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Mauna Kea famous 180 yard 3rd hole over the bay, Kona. A good round of arbitrage might get you a good round here. I bogied this the first time with a routine shot, parred it the second by hitting a lava outcrop and getting a lucky bounce onto the green. Sometimes luck helps.

Luck is not an issue in arbitrage.

Arbitrage

Lecture 5

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What we plan to do ...

1. Explain how arbitrage works
2. ... and how that puts upper and lower price limits on some futures
3. Index futures and index arbitrage
 - and micro variants
4. Other kinds of q-arbitrage
 - basis arbitrage
 - yield-spread arbitrage
 - risk yield-spread arbitrage
 - futures maturity arbitrage
5. Statistical arbitrage
 - and related issues and problems
 - Quantagion?

Arbitrage

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Arbitrage takes advantage of the fact that two or more commodities or financial assets are mispriced relative to each other. With true arbitrage, an automatic profit will be realized.

Usually arbitrage involves taking a long or short position in the primary asset and taking an opposite position in its derivative.

Suppose the spot price of gold is \$1200 per ounce.
Suppose the one-year future price of gold is \$1800 per ounce.
The interest rate for borrowed money is 5% (\$60 per ounce).
The storage cost of gold is \$40 per ounce.
The insurance cost for gold is \$20.
The initial margin is 10% of the price of gold (\$120) and the interest charge on that is \$6.

What do you do?

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1. Borrow \$1200 and pay \$60 interest.
2. Buy, store, and insure one ounce of gold.
3. Sell (short) a futures contract for \$1800.
4. Pay interest on the initial margin (implicitly)

Your “carry cost” on this contract is $\$126 = \$60 + \$40 + \$20 + \$6$.

No matter what happens to the price of gold, you are guaranteed an arbitrage profit of \$474 per ounce.

Why?

Note: This background material is not in Hull, as least not as I am presenting it here.

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Results from possible future gold prices

In one year you sell the gold that you bought for \$1200 at the new spot price (5 possibilities are shown below). You add the gain or loss on the margin account (you were short at 400, so the margin account grows when the price of gold falls).

Spot at end of year	Spot gain/loss	Margin gain/loss	less carry	Profit
1000	-200	800	-126	474
1200	0	600	-126	474
1400	200	400	-126	474
1600	400	200	-126	474
1800	600	0	-126	474
2000	800	-200	-126	474

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Future price upper limit (discrete)

Because the arbitrage possibility in the previous example would result in heavy purchases of gold at spot, raising the spot price, and heavy sales of gold futures, lowering the futures price, the spread in prices would narrow.

This implies that, given borrowing, storage, insurance, and other costs, there is an upper limit on futures prices for gold and similar commodities:

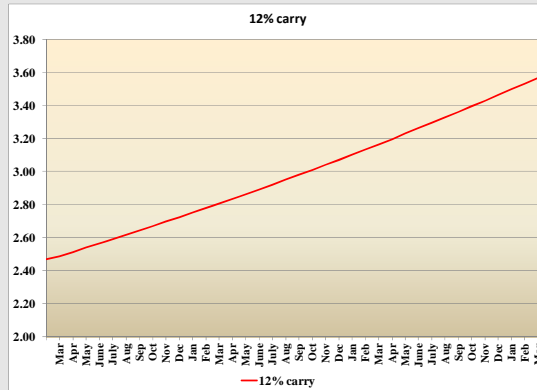
$$FPUL = S[1 + r + s + i + r(m)]^t$$

FPUL = Future price upper limit t = days in contract/365
 r = interest rate for borrowing S = Spot price
 s = storage cost as a percent
 i = insurance as a percent
 m = initial margin

Futures price upper limit (continuous)

$$FPUL = Se^{[r+s+i+r(m)]t}$$

For example, in our 2012 Natural Gas problem, a later graph will show the FPUL with carry cost of 12% [the sum of all the variables in square brackets] given a spot price of \$2.47 per mmBtu on Feb. 5, 2012.



Arbitrage setting a lower limit

Suppose the spot price of gold is \$1200 per ounce and the one-year futures price is \$900.

