The importance of quantitative strategies in the current investment landscape

Marco Avellaneda

Courant Institute, NYU

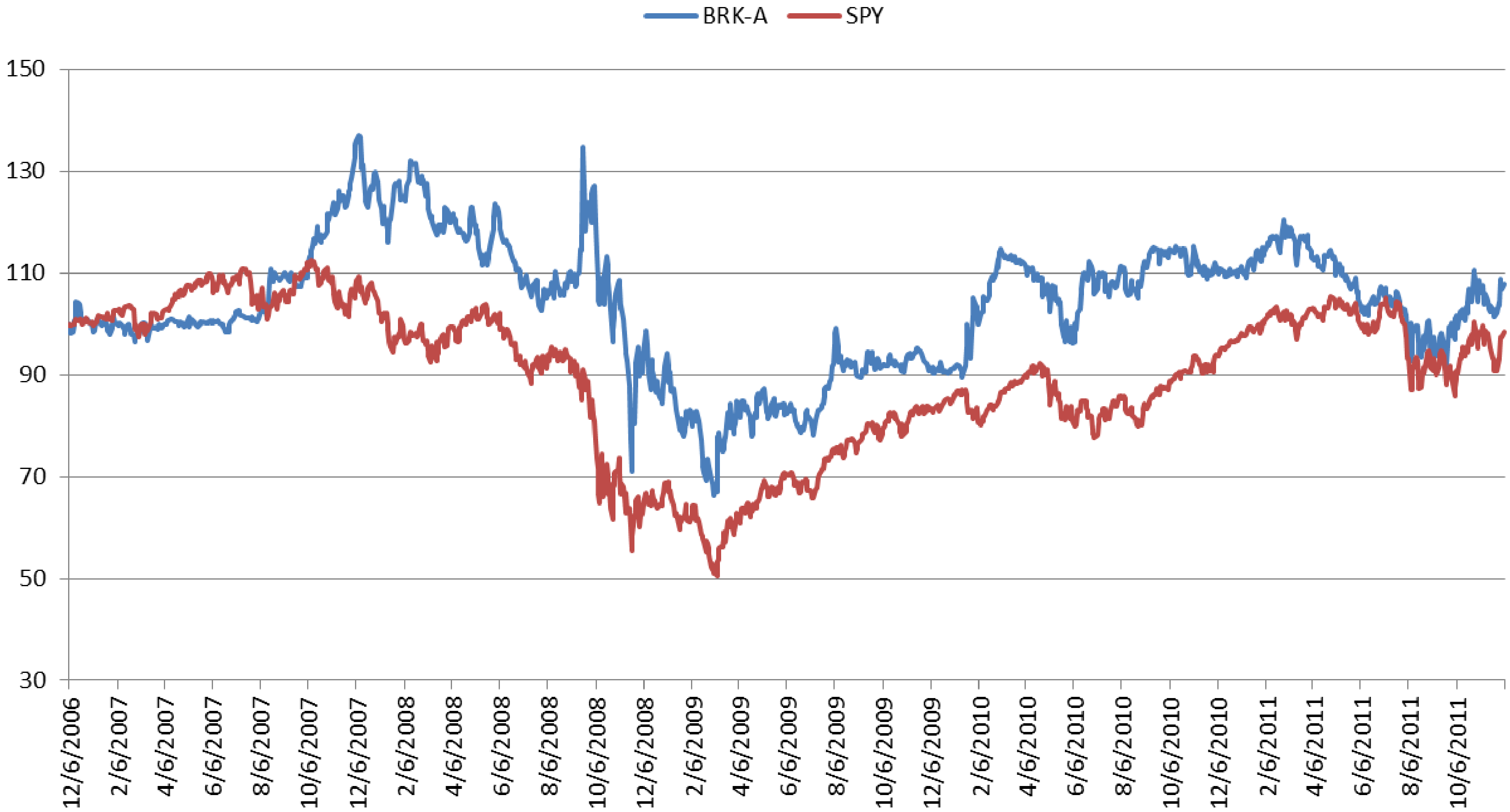
Finance Concepts

Quant Invest, New York , December 8 2011

The case for quant strategies

- Since Q4 2007, markets have experienced unprecedented volatility and inter-asset correlation
- Traditional long-only strategies are lackluster
- Warren Buffet's Berkshire Hathaway barely outperformed the S&P 500 over the last 5 years
- After making a killing in the subprime crisis, J. Paulson & Co. lost more than 46% in 2011
- Emerging markets strategies are being questioned given the macroeconomic outlook
- Deflation/inflation uncertainty and the European crisis make fixed-income unattractive as a buy and hold strategy. Same for credit.

Berkshire Hathaway vs. S&P 500



BRK information ratio=0.2, SPY information ratio=0.12

Paulson & Co. Hedge Funds in 2011

- Advantage funds (Advantage Plus and Advantage). Combined AUM= 11 billion USD.
  Performance: -46% and -32% respectively

- Gold Fund
  Performance: +11%

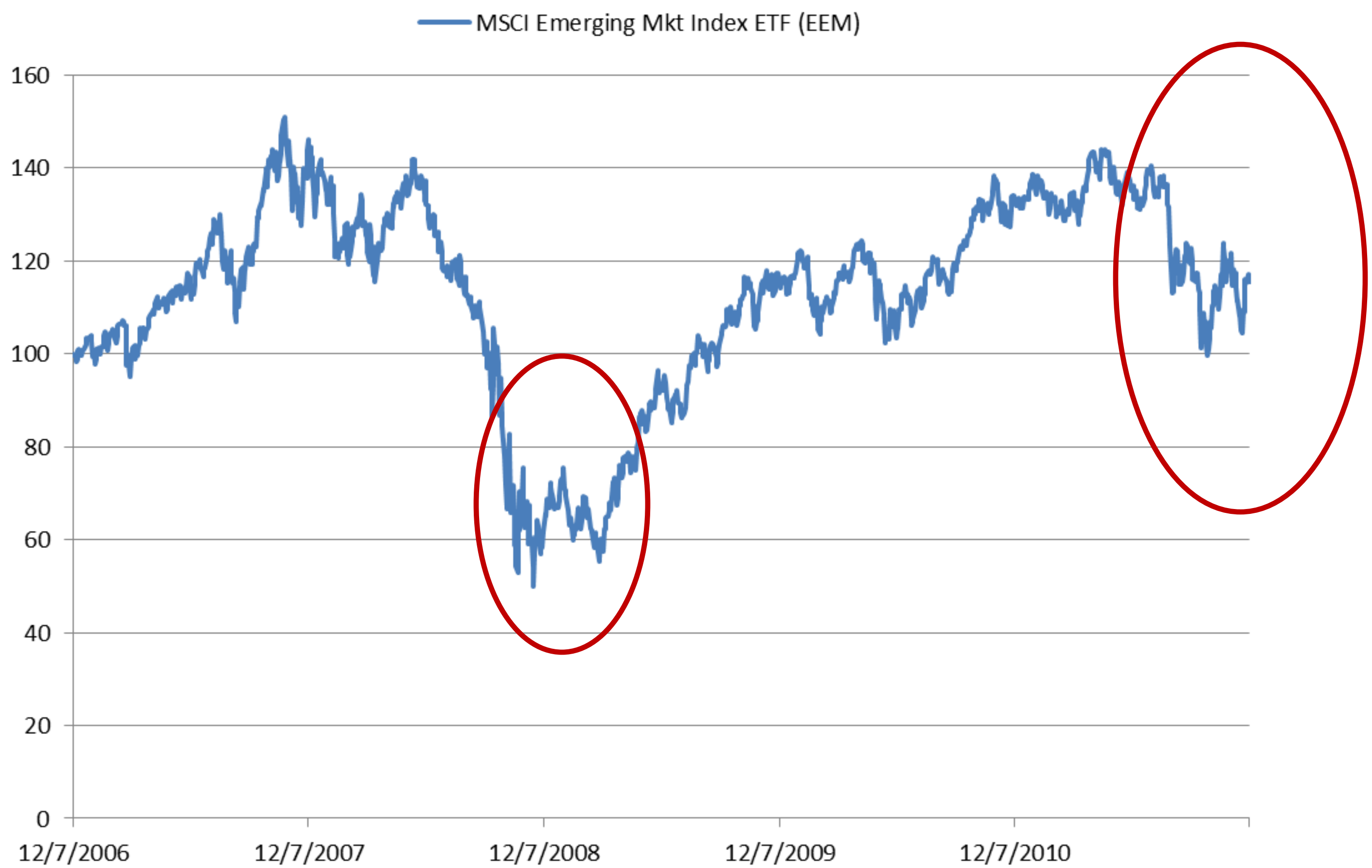
- Recovery Fund
  Performance: -28%

- Paulson Partners Enhanced Fund
  Performance: -18%

- Paulson Credit Opportunities
  Performance: -18%

Source: Bloomberg.com, Dec 5, 2011

Emerging Markets



High volatility and vulnerability to slow-down in China's economy

Capitalizing on equity market volatility

- The dearth of opportunities on fundamental equity strategies led investors to reduce market exposure

- Classical hedge fund strategies are less volatile than mutual funds but still carry significant Beta

- Market-neutral Equity quant strategies that can earn money from realized volatility become an important alternative to cash

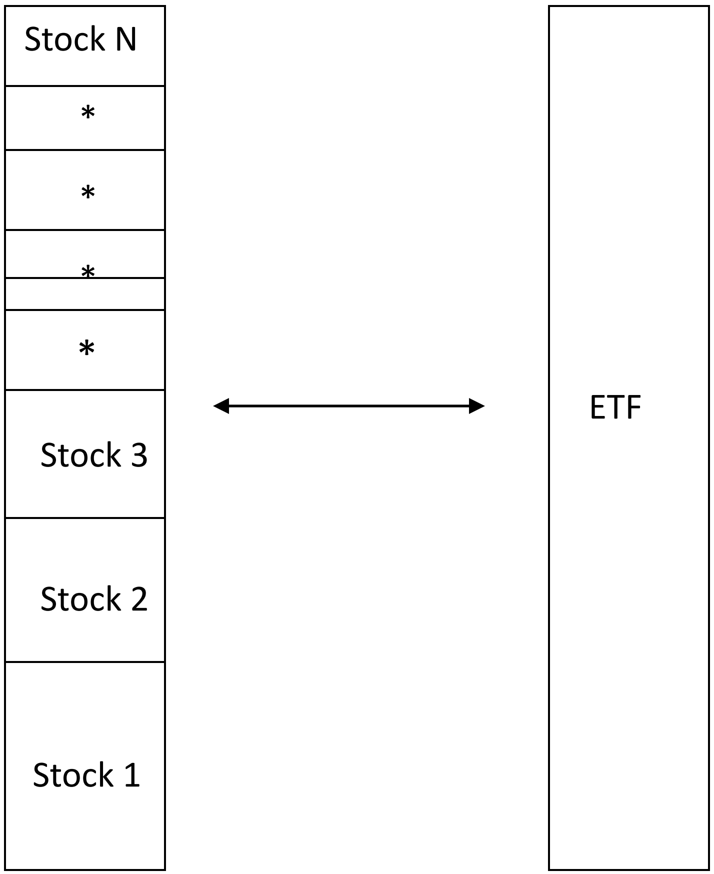
- Systematic trading rules with new ideas

- E.g.: arbitrage between ``similar'' equity products (and more products are similar due to volatility/correlation)

I. Examples of quant strategies that make use of algorithms & HFT

- Intraday index and ETF arbitrage
- Statistical arbitrage (``Stat Arb’’)
- Liquidity providing (``Market making’’)
- High frequency trading and price forecasting

