

# 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).
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- Author:
  - *Machine Trading: Deploying Computer Algorithms to Conquer the Markets* (Wiley 2017).
  - *Algorithmic Trading: Winning Strategies and Their Rationale* (Wiley 2013).
  - *Quantitative Trading: How to Build Your Own Algorithmic Trading Business* (Wiley 2009).
- Blogger: [epchan.blogspot.com](http://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](https://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](http://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

- **Finding** 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](http://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  
 $\text{cls}=[11 \ 12 \ 13 \ 14]'$  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.

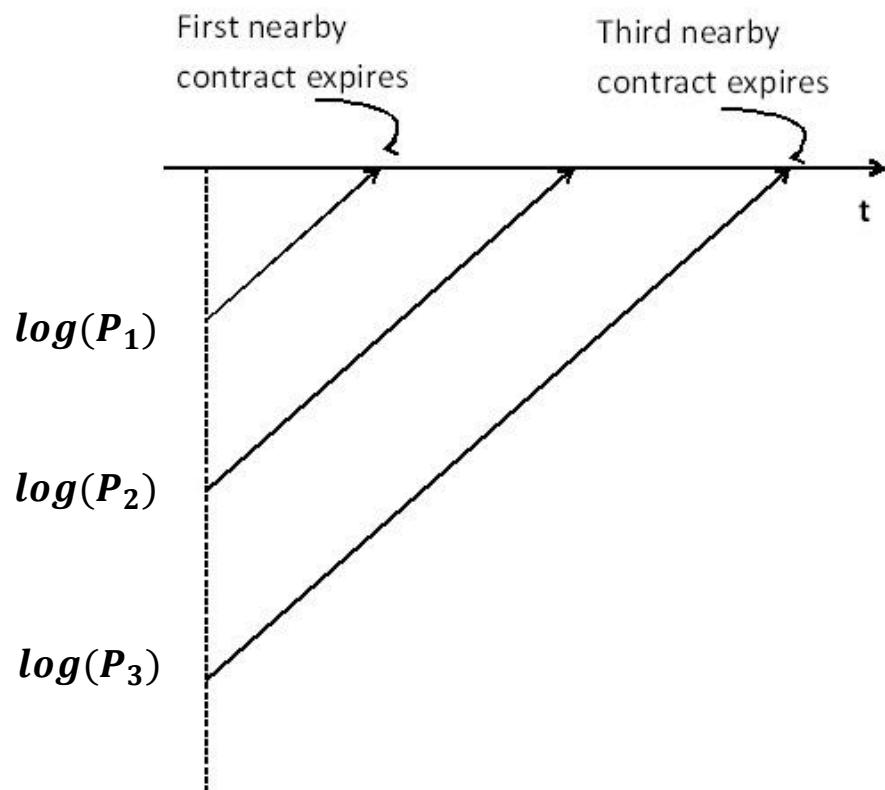
# More on MATLAB

- 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/](http://www.mathworks.com/moler/)
  - [cseweb.ucsd.edu/~datorres/docs/MatlabTip.pdf](http://cseweb.ucsd.edu/~datorres/docs/MatlabTip.pdf)
  - [en.wikibooks.org/wiki/MATLAB\\_Programming](http://en.wikibooks.org/wiki/MATLAB_Programming)

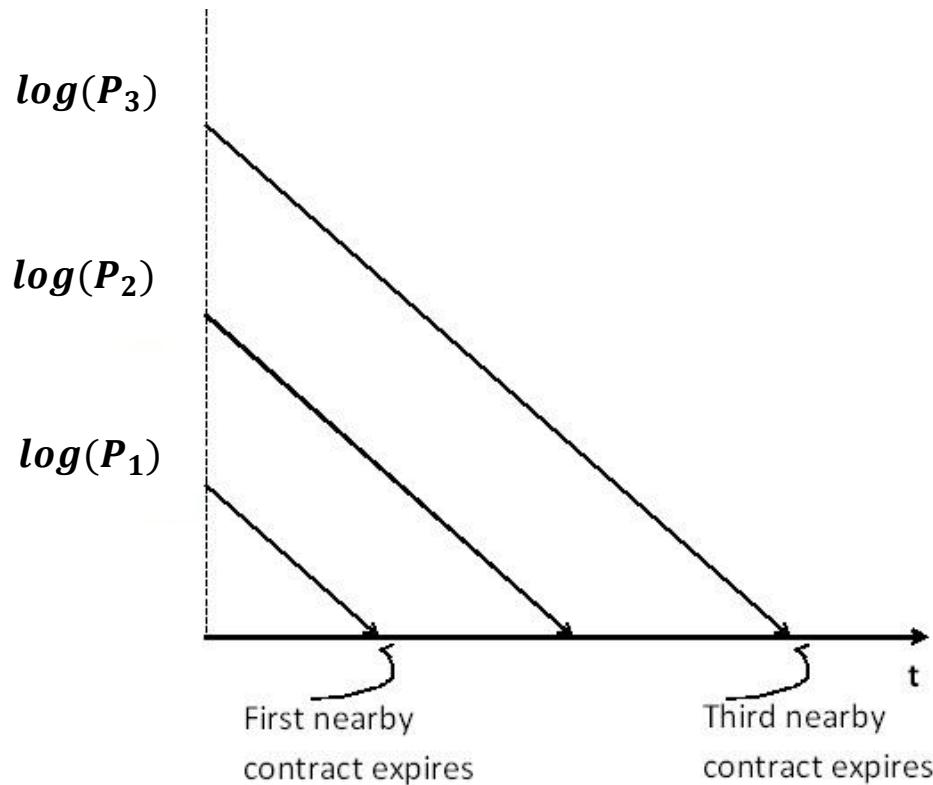
# Roll Returns As Driver of Futures Momentum

- 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



# 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.

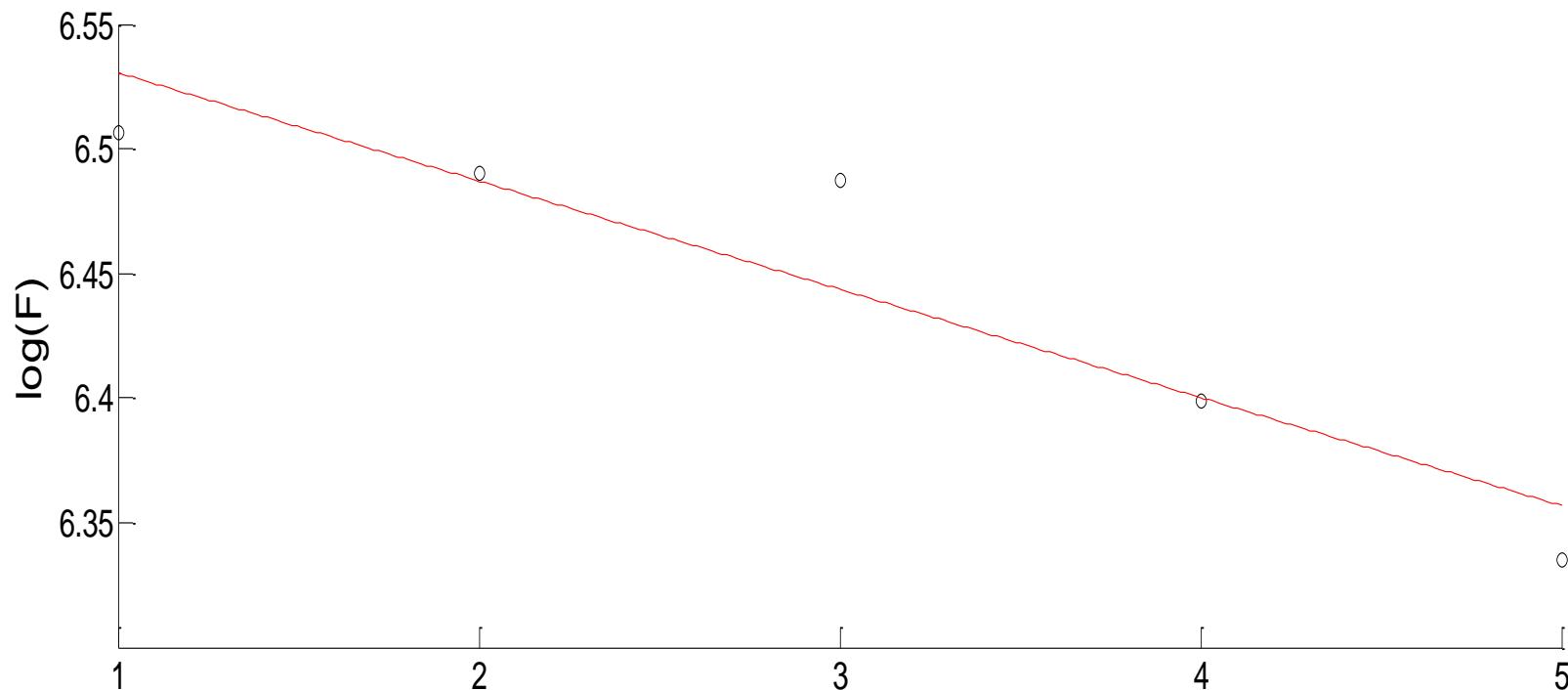
# *Exercise: Estimating Spot and Roll Returns*