1. Short one ounce of GLD
 - and pay the margin rate of 5% per \$1200.
2. Go long in a futures contract for one ounce at \$900
 - and pay a margin rate of 5% of the 10% initial margin.
3. Effectively take delivery of gold in the futures contract deliver it to satisfy your gold short position ...
 - by actually using the profit in you margin account to cover your short loss or the gain in your short position to cover your margin loss ... see example next slide

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Results from possible future gold prices

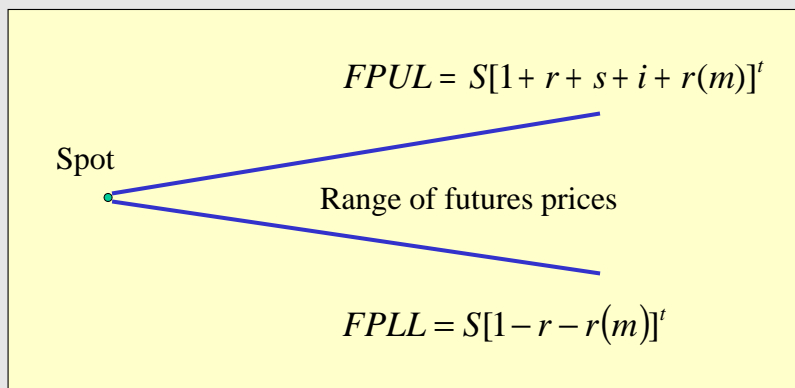
Spot at end of year	Short GLD gain/loss	Margin gain/loss	less carry	Profit
800	400	-100	-64.50	235.50
900	300	0	-64.50	235.50
1000	200	100	-64.50	235.50
1100	100	200	-64.50	235.50
1200	0	300	-64.50	235.50
1300	-100	400	-64.50	235.50

$$FPLL = S[1 - r - r(m)]^t$$

Note that the short position does not require storage nor insurance costs, at least not in this example.

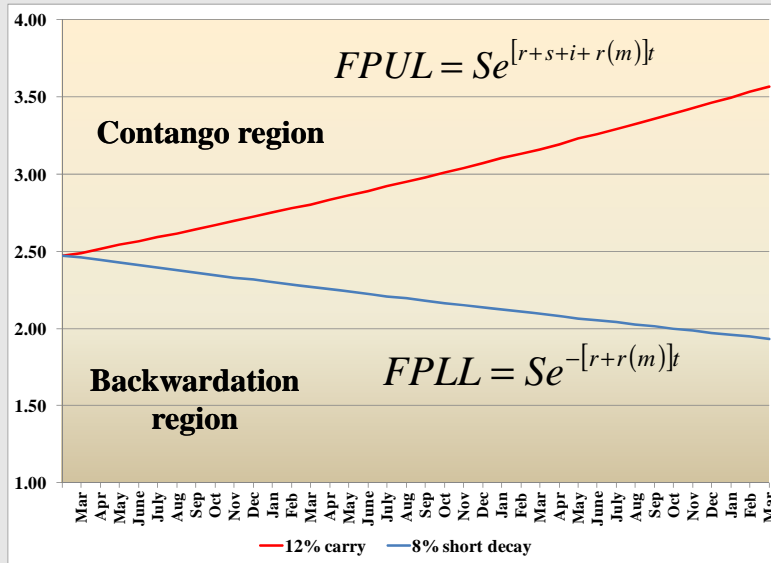
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Arbitrage restricts futures price ranges



Note: This is true only if arbitrage is possible, which in the case of physical commodities, requires the means and possibility of storage.

The continuous case for 2012 Nat Gas



The impact of arbitrage upon futures

- If the commodity can be stored arbitrage is probably possible.
- The formula must be adjusted for storage costs, distribution costs and other fees.
- Important! Even if the the commodity can be stored, storage capacity must be available!!

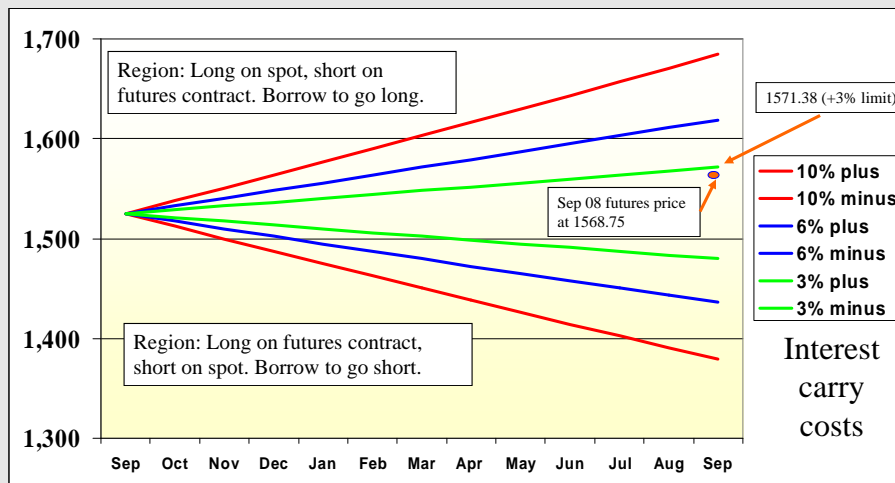
Arbitrage with the S&P500 and other indexes