Arbitrage of ETFs against the underlying basket



1. Buy/sell ETF against the underlying share holdings

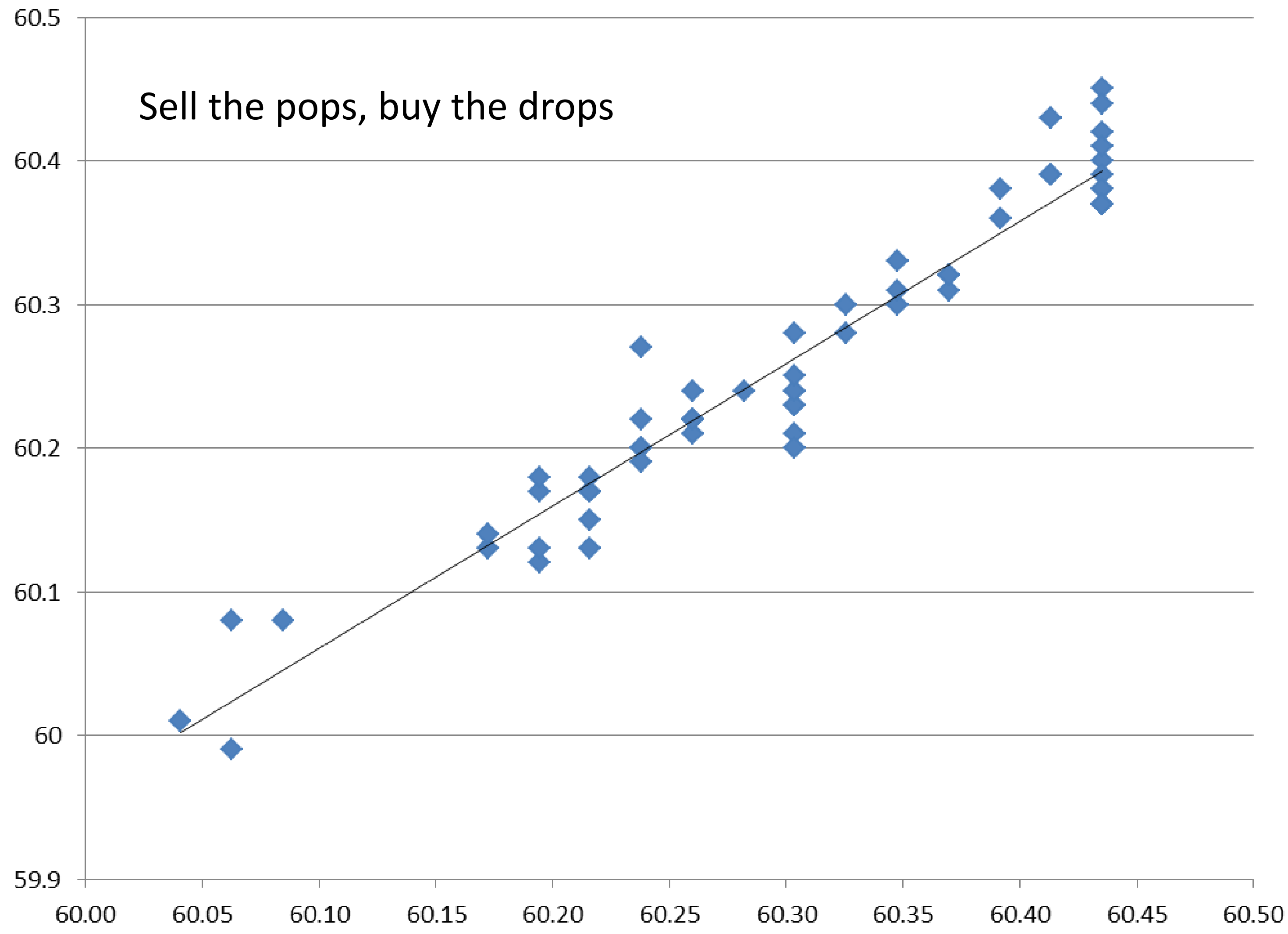
2. Creation/redemption of ETFs to close the trade

This requires high-frequency algorithmic trading to lock-in arbitrage opportunities

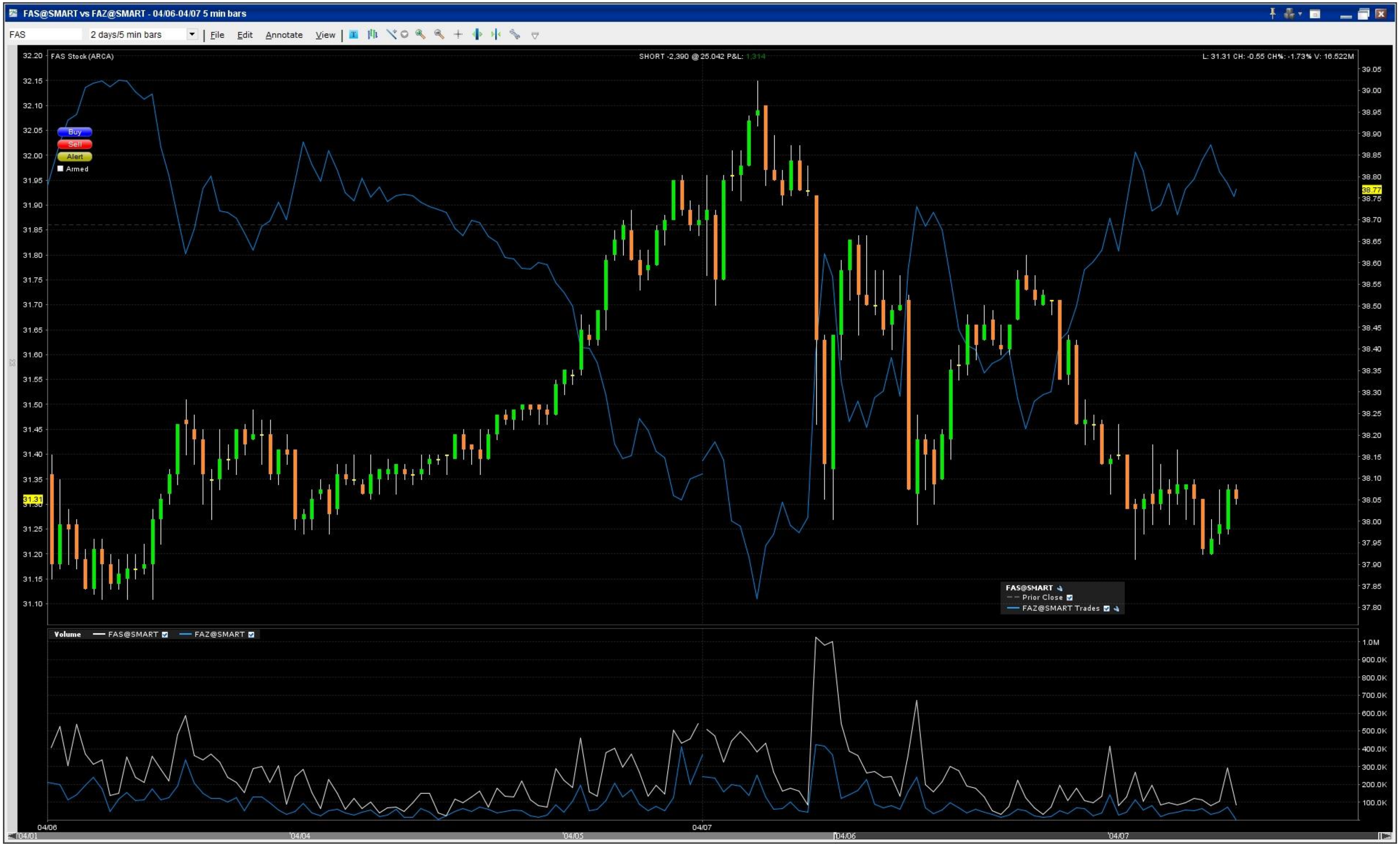
Also, ETFs vs futures (E-mini vs. SPY)

LETF versus inverse LETF…

Intraday LETF arbitrage
UYG referenced to IYF between 11 and 12 AM
July 15, 2011

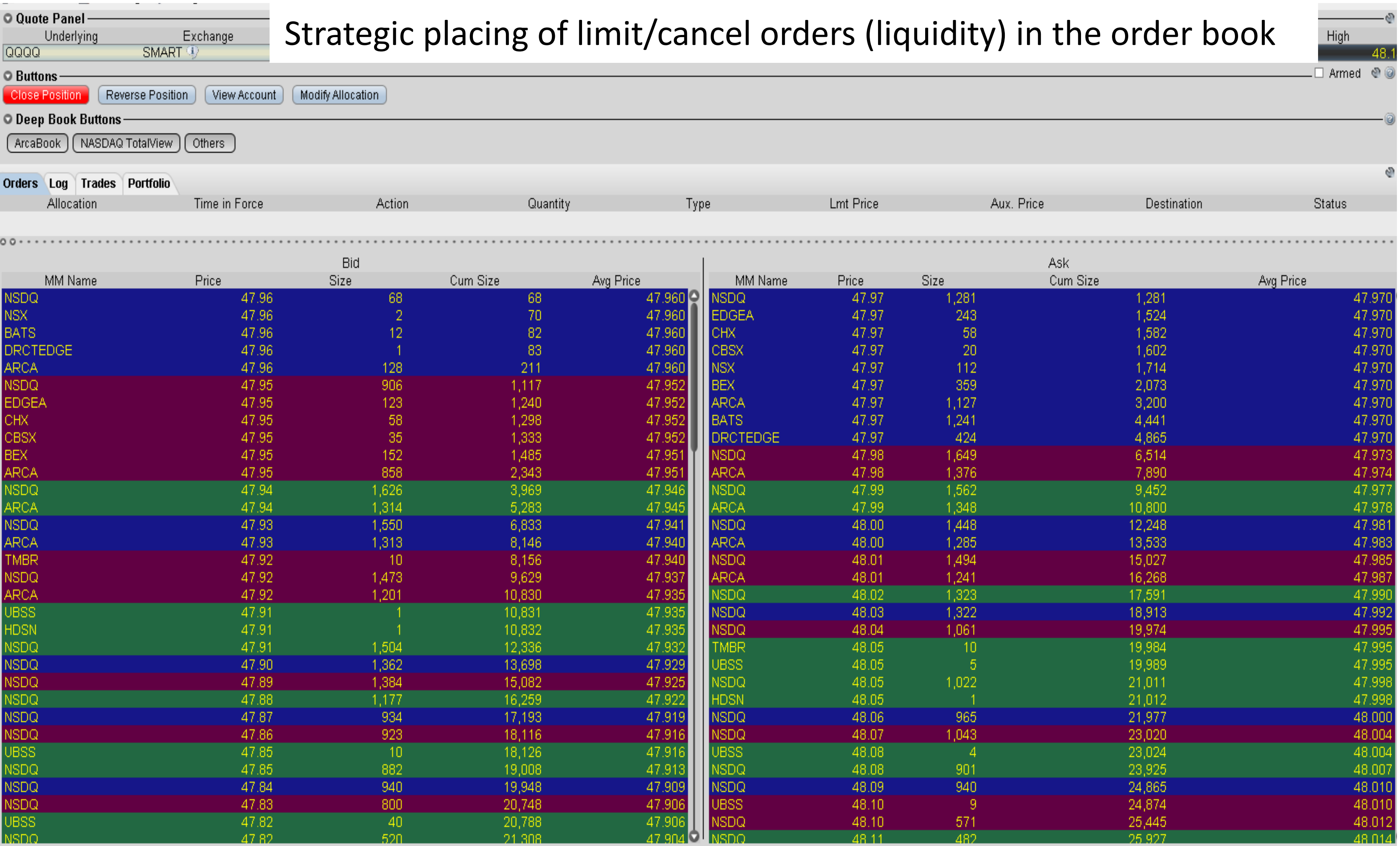


HF Pairs trading Intraday evolution of FAZ & FAZ (inverse leveraged ETFs)



