WORLDQUANT UNIVERSITY

# Compiled Notes Module 6

## MScFE 660

## Case Studies in Risk Management

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# Module 6: The 2010 Flash Crash

This module discusses the 2010 Flash Crash in the US. It focuses on the complexity and vulnerability of financial markets and the ability of the market to withstand wide ranging consequences of a crisis. The module begins with a description of the political and economic landscape in the late 2010 and the events that occurred during the US Flash Crash on May 6, 2010. It then explores how trades are executed to further explain the dynamics of the crash and concludes with an overview of the reaction to the crisis in terms of developing more robust regulations to mitigate risks.



# Unit 1: 36 Minutes

On the 6th of May 2010, American stock indexes and exchanges experienced a temporary slump in price value that lasted exactly 36 minutes. The rapid collapse and recovery of share price value, the first during the Great Recession, was hailed as a significant learning moment for the many investment institutions both in America and across the globe that were trying to recover from the crisis. What is important to gather from the so-called 'Flash Crash' is the affect high volume trading continues to have on stock exchanges, even when there are preventative measures that are put in place to prevent similar financial turbulence.

## Receding strength

The 2007-8 financial slump had manifested into the Great Recession, a period of ongoing economic and financial decline that affected the majority of the world's major economies. Perhaps the biggest cause for global concern at the time was the ongoing Eurozone crisis, and the decline of the Greek economy. The European debt crisis, one of the results of the financial crisis, was ongoing during the late 2000s and early 2010s, and the Greek economy was particularly weak. Despite its postwar economic growth, the weaknesses of the Greek economy were exposed by the Great Recession. A persistently weak manufacturing base and export economy made Greece reliant on tourism and small business. As the Recession began to hit major Western economies, tourism evaporated. That, coupled with rampant tax evasion and government corruption, contributed to a growing debt crisis. Perhaps if it had controlled its own currency, Greece might have devalued its currency to make what little exports it had more competitive on the global market or made travelling to Greece a little easier. But, no, authorities in the Eurozone and the European Central Bank demanded austerity measures to put the Greek government on the path to repaying its mounting debts. Any money that might have gone to a recovery ended up going to the creditors and the private economy cratered.

Facing an imminent collapse, the Greek government struggled to keep their financial system liquid as their government bonds and credit rating was junked by the international credit ratings agencies, requiring a bailout from the International Monetary Fund (IMF). As with any bailout (see Module 3, the Asian Crises), there is the need for some level of fiscal overreach and management courtesy of the IMF, and this applied to the austerity measures imposed on the Greek government. This bailout and austerity package, which was negotiated over a few months in early 2010, was finalized on the

2nd of May, causing a ripple effect in the markets that confirmed their concerns in the Greek economy.

## Splash and dash

The Flash Crash arrived on the 6th of May 2010, a particularly important day in the developed world. The United Kingdom, after nearly 13 years of a social democratic Labor government, was expected to vote in favor of a hung parliament between them and the right-wing Conservatives, a political upset that was creating tension on the floors of the London Stock Exchange and at the New York Stock Exchange. The British government had suffered a growing decline in popularity since the resignation of Prime Minister Tony Blair in 2007 and the onset of the Great Recession had caused severe social spending cuts and unpopular bailouts of the major banks. Globally, there was ongoing tension regarding the Greek crisis bailout which had been confirmed earlier that week.

In a matter of minutes, the unforeseen slump caused the Dow Jones Industrial Average (DJIA) to fall by several hundred points, prompting a decline in the equity market. Panic hit the NYSE and the various indexes tried to stem what they felt was a major leak in the financial market as the slump continued over the course of over a half an hour. The turbulence prompted a frenzy of trading as people dumped, shares to try and make the most of the perceived collapse in American indices. However, for some inexplicable reason, the fall stopped and shortly thereafter the market recovered most of what was lost during the day.

## What happened?

Upon stabilizing the market, American regulatory bodies launched an investigation into the unexplained 600-point slump in the market. While program trading was an area of concern, the 'fat-finger' theory was soon dispelled. The theory asserted that an accidental computer or data input caused a wave of uncertainty on the floor. Once corrected, the index stabilized. This was easily disproved as there were checks and balances on the systems that ran the program orders.

