Experimental Finance

IEOR

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Past Projects

Ideas, Implementations, Problems…
Project Types

• Class-based material:
  – Sticky strike or sticky delta analysis trading
  – Takeovers
  – Earnings
  – Pinning

• Other topics
  – option prices relative to IPOs
  – option prices of stocks in certain industries, as they relate to industry shocks (big swings in oil prices, crops freezing etc.)
  – option price changes relative to changes in dividends
  – dispersion trading options on indices
1

Study of Trading Strategies on Oil Correlated Indices
Study of Trading Strategies on Oil Correlated Indices

- Studied two indices potentially correlated to oil:
  - XOI – AMEX Oil Index
  - DTX – Dow Jones Transportation

- The evolution of XOI and DTX closely matches the evolution of the oil price

- Looked for big moves in crude oil, and found that post move, and within a very short term, the ATM implied volatility of the index tended to also make big moves – is there a pattern?

- Since the crude oil market is affected by myriad global supply and demand, as well as political moves, a price independent strategy was sought
Crude Facts

Oil prices have risen nearly 70% this year, topping $55 a barrel this month for the first time. Economists warn that surging prices threaten the world’s economic growth. But when adjusted for inflation, the cost of oil and two of its key products—gasoline and heating oil—still are below historic levels. Viewed in those terms, oil was briefly higher than it is now as recently as October 1990, before the first Gulf War. Only natural gas, amid rising demand, has reached new highs recently in today’s dollars.

All prices are in August 2004 dollars.
Study of Trading Strategies on Oil Correlated Indices

Moves are broken down into two categories:

- **Expected Moves**
  - Implied vols are generally high due to uncertainty (e.g. will OPEC rule one way or the other)
  - Once the market resolves the uncertainty, Oil makes a big move, and vols come in (as seen with earnings, takeovers etc.)

- **Unexpected**
  - 9/11
  - Saudi Arabia suddenly cuts production
  - Hugo Chavez announces free oil for residents in the Bronx
Trading Strategy

• Consider a short position of the short term straddle on the XOI and DTX indices right after a big movement on the crude oil market

• Criteria
  
  – Open: sell ATM Straddle
    • 1. on the 2\textsuperscript{nd} or 3\textsuperscript{rd} day after a big change of the oil price
    • 2. Implied volatility is at a relatively high level
    • 3. Option expiration is between 2 weeks and 1 month

  – Close: buy ATM Straddle
    • 1. Profit-taking point
    • 2. Stop-loss point
    • 3. one week before expiration (potential vol issues before exp.)
Definitions

- **Big Change**
  Those days with daily return of oil lying outside the 95% confidence interval

- **Relatively high implied volatility**
  The current implied volatility is larger than the historical implied volatility

- **Profit-taking point**
  The point corresponds to the 25% percentile

- **Stop-loss point**
  The point corresponds to the 5% percentile starting from the breakeven point
• Retrieved oil prices data from web source
• Determine big price moves between 1996-2005
• 1996 to 2002 was used for back-testing the pattern of change of straddle prices with the change of the oil market to determine:
  – Profit taking point (Straddle XOI: -10%, DTX: -13%)
  – Stop loss point (XOI: 2.8%, DTX: 1.8%)
• 2003 to 2005 was used to test the performance of the trading strategy
• Retrieved oil prices data from web source

• Determine big price moves between 1996-2005

• 1996 to 2002 was used for back-testing the pattern of change of straddle prices with the change of the oil market to determine:
  – Profit taking point
  – Stop loss point

• 2003 to 2005 was used to test the performance of the trading strategy

**Questionable?**
Results

- **XOI**
  - annualized return of 32.78%
  - 57% winning trades

- **DTX**
  - annualized return of 19.88%
  - 59% were winning trades

- **Assumptions:**
  - MBBO used instead of bid price
  - Cost of trading
Questions

• Why the calibration/strategy split in 2003 when the correlation seems to change. How would the strategy have done 1996-2003?

