Event-Driven Finance

IEOR – Fall 2017

Mike Lipkin, Sacha Stanton
• 6 months of JPM.
• There are days of high volatility and low; trending regions and mean-reverting regions; one flash crash.

Stock prices are linear, but option prices reflect the multidimensionality of time frames and expected uncertainty.

Put more succinctly- buying a stock over a time frame, \( T \), is a bet that this stock will rise during that time frame relative to the general economy.
• Buying options with expiry, T, are a bet that “volatility” will increase during the same time frame.

• At each time, t, we are, in principle, in possession of all “facts” prior to t. We also have a degree of knowledge of future events. These future events include earnings, corporate reports, analysts’ reports, interest rate changes, etc. and we are roughly in possession of the timing of these future events.

• As researchers or traders we would like to learn how the arrival of events and the expected future volatility reflecting upcoming events will lead to future returns.

• The elements of standard option pricing are typically a very simple model of future uncertainty- for instance a single parameter, $\sigma$, and the time to expiration.
• What is the reality?
• There are typically many more temporal scales than simply time to expiration.

• The additional time scales become reflected in prices both in systematic ways as well as irregularly.
• To succeed as traders we need to understand and be able to subtract out the systematic price changes.

• This course will look at many different financial situations with the above in mind.
• Here are some snapshots:
EUR per 1 USD

23 Jun 2016 00:00 UTC
USD/EUR close 0.87898

CENTRAL BANK RATES

<table>
<thead>
<tr>
<th>Currency</th>
<th>Rate</th>
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<tbody>
<tr>
<td>JPY</td>
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<tr>
<td>CHF</td>
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<tr>
<td>EUR</td>
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<tr>
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<tr>
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<tr>
<td>NZD</td>
<td>2.00%</td>
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<tr>
<td>GBP</td>
<td>0.25%</td>
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</table>

Event-Driven Finance
Mike Lipkin, Alexander Stanton
GBP per 1 USD

23 Jun 2016 00:00 UTC
USD/GBP close: 0.67098
Pressure Rising
Britain's poll results send global asset prices swinging

Normalized As Of 06/23/2016
- British Pound
- Yen/Dollar
- Gold
- S&P 500 Index Futures

Source: Bloomberg
Introduction
Introduction
Introduction

![Investing.com S&P 500 VIX Chart](image)

**CBOE Volatility Index (VIX)** - 23.22 +5.97 (+34.61%)

- **Prev. Close**: 17.25
- **Open**: 26.06
- **1-Year Return**: -5.2%
- **Volume**: -
- **Average Vol. (3m)**: -
- **Day's Range**: 19.48 - 26.24
- **52 wk Range**: 10.88 - 53.29
Introduction
GLD Overview

SPDR Gold Shares

Prev. Close 120.11
Open 126.62
Volume 34,344,847
Average Vol. (3m) 10,974,870
1-Year Return 1.33%

Day's Range 125 - 126.82
52 wk Range 100.23 - 126.82
Market Cap 37.03B
Total Assets 32.83B
Shares Outstanding 308,300,000

ROI (TTM) 3.04%
Dividends (TTM) -
Dividend Yield N/A
Beta 0.07
Asset Class Commodity
Lecture 0F

Introduction

Volume: 43,288,345 | Bid/Ask: 59.46 / 59.57 | Day's Range: 59.34 - 61.70

General | Chart | News & Analysis | Financials | Technical | Forum

Overview | Profile | Historical Data | Options | Index Component

JPM Overview

JPMorgan Chase & Co * 59.60 -4.45 (-6.95%)

<table>
<thead>
<tr>
<th>Prev. Close</th>
<th>Open</th>
<th>Day's Range</th>
<th>52 wk Range</th>
<th>Revenue</th>
<th>EPS</th>
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</thead>
<tbody>
<tr>
<td>64.05</td>
<td>60.48</td>
<td>59.34 - 61.7</td>
<td>50.07 - 70.61</td>
<td>100.46B</td>
<td>5.9</td>
</tr>
</tbody>
</table>
• What is Event-Driven Finance?