Human error was thus the main contributor to the crisis, and many cited the affect high volume trading has on indexes. When there are very high volumes, there is uncertainty about the actual value of securities. Some unscrupulous investment institutions are able to manipulate this into generating profit, making it a potential toxic space that allows for broader market manipulation. The prominent idea put across by regulatory bodies was that someone had fiddled with the system and

had somehow managed to cheat the indexes into believing there was a decline in share value, allowing them to capitalize on the turbulence. This could be achieved by placing a wager against the growth or in support of a decline in a batch of stocks or the index as a whole, and it would thus serve their purposes if the wager were to reap short term realization. This turned out to be a reality as the American government targeted bets made on the Chicago exchange by a trader, Navinder Sarao, though this is still a controversial finding by the American government. Sarao, it was found, 'spoofed the market', a process of disturbing the *status quo* of the market by applying algorithms that make the market assume there is interest in certain indexes, stocks or securities, creating a demand surge. This then creates a shortfall in value when the demand is not real, causing prices to be volatile and easy to manipulate. The process is illegal according to the regulations placed by the American and many other governments, resulting in Sarao being jailed in 2015. Market manipulation thus became a pressing concern and was labelled as the chief contributor for the completely unprecedent crash and recovery that was so remarkably short-lived.

The market decline and recovery caused a short-term fall in overall stock market confidence globally and many exchanges felt the pinch from the half hour of turbulence. Stock trading in Europe was affected for a long time after the Flash Crash, only stabilized after bailouts that aimed to save the Euro. In the United States, the government aimed to address the problem by increasing regulatory powers, more of which will be discussed in the notes on new regulations and trading curbs later in this module.

# Unit 2: A Slip in the Dow Jones

The literature on the 2010 Flash Crash is extensive and strongly debated. While in previous modules, we have identified key signals and conditions for failure, in this module we will spend time discussing the dynamics of market microstructure, the nature of liquidity on modern exchanges and the responses by exchanges and legislators to the events which transpired. These events have far-reaching implications for markets today, which can be both positive and negative. Fundamentally, we aim to understand the risks of sudden market events and consider deeply their implication for risk management.

Before we can discuss the causes of market collapse and the role of market microstructure, we must first discuss how trades are executed on an exchange and the role of various agents in facilitating trades on that exchange. This module will take an in-depth look at market microstructure, which is the specific trading mechanisms which drive the price formation process. Often this looks at things like trade execution, transaction costs and liquidity and how this informs the prices in a given market. This is very different from much of finance, which is concerned with the firm-specific structure and events, the macroeconomy and historical trends to inform price discovery and provides a very different look at how markets operate. While on a very theoretical level, we may discuss concepts of power and utility in defining price based on some notion of utility, in this module we are going to start by looking primarily at how trades are executed first to dissect the causes of the crash.

An order book is an electronic ledger of buy and sell orders for a specific security or financial instrument. The order book lists the number of shares being bid or offered at different price levels. These price levels are often referred to as **market depth** and provide insights into the speculation and liquidity requirements of market participants. On most exchanges, the order book often identifies market participants, though many may remain pseudo-anonymous in the market book.

Exchanges offer a number of types of order a trader can execute, but most simply, these can fall into two categories: **limit orders** and **market orders**. Limit orders allow traders to specify the price at which a trader is either willing to buy or sell a particular volume of stock, while a market order issues an order at the prevailing market price at that point in time. Buyers issue a bid price to signal the price they are willing to pay for a given volume of stock, while willing will issue an ask price indicating the price at while they are willing to sell a given volume or stock. In illiquid markets, Bids prices and

ask prices can be different, meaning buyers and sellers are unwilling to trade. We typically discuss liquidity in terms of some bid-ask spread, which is the normalized difference between the bid and ask prices over a given period of time.

| Bid | | | Ask | | |
|---|---|---|---|---|---|
| **ID** | **Price** | **Quantity** | **ID** | **Price** | **Quantity** |
| 1 | 10 | 1000 | 1 | 11.00 | 1000 |
| 2 | 9.70 | 500 | 2 | 11.50 | 1500 |
| 3 | 9.40 | 2000 | 3 | 11.70 | 500 |
| 4 | 9.30 | 1000 | 4 | 12.00 | 2000 |
| 5 | 9.20 | 400 | 5 | 12.20 | 4000 |

*Table 1: Order book*

In the table above, we can observe a rudimentary example of an order book. In this table, we can see that while the bid price is 10, the ask price is 11. As the bid-ask spread is the difference divided by the ask, the bid-ask spread is 9.1%.