Arbitrage with the S&P500 index is the basis of what is called *Program Trading*, which is done with computers. Generally, this kind of arbitrage is done by buying a portfolio of the S&P500 stocks (or an index mutual fund) and at the same time shorting one of the S&P500 futures. This is a closed contract. Generally you are buying the stocks with the intention of delivering them (or the equivalent) when the futures contract expires. (This can also be done with SPD, the S&P ETF).

Why would you do this?

Class discussion.

Upper/lower arbitrage ranges for the Sep 08 S&P500 futures contract



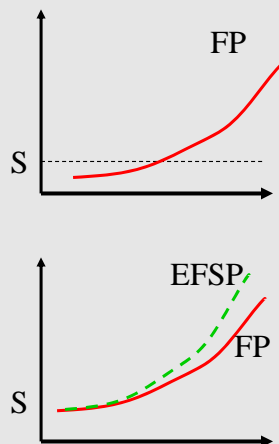
The theory of **Mudd Finance** Contango & Backwardation

Assumes that

- In any market, hedgers are on one side net (say net long) and speculators are on the other (net short).
- Speculators as a group are able to estimate the **future spot price** of a commodity, and they might agree.
- Speculators will go short in a future only if the futures price is **above** the estimated future spot price of a commodity, otherwise for them it is a zero sum game with risk.
- Therefore, hedgers must be willing to buy long at a price above the estimated future spot price, or the market won't clear – they are paying an **insurance rate** if they do this.
- Therefore, when the market clears, the futures price will be different than the expected future spot price.

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Misuse of this term



Some of the literature refers to any schedule of futures prices that is above the spot price and rising as the maturity extends, such as the graph on the left, as a **contango**. Because that is so common, that is the definition that we will use.

In some literature, a contango is defined as a pricing situation where the futures price is above the expected spot price.

The latter definition gives rise to the possibility of a rising future price line actually being in **backwardation** if it is below the expected future spot price.

This is relevant because in arbitrage we will consider the **Contango Spread**.

Example of true contango

Suppose the price of wheat is currently \$4.20 per bushel. Suppose that both millers and speculators think that the future spot price of wheat in six months will be \$4.60.

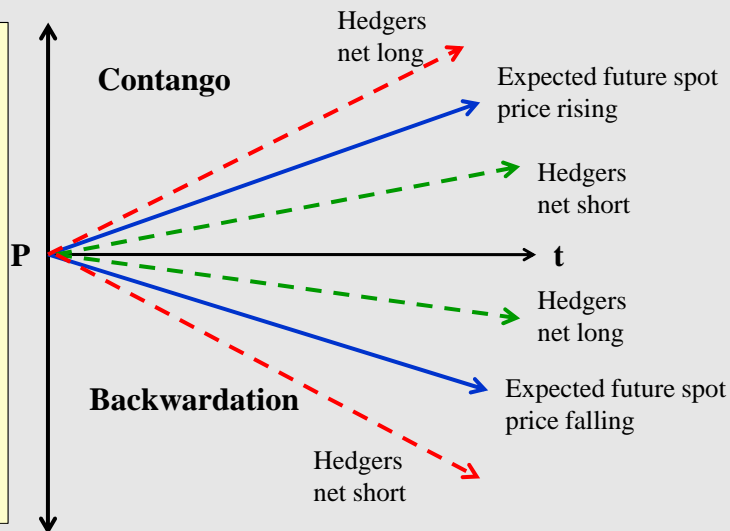
Millers will want to “lock in” the price that is paid for their wheat by going long in the wheat futures market at \$4.60, given that is still an acceptable value.

However, speculators will not agree to going short unless the price is above \$4.60.