• As we can observe, the date June 23, 2016, was a significant date in terms of global markets
• Prices of stocks, commodities, and rates all made changes which we associate with an event on that date
• Some price adjustment occurs prior to the date, some on the date, some subsequent to the date

• We therefore have an event *localized in time*, which is associated with *structures in price space*

• If we are pricing instruments with a model which *averages* stochastic events over time- then even if the frequency and size of *significant* events is formally included and correctly accounted for, the prices we calculate for instruments will be homogenized.
• Prices will usually be too high. Then if the significant event occurs our prices will be too low.
• Markets and trading occur on small temporal scales but pricing using a standard model occurs on mesoscopic (intermediate) scales.

• Models are only frameworks. They are not relevant or binding on traders and hedge funds or real markets.
• In this course, we are interested in understanding the behavior of securities proximate to events so that we can distinguish regularity and irregularity and conceive of trading schemes and robust pricing models.
• We will do this directly by identifying events and exploring experimentally the pricing behavior of stocks and options and ETFs temporally nearby, using two extensive databases.
• The computational skill needed to facilitate this study is SQL, the generic language (set) used to extract and manipulate large sets of data.
• The course is first, and foremost, EXPERIMENTAL. You must think of this course as a laboratory course, without the dryboxes and gloves.
• The learning comes through doing the Problem Sets, which are the experiments. We will experiment on many events: earnings, take-overs, drug announcements, etc.
• Then you will challenge yourselves with a project of your own choosing.
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All course material are located at https://experimental-finance.com/
Problem Sets are due as indicated in the Calendar located in the Course Package

Please make sure to carefully follow the instructions for sending solutions and work.
What is event-driven finance?

A first, naïve, answer is this: Event-driven finance concerns the pricing of (derivative) securities concomitant to some temporal event.

This first answer is somewhat tautological. And in any case, events happen all the time. So why might we wish to introduce this new category of finance?

To answer this question we need to reexamine our preexisting ideas about derivatives pricing.
• In the course of doing so we shall see that standard approaches to pricing involve assumptions of equilibrium.

• These assumptions include the notion that many events may be averaged over; the events form a heat-bath in whose presence the expected stock behavior may be calculated.

• BUT what if we are not interested in the average behavior of a stock, but only its behavior in the temporal vicinity of ONE event.

• We should expect the pricing of the derivative securities to have a prominent time dependence- and it does.
• So the story is two-fold:

Events are typically discrete changes in some characteristic at a fixed time;

And event-driven finance means that we are interested in the time-dependent price of securities near that time.

• Let’s look at some pictures:
• Here is a volatility surface for the stock, FDC, at the close of trading, September 15, 2005, (upper surface)

• And below it the surface for the same stock 1 day later
• Here is a volatility surface for the stock, FDC, at the close of trading, September 15, 2005, (upper surface)

• And below it the surface for the same stock 1 day later
FDC impact
• Over the course of a single day, there is a large drop in the implied volatilities.
• Clearly some event had occurred to lower the implied volatilities across all expiries.
• This means that theoretical pricing of securities required a discrete change of input parameters.
• We will discuss what happened later, but you may be surprised to note that classical stochastic models do not include a parameter which directly encompasses this change.
• Here is a graph of implied volatility for a period of four weeks in April, 2008 in the stock, AAPL
• For three of those weeks the implied volatility was steadily rising; after a crash, the volatility appears to flatten
AAPL vol crest

Implied Volatility of ATM Straddle for AAPL
(Earning Release of 08-04-23)

- Blue line: Expire on 08-05-16
- Red line: Expire on 08-06-20
- Green line: Expire on 09-01-16

Event-Driven Finance

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• Here is the rising portion of a similar graph for MSFT in October 2004
• For the previous two images, it is clear that while there appears to be an event date, the impact of the event is spread out over several earlier weeks broadly.