- 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,  $c$ ,  $\alpha$  (spot return), and  $\gamma$  (roll return) are constants.
- Input: Corn futures closing price data in a  $\mathcal{T} \times M$  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](http://epchan.com/book2/inputDataDaily_C2_20120813.mat) (userid/pw=kelly).
  - Contract ending in 0000\$ is spot price.

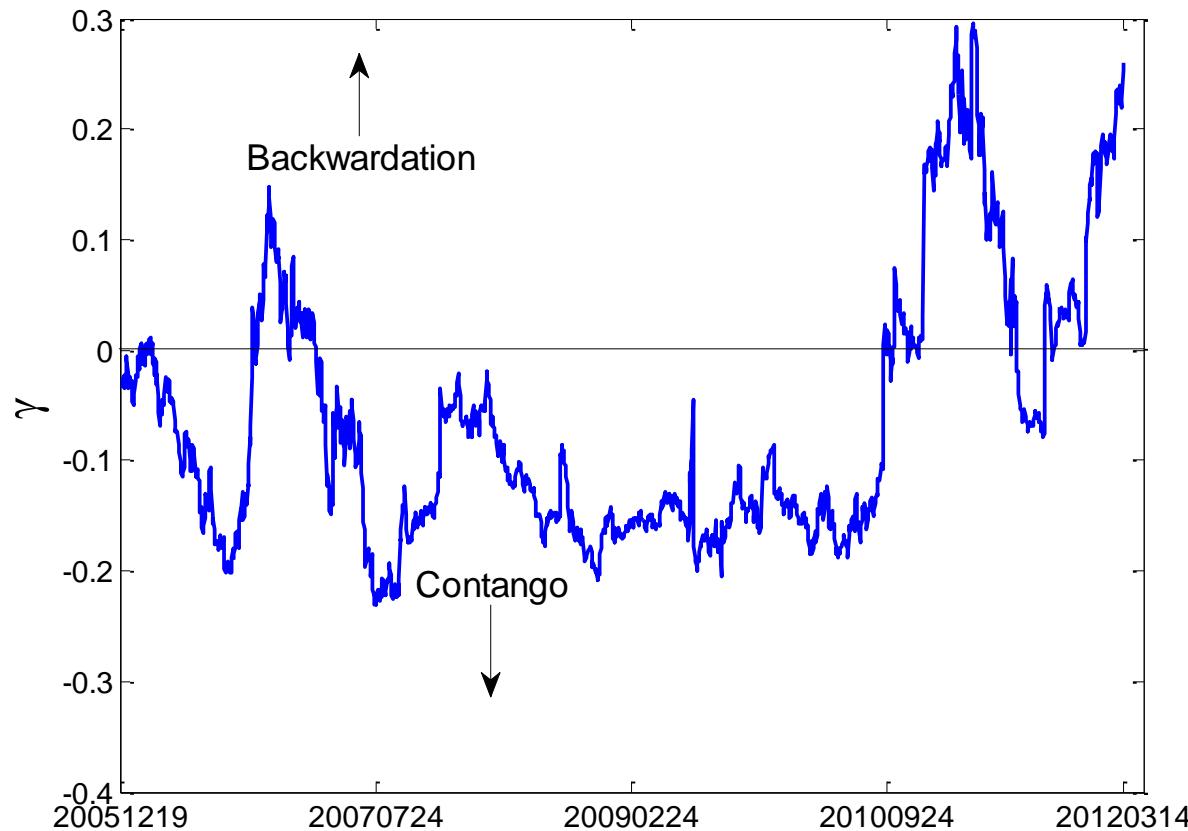
# *Exercise: Estimating Spot and Roll Returns*

- Take the log of the cash and futures prices.
- Use linear regression (*ols* from spatial-econometrics.com) on the cash prices to find  $\alpha$ .
- 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  $\gamma$ .
- Plot  $\gamma$  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

- $\alpha$  =slope of log cash prices vs time  
=2.8%
- $\gamma$  =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 arbitAGED 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`