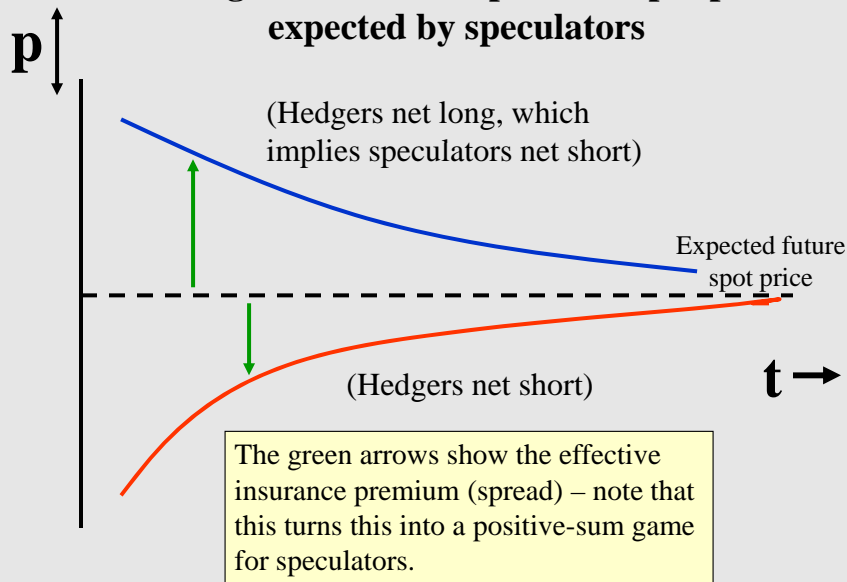
Therefore, if the millers want to hedge, they must agree to go long at a price above \$4.60, or the market won't clear, even though they estimate the future spot price to be \$4.60. Therefore the market might clear at \$4.70.

Contango/Backwardation possible scenarios

Red and Green lines show the actual futures prices relative to expected future spot prices (blue) depending upon whether hedgers are net long or net short in the futures contract in question.



**Convergence of futures prices to spot prices
expected by speculators**



Risk and quasi-arbitrage (q arbitrage)

- Many, many examples of types of arbitrage where there is some risk of loss (examples follow).
- As before, you are long (**short**) in the primary asset and short (**long**) in the derivative.
- The opportunity typically arises *when the spread is outside or inside some statistically determined "normal" range* (like two standard deviations outside of the range)
- The risk is there because maybe there is a reason for the unusual spread and it may get worse before it returns to "normal."



Contango/Backwardation Q-Arb Spreads

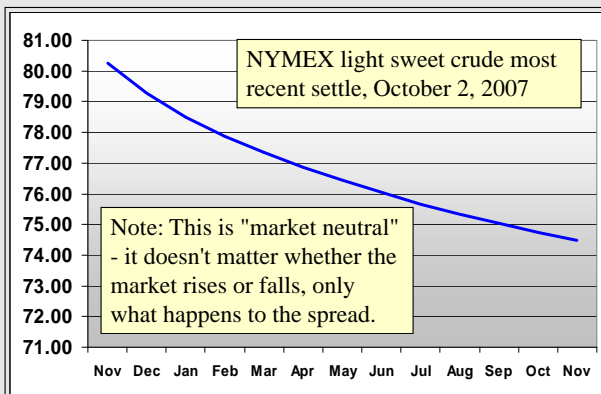
Maturity quasi-arbitrage, which is possible on a very small scale, even with single e-Mini contracts, arises when the spread in price between the nearest term futures contract and a more distant contract is unusually wide or narrow. This is typically when the chain is in contango or backwardation to some degree.

What you may regard as unusually wide or narrow may depend upon your knowledge of typical trading patterns or ranges for the commodity in question or upon statistical analysis of past spreads, or both.

In any case, you are going to be shorting one contract and going long in the other, matched, depending upon whether the spread is too wide or narrow, a contango or normal backwardation.

See the next slide of actual crude oil settlement data for 13 contracts from October 2, 2007.

Backwardation with a wide spread Nov to Nov.

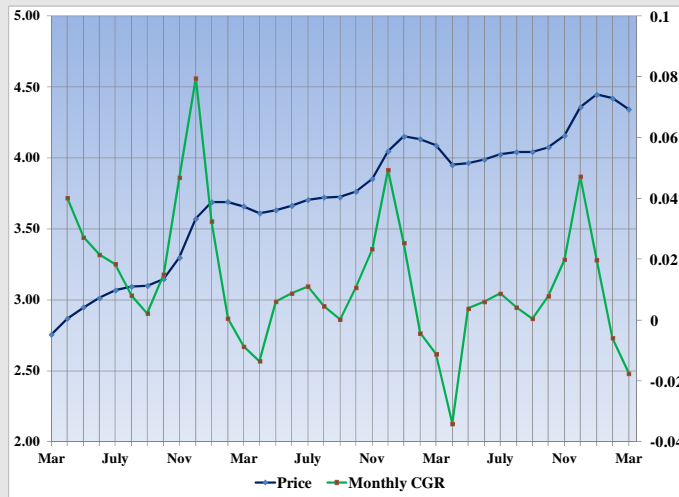


Settle		
2007	Nov	80.24
	Dec	79.28
2008	Jan	78.50
	Feb	77.87
	Mar	77.34
	Apr	76.86
	May	76.44
	Jun	76.05
	Jul	75.66
	Aug	75.34
	Sep	75.04
	Oct	74.76
	Nov	74.50