• This is typical of a certain class of events which we shall revisit in Lecture 6; they are clearly anticipatory in that we see effects in the volatility surface in advance of the event.
• The following is a graph of implied volatilities for several strikes in the stock, DIGI, for three months in 1998.

• At a certain date (ca. May 14) the volatility surface *pleats*- the front month at-the-money implied volatility dropping below the volatility of the next higher strike on a relative basis.
In Lecture 8 we will come back to this example and discuss what happens here in more detail. This is a complex event in that it has multiple parts.

Looking carefully at the long-term volatility, one sees that it drops abruptly in the first week of June.

This sudden drop in the long-term volatility is, in fact, what most people would identify as the event.

But while the volatility pleating of mid-May is consistent with the June occurrence it is not pre-ordained by it- nor the reverse!
• Here is a plot of stock price for the stock JDEC for a month (February - March) in 2001.

• The Japanese candlesticks indicate a large drop in daily volatility for the stock after Feb 27, and the stock zeroes in on the price of $10.
JDEC in March 2001

Large sale of options on this day
In case 1, an event on Sept 16 in FDC produced a discrete immediate response in the volatility surface.

In case 2, an event at a later date caused an anticipatory change in the volatility surface over several weeks.

In case 3, a complex event stretches over several months and has variable temporal effects on the volatility surface.

In case 4, -contrast with case 2- the event in JDEC can be associated with the date, Feb 27, but the effect on the volatility surface and stock price stretches forward in time. We will discuss this case in detail next Lecture.
• What each of these cases represent are what physicists would call a: 

\textit{dynamical phase transition},

or a,

\textit{dynamical change of state}
As long as flows continue into and out of the (sub)system, a large variety of ordered, disordered, slowly-varying or transitory states are possible.
• traditional finance and economics live in a thermodynamic world
• artifact of the origins of classical economics in a time of success for the science of thermal physics
• after all, thermodynamics can distill $10^{23}$ particle positions and momenta into a single temperature and a single pressure
• maybe economics could do the same for markets and their participants
as a result, we have simple stochastic models in finance:

\[ \frac{dS}{S} = f(\sigma(a,b,c...))d\Omega + \rho(u,v,w...)dt \]
\[ d\sigma/\sigma = g(\kappa)d\omega, \]
\[ E\{d\omega d\Omega\} = \nu dt \]

etc...

with the goal being to produce option prices:

\[ C(S,T-t,r,\sigma) = ... \]
• what these models give us are option prices intended to fit a “real” world
• And yet these models do not work to predict phase transitions or price options on both sides of these transitions**
• What we might do is write two separate models- one for before and one for after the transition has occurred
• But the main point is this: if all our (derivatives) prices are fit by calibrating an initial model- and then the prices no longer fit- we

• Cannot know if our model is now wrong
• Or if profitable trading is now possible
• This is so significant I will repeat it often
• Here are some pleasant movies to amuse and instruct....
  – Viscous fingering
  – Bénard cells
  – Bacterial inhibition
  – Bird clustering
A real economy is like a system of biology
The only biological systems which are in equilibrium are dead
The only economic (sub)systems which are in equilibrium are likewise inert
While they function, moneys and labor, nutrients and waste, flow in and out
The simplest cases we can hope to understand are dynamical steady-states
What are dynamical steady states?

They are subsystems which we hope can be described by a small number of slowly varying parameters.

In these cases we can treat the systems as if they were in a time varying (pseudo-) equilibrium.
• Let’s return to the four cases.
• What are they?

• Case 1:
  • On Sept 16, 2005 in a two-hour window a Bank America customer sold 150,000 FDC Jan 40 Calls on the AMEX.
  • The volatility declined as seen
  • We envision two quasi-steady states: a high volatility surface (before) and a low one (after)
• Case 2:
• AAPL (MSFT) declared earnings
• We postulate a volatility surface parameterized by time to earnings before and time-independent after
• Case 3:
• The market began to anticipate a *take-over* in the stock, DIGI
• We introduce an auxiliary parameter, $\varepsilon$, indicating the likelihood of a deal
• Case 4:
• A large sale in options (50,000) preceded the eventual *pinning* of the stock to the 10-strike
• We separate the system into three states: pre-large trade; post-large trade and pre-expiration; and post-expiration
• The middle state alone is parameterized by distance to strike, size of open-interest on the line and time to expiration
• The pre- and post-expiration states are considered to be independent of these parameters
the importance of b.c.