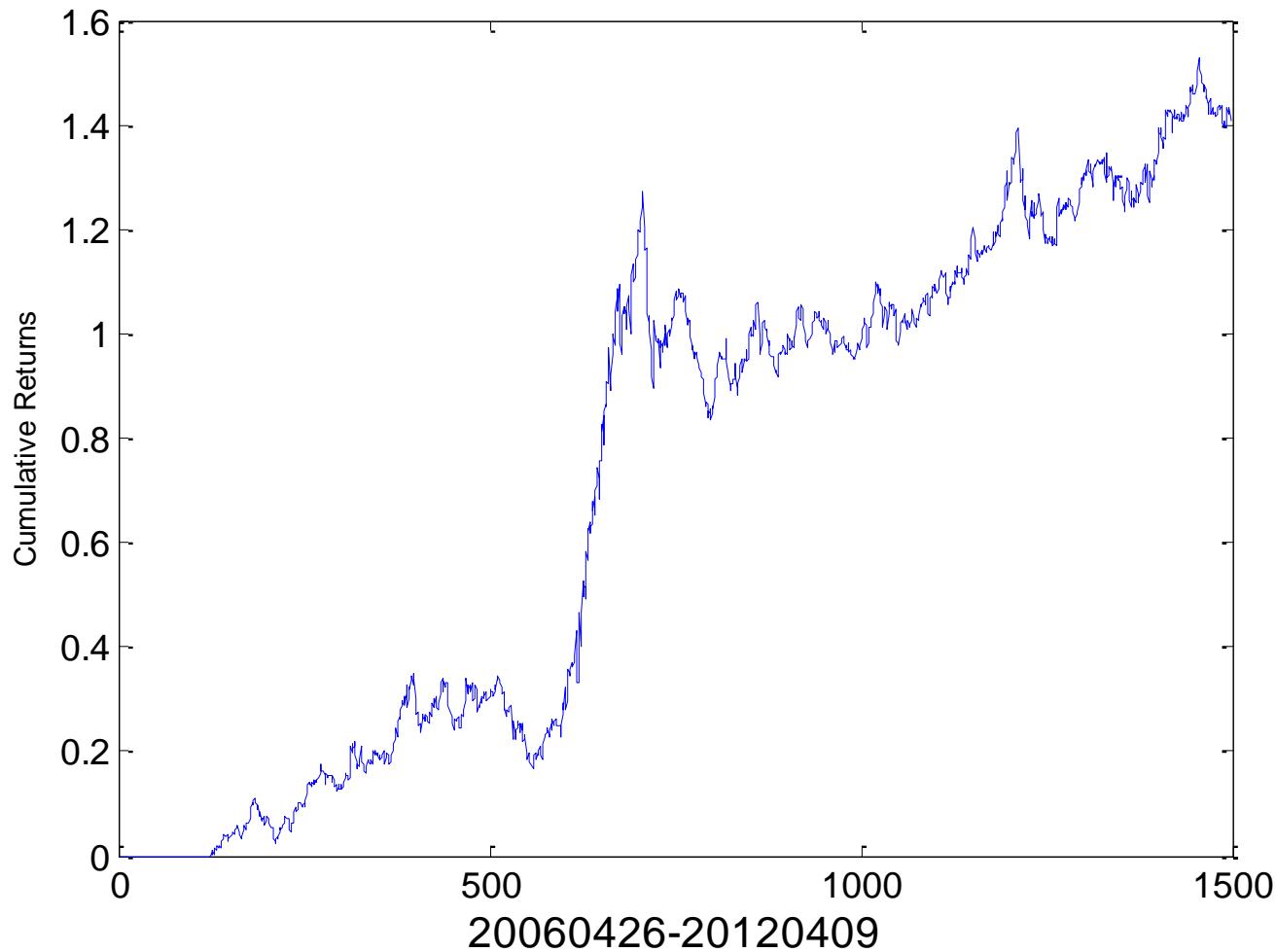
# Extraction of Roll Returns

- 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:

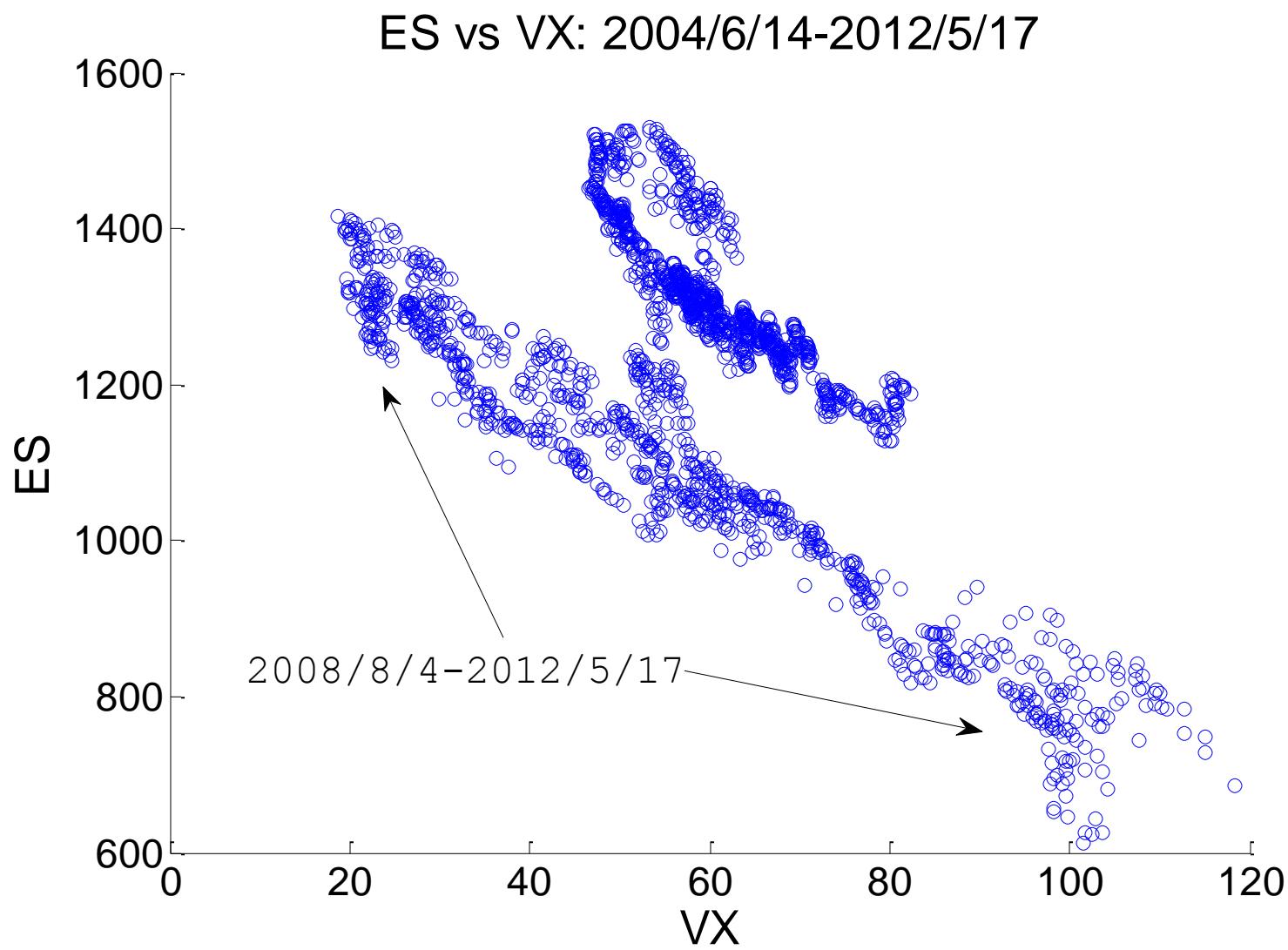
```
idxV=find(strcmp('VX', syms));
idxE=find(strcmp('ES', syms));

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);
```



# 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<sup>©</sup> 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)?