• What is the variance of the returns, were there massive losses that would have crossed unacceptable risk levels?

• Test different price move strengths - the strategy tested only 19 data points

• Test variations on stop loss, profit taking parameters

• Did XOI and DTX have the same PNL patterns? (i.e. make/lose money on the same days?)

• Other indices? General market moves? Prove it is your strategy that is being tested, and not a different market artifact that happens to hold true for a certain period
2

Pairs Trading Strategies
Idea

- Determine stocks historically highly correlated
- Buy the pair (buy low, sell high) when the gap is relatively large
- Sell the pair when the 2 stocks have the same value

![Graph showing price movements over trading days for Total S.A. and Frontline Ltd.](image-url)
• Extract prices for 500 stocks using SQL with highest market capitalization over each period

• Form 20 pairs of most correlated stocks on each 1 year rolling window
  – Formation period of 1 year, rolled-over by 1 month
  – Number of windows: 30 windows in the time period studied
  – In total, formed 600 pairs of correlated stocks

• Trade each pair on 6 month period following the formation period

• Project had significant automated VBA routine to import and massage data in excel

• Used Matlab to implement & back test the trading strategy
Data treatment

• Stock prices are normalized by mean over the year
• Minimize standard deviation of distance

\[
V^* = \frac{1}{N} \min_{S^2} \sum_i \left( S^1_{\text{normalized}}(t_i) - S^2_{\text{normalized}}(t_i) \right)^2
\]

• Compute return statistics of strategy over 600 pairs:
  – Mean annualized return & standard deviation
  – Sharpe ratio of strategy vs. market Sharpe ratio
  – Characteristics of return distribution

• Study impact of strategy parameters:
  – Opening & closing triggers
  – Independence of long / short legs
Impact of Triggers Levels

Also studied impact on Sharpe Ratio, length of position held...
### Results

<table>
<thead>
<tr>
<th>1996-2000</th>
<th>Pairs trading</th>
<th>Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean return</td>
<td>15.9%</td>
<td>5.79%</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>29.0%</td>
<td>23.7%</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>0.644</td>
<td>0.244</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>10.1</td>
<td>5.03</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.30</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Mean return for the buy leg: 18.4%
Mean return for sell leg: -1.22%

<table>
<thead>
<tr>
<th>% time that position is open</th>
<th>83.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average duration of a trade</td>
<td>29.5 days</td>
</tr>
<tr>
<td>% time that position is still open at end of trading period</td>
<td>89.3%</td>
</tr>
</tbody>
</table>
Importance of Time Periods/Scales
Bad News

• Found that testing the same strategy from 2000 onwards, there was a significant decrease in the returns, possibly indicating a mainstream use of the strategy

• This does not mean that pairs trading doesn’t work, just that the straightforward arbitrage is too common and has been squeezed out of the market

• Back to the drawing board, what about:
  – pairs trading more interesting instruments? (e.g. ETF: IAU vs. GLD, IVV vs SPX)
  – Incorporating volume information, general market information or verification on similar but untraded pairs
Pairs Trading in Options – 2nd project

- 385 optionable stocks from S&P 500
- Looked at interpolated 91-day 50-delta IV’s of calls to look for pairs from January 1, 2001 to January 1, 2005
- Trade real 50 delta options approximately 90 days to maturity
- Sell strategies
  - “Stop-Win”: sell if our difference gains 2 sd
  - “Stop-Win (close to expiration)”: under 30 days to exp, sell at a gain of 1.5 sd; under 25, sell at a gain of .75 sd
  - “Stop-Loss”: sell if we are 1 sd below our starting point for 2 days in a row
  - “Bail Out”: sell if the date reaches 20 days to expiration

Tried “naïve” SD-based vs. alpha based strategy using O.-U. mean reversion process
3