If you had reason to believe that the spread on this backwardation was unusually wide, how would you arbitrage it?

Teacher's note: The spread the week before, immediately after the surprise FRS 50 basis point rate cut, was much wider, with a top at nearly 83 and a bottom at 68. Alas, too much going on that week to gather the data!

Example: Spreading the Nat Gas contango of 2012



What we noticed at the start of class ...

A quick futures spread ...

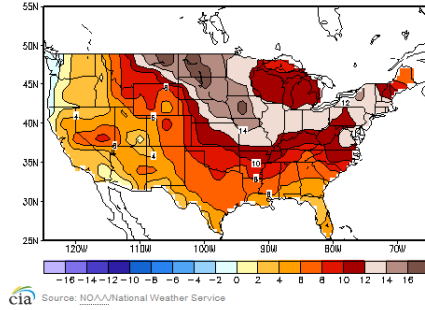
Settlement Calculation						
Natural Gas Spread of January 25, 2012						
CMEGroup Henry Hub (HH) Mar 2012 long, Mar 2013 short						
Day	Date	March 2012 (L)	March 2013 (S)	Settlement delta long	Settlement delta short	Notional value
W	1/25/2012	2.650	3.620	0	0	62,700
T	1/26/2012	2.756	3.659	1,060	-390	63,370
F	1/27/2012	2.774	3.675	180	-160	63,390
M	1/30/2012	2.756	3.659	-180	160	63,370
T	1/31/2012	2.713	3.607	-430	520	63,460
W	2/1/2012	2.503	3.482	-2,100	1,250	62,610
F	2/3/2012	2.499	3.622	-40	-1,400	61,170
M	2/6/2012	2.550	3.700	510	-780	60,900
T	2/7/2012	2.472	3.580	-780	1,200	61,320
W	2/8/2012	2.448	3.562	-240	180	61,260
F	2/10/2012	2.477	3.657	290	-950	60,600

We went long on the nearest term contract (March 2012) and shorted a contract one year later, knowing that gas has a one-year cycle,

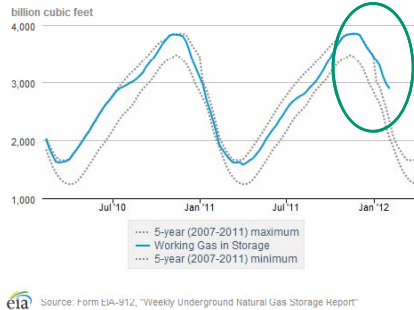
Background on Nat Gas 2012 contango

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Deviation between average and normal (°F)
7-Day Mean ending Feb 02, 2012



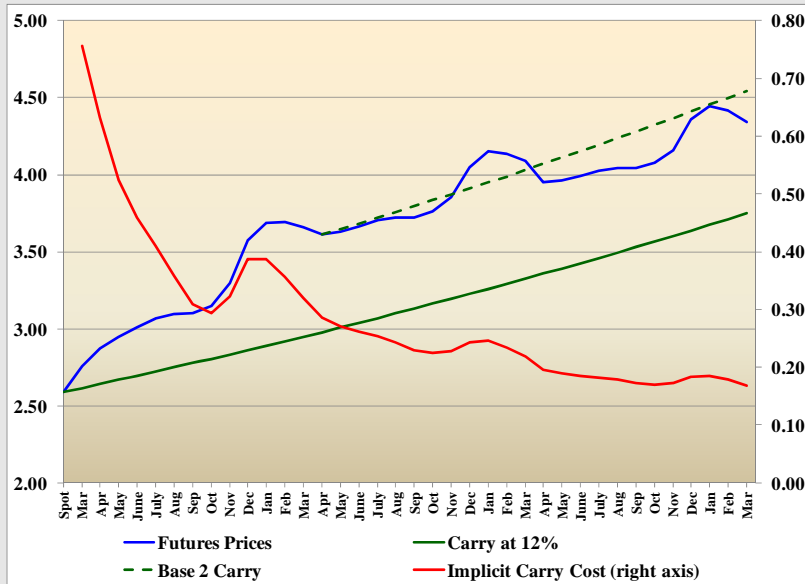
Working natural gas in underground storage



Because of the success of shale gas drilling (not shown) and because we are having one of the warmest winters on record (see heat map) underground inventory is full – there is no storage available for gas, which is why it can't be arbitrated. There is a massive supply glut.

