

- Roll returns are much less volatile than spot returns, and they maintain the same sign for long periods.
- If roll returns dominate total returns of a future (at long time-scale) $\Rightarrow$ time-series momentum.
- Even if spot returns dominate total returns, as long as they are not anti-correlated with roll returns, they can be arbitraged away in a long-short portfolio $\Rightarrow$ Cross-Sectional Momentum.

Extraction of Roll Returns

- Is there a more reliable way to extract roll returns?
  - Yes: arbitrage between future and spot prices.
    - E.g. GC (gold futures) vs GLD (gold trust ETF)
  - See "What's Behind the Metals Warehouse Debate?", Neeraj Batra, tabbforum.com, 4 Oct, 2013

  - *Exercise*:
    - GC is usually in contango: just short it while buy and hold GLD.
    - Find the annualized average return of this strategy.
    - Find the Sharpe ratio, assuming risk free rate is 2% p.a.
    - GC data (backadjusted continuous contracts) from inputData_GC_1600_20100802.mat, GLD data from inputData_ETF.
    - Solution program in GLD_GC.m

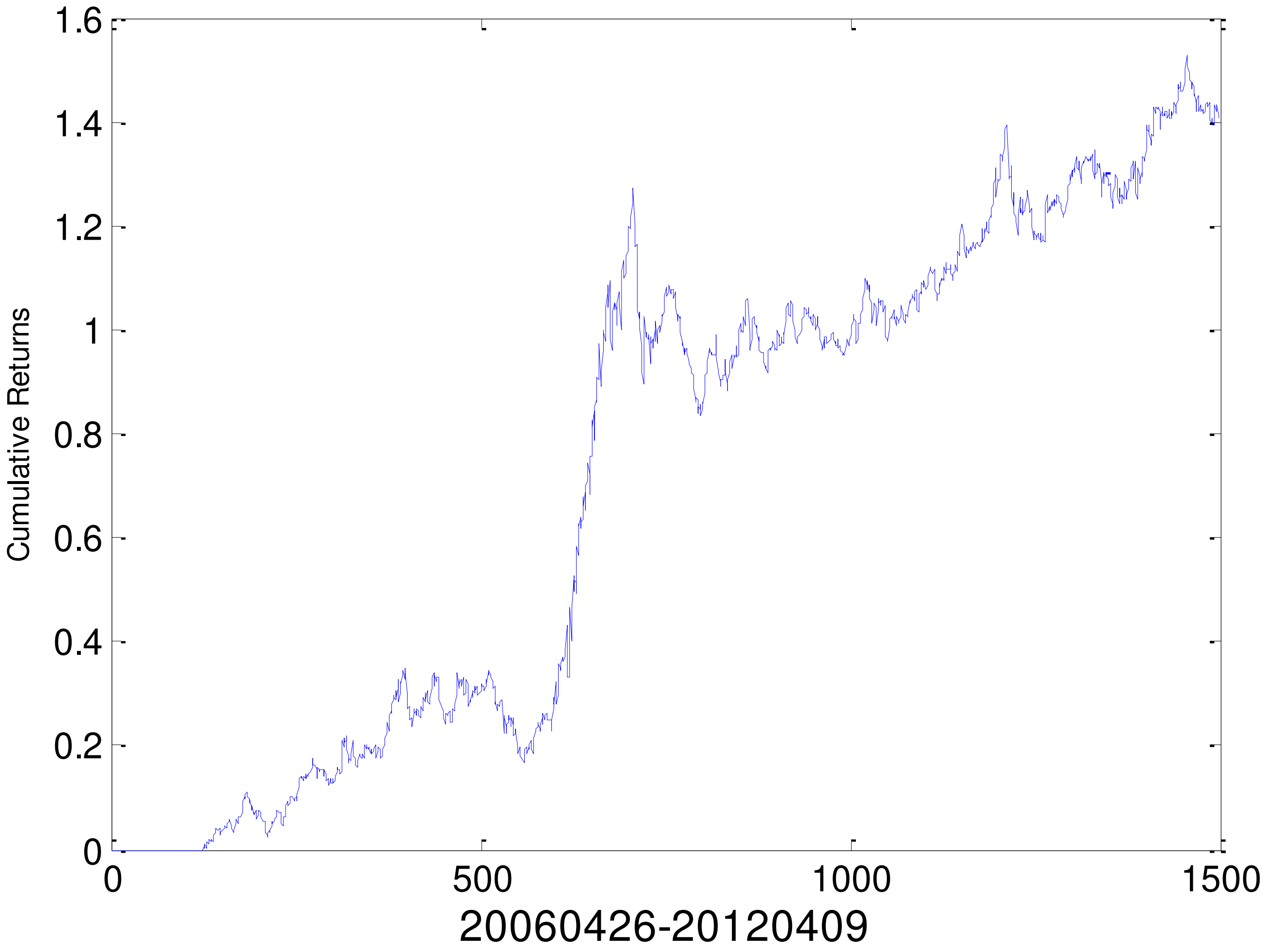
Extraction of Roll Returns

- What if there is no (readily traded) underlying asset?
  - Can still arbitrage between future and another traded instrument highly (anti-)correlated with the spot return of the future.
  - *Exercise*: Can you think of examples for
    - Futures vs ETF?
    - Futures vs futures?
    - Futures vs X?
    - ETF vs ETF?

Exercise: XLE vs USO

- Buy XLE and short USO whenever CL is in contango, and vice versa.
  - Find the annualized average returns and Sharpe ratio.
  - CL data in inputDataDaily_CL_20120502. XLE and USO data in inputData_ETF.
  - Solution program in XLE_CL_rollReturn.m

XLE vs USO arbitrage



The Case of VX

- VX has large roll return
  - 50% annualized
- VIX is highly anti-correlated with ES
  - Correlation between daily returns=-75%
- ES has little roll return of its own.
- Arbitrage between VX and ES should yield much of the roll return of VX!
- First find the hedge ratio appropriate for this arbitrage

```
load('inputDataOHLCDaily_20120517', 'syms', 'tday', 'cl');
```

VX-ES

- Use *scatter* to see relationship between VX and ES:

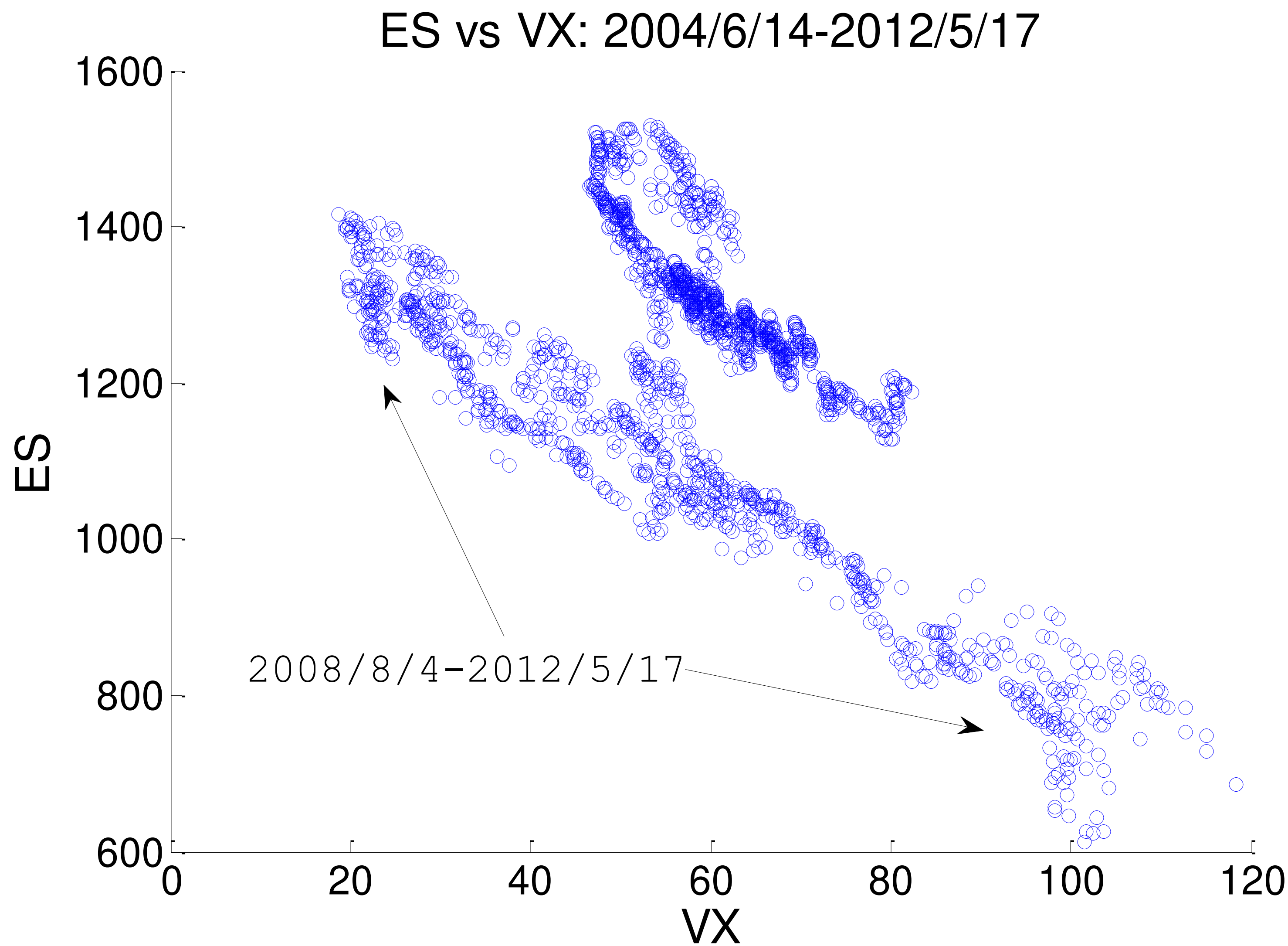
```
idxV=find(strcmp('VX', syms));
idxE=find(strcmp('ES', syms));

VX=cl(:, idxV);
tdayV=tday(:, idxV);

ES=cl(:, idxE);
tdayE=tday(:, idxE);

[tday idxV idxE]=intersect(tdayV, tdayE);
VX=VX(idxV);
ES=ES(idxE);

scatter(VX, ES);
```