Volume Analysis
Hypothesis

• large volume traded within a small change in price
  
i.e. small \(|ds/S| /\text{Volume turnover}\)

  massive trading within a certain price shows that current price agrees with most of people, therefore the future stock price might be steadier and might decrease the implied volatility

• small volume traded in large range of stock price
  
i.e. large \(|ds/S| /\text{Volume turnover}\)

  The future stock price might be more volatile because the opinion in the market varies. The implied volatility in the future might increase. So we assume that there is a positive relationship between \(|ds/S| / \text{Volume}\) and Implied Volatility
Idea

• Volume analysis

  I. Return vs. Volume Turnover
  II. Implied Volatility vs. Volume Turnover
  III. Volatility vs. Volume
  IV. Implied Volatility vs. \( \frac{|ds|}{S} / \text{Volume turnover} \)

• Adjusted Stock Price, Adjusted Volume, Shares Outstanding, Interpolated 50-delta Option Implied volatility in the period 2000-2005

• 10 Large cap: (>\$50 Billion)
  C, CSCO, GE, GM, GS, MSFT, ORCL, PG, T, WMT

• 10 Small cap: (<\$10 Billion)
  ADPT, ARIA, ARM, CVTX, DNDN, ENMD, HEPH, NANX, OSCI, USU
Return vs. Volume

\[
\frac{|S_t - S_{t-1}|}{S_{t-1}} = \alpha + \beta V_t + \varepsilon_t
\]

Proctor & Gamble

- In most of cases, there exists a positive correlation with Absolute Return and Traded Volume
- From the time series, it can be observed that return spikes accompanies with a Volume strike
\[
\frac{|S_t - S_{t-1}|}{S_{t-1}} = \alpha + \beta V_t + \varepsilon_t
\]

For Cisco on the other hand, not much to say….
1 day

- Stronger correlation when using a larger window for the accumulated volume

5 Day
Implied Volatilities for different periods

- Inherent volatility changes in the stock cause problems
- Selecting the period carefully causes correlations to appear
Experiment Results

I. Return vs. Volume
   – Most stocks showed positive correlation
   – Not significant in general

• II. Implied Volatility VS Volume Turnover
   – Most stocks showed positive correlation
   – Stocks’ performance depended on time periods

• III. Volatility vs Volume
   – Most stocks showed positive correlation

• IV. “|ds/S| /Volume turnover” and Implied Volatility
   – Most stocks showed positive correlation
Trading Model

\[ \Sigma_t = \alpha + \beta \frac{|s_t - s_{t-1}| / s_{t-1}}{V_t} + \epsilon_t \]

- Alpha and Beta are calculated by the data one year prior to the trading date.
- Trading Period: 2003/06 – 2005/05
- Initial Capital: $1000

- Long Volatility (Long ATM call, short delta shares of stock) when the implied volatility is below 10% of the value calculated by the Model. Close the position when the implied volatility converges to 1% difference with the Model.
- Short Volatility (Short ATM call, long delta shares of stock) when the implied volatility is above 10% of the value calculated by the Model. Close the position when the implied volatility converges to 1% difference with the Model.
Some unfortunate results…

<table>
<thead>
<tr>
<th></th>
<th>P&amp;L long C, short S</th>
<th>P&amp;L short C, long S</th>
<th>Total P&amp;L</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSFT</td>
<td>-6.04</td>
<td>4.39</td>
<td>-1.65</td>
</tr>
<tr>
<td>GM</td>
<td>-24.36</td>
<td>8.19</td>
<td>-16.18</td>
</tr>
<tr>
<td>GS</td>
<td>-101.49</td>
<td>0</td>
<td>-101.49</td>
</tr>
<tr>
<td>PG</td>
<td>-133.49</td>
<td>0.23</td>
<td>-133.26</td>
</tr>
<tr>
<td>WMT</td>
<td>-80.01</td>
<td>-8.97</td>
<td>-88.99</td>
</tr>
</tbody>
</table>

- However the analysis was very sound
- The trading strategy was a quick hopeful attempt and was not extensively studied – there may be room for profit-taking
4

IPO Trading
• Believe that the market over-prices volatility during the initial break-in period.
• This effect should be reflected in option prices, so
  1. Sell shortest-maturity ATM straddles as soon as they start trading on the IPOed stock
  2. Delta-hedge the position daily and record P&L
  3. Buy back the straddle in one week or two weeks (closing positions)
• Why should this work?
Strategy

- Believe that the market over-prices volatility during the initial break-in period.