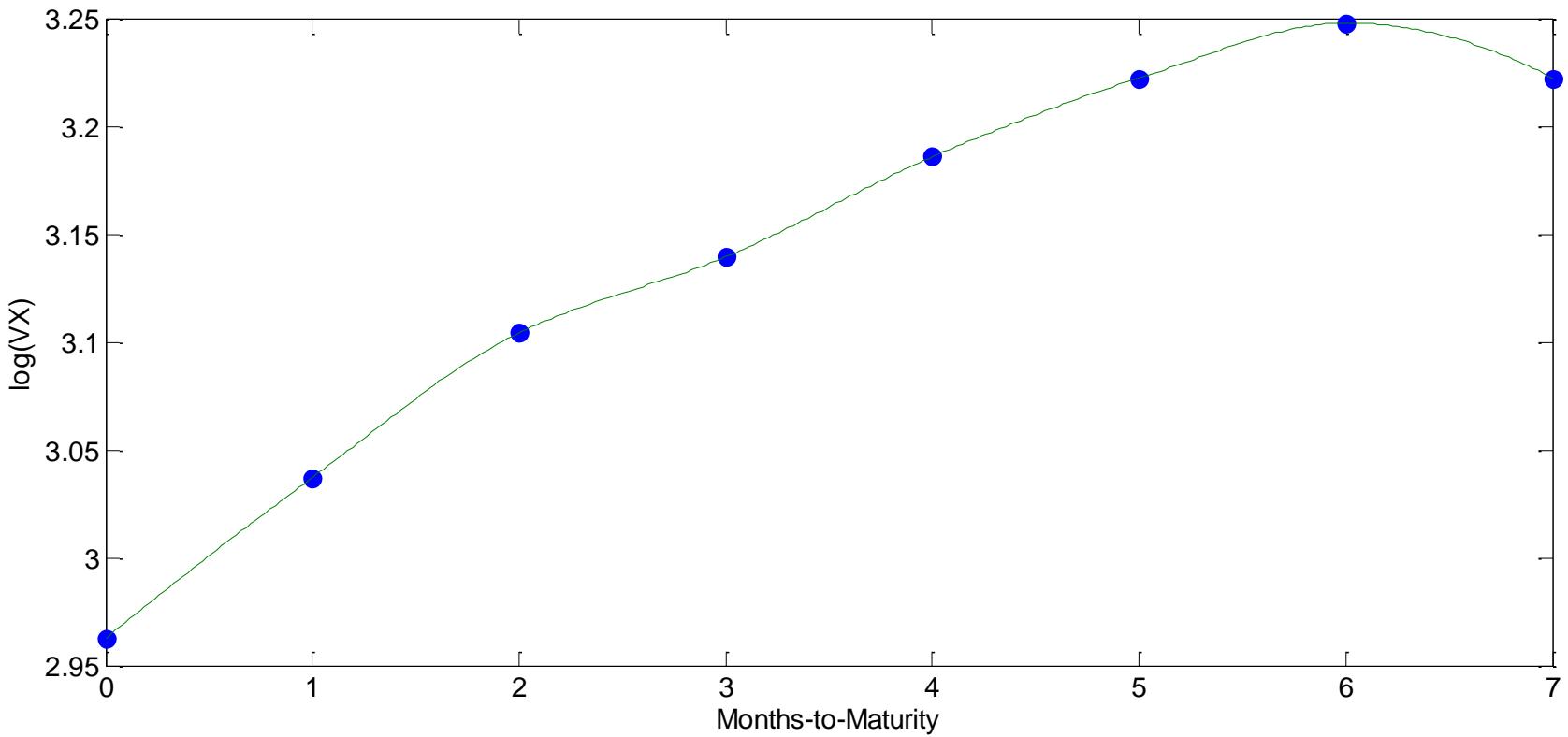
# VX-ES

- 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  $(VIX-VX)/\text{Time-to-settlement}$ .
  - If  $VIX-VX > 0.1 * \text{number of trading days till settlement}$ , buy 0.3507 contract of VX and buy 1 contract of ES. Hold 1 day.
  - If  $VX-VIX > 0.1 * \text{number of trading days till settlement}$ , short 0.3507 contract of VX and short 1 contract of ES. Hold 1 day.

# VX-ES

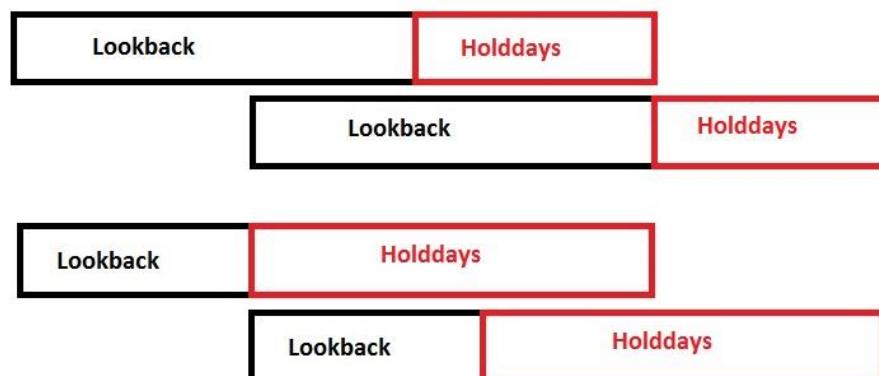
- The code for this is a bit complicated because we need to know the settlement date for each front contract. (VX\_ES\_rollreturn.m)
- Results: APR=6.9%, Sharpe Ratio=1 (with tcost=1bps).
- (Ref: Simon, David P., and Campasano, Jim. 2012. The VIX Futures Basis: Evidence and Trading Strategies. Available at [papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2094510](http://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  $z(t)$   
$$\text{Var}(\tau) = \langle |z(t + \tau) - z(t)|^2 \rangle$$
  - If  $z(t)$  is a random walk,  $\text{Var}(\tau) \sim \tau$ .
  - If  $z(t)$  has momentum,  $\text{Var}(\tau) \sim \tau^{2H}$ ,  $H > 0.5$ .

# 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
$$\frac{Var(z(t) - z(t - \tau))}{\tau Var(z(t) - z(t - 1))}$$
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<sup>©</sup> Econometrics Toolbox.)
  - Solution program in TU\_mom.m

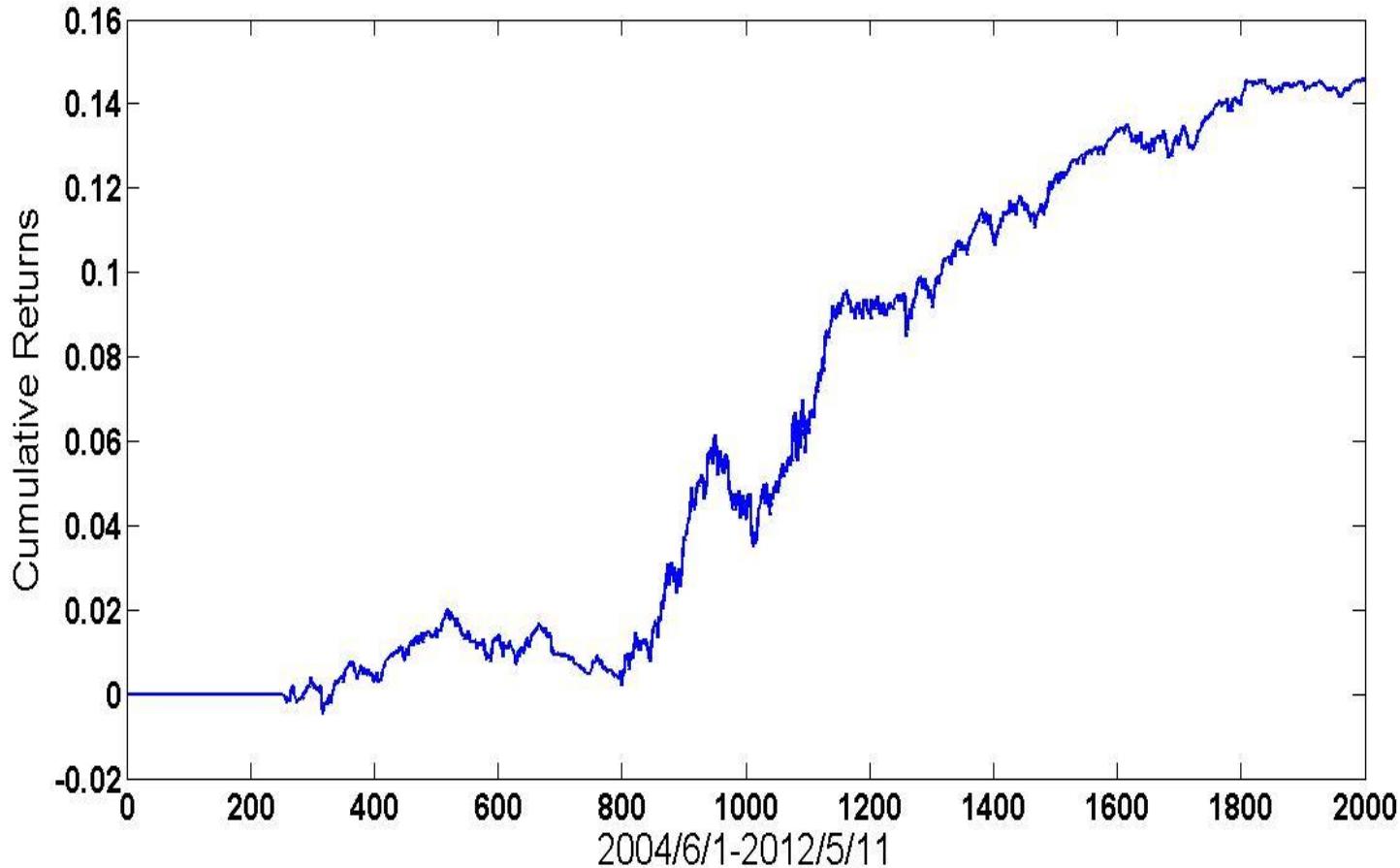
# Time Series Momentum Strategy

- 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:

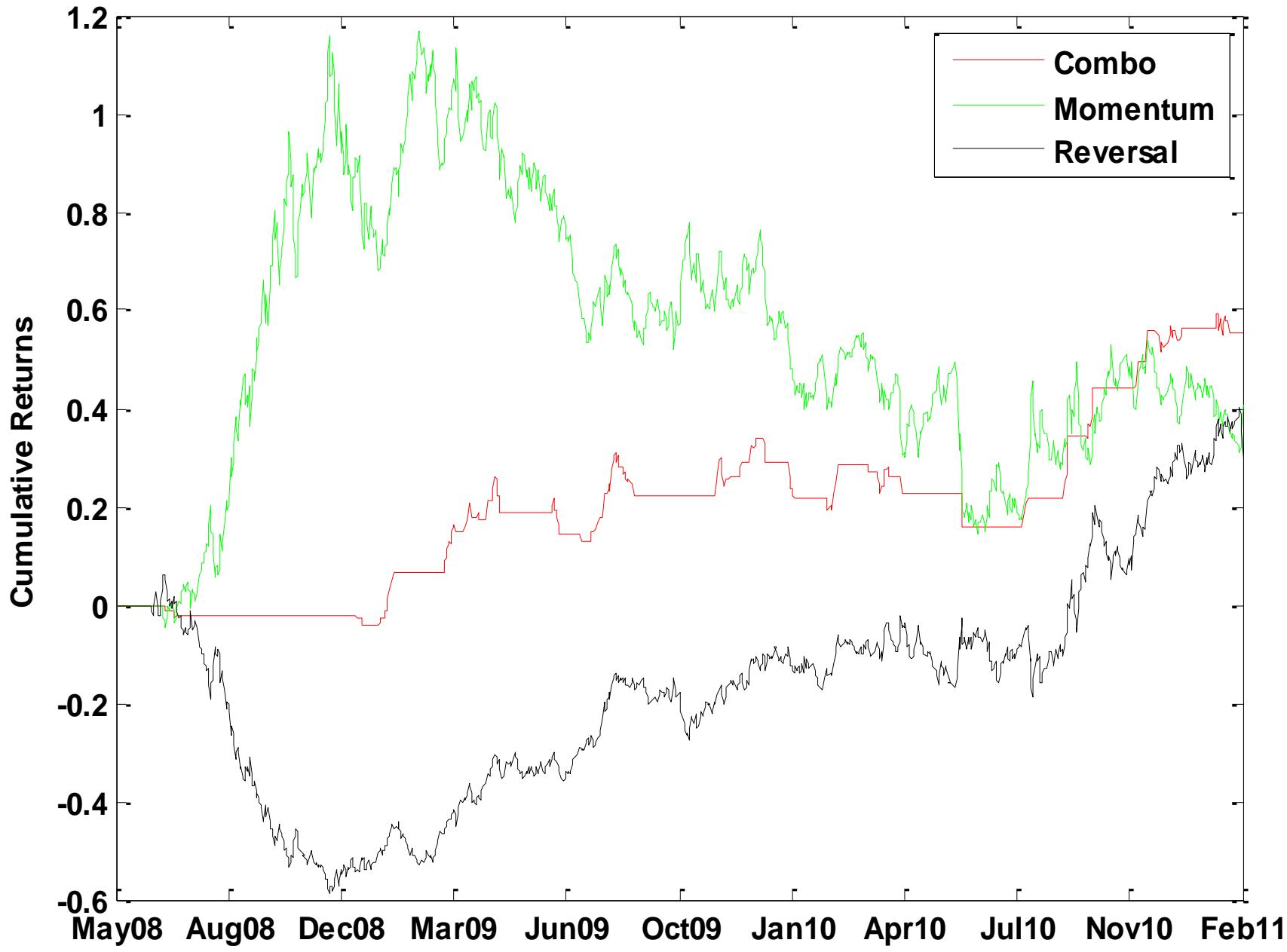
Symbol	Lookback	Holding days	APR	Sharpe ratio	Max Drawdown
VX (CFE)	50	5	35.2%	1.09	-33.2%
BR (CME)	100	10	17.7%	1.09	-14.8%
HG (CME)	40	40	18.0%	1.05	-24.0%
TU (CBOT)	250	25	1.7%	1.04	-2.5%

# Indicators for TS Momentum

- Roll returns,  $\text{sign}(\text{lagged-returns})$
- Buy when price reaches new N-day high
- Buy when price exceeds MA or EMA
- Buy when price exceeds upper Bollinger band
- Buy when  $\text{num(up days)} > \text{num(down days)}$
- 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!



# 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: [www.columbia.edu/~kd2371/papers/unpublished/mom4.pdf](http://www.columbia.edu/~kd2371/papers/unpublished/mom4.pdf)

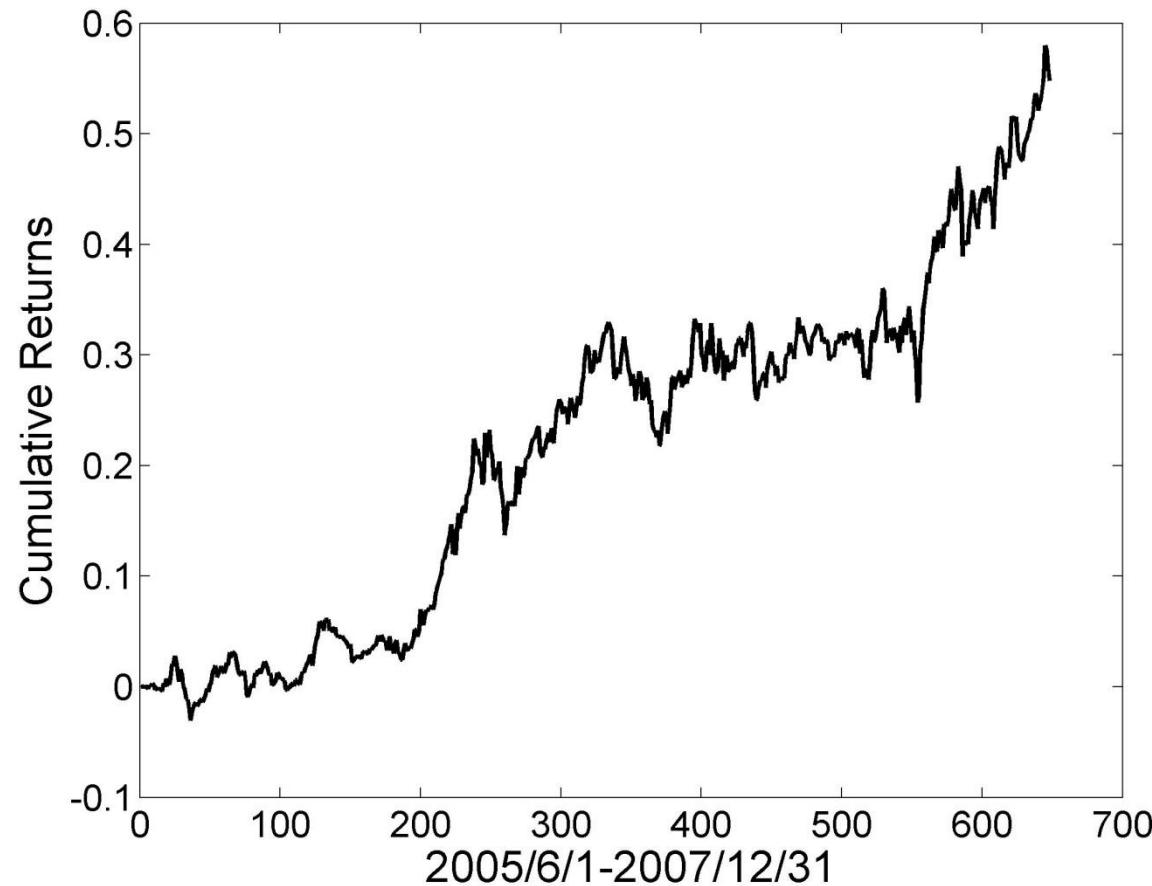
# Cross-Sectional Futures Momentum

- Results:

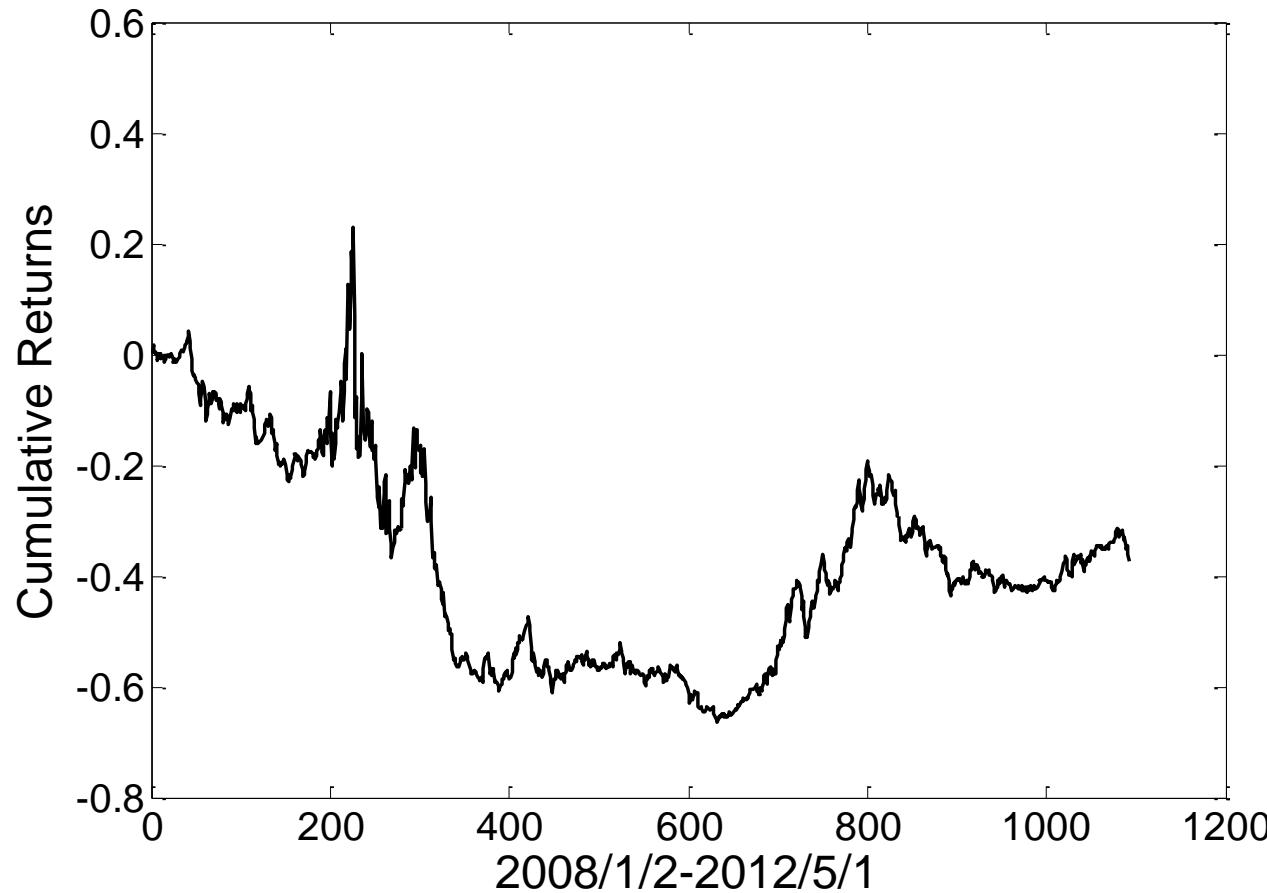
	APR	Sharpe Ratio
2005/6/1-2007/12/31	18%	1.4
2008/1/2-2009/12/31	-33%	-0.6
2010/1/4-2012/05/01	16%	0.7

- 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  
$$\partial \log(F(t, T_1)) / \partial t - \partial \log(F(t, T_2)) / \partial t$$
- 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

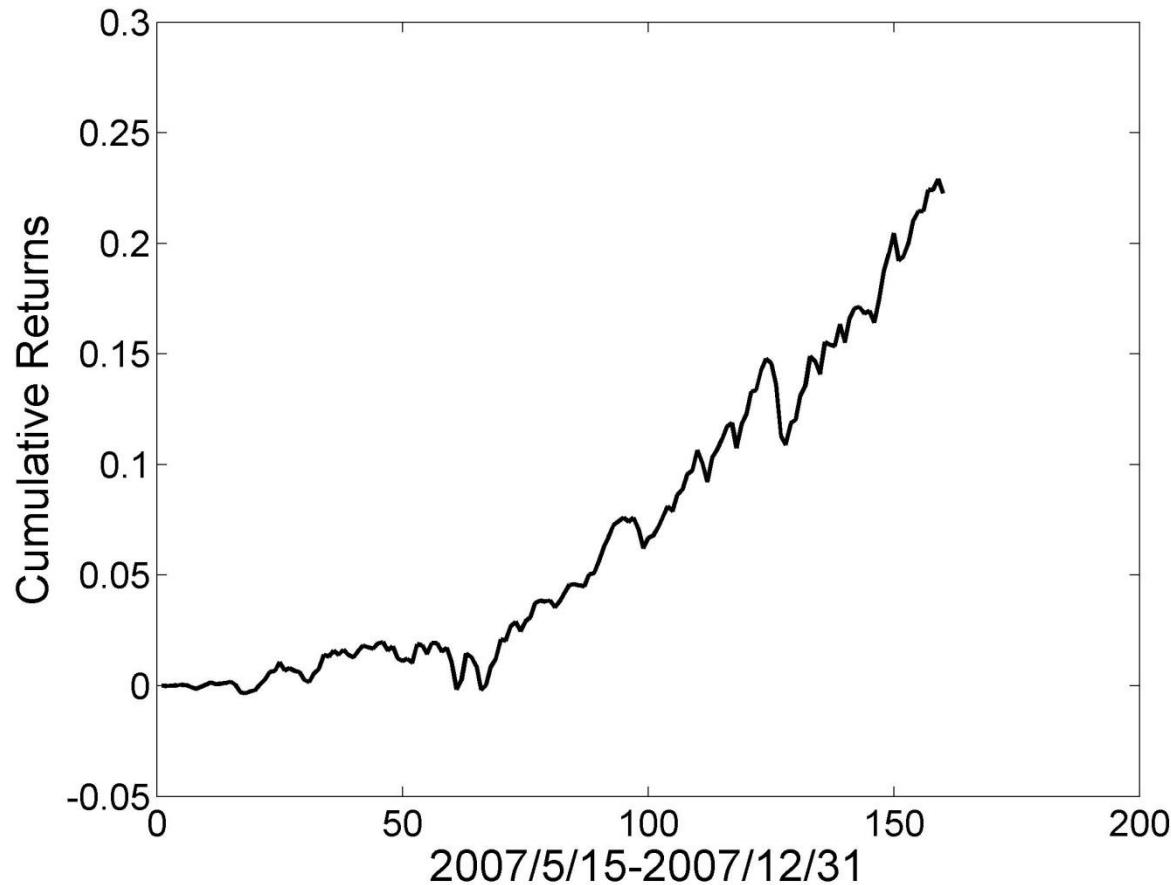
- Cross-sectional momentum also present in S&P 500 stocks.
  - Total return = market return + factor returns + residual returns
  - Factor returns change slowly.
  - Long-short portfolio will hedge away market return.
- Strategy:
  - Rank the 1-year return of S&P 500 stocks every day.
  - (Universe can 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