In order to understand the market microstructure and the role of various agents on an exchange, one must gain a deep understanding of how exchanges have developed over time and the role computerized trading plays in modern markets. Historically, while some traders made deals directly with other traders, many traders looking for liquidity would typically go to a market-maker who would quote hold some inventory of stocks which they would sell to the trader at a fixed spread. For liquid stocks, the spread would be less as the broker would be confident that they could buy from a trader at a lower price and sell at a higher price easily. If markets were less liquid, they might charge a larger spread, as the cost and risk of holding the investment would be greater. Under this quote-driven market, traders are quote driven as most traders look to a quote from the broker in order to decide on a trade. Electronic exchanges change this dynamic dramatically, as exchanges become order-driven and traders issue market and limit orders directly to other traders through the exchange with little need for market-makers to facilitate or provide liquidity for such a trade.

Despite this, today still there exist market-makers and high-frequency traders, who, while implementing varying strategies, try to fill the order book with trades either above or below the market price at some profitable 'spread '. These traders issue these trades in the hope of being first in line when large orders hit the order book, allowing them to make some small profit over the prevailing market price over time. For high-frequency traders, this may involve quickly responding

to traders and changing market conditions. Traders may involve themselves in a process of "penny jumping" to respond to large orders by dropping the price on one's ask order by a few cents to ensure it is executed ahead of other traders in the order book when a large order is looking to be cleared. While these agents can make varying levels of profit, they offer varying levels of liquidity to the market, ensuring a sufficient number of willing buyers or selling at any given time to stabilize the price against sudden jumps. For traders, the existence of market-makers can severely limit the impact cost of trying to execute a trade or the cost that a buyer or seller of stocks incurs while executing a transaction due to the prevailing liquidity conditions in the market.

In a seminal paper published in early 2011 entitled, "The Flash Crash: The Impact of High Frequency Trading on an Electronic Market" three primary questions are asked which we must ask today:

1. How did high-frequency traders and other categories trade on May 6?
2. What may have triggered the Flash Crash?
3. What role did the high-frequency traders play in the Flash Crash?

In answering these questions, we will be forced to discuss the composition of the market at the time, the responsiveness to the market, and the role this composition had on market dynamics. Unlike previous modules which have thought global in considering political and economic trends and their influence on markets and market conditions, we will be looking at markets themselves to understand the effects which market structure, liquidity and environment in order to dissect this Crash.

# Unit 3: The Mathematics Behind It

## Form over substance

So, what made the 2010 Flash Crash different? In research into the Crash, researchers identify three defining attributes: time, severity and impact. Here time indicates the time over which the crash and recovery took place, severity indicates the size of the price impact and impact indicates the important distinction between a "micro" and "macro" Flash Crash, which had proven valuable in more recent market events.

In the months after the 2010 Flash Crash, smaller crashes have also affected markets. On September 27, 2010, Progress Energy fell almost 90% from around $44.50 over a period of about five minutes. In the months since the crash, similar events have also affected well-known stocks, such as Citigroup and the Washington Post Company. The major distinction between these extreme events and that of the Flash Crash has been contagion and familiarity, as the 2010 Flash Crash presented itself as one of the first and most severe of its kind.

In the months following the Crash, a number of theories had developed over the causes of such a market event. Early theories speculated a presence of a so-called “fat finger”, that entered in an order incorrectly or a software bug, malicious attack or deliberate “denial of service” type attack all intended to damage the financial system. However, subsequent research by Academics, the **Commodities Futures Trading Commission** (CFTC) and **Securities and Exchange Commission** (SEC) appears to have identified a cohesive story around the causes of the Crash. Despite this story, its interpretation still leaves room for further insight and discussion as to the nature of modern markets. The questions researchers ask is: why did it happen then?