- This effect should be reflected in option prices, so
  1. Sell shortest-maturity ATM straddles as soon as they start trading on the IPOed stock
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- Why should this work? A straddle allows us to trade volatility and not direction

Hope Gamma and Theta cancel each other, so that Vega is left
Challenges

- Finding options right after IPO
- Shorting IPO stocks initially (illiquidity)
- Stock price is extremely volatile, difficult to delta hedge precisely
- Gamma and Theta side-effects

Selection Criteria

- Sell Straddles as soon as they are available within 14 days
- **Strategy 1**: Close positions after 7 days
- **Strategy 2**: Close positions after 14 days
SELECT s.securityid, MIN(sp.date) startdate
    INTO stock_startdates
FROM security_price sp
INNER JOIN security s ON sp.securityid = s.securityid
WHERE (s.issuertype != 'A' AND s.issuetype !='7' AND s.issuetype !='F' AND s.issuetype !='%')
    AND s.indexflag = 0 AND s.ticker != '?'
GROUP BY s.securityid
HAVING MIN(sp.date) > '1996-01-02'
ORDER BY s.ticker

Reduce data set further to stocks that trade options within 14 days – further weed out new merger/splits/acquisitions that generate new companies that were not conventional IPOs
• Used Yahoo Finance & MSN Money to verify each ticker. *(found instances where Yahoo Finance was wrong!)*

• Discard unlisted tickers and wrong IPO start dates

• **Result: 61 Stocks**

• Look at historical Vols:

![Change in Stock Volatility From First to Second Month after IPO]
Experimentionation

- Used EXCEL to cleanup data
- Select and track the ATM call and put option
- Delete cases of bad option delta
- **Result: 37 useable stocks (out of about 3000!)**
Returns holding 1 vs. 2 weeks

**Returns (1 Week)**

<table>
<thead>
<tr>
<th>Returns</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>-90.00%</td>
<td>1</td>
</tr>
<tr>
<td>-80.00%</td>
<td>1</td>
</tr>
<tr>
<td>-70.00%</td>
<td>3</td>
</tr>
<tr>
<td>-60.00%</td>
<td>3</td>
</tr>
<tr>
<td>-50.00%</td>
<td>1</td>
</tr>
<tr>
<td>-40.00%</td>
<td>1</td>
</tr>
<tr>
<td>-30.00%</td>
<td>2</td>
</tr>
<tr>
<td>-20.00%</td>
<td>3</td>
</tr>
<tr>
<td>-10.00%</td>
<td>3</td>
</tr>
<tr>
<td>0.00%</td>
<td>4</td>
</tr>
<tr>
<td>10.00%</td>
<td>4</td>
</tr>
<tr>
<td>20.00%</td>
<td>8</td>
</tr>
</tbody>
</table>