Liquidity providing (high frequency)

Strategic placing of limit/cancel orders (liquidity) in the order book



Bid					Ask				
MM Name	Price	Size	Cum Size	Avg Price	MM Name	Price	Size	Cum Size	Avg Price
NSDQ	47.96	68	68	47.960	NSDQ	47.97	1,281	1,281	47.970
NSX	47.96	2	70	47.960	EDGEA	47.97	243	1,524	47.970
BATS	47.96	12	82	47.960	CHX	47.97	58	1,582	47.970
DRCTEDGE	47.96	1	83	47.960	CBSX	47.97	20	1,602	47.970
ARCA	47.96	128	211	47.960	NSX	47.97	112	1,714	47.970
NSDQ	47.95	906	1,117	47.952	BEX	47.97	359	2,073	47.970
EDGEA	47.95	123	1,240	47.952	ARCA	47.97	1,127	3,200	47.970
CHX	47.95	58	1,298	47.952	BATS	47.97	1,241	4,441	47.970
CBSX	47.95	35	1,333	47.952	DRCTEDGE	47.97	424	4,865	47.970
BEX	47.95	152	1,485	47.951	NSDQ	47.98	1,649	6,514	47.973
ARCA	47.95	858	2,343	47.951	ARCA	47.98	1,376	7,890	47.974
NSDQ	47.94	1,626	3,969	47.946	NSDQ	47.99	1,562	9,452	47.977
ARCA	47.94	1,314	5,283	47.945	ARCA	47.99	1,348	10,800	47.978
NSDQ	47.93	1,550	6,833	47.941	NSDQ	48.00	1,448	12,248	47.981
ARCA	47.93	1,313	8,146	47.940	ARCA	48.00	1,285	13,533	47.983
TMBR	47.92	10	8,156	47.940	NSDQ	48.01	1,494	15,027	47.985
NSDQ	47.92	1,473	9,629	47.937	ARCA	48.01	1,241	16,268	47.987
ARCA	47.92	1,201	10,830	47.935	NSDQ	48.02	1,323	17,591	47.990
UBSS	47.91	1	10,831	47.935	NSDQ	48.03	1,322	18,913	47.992
HDSN	47.91	1	10,832	47.935	NSDQ	48.04	1,061	19,974	47.995
NSDQ	47.91	1,504	12,336	47.932	TMBR	48.05	10	19,984	47.995
NSDQ	47.90	1,362	13,698	47.929	UBSS	48.05	5	19,989	47.995
NSDQ	47.89	1,384	15,082	47.925	NSDQ	48.05	1,022	21,011	47.998
NSDQ	47.88	1,177	16,259	47.922	HDSN	48.05	1	21,012	47.998
NSDQ	47.87	934	17,193	47.919	NSDQ	48.06	965	21,977	48.000
NSDQ	47.86	923	18,116	47.916	NSDQ	48.07	1,043	23,020	48.004
UBSS	47.85	10	18,126	47.916	UBSS	48.08	4	23,024	48.004
NSDQ	47.85	882	19,008	47.913	NSDQ	48.08	901	23,925	48.007
NSDQ	47.84	940	19,948	47.909	NSDQ	48.09	940	24,865	48.010
NSDQ	47.83	800	20,748	47.906	UBSS	48.10	9	24,874	48.010
UBSS	47.82	40	20,788	47.906	NSDQ	48.10	571	25,445	48.012
NSDQ	47.82	520	21,308	47.904	NSDQ	48.11	482	25,927	48.014

Forecasting prices in HF?

- Based on models for the dynamics of order books

- Computing the probabilities of price changes (up or down)
  given liquidity on the bid side and ask-side
  (Avellaneda, Stoikov, Reed, 2010: pre-published in SSRN, Oct-10)

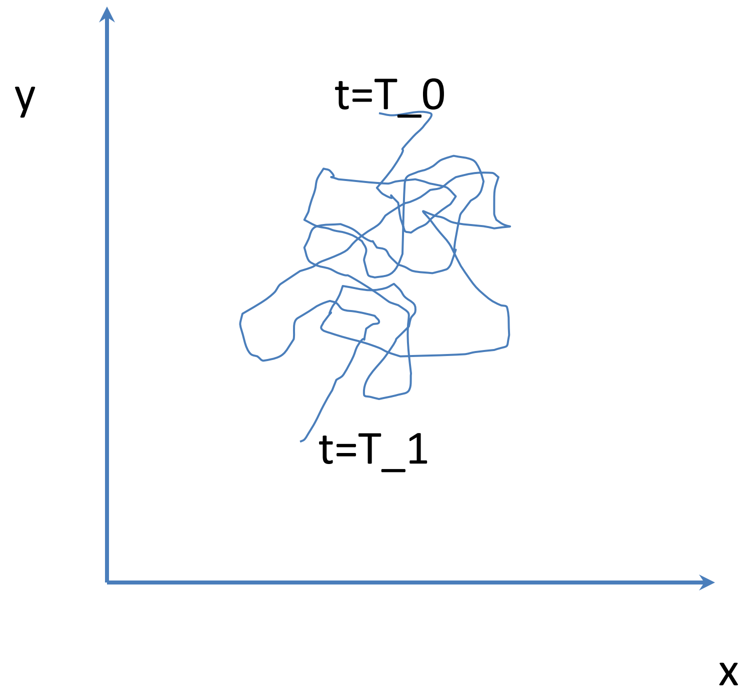
Bid	Q(bid)=x	Ask	Q(ask)=y
100.01	527	100.03	31

- Modeling **hidden liquidity** in the market (not visible in the OB)

Level 1 Quotes: can imbalance predict price changes?

Quote size depletion may be a precursor for a price move.

Mathematical framework: Diffusion Approximation for Quote Sizes (Level I)



X= bid size
Y = ask size

$$X_t = \sigma W_t$$
$$Y_t = \sigma Z_t$$
$$E(dW_t dZ_t) = \rho dt$$

A price change occurs when (i) one of the sizes vanishes and (ii) either there is a new bid or a new ask level

(See Rama Cont & collaborators for a full study of modeling quote dynamics)

Probability that the Ask queue depletes before the Bid queue

$$u(x,y)=\frac{1}{2}\left(1-\frac{\tan^{-1}\left(\sqrt{\frac{1+\rho}{1-\rho}}\,\frac{y-x}{x+y}\right)}{\tan^{-1}\left(\sqrt{\frac{1+\rho}{1-\rho}}\right)}\right)$$

$$\rho=0 \quad\Rightarrow\quad u(x,y)=\frac{2}{\pi}\tan^{-1}\left(\frac{x}{y}\right)$$

$$\rho=-1 \quad\Rightarrow\quad u(x,y)=\frac{x}{x+y}$$

$$p\uparrow(x,y,H)=u(x+H,y+H)$$

Probability
of an upward
price change.

H=`hidden liquidity'.

Estimating hidden liquidity in different exchanges (ability to forecast price moves)

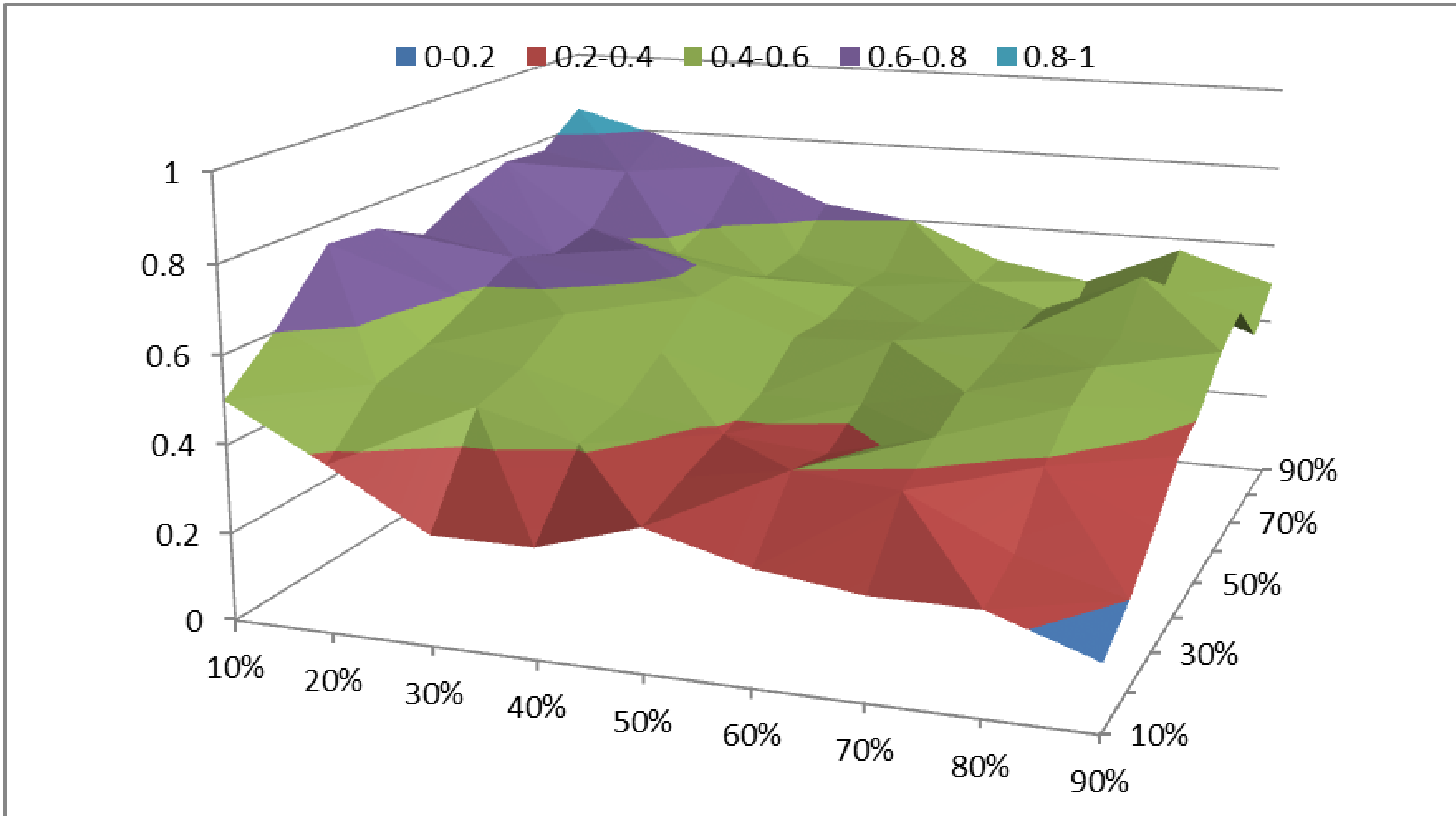
Sample data

symbol	date	time	bid	ask	bsize	asize	exchange
QQQQ	1/4/2010	9:30:23	46.32	46.33	258	242	T
QQQQ	1/4/2010	9:30:23	46.32	46.33	260	242	T
QQQQ	1/4/2010	9:30:23	46.32	46.33	264	242	T
QQQQ	1/4/2010	9:30:24	46.32	46.33	210	271	P
QQQQ	1/4/2010	9:30:24	46.32	46.33	210	271	P
QQQQ	1/4/2010	9:30:24	46.32	46.33	161	271	P