ES vs VX: 2004/6/14-2012/5/17
1600
1400
1200
1000
800
600
0
20
40
60
80
100
120
ES
VX
2008/8/4-2012/5/17

VX-ES

- More than 1 regimes are evident!
- *Exercise:* What can you say about the 2 different regimes pre- and post-2008 financial crisis?

VX-ES

- Post financial crisis, lower VX for same level of ES.
  - Market is less volatile now, though volatilities can be more extreme!
  - Alternatively: market has lower stock index level now.
- However, post financial crisis, more extreme volatilities.
- We should only use post-Aug 2008 data for regression fit.
  - Use the MATLAB© Statistics Toolbox function regress. (Can also use *ols*).
  - Program in VX_ES.m

VX-ES

```
post200808=find(tday>=20080801);
hedgeRatio=regress(50*ES(post200808), [1000*VX(post200808)
ones(length(post200808), 1)]);
% Result:
% hedgeRatio(1)=-0.3507
```

- *Exercise*: What is the simplest trading strategy we can apply to VX-ES (with the appropriate hedge ratio)?

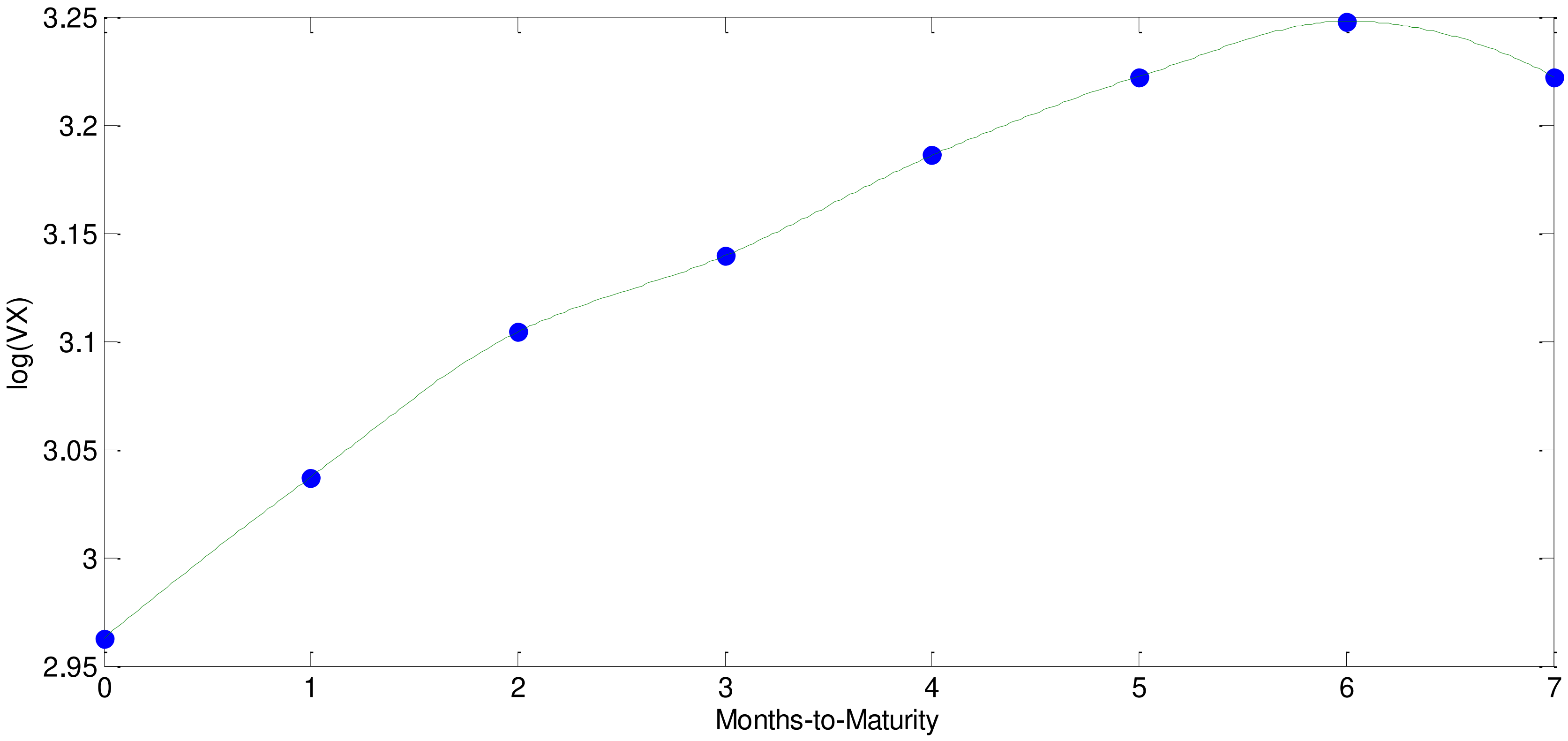
VX-ES

- Strategy:
  - If VX's roll return > threshold: Buy VX, buy ES
  - If VX's roll return < -threshold: Sell VX, sell ES
- *Exercise*: How should we compute roll returns for VX?
  - Download inputDataDaily_VX_20120507.mat.
  - Download inputDataOHLCDaily_20120507.mat and select the column for ES (backadj. continuous contract)

VX-ES

- Should we use the same *ols* method as before to find corn futures' roll returns?
- *Exercise*: Plot the (log) forward curve of VX.
  - Program in VX_ES_rollreturn.m

VX Forward Curve



VX-ES

- The (log) forward curve doesn't fall on a straight line!
- Instead, just use the nearest contract, and compute roll return as (VIX-VX)/Time-to-settlement.
  - If VIX-VX > 0.1* number of trading days till settlement, buy 0.3507 contract of VX and buy 1 contract of ES. Hold 1 day.
  - If VX-VIX > 0.1* number of trading days till settlement, short 0.3507 contract of VX and short 1 contract of ES. Hold 1 day.

VX-ES

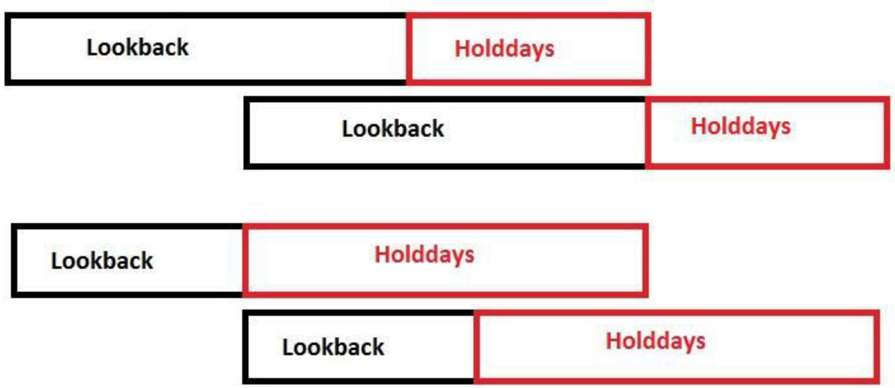
- The code for this is a bit complicated because we need to know the settlement date for each front contract. (VX_ES_rollreturn.m)
- Results: APR=6.9%, Sharpe Ratio=1 (with tcost=1bps).
- (Ref: Simon, David P., and Campasano, Jim. 2012. The VIX Futures Basis: Evidence and Trading Strategies. Available at papers.ssrn.com/sol3/papers.cfm?abstract_id=2094510.)

Other ways to extract futures momentum

- Happy situations like VX-ES do not happen often.
  - In general, not easy to find a future that anti-/ correlates with spot returns with another future.
- No worries: time-series and cross-sectional momentum can still be extracted as long as long term spot returns are uncorrelated or smaller in magnitude than roll returns.
- First, we need some tests to see if this is possible for a specific future.