**Returns (2 Week)**

<table>
<thead>
<tr>
<th>Returns</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>-90.00%</td>
<td>1</td>
</tr>
<tr>
<td>-80.00%</td>
<td>1</td>
</tr>
<tr>
<td>-70.00%</td>
<td>3</td>
</tr>
<tr>
<td>-60.00%</td>
<td>2</td>
</tr>
<tr>
<td>-50.00%</td>
<td>5</td>
</tr>
<tr>
<td>-40.00%</td>
<td>2</td>
</tr>
<tr>
<td>-30.00%</td>
<td>3</td>
</tr>
<tr>
<td>-20.00%</td>
<td>4</td>
</tr>
<tr>
<td>-10.00%</td>
<td>4</td>
</tr>
<tr>
<td>0.00%</td>
<td>5</td>
</tr>
<tr>
<td>10.00%</td>
<td>3</td>
</tr>
<tr>
<td>20.00%</td>
<td>3</td>
</tr>
<tr>
<td>30.00%</td>
<td>3</td>
</tr>
<tr>
<td>40.00%</td>
<td>2</td>
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<tr>
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<tr>
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<tr>
<td>70.00%</td>
<td>3</td>
</tr>
<tr>
<td>80.00%</td>
<td>3</td>
</tr>
<tr>
<td>90.00%</td>
<td>1</td>
</tr>
</tbody>
</table>
Profit / Loss by IPO Year (1 Week)

- Frequency
- Positive
- Negative
- Profit/Loss values: -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6, 7
• Money can be made by trading IPO volatility

• **Best**
  Year: 2002 & 2005
  Industry: Service & Financials

• **Worst**
  Year: 2001 & 2003
  Industry: Technology & Consumer Goods

• **Improvements**
  – Increase sample space
  – Increase the monitoring period between IPO and option
  – Use trading days instead of calendar days
  – Incorporate transaction costs
5

OIL Stock return vs. Industry
Intuition

- When there is a big movement in crude oil price, the volatility of oil stocks increase
- The event leads to divergence of oil stock returns from the industry trend, which is tracked by indices/ETFs, like XLE
- Over time, the stocks will again converge to the industry trend
- Possible opportunities for divergence trading
Preliminary Tests

- Stock return diverges more from index return immediately after a big movement of oil price

- E.g. average divergence from XLE return

<table>
<thead>
<tr>
<th>Ticker</th>
<th>Normal Time</th>
<th>After Big Move in Oil</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>BJS</td>
<td>1.68%</td>
<td>2.29%</td>
<td>36.3%</td>
</tr>
<tr>
<td>CAM</td>
<td>1.49%</td>
<td>2.06%</td>
<td>38.3%</td>
</tr>
<tr>
<td>CHK</td>
<td>2.12%</td>
<td>2.81%</td>
<td>32.5%</td>
</tr>
<tr>
<td>MEE</td>
<td>2.16%</td>
<td>2.92%</td>
<td>35.2%</td>
</tr>
</tbody>
</table>

* From 1998-2005
* Big Move is defined to be >7% over the past 5 days

- In average, divergence increases by 17.4%
• “For every $p_1\%$ change in the oil price over $p_2$ days, check if at least $p_3$ oil stocks diverged by at least $p_4\%$ from XLE within the next $p_5$ days”

• “If so, short $1000$ of those that diverge high, buy $1000$ of those that diverge low (assuming you started that day with $1000$)”

• “Stop the trade if you gain $p_6\%$ or lose $p_7\%$, or if $p_8$ days pass”
### Parameters for Entering the Trade

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Intuition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_1 ) % change in oil price…</td>
<td>At least 5%, otherwise the shock is too small</td>
</tr>
<tr>
<td>…over ( p_2 ) days</td>
<td>Over several days, to ensure a definite trend and exclude noise</td>
</tr>
<tr>
<td>At least ( p_3 ) stocks to diverge…</td>
<td>Need divergence in many stocks, to exclude company-specific events (e.g., earnings)</td>
</tr>
<tr>
<td>…by at least ( p_4 ) % from the index…</td>
<td>To trade on a clear divergence, instead of noise</td>
</tr>
<tr>
<td>…within the next ( p_5 ) days* (Look Window)</td>
<td>There are possible lags between oil price shock and divergence of stocks</td>
</tr>
</tbody>
</table>

* Including day of shock itself
### Parameters for Exiting the Trade

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Intuition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop gain $p_6%$</td>
<td>Stop after stocks converge, or stop losing if they continue to diverge.</td>
</tr>
<tr>
<td>Stop loss $p_7%$</td>
<td></td>
</tr>
<tr>
<td>Stop after $p_8$ days if no stop gain/loss (Trade Window)</td>
<td>Effect of shock decays over time.</td>
</tr>
</tbody>
</table>
Results Very Sensitive to Parameters