- It is possible to feel overwhelmed by the varieties of dynamical ordering and phase transitions,
- And in fact they are virtually infinite
- But there is a key point here which should not be missed:
  - What is possible will be constrained and ordered by boundary conditions
• In the pretty movies, the geometrical constraints were pretty clear:
  – Closest packing of birds
  – Hexatic symmetries
  – Fractal area maximization, etc.

• In our four cases the boundaries divide the phase space as follows:
  – Before and after a big trade
  – Before and after earnings
  – Before and after a change in takeover probability
  – After a big trade and before option expiration
• Let’s jump in with a real world example:
Lecture 1

The Market (Reality)

- Suppose you are working at a desk and running a variant of Black-Scholes, as sophisticated as you care to make it, and a hedge fund shows you 15000 contracts $0.15 through your theoretical value: “I can sell you 15000 VMW Apr 85 calls for $7.46.”
Lecture 1

The Market (Reality)

- Here is another page of VMW quotes:
EMC to maintain 80% VMware stake
EMC Corp., which specializes in high-end computer storage systems, is based in Hopkinton. (Neal Hamberg/Bloomberg News/ File 2004)
Bloomberg News / March 3, 2010
• Do you buy them?
  – What considerations do we need make?
  – What if the hedge fund wanted to sell 500 options only?
• Volatility/Vega
• Risk
• The above is an example of a volatility depression (spike). After the trade there will be a new volatility profile.
• What will that profile look like?
• Would it surprise you to know that there is no existing, accepted theory of the \textit{dynamics} of pricing?
  – What we are interested in having at our disposal is not a \textit{static} (or thermodynamic) model which allows stochastic volatility, but a way of learning about the \textit{response function} of a real market.

• In a sophisticated theory, the following kind of mathematical object would be calculable: \(<\Delta \sigma(K_1,t_1)\Delta \sigma(K_2,t_2)>\).
Lecture 1  The Market (Reality)

• As you can imagine. If we do decide to buy the Apr 85 calls we will have greatly increased our Vega. From the discussion it is clear that in any case, prices will decline in other strikes and series.
  – By how much?
  – No one knows. There is (almost) a complete absence of theory.
• If the Apr 85 calls decline by 1.5 (implied) vol points,
  – how many points will the Apr 90 calls come in by?
• The market there is $5.40-$5.60.
  – Does it make sense to *hit* the bid? (What does *hit* mean?)
• The July 85 calls are $10.40-$10.60.
  – Should you sell the calls at $10.40 as a hedge?
  – Is this better than the $5.40 sale?
  – What if there are earnings between April and July?
• **Should you sell EMC volatility instead?!?**

• Suppose that the hedge fund “informs” you that the calls will trade.
  – Should you be *leaning* short?
  – What does this say about the assumption that the stock process is independent of option trading?
  – Is there a flaw in the Martingale assumption?

• Later (Lecture 2) we will see that option volume can affect stock prices.

• Here are some Real World examples:
Lecture 1  The Market (Reality)

- On September 16, 2005, a BA customer sold 150,000 **FDC Jan 40 calls** to market-makers, mostly within a two-hour window.

- The implied volatility of at-the-money options went from 23 to 19 in January and from 28 to 20 in November.

  this was **case 1** above

- On Tuesday, May 23, 2006, market-makers were told “133,000 **RAD Jan ’08 2½ calls** will trade at 2.35 vs. 4.38 stock. How much would you like to sell?”
Lecture 1

The Market (Reality)

2.30 = 50.5 vol
.80 = 38.25
.25 = 37.80
RAD = $4.38
133,300 CONTRACTS TRADE 2.35

DO YOU SELL?
Lecture 1

The Market (Reality)
Let’s take the previous slide of VMW as a template.