Testing for Time-Series Momentum

- The literal way: Test for positive serial correlation of returns.
  - First find non-overlapping periods between backward (lookback) and forward (holding days) returns.



Testing for Time-Series Momentum

- Use the *corrcoef* function to compute correlation of returns, and the p-value for the null hypothesis that the correlation is zero.

- *Exercise*: Try this on the 2-year Treasury note future TU on CME, for various values of lookback and holddays.
  - Use inputDataOHLCDaily_20120517.mat
  - Solution program in correlationTest.m

Lookback	Holddays	Correlation coefficient	p-Value
25	1	-0.0140	0.5353
25	5	0.0319	0.5276
25	10	0.1219	0.0880
25	25	0.1955	0.0863
25	60	0.2333	0.0411
25	120	0.1482	0.2045
25	250	0.2620	0.0297
60	1	0.0313	0.1686
60	5	0.0799	0.1168
60	10	0.1718	0.0169
60	25	0.2592	0.0228
60	60	0.2162	0.2346
60	120	-0.0331	0.8598
60	250	0.3137	0.0974
120	1	0.0222	0.3355
120	5	0.0565	0.2750
120	10	0.0955	0.1934
120	25	0.1456	0.2126
120	60	-0.0192	0.9182
120	120	0.2081	0.4567
120	250	0.4072	0.1484
250	1	0.0411	0.0857
250	5	0.1068	0.0462
250	10	0.1784	0.0185
250	25	0.2719	0.0238
250	60	0.4245	0.0217
250	120	0.5112	0.0617
250	250	0.4873	0.3269

TU Momentum

- Sign & magnitude of correlation coefficients, magnitude of p-Value, all point to existence of time series momentum in TU.
- Correlations can also be computed between the *signs* of the past and future returns.

TU Momentum

- Alternative tests: Hurst exponent and Variance Ratio Test.
- **Hurst exponent**: Test for long-term momentum
  - Compute the variance of the log prices $z(t)$
  $$\mathrm{Var}(\tau) = \langle |z(t+\tau) - z(t)|^2 \rangle$$
  - If $z(t)$ is a random walk, $\mathrm{Var}(\tau) \sim \tau$.
  - If $z(t)$ has momentum, $\mathrm{Var}(\tau) \sim \tau^{2H}$, H>0.5.

Hurst Exponent and Variance Ratio Test

- Suppose we find H>0.5, what is the probability that the "real" H is actually 0.5?
- **Variance Ratio Test** will find probability that

$$\frac{Var\big(z(t)-z(t-\tau)\big)}{\tau Var\big(z(t)-z(t-1)\big)}$$

  is actually 1.
- Unfortunately, these tests only apply to long-term momentum, which is seldom present.

Hurst Exponent and Variance Ratio Test

- *Exercise*: Apply the *genhurst* and *vratiotest* functions on TU to see if it has long-term momentum.
  - (Hint: Google "genhurst" to download, *vratiotest* is available on MATLAB© Econometrics Toolbox.)
  - Solution program in TU_mom.m

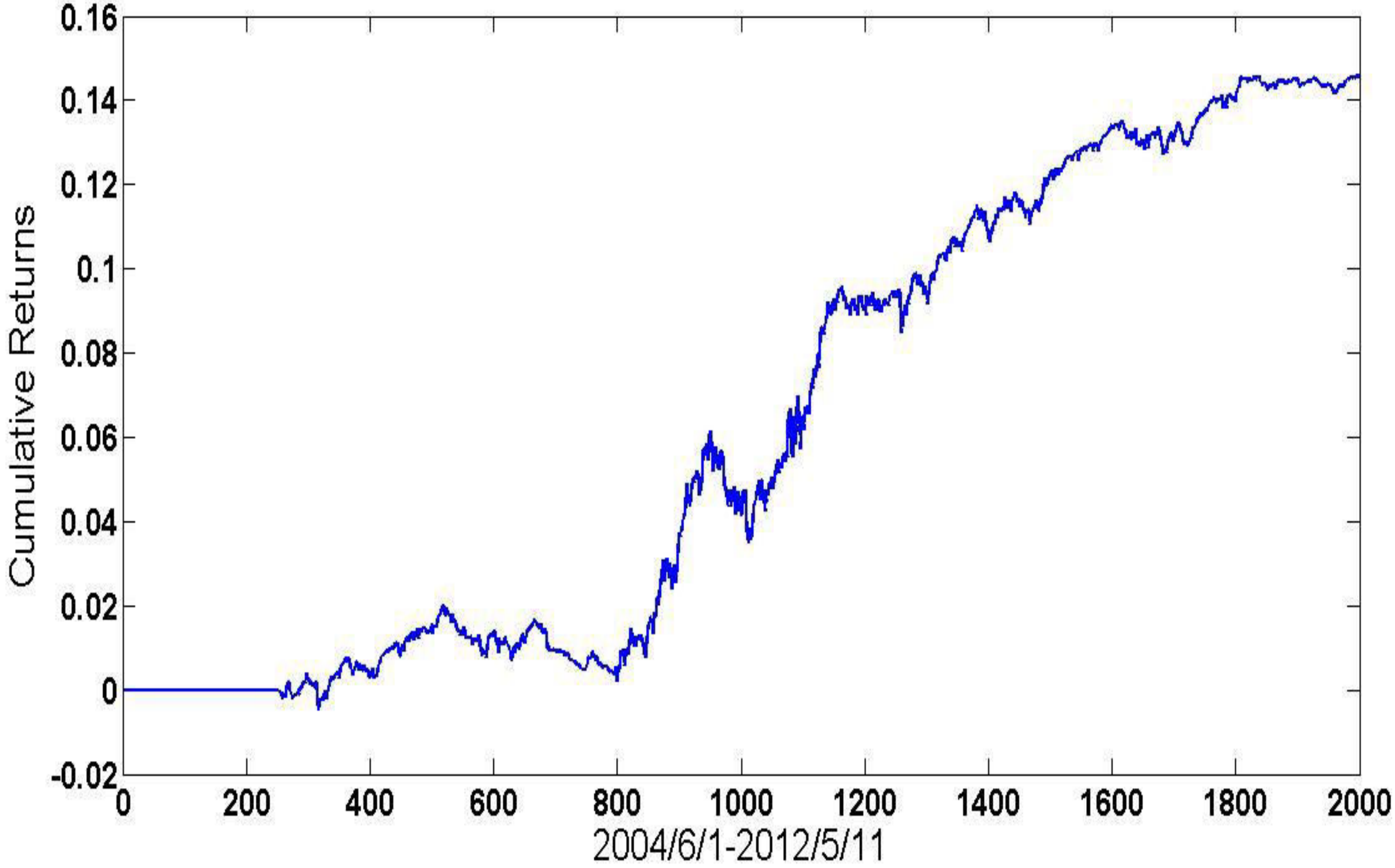
Time Series Momentum Strategy

- Note lookback=250, holding-days=25, have correlation=0.27, p-Value=0.024.
- Holding-days is short enough for a decent Sharpe ratio.
- Strategy:
  – Buy (sell) TU if it has positive (negative) 12-month return, and hold for a month.
  – Start a new (staggered, “pyramided”) position every day within that month.

Time Series Momentum Strategy

- *Exercise*: Backtest this strategy!
  - Solution program in TU_mom.m
- APR=1.7%, Sharpe Ratio=1.0, max drawdown=-2.5%. (All without tcost.)

TU Momentum Strategy



Time Series Futures Momentum Strategy

- Other futures that exhibit time series momentum:

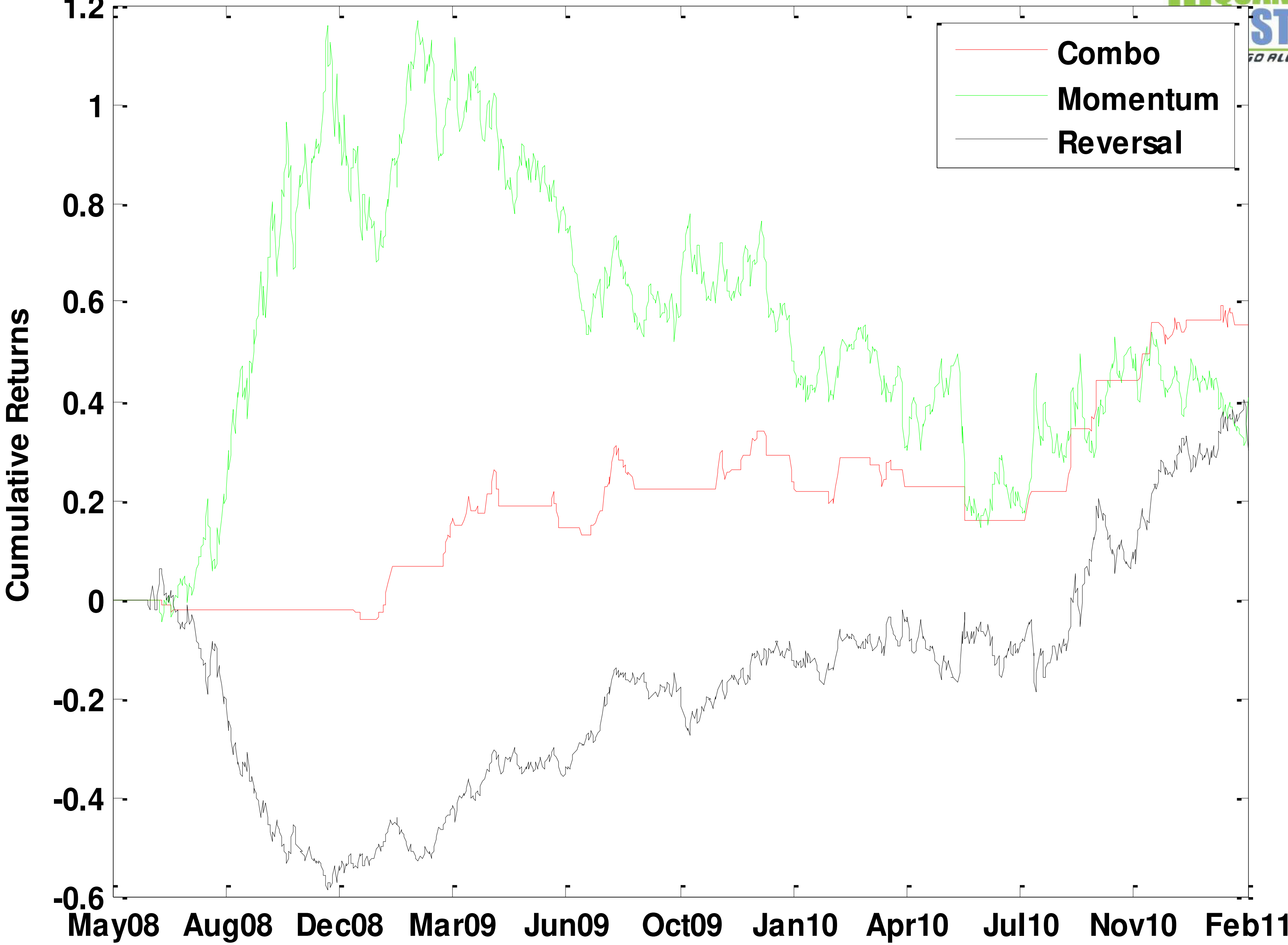
Symbol	Lookback	Holding days	APR	Sharpe ratio	Max Drawdown
VX (CFE)	50	5	35.2%	1.09	-33.2%
BR (CME)	100	10	17.7%	1.09	-14.8%
HG (CME)	40	40	18.0%	1.05	-24.0%
TU (CBOT)	250	25	1.7%	1.04	-2.5%

Indicators for TS Momentum

- Roll returns, sign(lagged-returns)
- Buy when price reaches new N-day high
- Buy when price exceeds MA or EMA
- Buy when price exceeds upper Bollinger band
- Buy when num(up days) > num(down days)
- Alexander Filter: buy when daily return moves up at least x%, sell & short when price moves down at least x% from subsequent high.

Indicators for TS Momentum

- Best: combine long-term momentum indicator with short-term reversal indicator
- *Exercise*: Buy CL future at close if price is lower than 30 days ago but is higher than 40 days ago. Vice versa for shorts.
  - Data from inputDataOHLCDaily_20120504.mat
  - Solution program in CL_rev.m
  - Try either the momentum or the reversal rule alone and see what the performance is.
  - Plot momentum, reversal, and combo on same axis with dateaxis to see when each worked well!


Cumulative Returns
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
May08
Aug08
Dec08
Mar09
Jun09
Oct09
Jan10
Apr10
Jul10
Nov10
Feb11
Combo
Momentum
Reversal

Cross-Sectional Futures Momentum

- Cross-sectional momentum in physical commodities futures is also present.
  - Spot returns tend to be positively correlated.
  - Buy those with positive roll returns and short those with negative roll returns should generate net positive returns.
- Strategy:
  - Rank the 1-year return of 52 physical commodities futures every day.
  - Buy (short) the top (bottom) future and hold for a month.
  - Ref: https://www.nber.org/system/files/working_papers/w20439/w20439.pdf

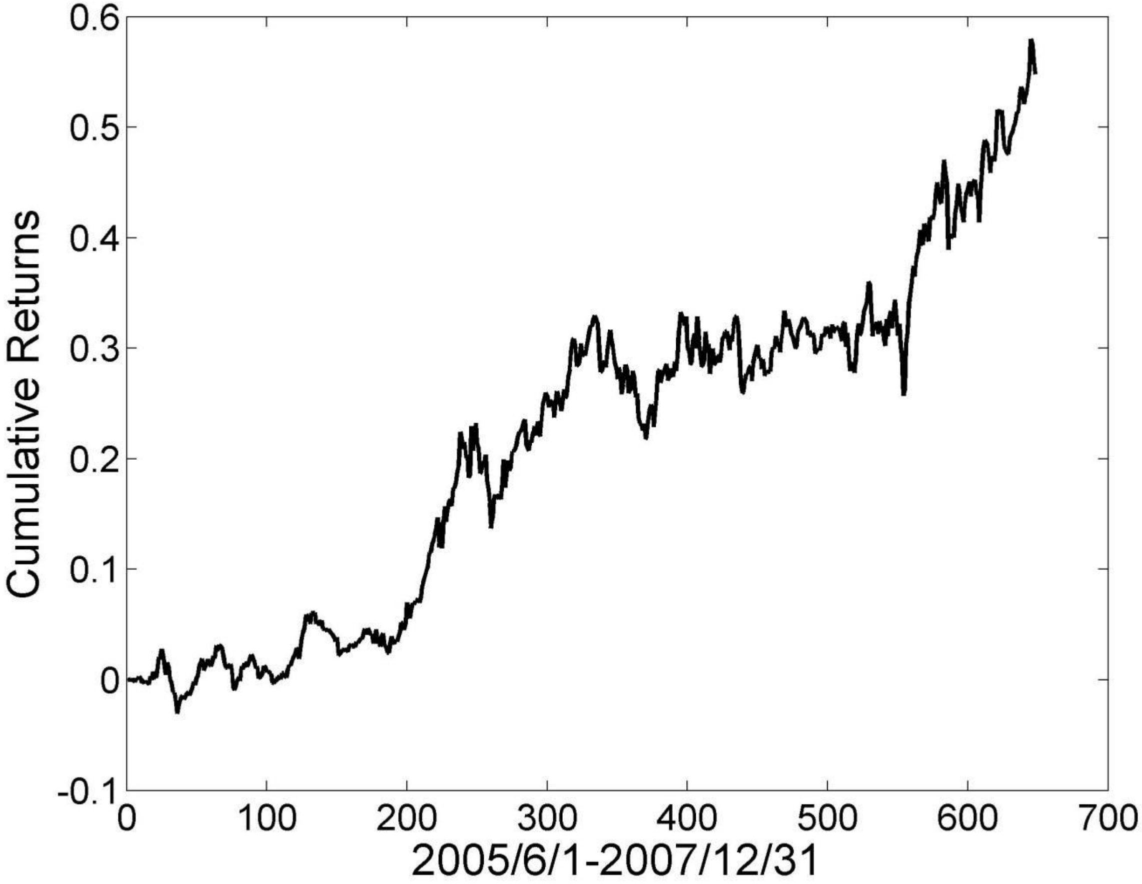
Cross-Sectional Futures Momentum

- Results:

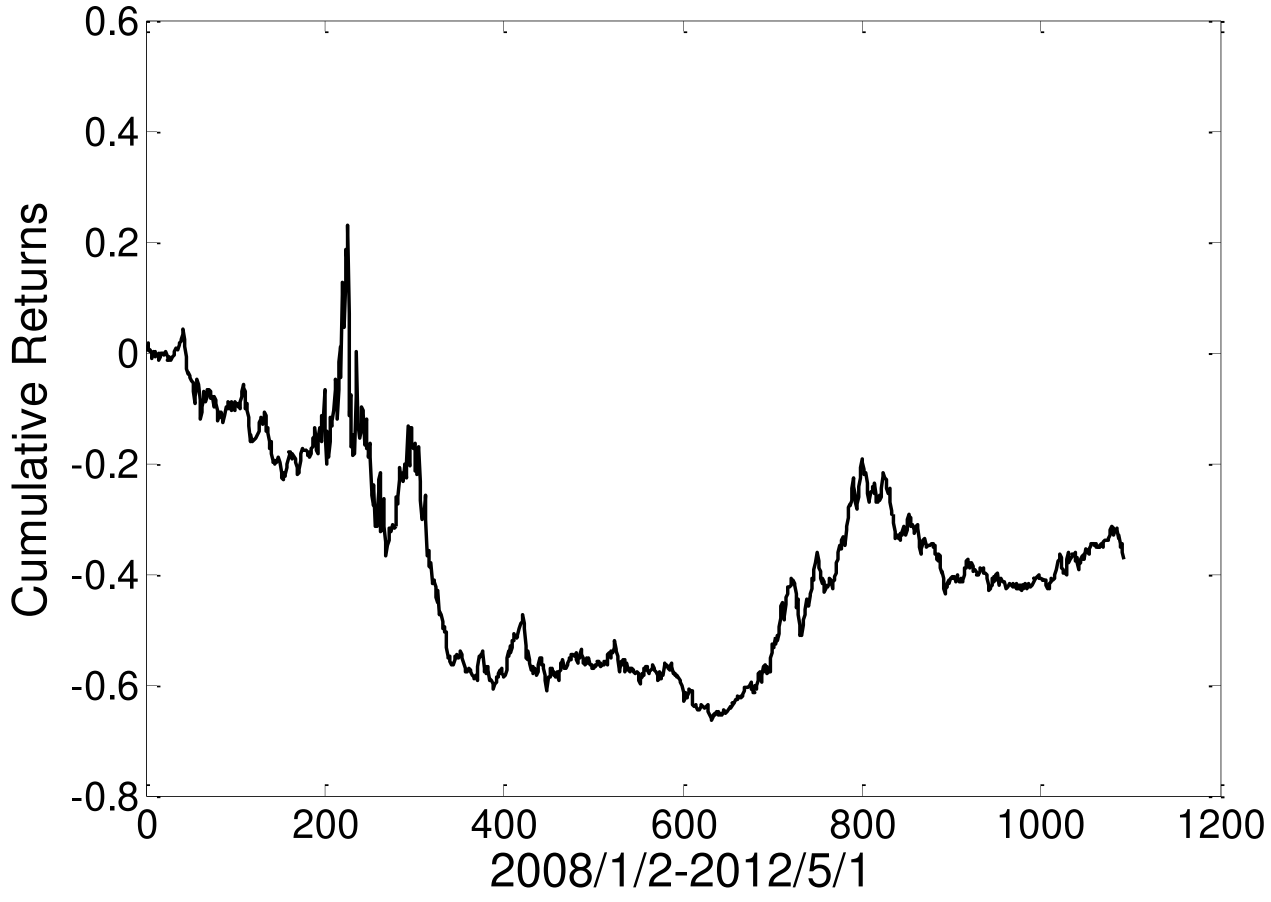
	APR	Sharpe Ratio
2005/6/1-2007/12/31	18%	1.4
2008/1/2-2009/12/31	-33%	-0.6
2010/1/4-2012/05/01	16%	0.7

- Why the poor performance 2008/1/2-2009/12/31?
  - Will reveal later!

Cross-Sectional Futures Momentum: Pre-crisis



Cross-Sectional Futures Momentum: Post-crisis



Do Calendar Spreads Trend?

- For a future whose underlying is a traded asset (counter-example: VX),

$$F(t,T) = S(t)exp(\gamma(t-T))$$

 where S(t) is spot price.
- Log returns of a calendar spread between T_1 and T_2 is

$$\partial \log(F(t, \mathrm{T}_1))/\partial \mathrm{t} - \partial \log(F(t, \mathrm{T}_2))/\partial \mathrm{t}$$

- This is exactly 0 if forward curve has zero curvature!
- Calendar spread will trend only if difference in curvatures has same sign over time.
- Assuming shape of forward curve is unchanged over time, can you imagine what kind of forward curves will fit this criterion?

Cross-sectional Stocks Momentum

- Cross-sectional momentum also present in S&P 500 stocks.
  - Total return = market return + factor returns + residual returns
  - Factor returns change slowly.
  - Long-short portfolio will hedge away market return.

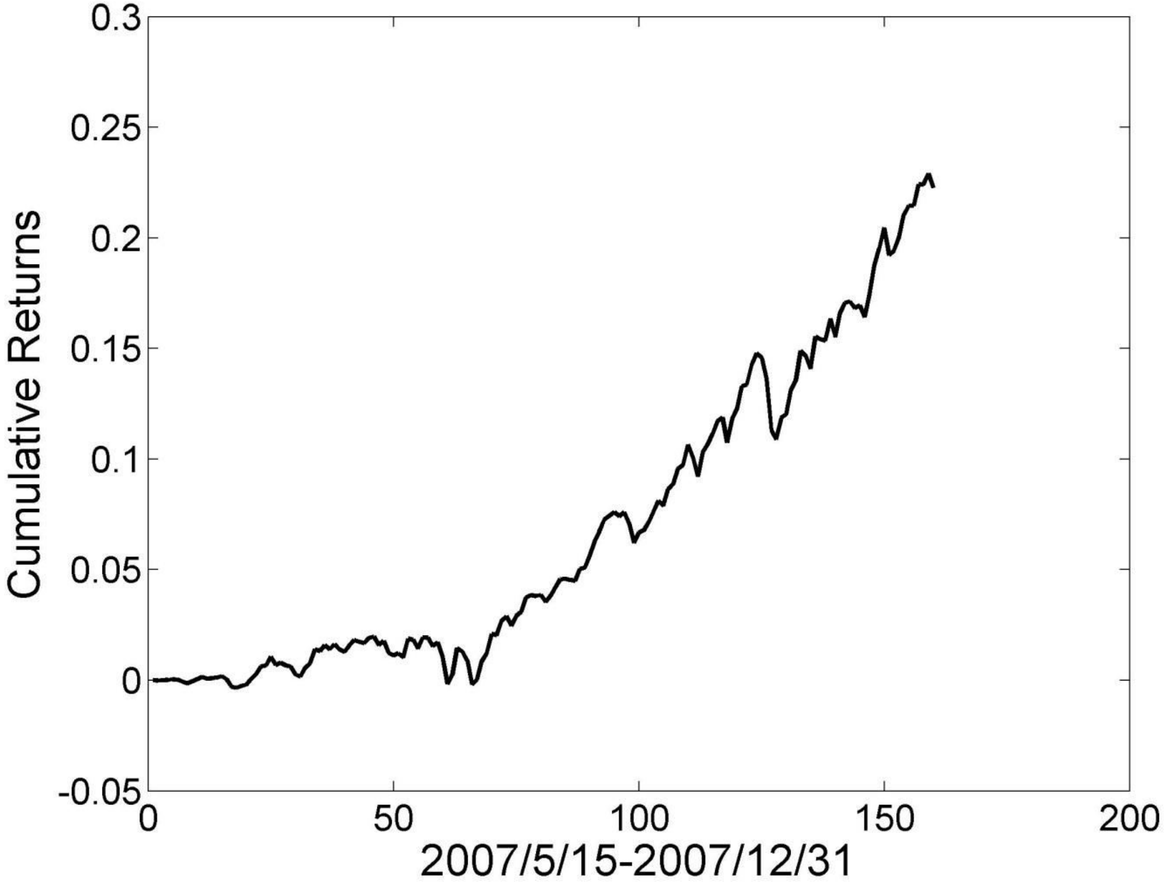
- Strategy:
  - Rank the 1-year return of S&P 500 stocks every day.
  - (Universe can be arbitrarily large: constrained only by liquidity.)
  - Buy (short) the top (bottom) decile and hold for a month.
  - Exercise: Data in inputDataOHLCDaily_stocks_20120424
  - Program in kentdaniel.m