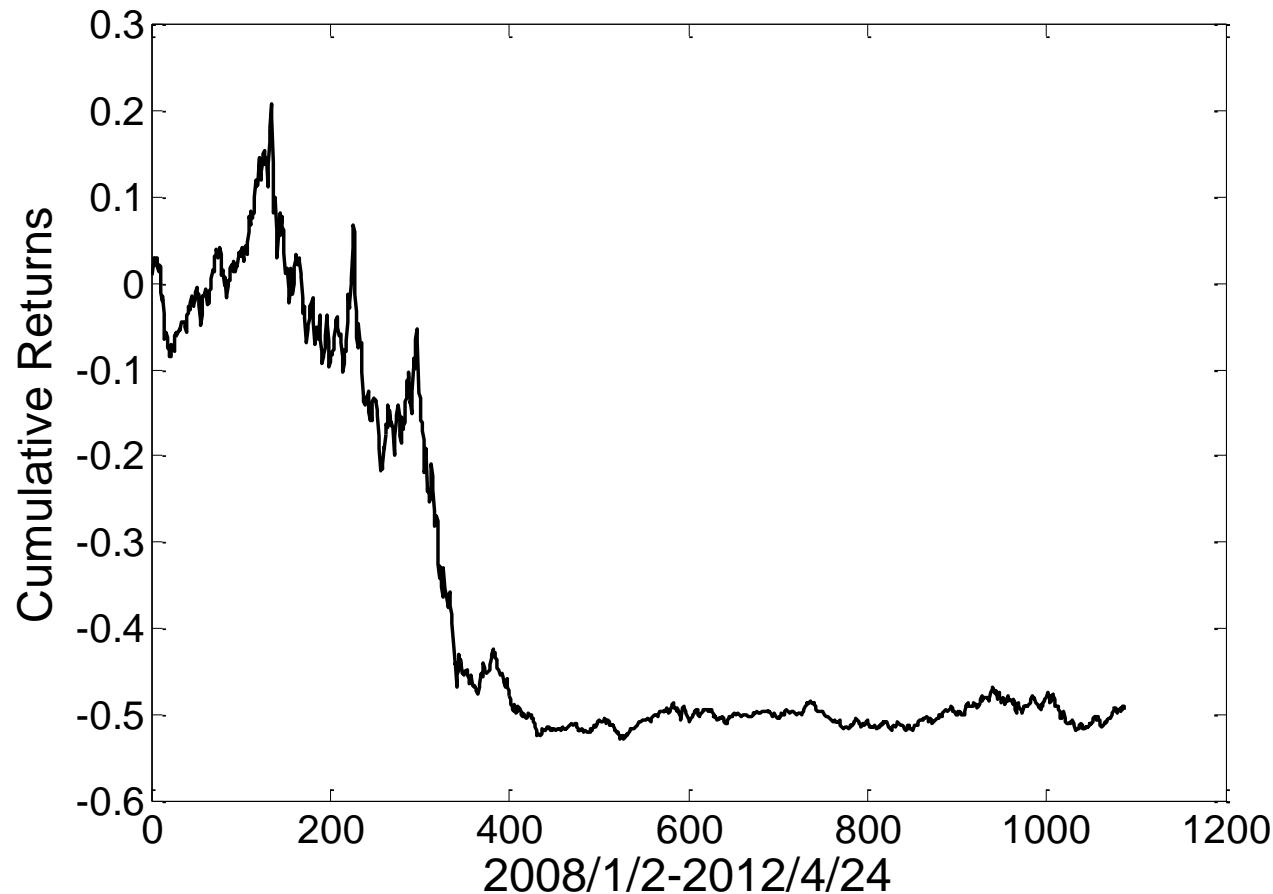
- Results:

	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

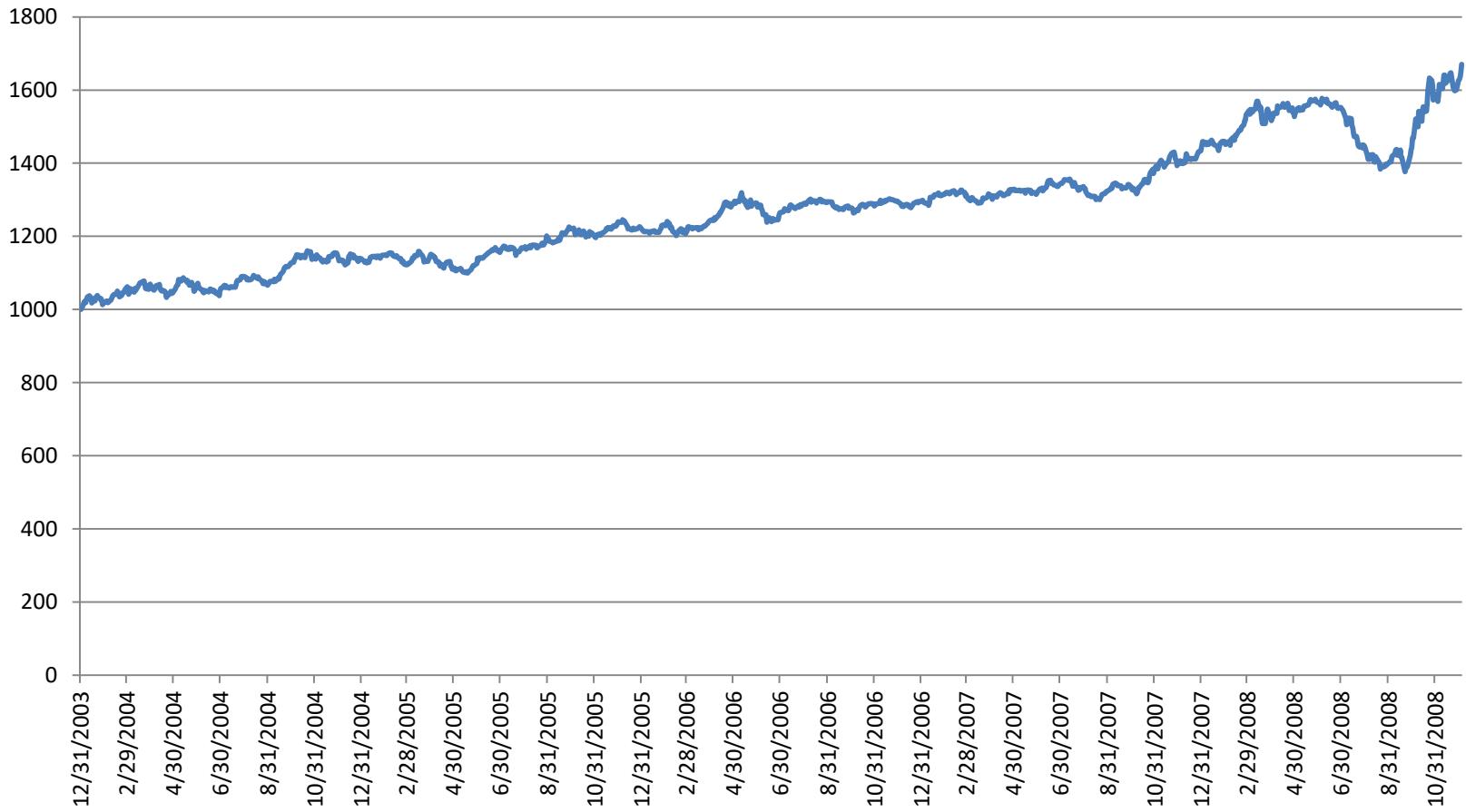
- Look at a “momentum strategy index”: Diversified Trends Indicator DTI.
  - Mutual fund RYMFX and ETF WDTI track this index.