(Note: from here on, all charts assume 0.5% bid-ask spread)
More Sensitive to Stop Gain than Stop Loss

- Possible reason: lack of proper "convergence" criteria to close the trade in time
Sensitivity to Min. Number of Stocks per Trade

- Too small: possibly trading on company-specific events
- Too large: not enough trades, missing opportunities
• Fewer big moves in oil
• Less divergence: more investors implementing trade?
Sensitivity to “Trade Window”

![Graph showing the relationship between maximum number of days per trade and Sharpe Ratio. The graph indicates that the Sharpe Ratio increases as the maximum number of days per trade increases, reaching a peak around 11 days, and then fluctuates but remains relatively stable.](image-url)
“Reverse Strategy” Fails

- Reverse strategy: check for divergence on every day, instead of only days following oil price shock
• Fewer trades after calibration period
• Less divergence when Fed Interest Rate 1% (fewer surprises)?
- Strategy works – but possibly with luck
- No trades after 2003
Conclusions
The Better Projects

- Understood the characteristics of the instruments they were trading (sectors, event-based, small vs. large cap, hard to borrow, fundamental regime changes in the market etc.)
- Carefully segmented data appropriately to their strategy, including control groups
- Properly cleaned and massaged the data (very important – there is no hope in “quickly testing” something against historical data without understanding the data)
- Performed thorough analysis by binning/testing various parameters, not only the ones of direct interest

Spend a lot of time understanding the data, rather than constructing extremely complicated models you think should work.
Example of Pitfalls – Dispersion Trading the SP500

- Since S&P 500 Stocks are added and removed, reduced set to only stocks that stay in the index for whole year to track the index for that particular year.

- Create a table to store the tickers of those stocks that stay in the index from year 2000 to 2005. (According to data from Standard and poor’s)

- Since S&P500 rebalance is not prescheduled, can the add/remove effect on the volatility be ignored?

- For implied volatility, due to the large amount of data we have to handle, we use only 1-month, 50 delta option to represent all the options for a certain stock.

- Stocks and their options don’t necessarily always have good data for a given day, and options might have meaningless Greeks on several days. How is the trading strategy affected?
Use Scientific Method

- Form a theory and experiment using solid data analysis, control groups (market/sector performance) and cross-checks (does the strategy lose money when the reverse strategy is chosen)

- You can’t use double blind tests, so be very careful when processing data
  - Eliminating “problem” stocks/options
  - Human Bias
    (i.e. don’t only include profitable results – show both, and reason why the behavior is different)

- Make detailed quantitative assessment about the phenomena the theory seeks to explain

- Refute your theory if the numbers lack predictive power

We are not rewarding positive PNL but rather critical thinking and good experimentation
$ – Initial entry (start of historical record)
A – The security is inactive (no longer being priced)
C – The security has been purged due to inactivity
D – The security has been delisted
E – The security’s exchange has changed
N – The security has been newly listed (but not yet priced)
S – Trading in the security has been suspended
X – Security is inactive due to an acquisition or merger
3 – The security has been reactivated, and this is the first day priced
4 – The security is new, and this is the first day priced
U - Non-NASDAQ OTX
00000 – Currently delisted
32768 – The security is an index
0 – Unknown or not yet classified
1 – Regular dividend
2 – Split
3 – Stock dividend
4 – Capital gain distribution
5 – Special dividend
6 – Spin-off
7 – New equity issue (same company)
8 – Rights offering
9 – Warrants issue
% – Regular dividend projection

Dividends
0 – Amount field is exact
1 – Amount field is approximate

0 – Common Stock
A – Market index
7 – Mutual or investment trust fund
F – ADR/ADS
% – Exchange-traded fund
Good Luck!