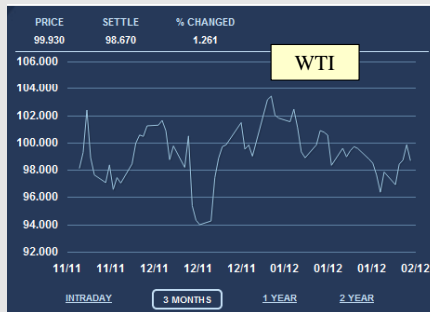
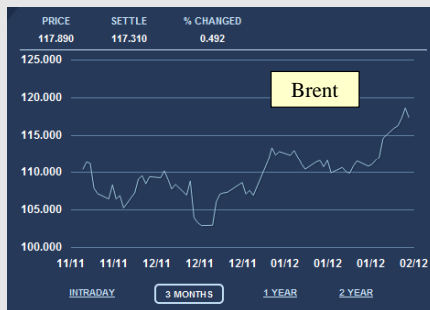
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Reconsidering the contango spread



How to interpret the natural gas contango

- The red line is an assumed 12% continuous carry cost line, which shows that this chain was hugely in contango on February 2, 2012.
- The green line (right axis) shows the implicit annualized carry cost for each contract month discounted back to spot (2.47) –they converge to about 18% in the leaps.
- The dashed red line shows assumed 12% carry from April 2013 onward, below severe contango, and I interpret that to mean that the market regards about \$3.60 as the expected future spot price of gas.
- Implied carry peaks in December and by May the winter season is over, so I think the ideal spread to do **now** is May short December long.



Spread arbitrage:

The spread between ICE WTI (Cushing, Oklahoma) and ICE Brent Light Sweet Crude (Europe) has recently spread to record levels, ICE over CME. Is this an q-arbitrage spread opportunity?

[Cushing pipeline glut] Not necessarily – this might be a classic example of why you can't rely upon statistics alone to identify spreads. You have to know the business to know if anything has permanently changed.

Source: ICE, February 13, 2012

Direct Spreads: ICE Brent-WTI futures spread



Description The ICE Brent/WTI Futures Spread allows you to trade the spread between ICE Brent Futures and ICE WTI Futures. Trading a position in the spread results in two separate positions in the underlying futures legs i.e. a long position in ICE Brent Futures and a short position in ICE WTI Futures. All positions are financially settled and appeal to both physical and financial traders.

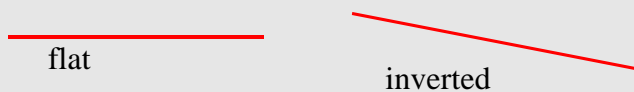
Source: ICE, February 13, 2012

Yield-spread q-arbitrage

Normally the yield curve (say for Treasuries) looks like this:



But what if it looks like this or this?:



Why is the normal yield curve typical? If flat or inverted, what arbitrage do you undertake?

More on Treasury q-arbitrage:



You may conclude that the spread shown here is unusually wide at nearly 500 basis points (where it was last year) and that the play is to go **long (not short)** on 30-year Treasuries and short on short term.

This would have netted a big gain last year.

But long-bond futures contracts are not very liquid and extremely complicated (delivery conditions).

No problem. We can go long with **TLT** or short with the **TBT 2X uShort** (or use calls) and long **DTUS** (or puts on **SHY**).

Risk Yield Spread Arbitrage

Corporate bonds, CBOs, munis, and international bonds are all assigned risk ratings by rating agencies like Standard & Poors, Fitch, and Moody. For equivalent maturities there is a spread in yields reflecting this risk (see next slide for a typical table).

If the yield on a bond (say an international government bond) is statistically unusually high given its risk profile relative to other bonds with similar maturities, a hedge fund or wealthy speculator might arbitrage this by going (long or short?) on the high-yield bond and the opposite way on one of the “normal” or base bonds.

A more sophisticated and complex arbitrage can be developed when *both* risk differences *and* maturities are considered.