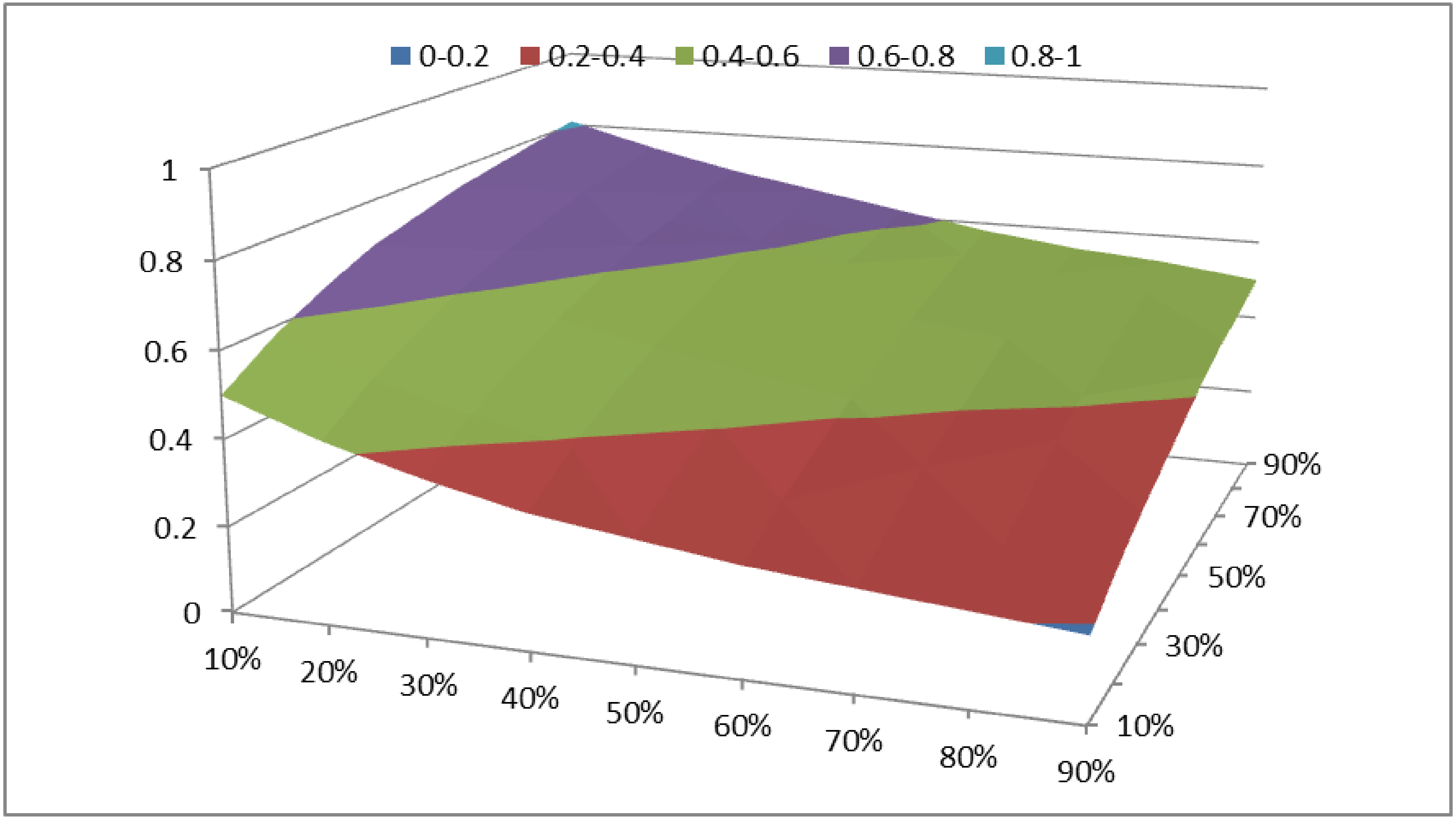
Estimated H across markets

Ticker	NASDAQ	NYSE	BATS
XLF	0.15	0.17	0.17
QQQQ	0.21	0.04	0.18
JPM	0.17	0.17	0.11
AAPL (s=1)	0.16	0.9	0.65
AAPL (s=2)	0.31	0.6	0.64
AAPL (s=3)	0.31	0.69	0.63

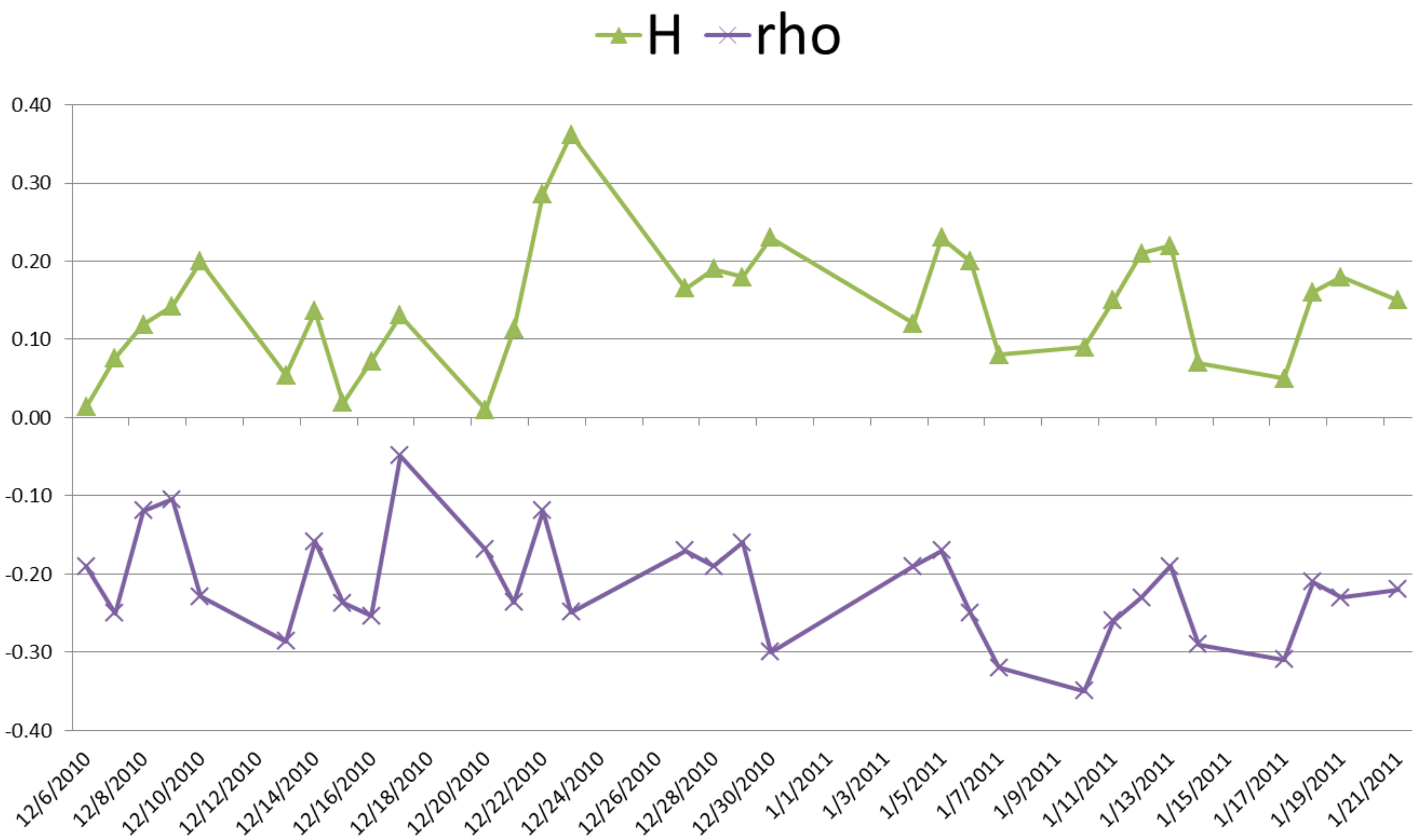
Empirical Probabilities for upward price move conditional on the quote (XLF)



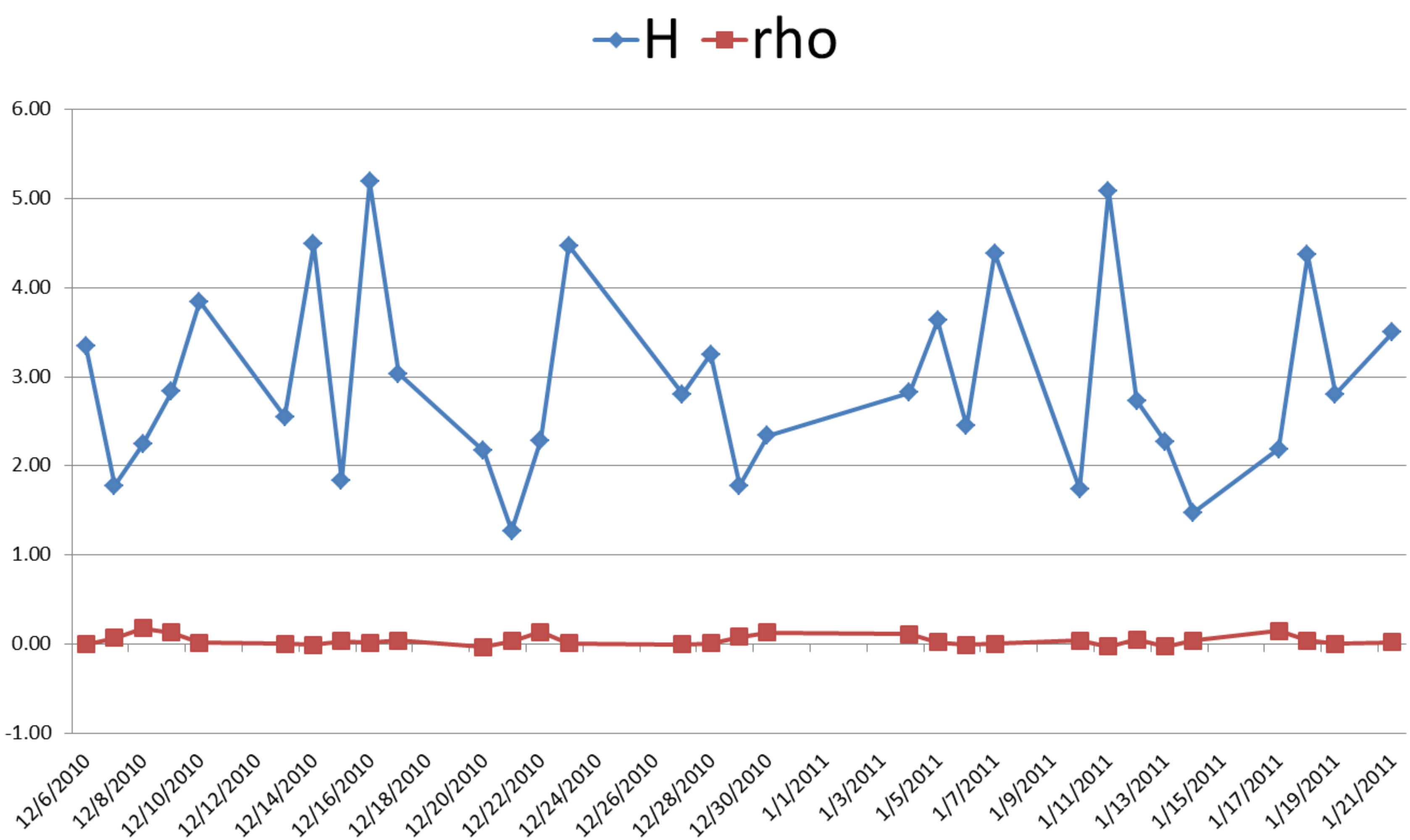
Fitted model (XLF)