The standard approach to market pricing is calibration. All market models take input data from the actual prices out there. Suppose that the resultant model now “fits” the market, in the sense that no theoretical prices lie outside the bid-offer spreads.

– Does this mean that the market is correctly priced?

Suppose that over the next week, buyers show up for all the VMW 87.5 line options (previous slide $S_0=83.77$). As a result,

– what will happen to the normal skew?

If the skew “inverts”, does this mean that the prices are wrong?

We will see, (Lecture 8), that under certain circumstances such as take-overs the skew can take a strange but characteristic shape.
The main point is this: if all our (derivatives) prices are fit by calibrating an initial model and then the prices no longer fit we…

- cannot know if our model is now wrong
- or if profitable trading is now possible
- This is because events create a phase change in the system we are studying/trading

- Case 2: earnings dates in AAPL and MSFT
- Case 3: anticipation of, and then take-over of DSC (DIGI) by Alcatel
- Case 4: the expiration pinning of JDEC
• Let’s try to summarize some of the ideas we have discussed.
• The size of a trade matters. The time scale for the relaxation of the market subsequent to a trade matters. A quant analyzing the thermodynamics of the market will not see many of the time scales needed to understand market dynamics.
• It is important to pay strict attention to time scales.
• Ex.: Optionmetrics IVY database – closing prices
• This time scale suffices to look at earnings, drug announcements, take-overs and mini-crashes (Lectures 3 and 4). It does not allow us to look at the response to size trades.
  – What kind of database would you need for that?
  – Would such a database be useful for a trading house?
  – Do you think the elasticity of the response is a function of the individual stock? the open interest? the illiquidity of the stock? Anything else?
• Let’s conclude this introductory talk by considering a typical problem about which there is a lack of theoretical understanding. The objective will be to abstract the nature of the problem, consider the time scales involved, and finally to propose a database *experiment* to search for market behavior.

• Let’s take the VMW, EMC example. These are two related companies. Suppose we run a book with positions in VMW and EMC. When we are offered a large trade in VMW, we would like to know if we need to be hedging in EMC. Notice that this is not asking if stock prices are correlated (although they may be), but rather if volatility surfaces are correlated.

• For example, suppose that we are short 5000 Vega in VMW and long 5000 Vega in EMC. If we buy VMW premium we will become flat, say.
  – Do we need to sell some amount of EMC volatility?
  – If that is true, what would that tell us and how would we quantify it?
  – What time scale would the vol changes occur on?
To begin with we need to locate significant volatility changes in the histories of VMW and EMC. We need these changes to occur over a characteristic time scale, say one or two days, and then we need to see if there is a subsequent change in the volatility of the partner stock. The following quantities may be relevant:

\[ \langle \Delta \sigma_{VMW}(t,K_{\Delta 1}) \Delta \sigma_{EMC}(t+\tau,K_{\Delta 1}) \rangle \quad (1) \]

• What is this object? \( \Delta \sigma \) is the change in vol, \( \tau \) is the lag time (unknown but possibly very short) between the change in VMW vol and the subsequent change in EMC vol, \( \tau > 0 \) assumed. \( K_{\Delta 1} \) is the strike corresponding to similar deltas in both products. (Notice how the assumptions are multiplying!!) From the physics of dynamical systems, this quantity is called a response function– for obvious reasons.
moving onward

• Impact is frustrating (for me) in that it exposes the lack of theory.
• Given some set of parameters involving market cap, supply/demand, initial volatility surface, etc., a complete theory would explicitly yield the new volatility surface which results, given a large instantaneous trade of size, Q.
• This is far away, however:

• A “complete” solution exists for stock pinning (Lec. 3)
• “Partial” solutions exists for earnings and take-overs (Lecs. 6 and 8)
• A “complete” (hard) solution exists for hard-to-borrowness (Lec. 7)
• The general technical approach is to identify slow variables in which reformulated static modeling approximately holds.

• **We will see this next time…**