Cross-Sectional Stock Momentum

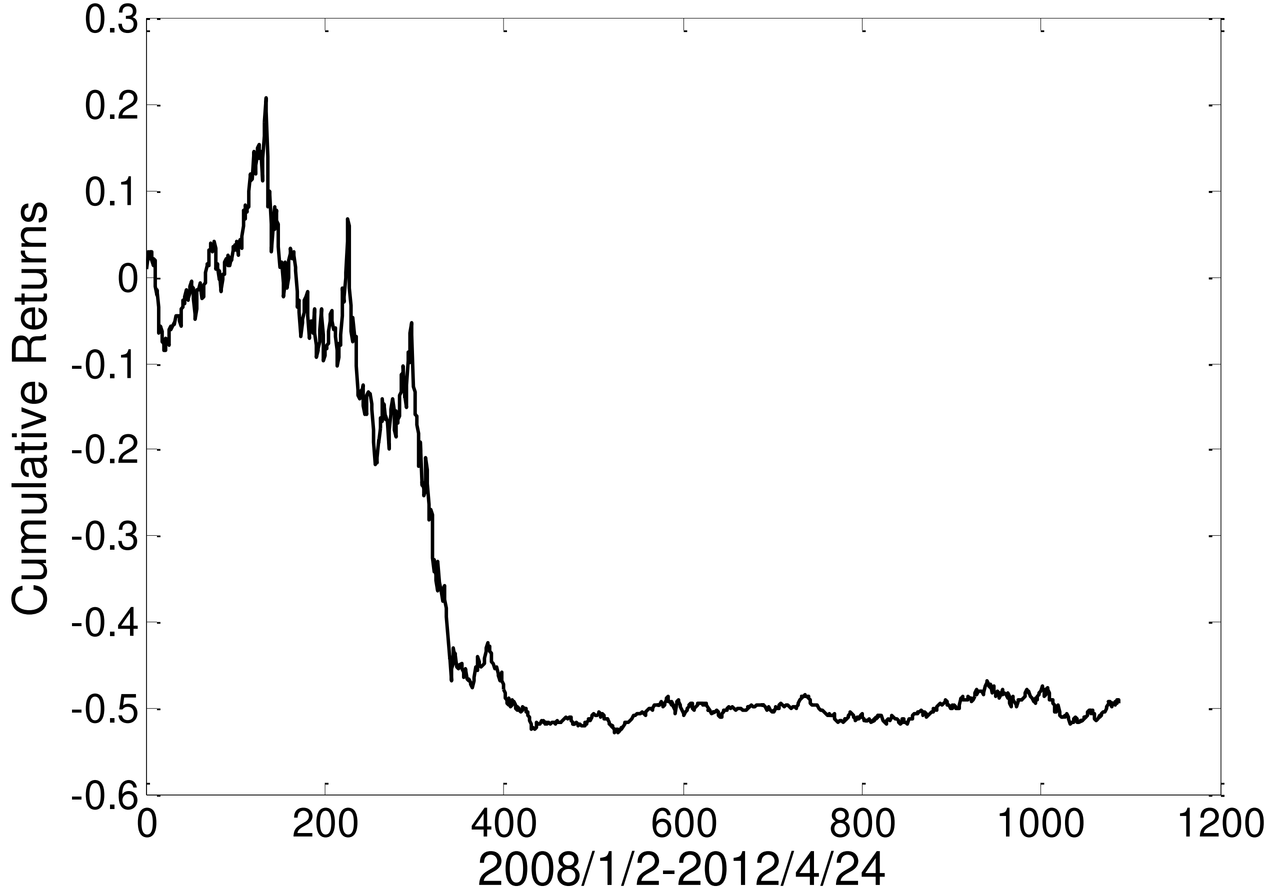
- Results:

	APR	Sharpe Ratio
2007/5/15-2007/12/31	37%	4.1
2008/1/02-2009/12/31	-30%	-1.3
2010/1/04-2012/04/24	1%	0.2

Cross-Sectional Stock Momentum: Pre-crisis



Cross-Section Stock Momentum: Post-crisis



Momentum Crashes

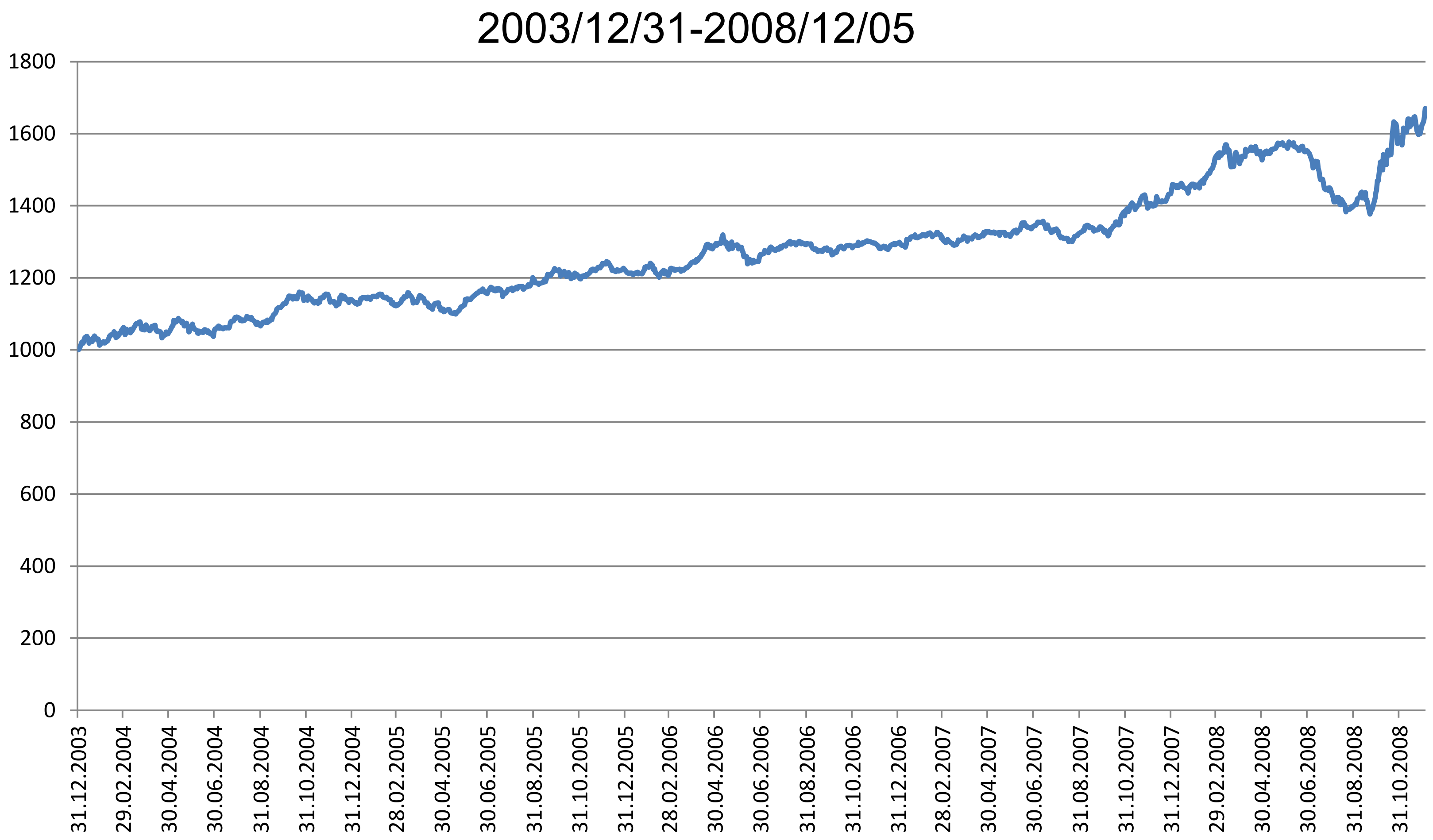
- Once again, performance during 2008-2009 is very poor.
- This is common to most momentum strategies during and in the aftermath of a financial crisis.
  - Called "Momentum Crashes" by the researchers Kent Daniel *et. al*.
  - In the aftermath of the market crash of 1929, the drawdown duration for a prototypical momentum strategy is 30 years!
  - Main reason for "crash" is strong rebound of short positions after a crash.

Momentum Crashes

- Look at a “momentum strategy index”: Diversified Trends Indicator SPDTP.
  - Mutual fund RYMFX and ETF WDTI used to track this index.

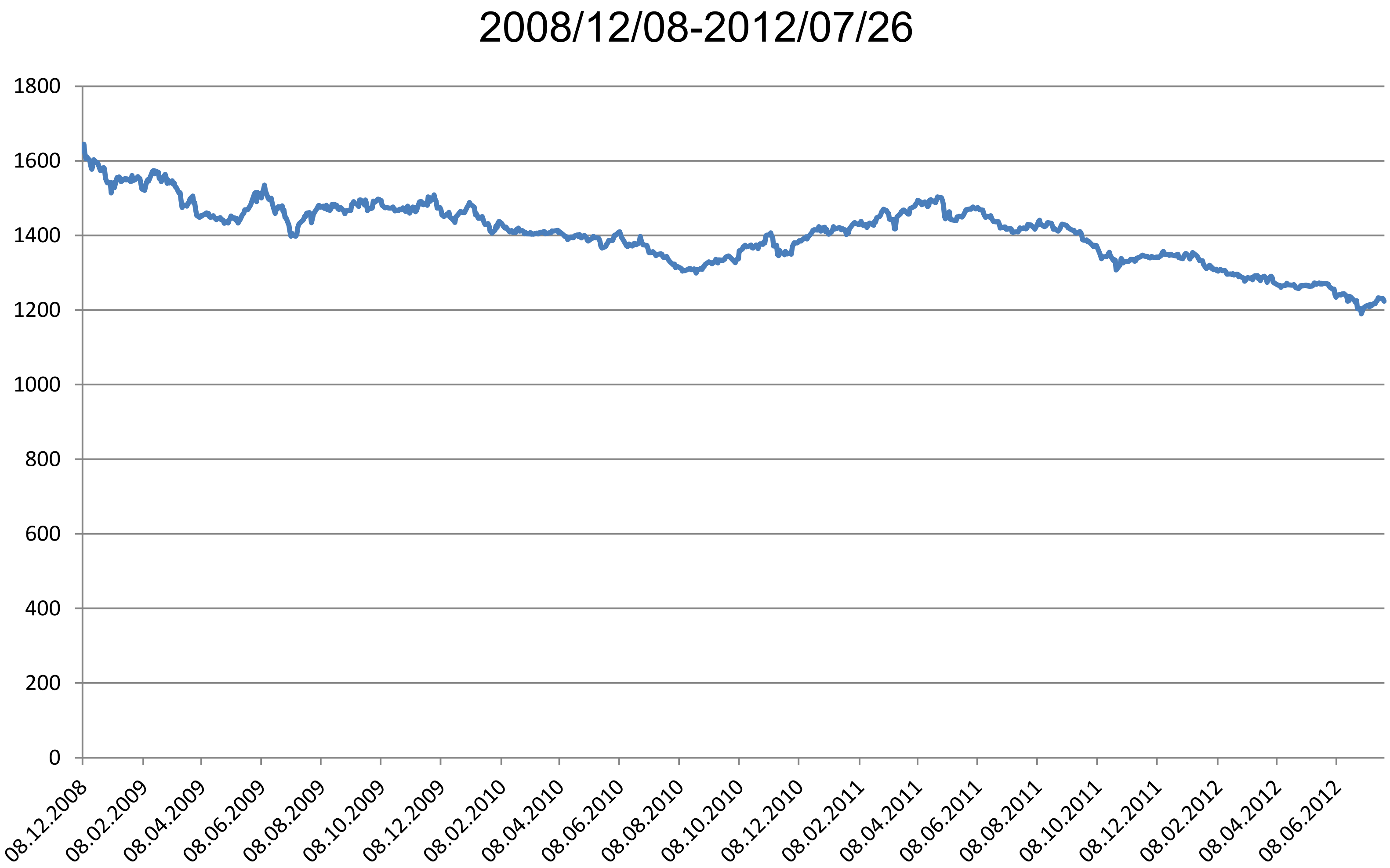
	APR	Sharpe Ratio
2003/12/31-2008/12/05	10.8%	1.3
2009/01/02-2012/07/26	-8.2%	-1.0