USD-BRL Futures (DOLc1)
Low H: imbalance is predictive



Bovespa Index Futures (INDc1)
High H: imbalance is not predictive



II. Statistical Arbitrage

systematic component

idiosyncratic component

$$\frac{dS_i(t)}{S_i(t)} = \beta_i \frac{dI(t)}{I(t)} + \varepsilon_i(t)$$

Stock return is compared to the return on the **corresponding sector ETF** (regression, co-integration)

$$\varepsilon_i(t) = \alpha_i dt + dX_i(t)$$

Residuals: modeled as a mean-reverting process

$$dX_i(t) = \kappa_i(m_i - X_i(t))dt + \sigma_i dW_i(t)$$

Ornstein-Uhlenbeck (AR-1)

Example of sampling window =3 months (~ 60 business days)
Medium frequency rebalancing/ fully systematic

Building a portfolio from ETF-based signals: the ``PLATA'' strategy

-- Large, diversified trading universe of equities (~ 500 names)

-- Select those stocks within the trading universe that have a trading signal via co-integration and open trades

-- All trades consist of stocks paired with ETFs

-- Monitor for closing trades through co-integration

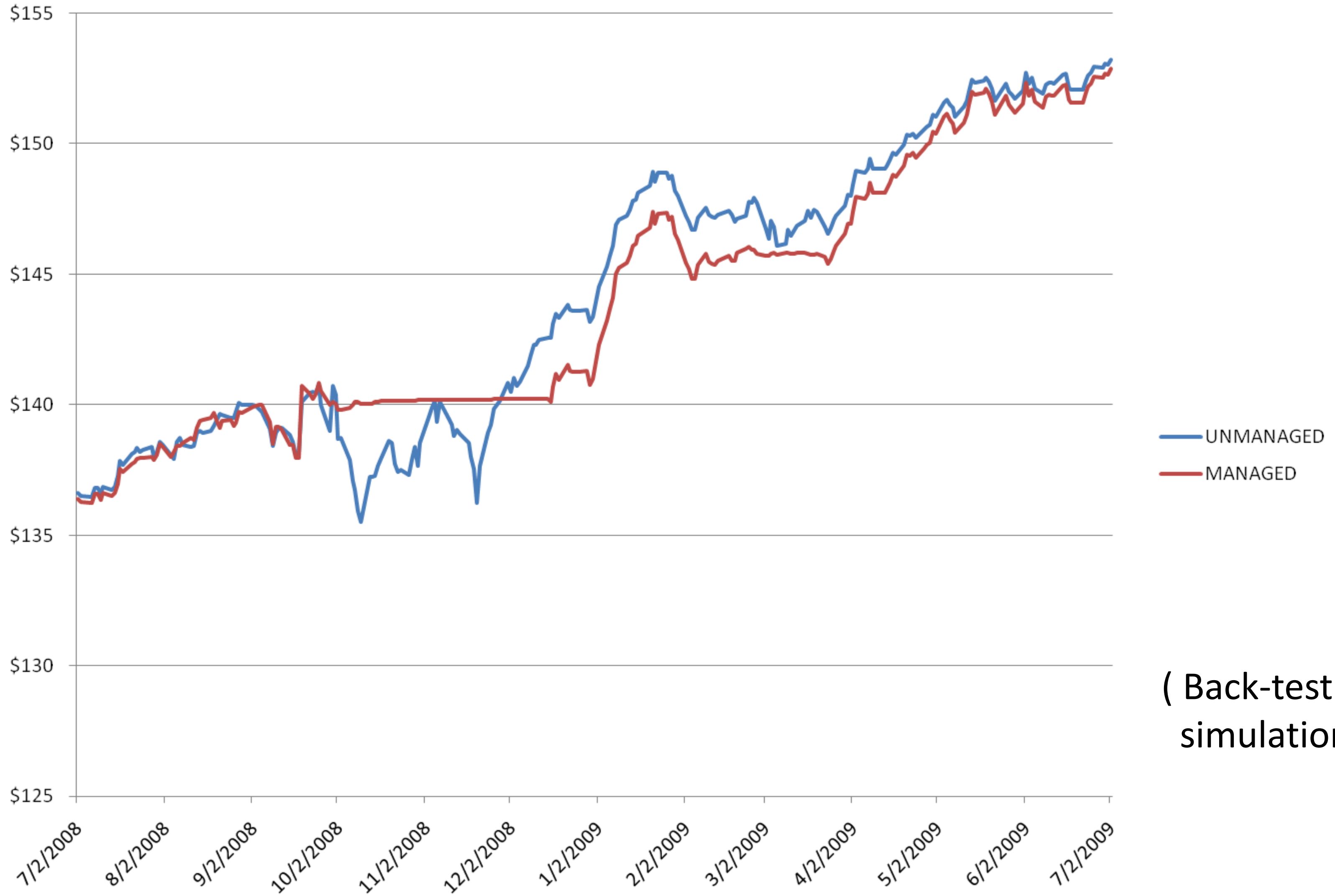
-- Monitor for degradation of statistical parameters, stop-losses, etc.

-- Investment per stock ~ 25 bps (~250K per 100MM notional capital)

-- Typical profile 30 to 50 % long / 30 to 50 % short, dollar-neutral.

-- Portfolio-level risk management used to ``vet'' trades.

Difference between managed risk and unmanaged risk in the Fall of 2008



(Back-testing simulation)

SPY+PLATA: a synthetic 130/30 fund

Based on a notional amount of 100 MM:

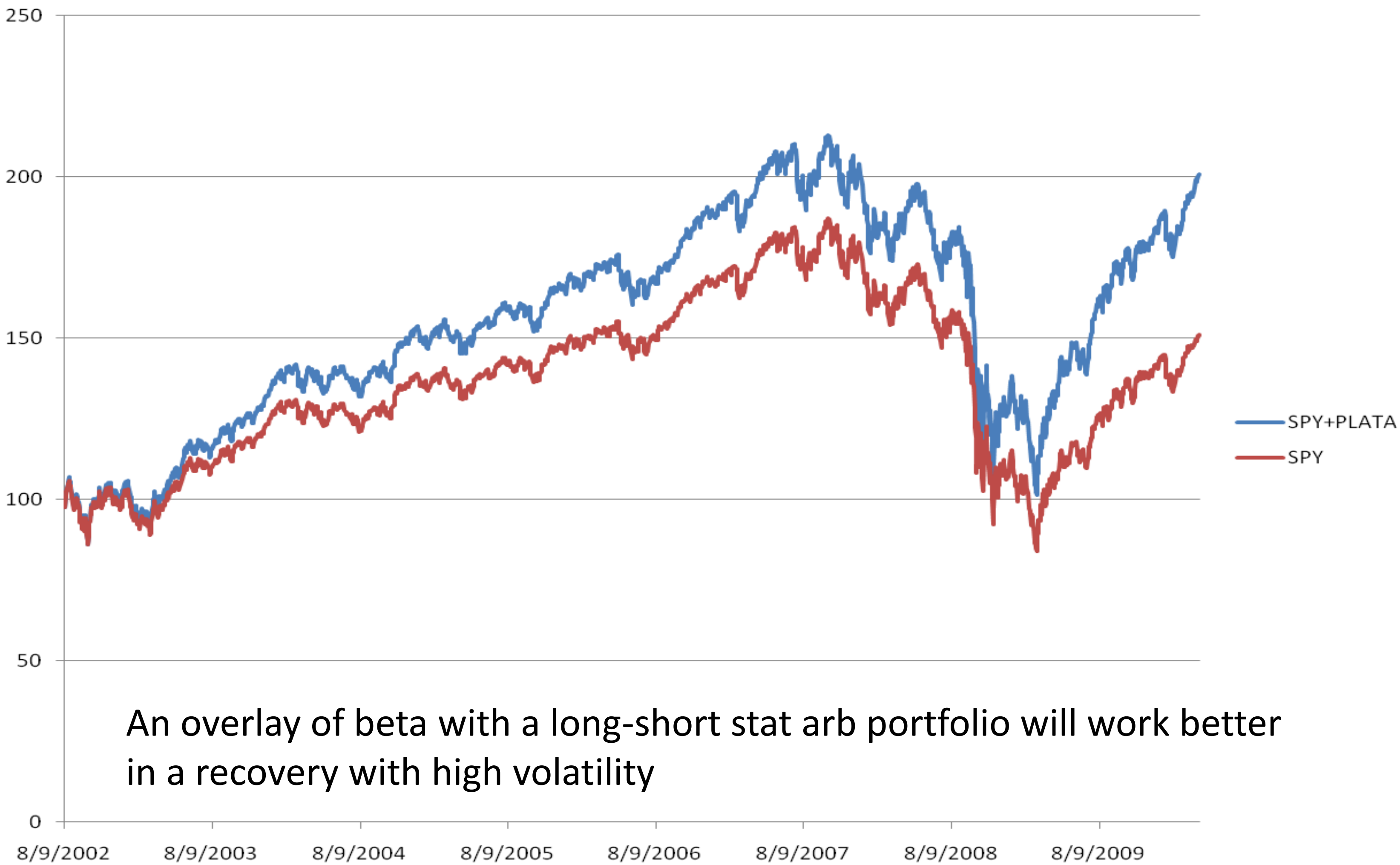
-- go long 100 MM SPY and

-- implement a PLATA strategy based on 100MM notional amount
(30 to 50 mm long/ 30 to 50 mm short)

(parameters for PLATA: big universe, 25bps per stock,
target daily stdev of portfolio=40bps)

Due to market-neutrality of PLATA, this portfolio looks essentially like a 130/30 to a 150/50 depending on the volatility in the market and the turnover.

Comparing SPY+PLATA with SPY



An overlay of beta with a long-short stat arb portfolio will work better in a recovery with high volatility

III. Quantitative Low-Frequency ETF strategies

- **Contango/backwardation** in commodity- and volatility-based ETFs
- **Path-dependence and volatility exposure** in Leveraged ETFs

Contango implies futures drop towards spot

$$F_t^{(i)} = S_t e^{(r_i - d_i)(T_i - t)} \qquad \text{contango} \Rightarrow r_i - d_i > 0$$

$S_t = \text{spot price}$

$r_i = \text{ rate for expiration } T_i$

$d_i = \text{convenience yield - storage cost for mat. } T_i$

$$\frac{dF_t^{(i)}}{F_t^{(i)}} = \frac{dS_t}{S_t} - (r_i - d_i)dt,$$

Negative drift

Futures-based ETFs: the rolling conundrum

ETF mandate (prospectus):

-- roll position in one or more contracts, aiming to carry a fixed-maturity

-- change contracts systematically as expiration arrives

$$\frac{dI_t}{I_t} = a(t)\frac{dF_t^{(1)}}{F_t^{(1)}} + (1 - a(t))\frac{dF_t^{(2)}}{F_t^{(2)}} + r\,dt$$

$$I_t = \text{ value of the index at date } t$$

$$F_t^{(i)} = \text{futures with settlement date } T_i$$

Consequence for futures-based ETFs

$$\frac{dI_t}{I_t} = a(t)\frac{dF_t^{(1)}}{F_t^{(1)}} + (1 - a(t))\frac{dF_t^{(2)}}{F_t^{(2)}} + rdt$$

$$= \frac{dS_t}{S_t} - [a(t)(r_1 - d_1) + (1 - a(t))(r_2 - d_2)]dt + rdt$$

$$= \frac{dS_t}{S_t} + [a(t)d_1 + (1 - a(t))d_2]dt$$

Negative drift if convenience yields are negative

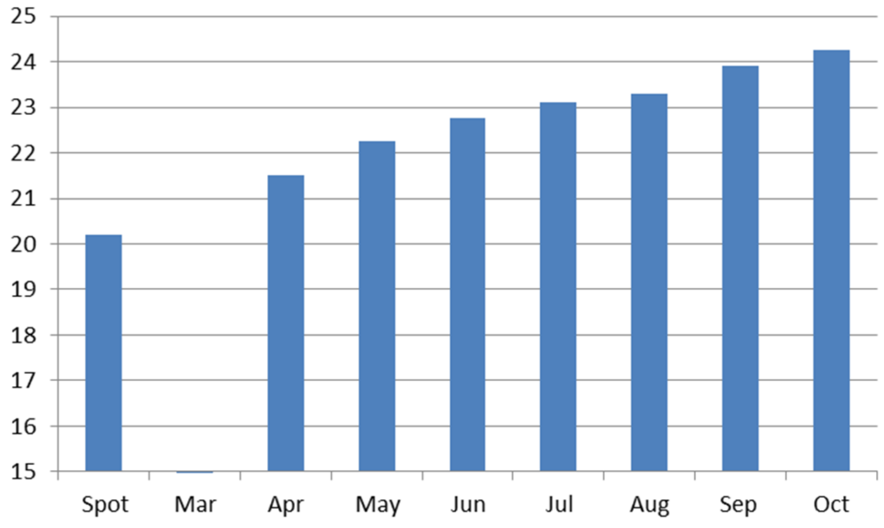
VIX Futures

Contracts with monthly expirations settling on spot VIX.