Corporate Yield Spreads

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June 30, 2004

This shows spread above underlying Treasury Issue in basis points.

Reuters Corporate Spreads for Industrials*

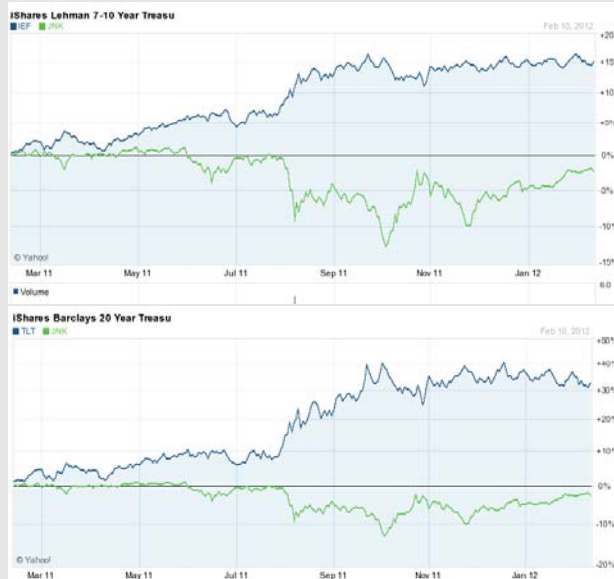
Rating	1 yr	2 yr	3 yr	5 yr	7 yr	10 yr	30 yr
Aaa/AAA	5	10	15	22	27	30	55
Aa1/AA+	10	15	20	32	37	40	60
Aa2/AA	15	25	30	37	44	50	65
Aa3/AA-	20	30	35	45	53	55	70
A1/A+	30	40	45	58	62	65	79
A2/A	40	50	57	65			
A3/A-	50	65	79	85			
Baa1/BBB+	60	75	90	97			
Baa2/BBB	65	80	88	95	126	149	175
Baa3/BBB-	75	90	105	112	116	121	146
Ba1/BB+	85	100	115	124	130	133	168
Ba2/BB	290	290	265	240	265	210	235
Ba3/BB-	320	395	420	370	320	290	300
B1/B+	500	525	600	425	425	375	450
B2/B	525	550	600	500	450	450	725
B3/B-	725	800	775	800	750	775	850
Caa/CCC	1500	1600	1550	1400	1300	1375	1500

Maybe arbitrage if a "junk" is well above this spread.

Source: www.bondsonline.com

We will do this with ETF options later ...

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IEF vs. JNK

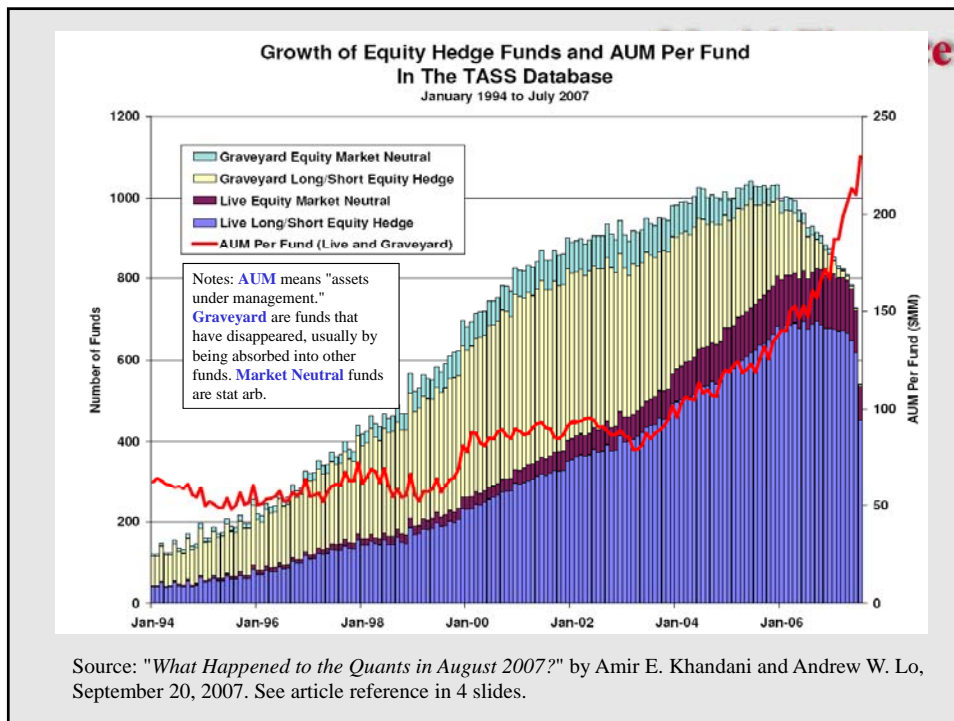
TLT vs. JNK

Statistical Arbitrage (stat arb)

Statistical Arbitrage (called stat arb) is a "quant" strategy used by many of the largest hedge funds, like Citadel. Generally stat arb involves building an equity portfolio of mixed long and short positions in stocks.