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

- <http://www.aftllc.com/dti.html>

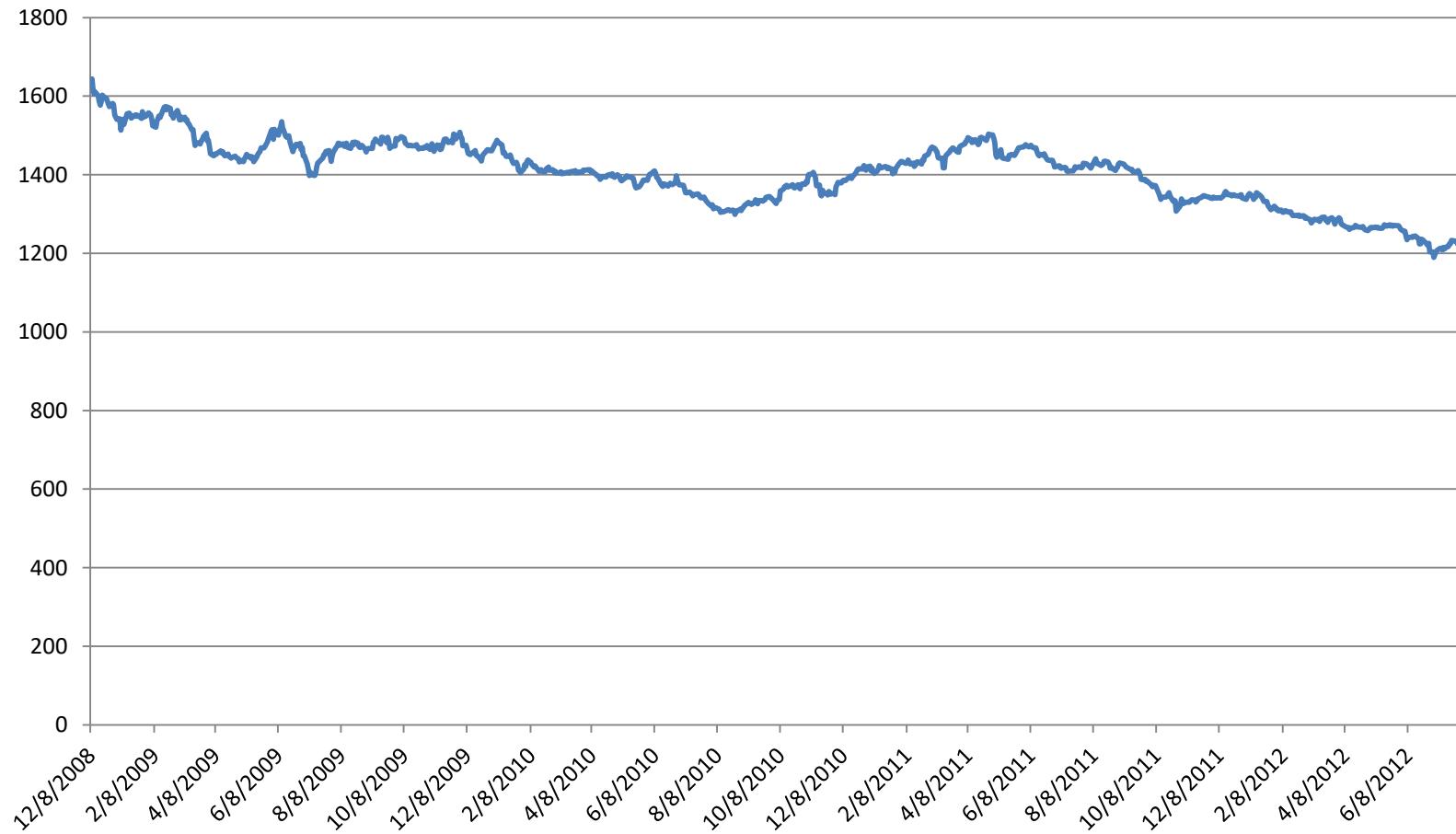
# DTI Index

2003/12/31-2008/12/05



# DTI Index

2008/12/08-2012/07/26



# 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.
  - [www.ravenpack.com/research/shorttermstockselectionpaperform.htm](http://www.ravenpack.com/research/shorttermstockselectionpaperform.htm)
- 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  $\text{retC2O}$  is greater (less) than  $(-)0.5 * \text{stddev}(\text{retC2O}, 90\text{-day})$
  - Exit at market close.
- *Exercise:* Backtest this strategy!
  - Stock prices in *inputDataOHLCDaily\_stocks\_20120424*, earnings announcements in *earnannfile* ( $\text{earnann}==1$  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. [ravenpack.com/research/marketresponsepaperform.htm](http://ravenpack.com/research/marketresponsepaperform.htm).
  - 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 Courtnay, 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  $\alpha$  suffers heavy, possibly unrelated loss.
    - Risk manager (via Kelly formula?) of  $\alpha$  demands portfolio size reduction.
    - $\alpha$  sells stock A.
    - Stock A goes down in price.
    - Fund  $\beta$  now suffers heavy loss if they hold A and other such stocks.
    - Risk manager of  $\beta$  demands **deleveraging**.
    - $\beta$  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?” [web.mit.edu/alo/www/Papers/august07.pdf](http://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  $\alpha$  suffers heavy, possibly unrelated loss.
    - Investors of  $\alpha$  redeem their investments.
    - $\alpha$  sells stock A.
    - Stock A goes down in price.
    - Fund  $\beta$  now suffers heavy loss if they hold A and other such stocks.
    - Investors of  $\beta$  redeem their investments.
    - $\beta$  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!  
([www.people.hbs.edu/estafford/Papers/AFS.pdf](http://www.people.hbs.edu/estafford/Papers/AFS.pdf).)
- Mutual funds holdings and returns are stable and can be obtained via public filings.
- Can construct selling (buying) pressure on stock  $s$  at time  $t$  :

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

# 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) ⇒ mean reversion.
  - If price change is due to change in fundamentals ⇒ 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=  $3 \times \$270M = \$810M$
- 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=  
 $3 \times \$253.8M = \$761.4M$
- Market value of holdings at today's close=  $\$810M - \$16.2M = \$793.8M$
- Need to sell=  $\$793.8M - \$761.4M = \$32.4M$

# Levered ETF Momentum

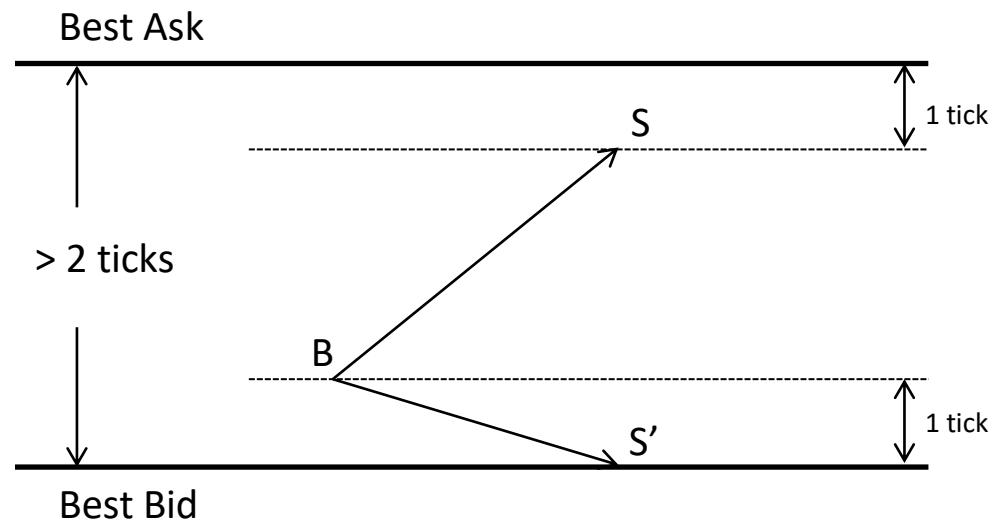
- This selling of \$32.4M of holdings towards market close, in an already down market, generates momentum in UPRO, as well as in the SPX component stocks themselves.
- Strategy:
  - Buy(sell) UPRO if return from previous day's close to 15 minutes before today's close is greater(smaller) than (+/-)2%.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



# 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  $\Rightarrow$  Momentum Reversed  $\Rightarrow$  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 my blog: [epchan.blogspot.com](http://epchan.blogspot.com)
- Through my website: [www.epchan.com](http://www.epchan.com)
- Follow me on Twitter: @chanep