VIX is generally in contango (like index option volatility)

- Intuitively, in a `bull market', option implied volatility is higher for longer maturities unless the market is very stressed.

- Slope is less steep for longer maturities, although this has changed in the past year (Black Swan funds buying long-dated volatility?)



VIX, 3/22/2011

The VXX and VXZ ETNs

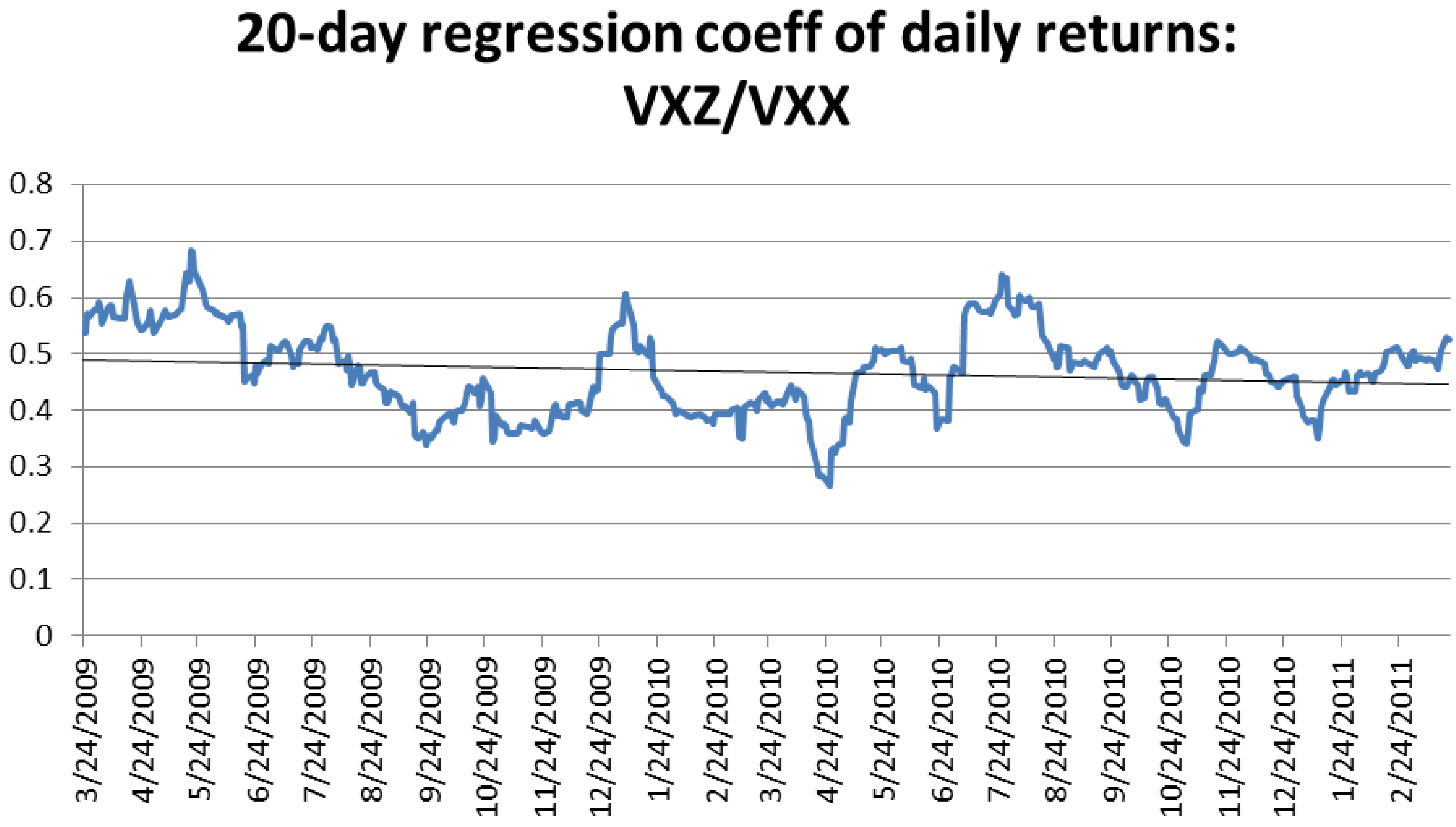
VXX: iShares ETN which tracks short term VIX futures (months 1 and 2)
target maturity 30 days; continuous roll

VXZ: iShares ETN, tracks mid-term VIX futures (months 4 through 7);
target maturity 120 days; continuous roll

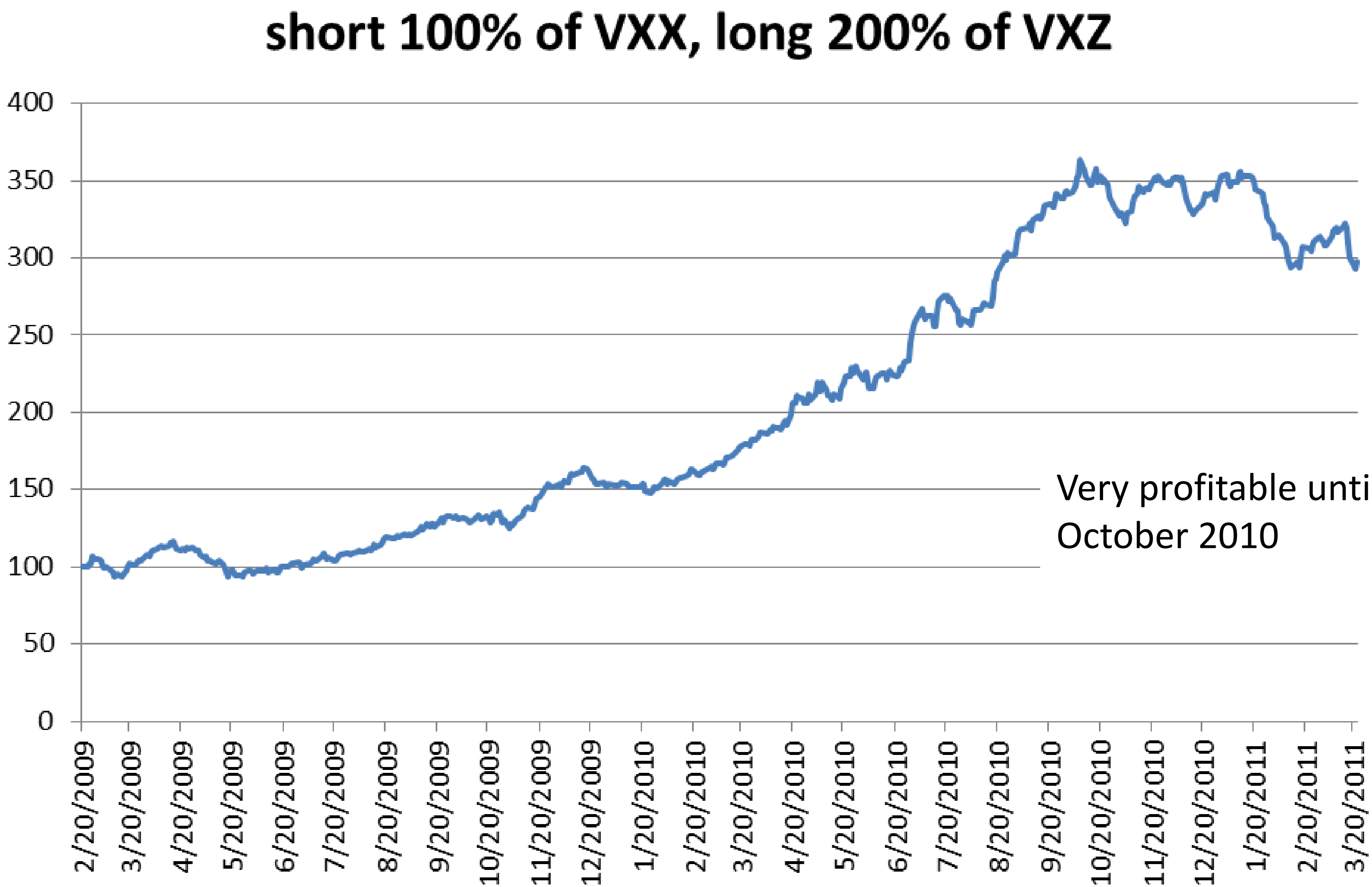
Both securities have negative drift and are correlated to the same underlying asset.

This gives rise to the possibility of arbitrage by building a long-short position

Connecting the volatilities of both products empirically



Short the front-month ETN, long the back-month × 2 (since inception)