DTI Index



2003/12/31-2008/12/05
1800
1600
1400
1200
1000
800
600
400
200
0
31.12.2003
29.02.2004
30.04.2004
30.06.2004
31.08.2004
31.10.2004
31.12.2004
28.02.2005
30.04.2005
30.06.2005
31.08.2005
31.10.2005
31.12.2005
28.02.2006
30.04.2006
30.06.2006
31.08.2006
31.10.2006
31.12.2006
28.02.2007
30.04.2007
30.06.2007
31.08.2007
31.10.2007
31.12.2007
29.02.2008
30.04.2008
30.06.2008
31.08.2008
31.10.2008

DTI Index



2008/12/08-2012/07/26
1800
1600
1400
1200
1000
800
600
400
200
0
08.12.2008
08.02.2009
08.04.2009
08.06.2009
08.08.2009
08.10.2009
08.12.2009
08.02.2010
08.04.2010
08.06.2010
08.08.2010
08.10.2010
08.12.2010
08.02.2011
08.04.2011
08.06.2011
08.08.2011
08.10.2011
08.12.2011
08.02.2012
08.04.2012
08.06.2012

Indicators for CS Momentum

- What "factors" can be used for ranking?
  - (Previously described) Lagged returns (or roll returns).
  - Fundamental macro-economic factors (futures)
  - Principal Component Analysis (futures/stocks)
  - Earnings growth (stocks)
  - Book-to-price ratio (stocks)
  - Linear combination of all of above!

News Sentiment

- A new factor available for stocks.
- Natural language processing algorithms used to parse and analyze all news feed automatically.
- “Sentiment score” assigned to each story indicating possible price impact.
- Aggregation of sentiment score from fixed period is predictive of future returns.

News Sentiment

- Strategy: form long-short portfolio using sentiment score as ranking factor.
  - APR=52% to 156%, Sharpe=3.9 to 5.3 before tcost.
  - https://www.ravenpack.com/research/short-term-stock-selection-using-news/
  - Success of strategy demonstrates the slow diffusion, analysis, and acceptance of news is cause of momentum.
- Instead of general sentiment, we can identify predictive power of each specific type of events.

Event-driven Momentum

- E.g. Post Earnings Announcement Drift (PEAD)
- Studied since 1968, still profitable today!
  - See review by Bernard, Victor L., and Thomas, Jacob K. 1989. Post-Earnings-Announcement Drift: Delayed Price Response or Risk Premium? Journal of Accounting Research, 27, 1-36.
- Duration of momentum has decreased over the years.

PEAD

- Strategy:
  - Buy (sell) at open if there was an earnings announcement since previous close, and the return since previous close retC2O is greater (less) than (-)0.5*stddev(retC2O, 90-day)
  - Exit at market close.
- *Exercise*: Backtest this strategy!
  - Stock prices in *inputDataOHLCDaily_stocks_20120424*, earnings announcements in *earnannfile* (earnann==1 if announced after previous MKT CLS and before today's MKT OPN.)
  - Try holding overnight too.

PEAD

- Solution program is *pead.m*
- Results from 2011/1/3-2012/4/24 for SPX stocks:
  - APR=6.7%, Sharpe Ratio=1.5.

Other events driving momentum

- Earnings announcement is not the only event driving momentum.
- A partial list includes:
  - Earnings guidance
  - Analyst ratings change
  - Analyst recommendation change
  - Same store sales announcement
  - Airline load factors announcement
  - Mergers and acquisitions announcement
  - Macroeconomic data release (ETF/Futures/FX)
  - Interest rate announcement (ETF/Futures/FX)

Other events driving momentum

- Contemporary, comprehensive study of events: Hafez, Peter A. 2011. Event Trading Using Market Response. https://www.ravenpack.com/research/event-trading-using-market-response/
  A surprise: After a M&A announcement, acquiree's stock price falls more than acquirer's.
- Some momentum duration may last only minutes.
  - E.g. BOE interest rate announcement induced GBPUSD momentum for 10 minutes. (Clare and Courtnenay, 2001).

Forced Sales and Purchases

- Next cause of momentum: Forced sales or purchases of assets by hedge/mutual/index/exchange-traded funds.
  - Contagion due to
    - Risk management (levered hedge funds)
    - Investor redemption/subscription (mutual funds)
  - Index composition changes
  - Levered ETFs: Forced rebalancing at market close.

Contagion leads to momentum

- Contagion due to risk management.
  - Suppose stock A is commonly long by **levered** hedge funds.
    - Suppose fund α suffers heavy, possibly unrelated loss.
    - Risk manager (via Kelly formula?) of α demands portfolio size reduction.
    - α sells stock A.
    - Stock A goes down in price.
    - Fund ß now suffers heavy loss if they hold A and other such stocks.
    - Risk manager of ß demands **deleveraging**.
    - ß sells stock A.
    - Stock A goes down further in price: contagion leads to momentum!
    - (Same logic for short positions.)
- Key driver: the need to maintain constant leverage in face of loss.

Contagion leads to momentum

- This actually happened in August of 2007.
  - See Khandani, Amir, and Lo, Andrew. 2007. “What Happened to the Quants in August 2007?” https://web.mit.edu/Alo/www/Papers/august07.pdf
  - Unfortunately, hedge funds holdings change rapidly– hard to know which stock is commonly held, long or short, at any given time.
  - On the other hand, mutual funds holdings are more stable!

Mutual Funds Asset Fire Sale and Forced Purchases

- Contagion due to investors punishing/rewarding funds holding common stocks
  - Suppose stock A is commonly held by **mutual funds**.
    - Suppose fund α suffers heavy, possibly unrelated loss.
    - Investors of α redeem their investments.
    - α sells stock A.
    - Stock A goes down in price.
    - Fund ß now suffers heavy loss if they hold A and other such stocks.
    - Investors of ß redeem their investments.
    - ß sells stock A.
    - Stock A goes down further in price: contagion leads to momentum!
- Key driver: herding behavior of retail investors.

Mutual Funds Asset Fire Sale and Forced Purchases

- Research by Coval and Erik show that this happens regularly! (https://papers.ssrn.com/sol3/papers.cfm?abstract_id=727137.)
- Mutual funds holdings and returns are stable and can be obtained via public filings.
- Can construct selling (buying) pressure on stock s at time t :

$$PRESSURE(s,t) = \frac{\sum_f (Buy(f,s,t)|flow(f,t) > 5\%) - \sum_f (Sell(f,s,t)|flow(f,t) < -5\%)}{\sum_f Own(f,s,t-1)}$$

Mutual Funds Asset Fire Sale and Forced Purchases

- $Buy(f, s, t) = 1$ if fund f increased its holding in stock s during the quarter t and if the fund experienced inflows greater than 5% ($flow(f, t) > 5\%$) of its NAV, and zero otherwise. $Sell(f, s, t)$ is similarly defined for decreases in holdings.
- $\sum_f Own(f, s, t-1)$ is the total number of mutual funds holding stock s the beginning of quarter t.

Mutual Funds Asset Fire Sale and Forced Purchases

- Note the condition that buying/selling of a stock is due to investor subscription/redemptions, not to investment decisions based on information specific to that stock.