Typically the hedge fund strives to make the portfolio "market neutral," meaning that performance does not depend upon a rising or falling market.

Because the return margins on these enormous portfolios are usually pretty thin, stat arb portfolios are usually hugely leveraged (maybe 100 to 1) by cheap borrowed money (e.g. carry trade or commercial paper).



Obviously an old example

Stat Arb (cont.)

Dow Jones Industrial Averages 30 components

AA	Alcoa	HD	Home Depot	MO	Altria
AIG	AIG	HON	Honeywell	MRK	Merck
AXP	American Express	HPQ	Hewlett Packard	MSFT	Microsoft
BA	Boeing	IBM	IBM	PFE	Pfizer
C	Citicorp	INTC	Intel	PG	Procter Gamble
CAT	Caterpillar	JNJ	Johnson & Johnson	T	AT&T
DD	Du Pont	JPM	JP Morgan Chase	UTX	United Technologies
DIS	Disney	KO	Coca Cola	VZ	Verizon
GE	General Electric	MCD	McDonalds	WMT	Wal Mart
GM	General Motors	MMM	3M	XOM	Exxon Mobile

Suppose we take a market basket of stocks, like the index above (but not restricted to indexes ... this is an example), and suppose we are bullish on the index, but not every stock in the index. We therefore decide to go long in most stocks but short some of them (shown in red in the example above, based upon late 2007 markets). But in what quantities? This is where **stat arb** begins, with a portfolio of longs and shorts, like any hedge fund. But **stat arb** also aspires to be *market neutral*.

Stat Arb Market Neutrality

Statistical Arbitrage builds an equity portfolio of longs and shorts (see previous slide) but stat arb also typically aspires to be "market neutral." This means that ideally the portfolio's performance is not improved by either a rise or decline in the overall index (or portfolio). In the previous example, this portfolio, if correctly weighted to be "market neutral," would be insensitive to a rise or fall in the DJIA. [Your teacher once asked a stab arb desk supervisor, a Mudder, whether he thought the market was going to rise or fall in emerging months. His answer was, "Who cares?"].

How do they achieve market neutrality? On the risk side, they use some very complicated algorithms to assess portfolio risk to make the portfolio risk neutral. We will learn that approach in a few weeks when we cover advanced volatility.

What therefore is the basis of profitability? Generally, you have to be more or less right about the longs and the shorts. In a rising market, the longs have to rise more than the shorts. In a falling market, the shorts have to fall more than the longs.

Stat Arb Problems??

Stat arb has been seen in recent years as the coolest of the quant strategies, but in the fall of 2007, in the midst of the sub-prime meltdown, that some stat arb hedge funds had been losing money, something they were not supposed to do.

At issue (teacher's comments):

1. They are heavily leveraged.
2. Their borrowing source is (was) a troubled market.
3. Some bullish bias may have been built into some of these funds.
4. "Quantagion?"

Financial Contagion or "Quantagion" (a dangerous new phenomenon?)

[Not required, but recommended, for class]: see "*What Happened to the Quants in August 2007?*" by Amir E. Khandani and Andrew W. Lo, September 20, 2007 draft available on <http://www2.hmc.edu/~evans/khandanilo.pdf>
later versions possibly available on http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1015987.

What happens when large hedge funds use huge amounts of leverage and start using identical or nearly identical trading strategies?

First, profit ranges must narrow, which may require even more leverage.

Margin calls, credit drying up, etc., may force severe correlated liquidation.

Some trading advice from your Prof:

1. Always know why, in explainable detail, that you are going into a trade.
2. Have a clearly defined entrance and exit strategy for the trade and then act on it. The exit can and should have an exit-with-loss component. **Do not let market emotion override your strategy – you will never make money trading.**

About spread q-arbitrage:

1. Evaluate a spread statistically.
2. Figure out **why** the spread is atypical, and given that, whether the spread may become more atypical.
3. Determine exit strategy and offset conditions and stick to them.