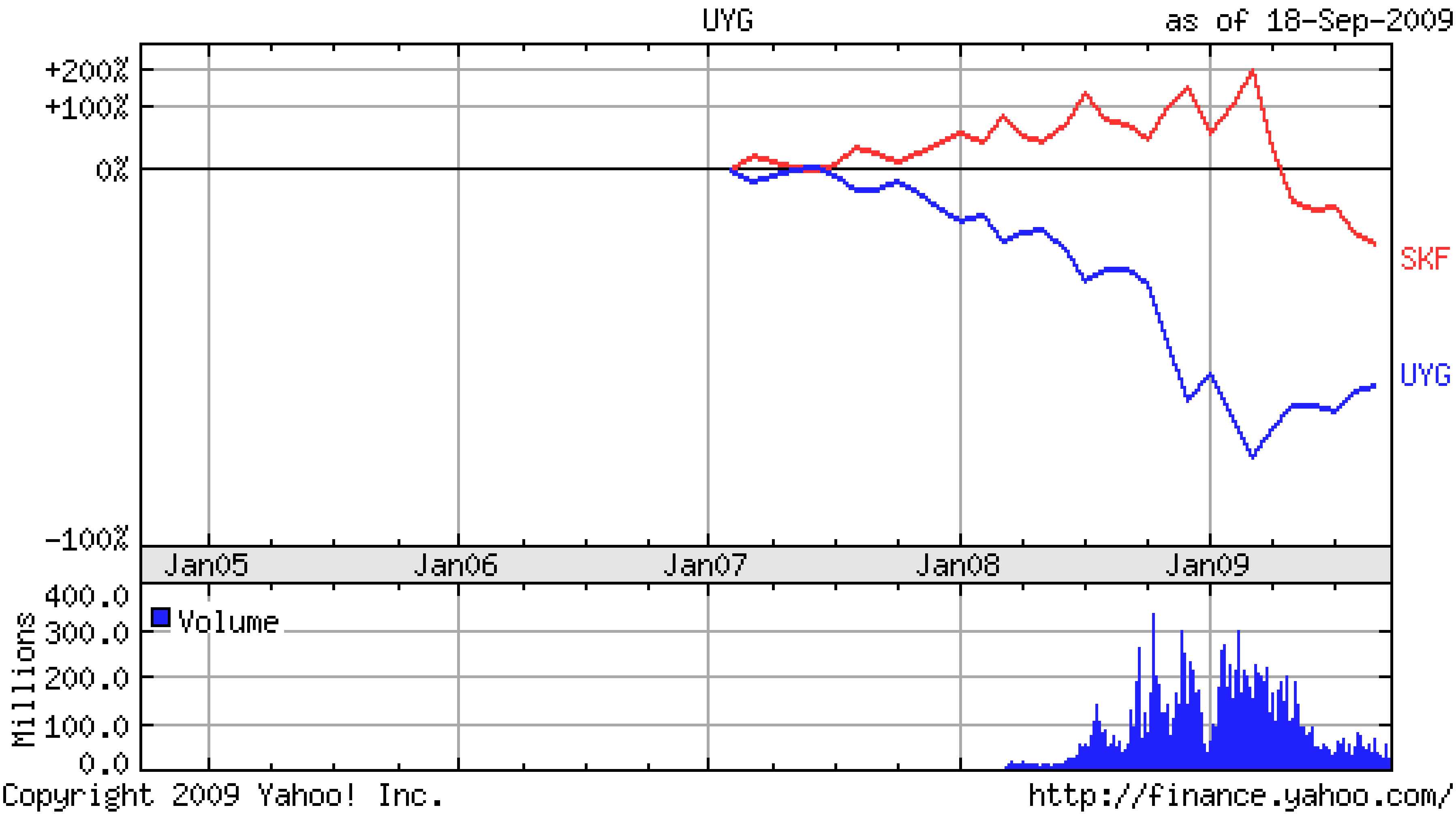


Very profitable until October 2010

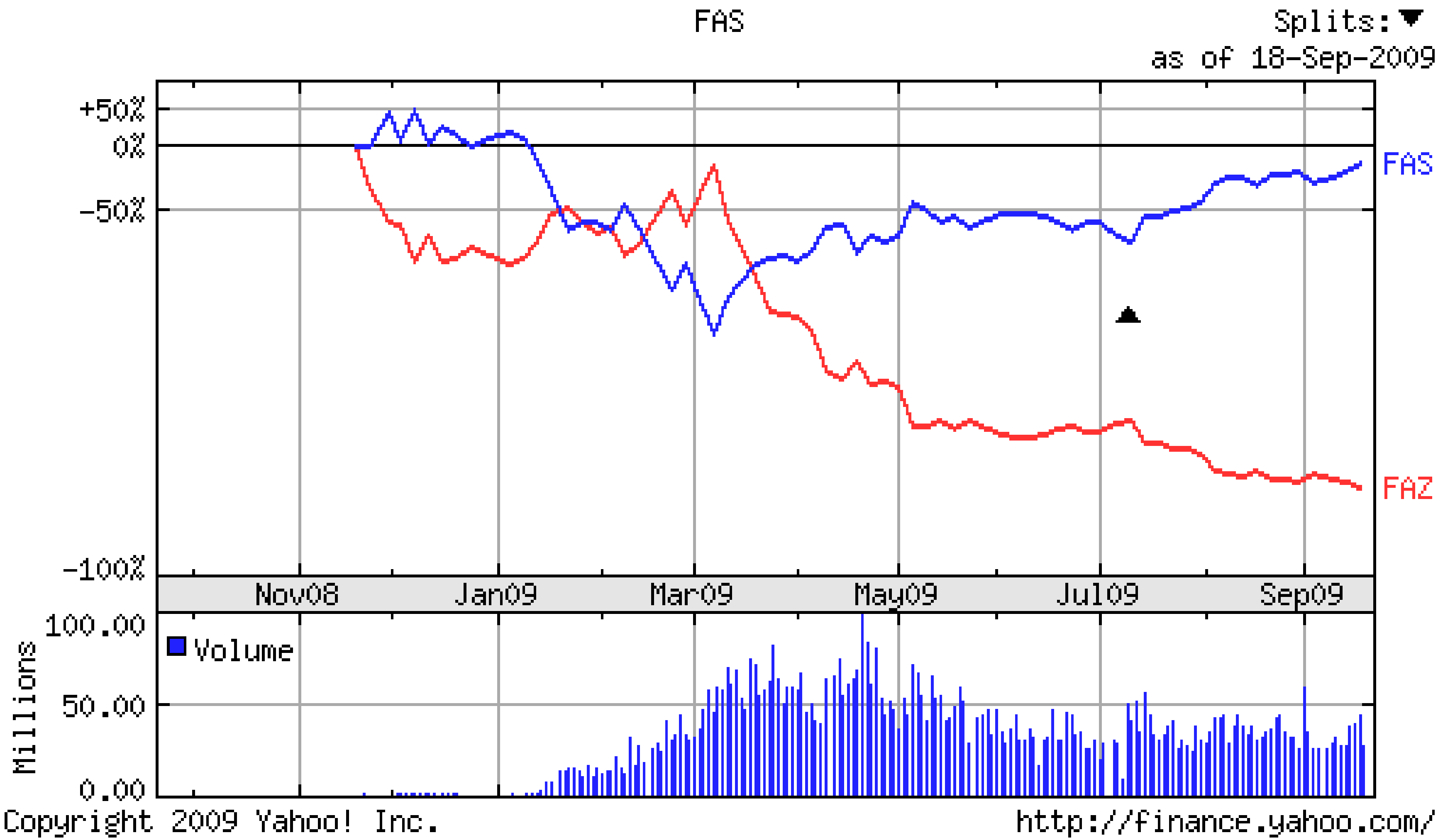
Arbitrage Strategies with Leveraged ETFs

- Leveraged ETFs must rebalance daily their position in the underlying asset to maintain fixed market exposure (2X, 3X)
- Even though this is done via total return swaps, the hedging of the swaps will induce a **market impact** unfavorable to the fund
- **Volatility** plays against LETFs
- **Borrow costs** of LETFs diminish, but not eliminate, arbitrage opportunities
- **A structural arbitrage** : short LETFs and hedge market exposure

SKF/UYG Since inception



Another example: FAS/FAZ
Direxion 3X and -3X Financial ETF



Relation between LETF and underlying index

$$\frac{L_t}{L_0} = \left(\frac{S_t}{S_0}\right)^{\beta} \exp\left[(1-\beta)rt - ft - \frac{1}{2}\left(\beta^2 - \beta\right)\int_0^t \sigma_s^2 ds\right]$$

Leveraged funds have *negative exposure to volatility*.

Avellaneda & Zhang (2009), Cheng and Madhavan (2009)

Analysis of Borrow costs

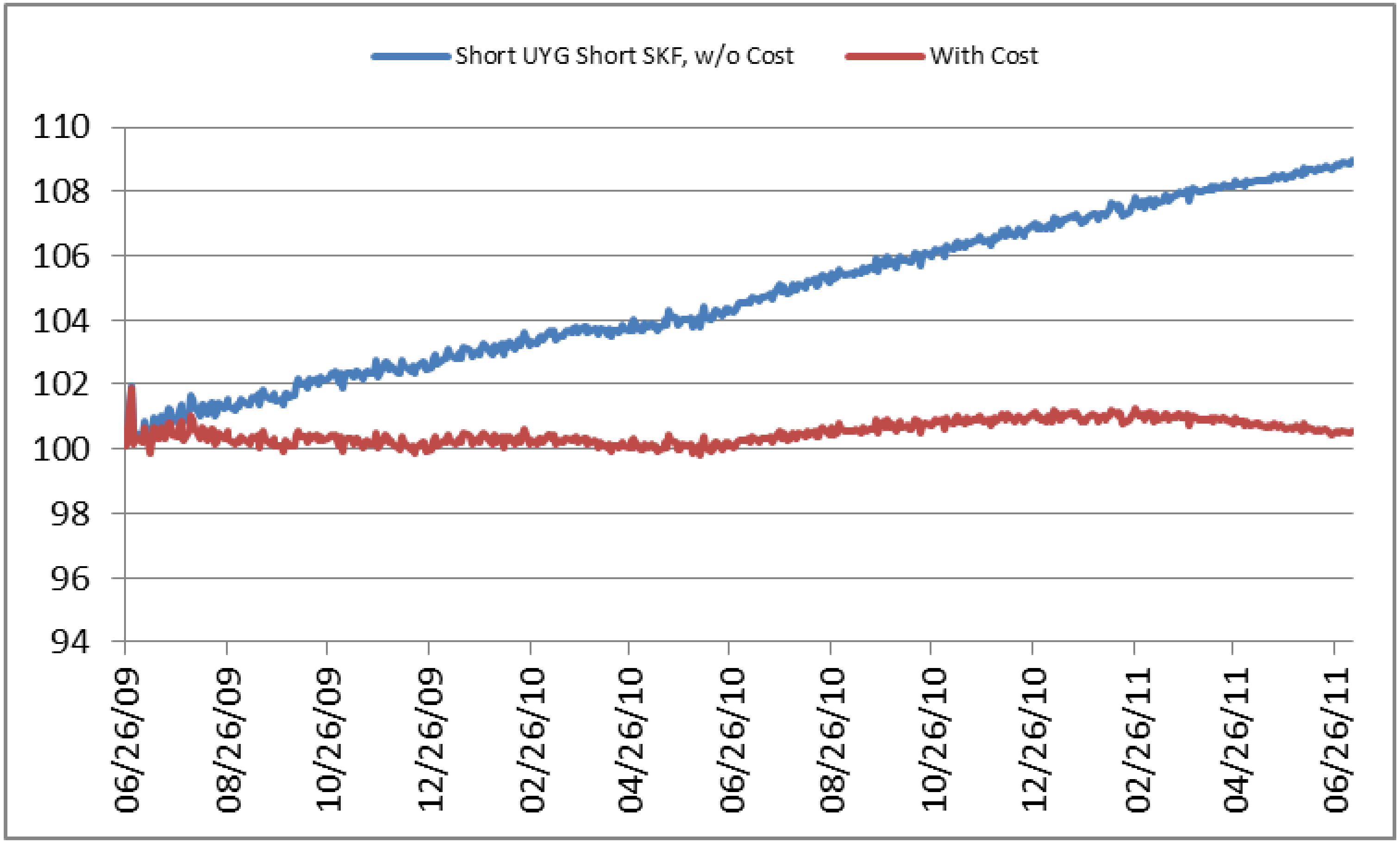
- In the current market, LETFs trade at a **negative borrow rate**.

- However, LETFs typically underperform their benchmark over a **single trading date** due to market impact (slippage).

- The rate of return of this trade excluding shorting costs can exceed 10% per year (4 bps per day).