Mutual Funds Asset Fire Sale and Forced Purchases

- Can form market-neutral portfolio based on the Pressure factor: long the top decile and short the bottom decile.
  - Re-balance quarterly.
  - Ann return=17% before transaction costs.
- If we predict the in/outflows of capital based on past performance, we can predict future value of Pressure factor. (*i.e.* predict investor herding)
  - Another 17% ann return.
- Mean reversion of Pressure after 1 quarter
  - Another 7% ann return.

Mutual Funds Asset Fire Sale and Forced Purchases

- General behavior of asset prices:
  - If price change is due to temporary liquidity demands (e.g. need to raise cash to satisfy investor redemptions) $\Rightarrow$ mean reversion.
  - If price change is due to change in fundamentals $\Rightarrow$ price will move permanently to new level.
- Mutual fund holdings data from CRSP.
- Strategy has diminishing returns due to "crowding".

Other Examples of Forced Sales and Purchases

- Index composition changes forced index funds to buy/sell stocks that are listed/delisted.
  - Momentum used to last multiple days.
    - Shankar, S. Gowri, and Miller, James M. 2006. Market Reaction to Changes in the S&P SmallCap 600 Index. The Financial Review, 41(3).
  - Recent tests suggest momentum reduced to intraday.

Levered ETF Momentum

- Levered ETFs must keep ratio of market value of holdings to net asset value constant at market close.
  - E.g. UPRO is levered 3x of SP 500 returns.
- If market index return is negative (positive), sponsor of ETF need to sell (buy) stocks to maintain leverage.
- *Exercise*: Suppose UPRO has about \$270M assets at previous close. If SPX goes down 2%, what's the market value of the holdings it needs to sell?

Levered ETF Momentum

- Market value of holdings at previous close=3x$270M=$810M
- Decrease in NAV due to -2% market return=$16.2M
- NAV at today's close=

  $270M-$16.2M=$253.8M
- Target market value at today's close=

  3x$253.8M=$761.4M
- Market value of holdings at today's close=$810M-$16.2M=$793.8M
- Need to sell=$793.8-$761.4M=**$32.4M**

Levered ETF Momentum

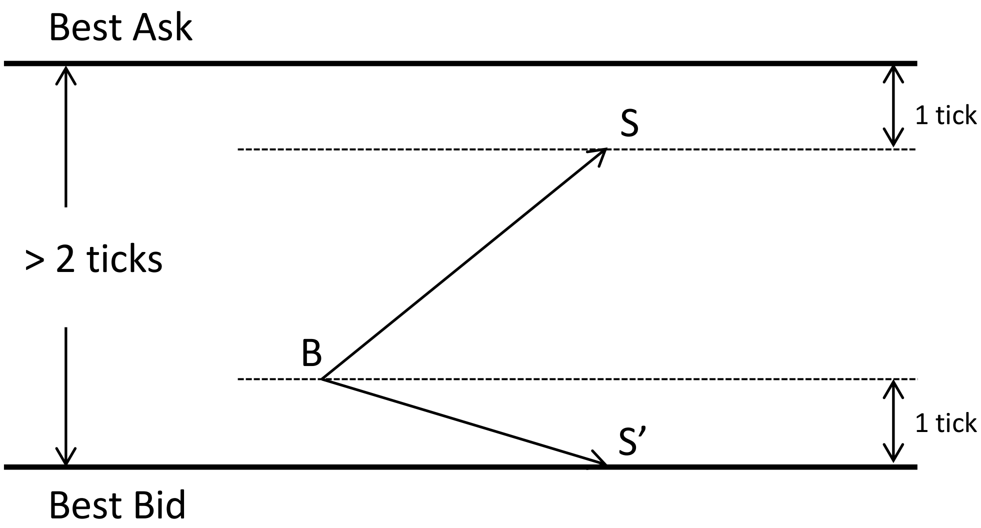
- This selling of $32.4M of holdings towards market close, in an already down market, generates momentum in UPRO, as well as in the SPX component stocks themselves.
- Strategy:
  – Buy(sell) UPRO if return from previous day's close to 15 minutes before today's close is greater(smaller) than (+/-)2%.
  – Exit at market close.
- APR=32%, Sharpe Ratio=2.2 from mid-2011 to mid-2012.

HFT: Ratio Trade

- Applies to futures markets which fill orders on a pro-rata basis (not time-priority). E.g. Eurodollars on CME.
- Join the best bid if bid size $\gg$ ask size.
- Once filled, place sell order at best ask.
- If sell order not filled, sell at original best bid.

HFT: Ticking

- Applies if bid-ask spread > 2 ticks.
- Place buy order at best bid + 1 tick if bid size $\gg$ ask size.
- Once filled, place sell order at best ask – 1 tick.
- If sell order not filled, sell at original best bid.


Best Ask
S
1 tick
> 2 ticks
B
S’
1 tick
Best Bid

HFT: Momentum Ignition

- If there is no natural momentum, you can ignite it!
- “Flipping”
  - Place large buy order at best bid, and a small sell order at best ask, to create impression of buying pressure.
  - Other traders fooled to buy at ask due to perception of buying momentum.
  - Once our sell order filled, cancel buy order.
  - Disappearance of buying “pressure” causes other traders sell at bid.
  - We cover short position at bid.

HFT: Momentum Ignition

- "Stop Hunting"
  - Support and resistance levels often well-known, often at round numbers.
    - E.g. $17.00 instead of $17.15.
  - Stop orders often cluster at these levels.
  - HFT can submit large sell orders near support level so price drops below support.
  - Sell stop orders are triggered.
  - Price drops further.
  - HFT buy covers.
  - Ref. Osler, Carol. 2000. Support for Resistance: Technical Analysis and Intraday Exchange Rates. Federal Reserve Bank of New York Economic Policy Review 6 (July 2000): 53-65.

HFT: Order Flow

- Order flow leads price change
  - Order flow is *signed* transaction volume.
    - Buy *market* order is filled $\Rightarrow$ order flow > 0.
    - Sell *market* order is filled $\Rightarrow$ order flow < 0.
  - Order flow can be aggregated over some time interval to serve as indicator.
  - Researchers found that order flow is positively correlated with future price change.
    - Lyons, Richard. 2001. "The Microstructure Approach to Exchange Rates"
  - Therefore, order flow can be used to "front-run" market.

HFT: Order Flow

- How do we obtain order flow info if we are not large market makers or exchange operators?
  - In futures, can compute tick-by-tick whether trade executed at ask (positive flow) or bid (negative flow).
  - In stocks, more difficult due to fragmented markets and dark pools that do not report quotes and report only delayed trades.
  - In currencies, often impossible, but can monitor currency futures instead.
  - See also Easley *et al.* 2012. “Bulk Classification of Trading Activity”.
- Signed volume is a much better predictor of momentum than unsigned volume.
- (Note fund flow is a form of order flow.)

Exit Strategies

- Time-based
  - E.g. Gap strategies should exit at market close.
- New entry signal
  - E.g. if return goes from positive to negative, flip position from long to short
- Stop loss
  - If position incurs a loss, it means momentum w.r.t. entry price has reversed: exit is logical!
- Trailing stop loss
  - Momentum w.r.t. recent high has reversed: exit is logical!

Advantages of Momentum Strategies

- Ease of risk management
  - Stop loss is logical.
  - Loss ⇒ Momentum Reversed ⇒ Flatten or take opposite position.
  - "Black Swan" events usually generate abnormal upside, while downside is limited by stop loss.
    - High kurtosis in returns distribution benefits momentum strategies, but devastate mean-reverting ones.
- Diversification
  - Futures exhibit momentum due to roll returns.
  - Futures markets are more diversified than equities.
  - "Following The Trend: Diversified Managed Futures Trading" by Andreas Clenow

Advantages of Momentum Strategies

- *Exercise*:
  - Recall the momentum strategy TU_mom.m?
  - Compute the first 4 moments of the daily returns of TU.
  - Use function *pearsrnd* to generate 10,000 *simulated* returns series of same length as real one, and with same 4 moments as real one. (Need Statistics Toolbox)
  - Run strategy on each simulated series, and see what % of samples generate avg returns $\geq$ historical avg return.
  - Solution program in TU_mom_hypothesisTest.m

Disadvantages of Momentum Strategies

- Futures momentum often requires long holding period.
  - Few independent trades.
  - Low Sharpe ratio and statistical significance.
- Event-driven momentum duration can shorten over time.
- Momentum crashes – underperformance for prolonged period in aftermath of financial crisis.

Summary

- Causes of momentum:
  - Futures roll returns
    - Time-series and cross-sectional momentum strategies.
    - Arbitrage between futures and spot returns.
      - E.g. VX-ES
  - Slow diffusion of news
    - PEAD and other event-driven strategies.
  - Forced sales and purchases by funds.
    - Risk management contagion.
    - Investors redemptions/subscriptions contagion.
    - Index funds additions/deletions.
    - Levered ETFs rebalancing.

Summary

- HFT momentum: manipulation of order book.

Keep in touch!

- Through email: ernest@epchan.com
- Through my blog: epchan.blogspot.com
- Through my website: www.epchan.com
- Follow me on Twitter: @chanep
- **Don't forget to zip up C:/MomentumWS/ and email to yourself!**