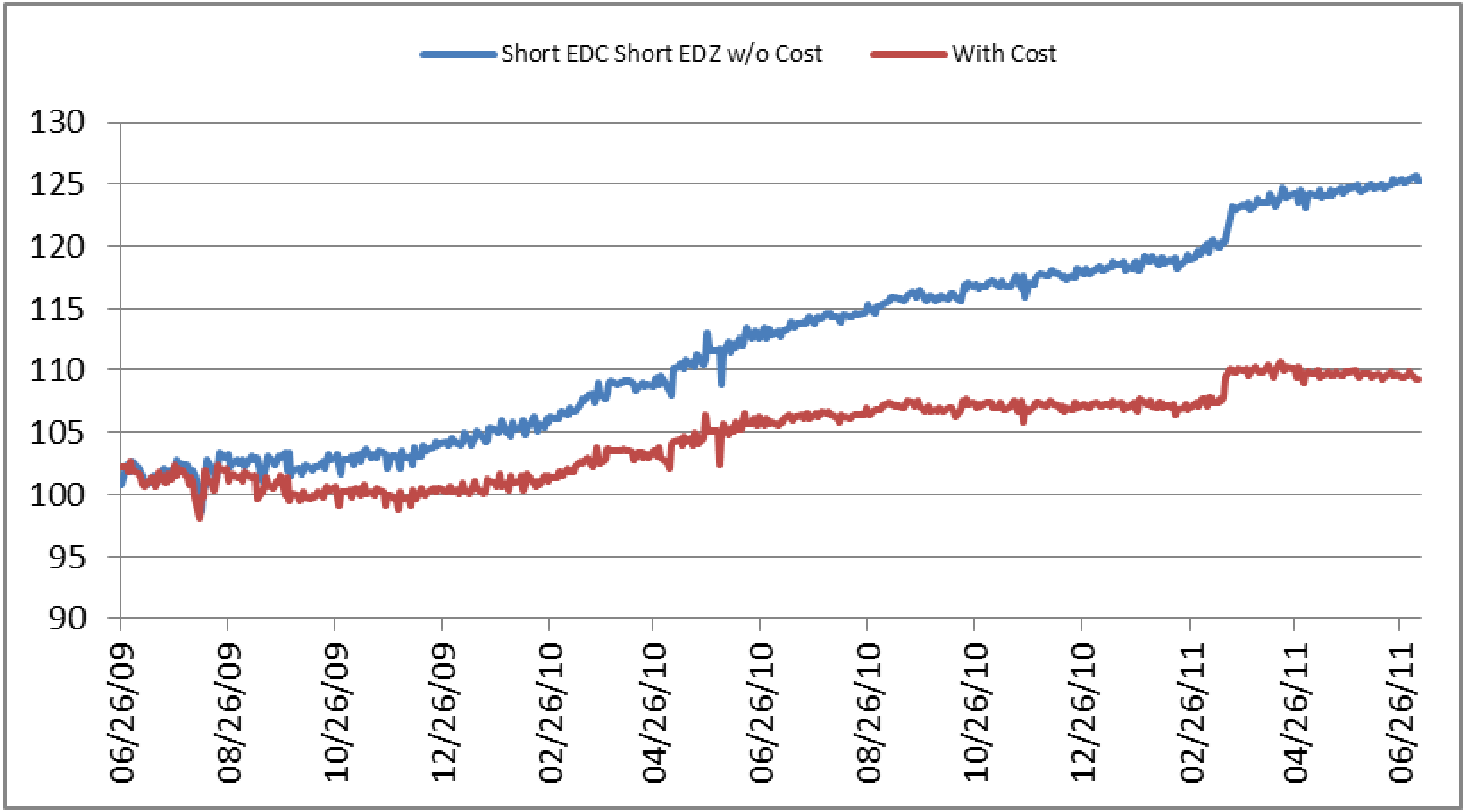
- Except for the case of EEM, a study based on data from June 2009 until now suggests that the borrowing costs charged by one major brokerage (Interactive Brokers) typically offset the gains from slippage in the LETFs.

Short UYG/Short SKF, daily rebalancing



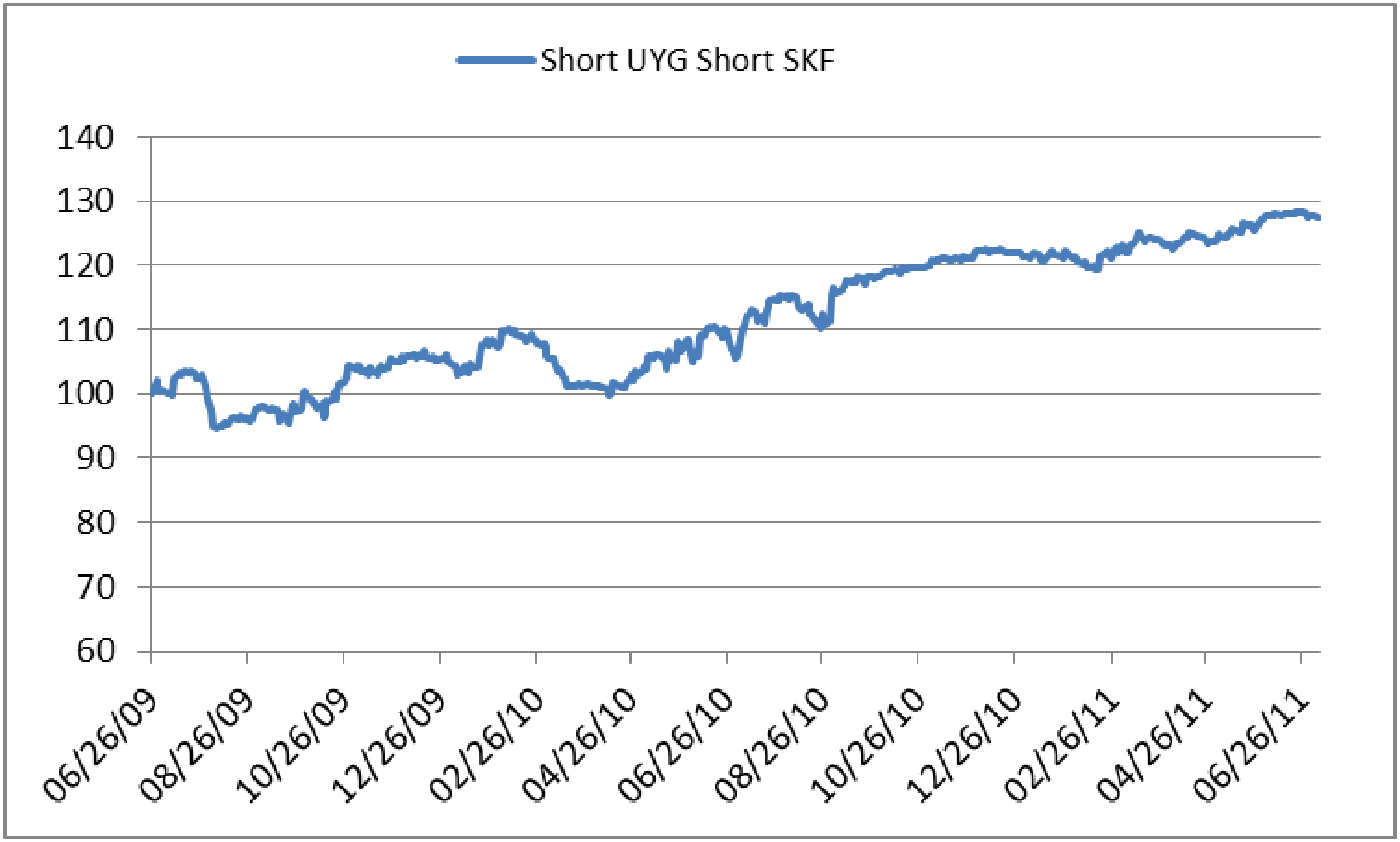
Ann return before costs= 9% or 2.4 bps per day

Short EDC/Short EDZ, daily rebalancing

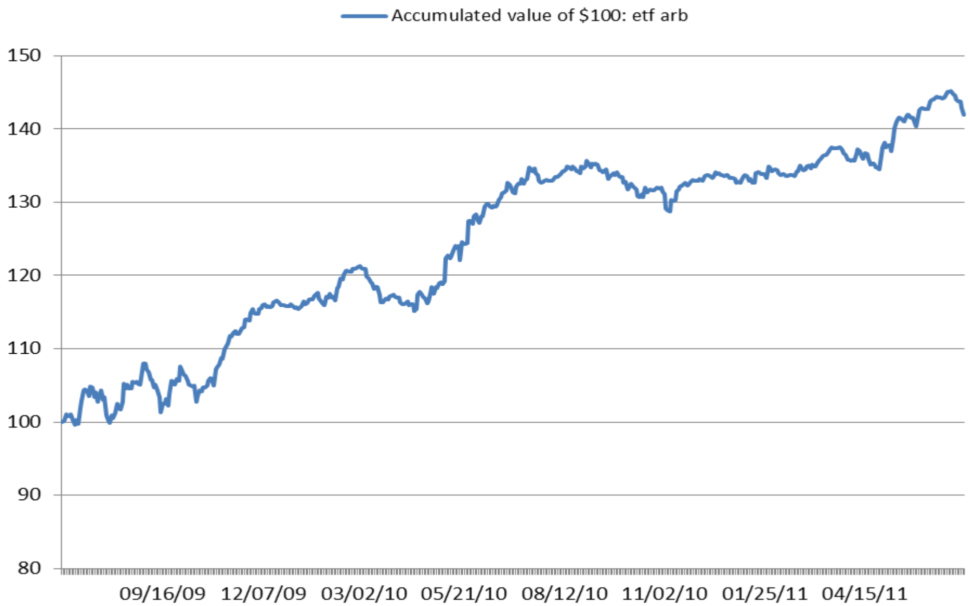


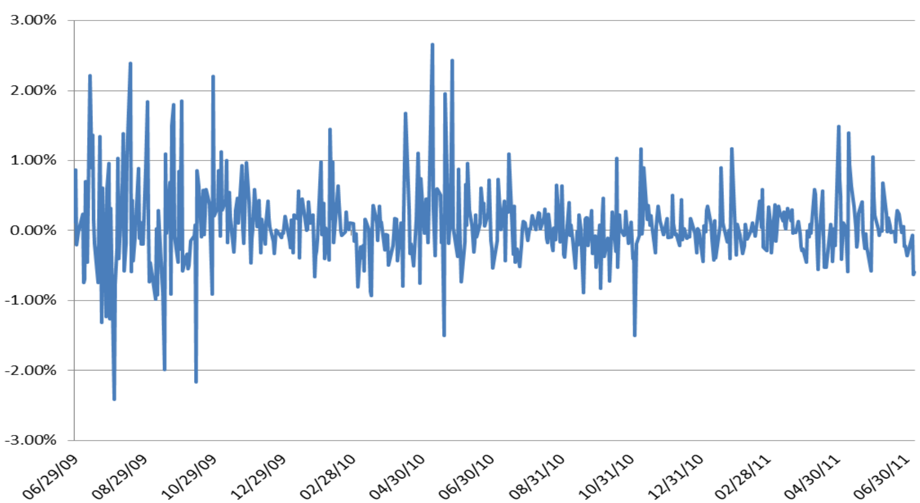
Ann return before costs= 25% or 10 bps per day, after costs= 10% or 4 bps per day.

UYG/SKF short-short, managed exposure



Pro-forma performance of a portfolio of LETF trades (June 26, 2009 to Aug 7, 2011)





<u>Return</u>

Initial Value=$100
Final Value= $141.96

Leverage = 3 (1.5/1.5)

Cumulative 2-year return= 41.96%

<u>Daily Risk Stats</u>

99% VaR=-150 bps
99.5% VaR=-240 bps

Sharpe Ratio=2

Conclusions

- Present market conditions favor quant strategies which are market neutral and/or positioned to capitalize on excess realized volatility

A few promising themes:

- Intraday index/etf/letf/futures arbitrage -- they require HFT technology (Market making also)
- Price-forecasting based on order book imbalance
- Intermediate-frequency trading based on mean-reversion
- Contango/backwardation trades in commodities and VIX
- Leveraged-etf trades to capitalize on high realized volatility