While many focus on the discussion around the role and presence of liquidity in causing the crash, other researchers have discussed more generally the popularity of new and exotic exchange-traded funds across exchanges around the world. While this may appear simple, we need to understand the changing structure and composition of the market and the possible causes for contagion over other extreme market events. In the analysis of the events of the Flash Crash, academics cite the effect these exchange-traded funds have had on both on liquidity and on pricing. While the mandate of ETF's is clear and the funds are often highly transparent, they offer a challenge for replication and sampling as more and more ETFs enter the marketplace and try to track the exchange or some



benchmark. A major criticism of index funds more generally raised in previous modules has been the role they play in price discovery. While index funds have been offering consistent returns to investors for low fees, many argue such funds rely on the price discovery of active investors in order to piggy-back on market efficiency. The challenge many investors raise with ETF is how to price these assets accurately. This may seem simple: take the weighted sum of the last known historic market price for every asset in the ETF, but don't be fooled. Given their holdings in small, often illiquid companies, during times of extreme market volatility, ETFs can see massive price movements and investors often debate over this period their value, given these liquidity concerns and the uncertainty over price. In this Module, we have already identified the disproportionate impact of the Crash on ETFs, and we see how their role drives uncertainty given their requirement for large inventories of stock across the exchange. But how do other traders compare?

Intermediaries and **high-frequency traders** (HFT) trade much differently than their fundamental trader and mutual fund counterparts. In most markets, fundamental traders and mutual funds are considers liquidity takers, often executing large trades and hosting inventory for longer periods of time, while intermediaries and HFT's often are seen as liquidity providers, holding limited levels of stock at any given moment and rapidly buying and selling stock as the market requires it. If a large trade comes in HFTs will often compete to provide and predict the liquidity requirements for these large trades, profiting over many transactions. While HFTs usually have some limited impact on price large trades by mutual funds or fundamental traders raise concerns over price impact, as they consider the effect their trade itself will have on both price and liquidity in the market and visa versus. In order to limit trading costs and trading impact, most traders will opt to make use of automatic trading systems which attempt to analyze liquidity in the market and price movements, in order to break up trades and spread them evenly over a day or many days. While HFTs and intermediaries will issue bids and asks either size of the market price, fundamental traders are far more directional in their trades and, depending on liquidity, can send markets spiraling if liquidity is absent.

Typically, market participants can also be characterized by their level of aggressiveness in the market. The CME Globex platform automatically classifies an order as ‘aggressive’ when it is executed against a ‘passive’ order that was resting in the limit order book. From a liquidity standpoint, a passive order (either to buy or to sell) has provided visible liquidity to the market, and an aggressive order has taken liquidity from the market. Typically, the 'aggression' of an investor is

characterized using an 'aggressiveness ratio', which is calculated as the ratio of aggressive trade executions to total trade executions. Typically, mutual funds and fundamental traders will have far higher aggressiveness ratios of around 60% against Intermediaries and HFT, with a typical aggressiveness ratio of around 30%.

In the lead-up to the Crash, the composition of key markets appeared to shift dramatically. On key futures contracts, like the E-mini S&P 500, HFT's went from accounting for 34% of total trading volume during May 3-5 and 29% of trading volume on the day of the Crash. Intermediaries went from 10.5% to 9%, and Fundamental Buyers and Sellers remained at roughly 12% of the market. These classifications are made not only by an understanding of trading strategies but also characteristics such as net holdings, percent of total trading volume, number of bid and asks and order characteristics.

It is these key features which help us identify the conditions and structure of the exchange in the run-up to the Flash Crash. Understanding the composition and characteristics of market participants and their changing dynamics, we can begin to identify scenarios which trigger contagion. As we delve further into the crash, we will look at these series of events and begin to uncover the structures and nature of modern exchanges. Using this knowledge, we can begin to apply these concepts to risk management, using these to identify the conditions for crisis and collapse.

# Unit 4: Commissions and Reactions

The impact of the 2010 Flash Crash was felt largely in the wave of regulation and reaction to the price 'spoofing' and blatant manipulation of the American stock indices. Though the economic and financial aftermath were not as severe as previous major slips in share value, there is nonetheless the need to assess first the real harm caused by a person or a group of people manipulating any stock exchange, and then assess the ways in which these kinds of actions can be curtailed, detected early or otherwise ended.

## The bottom line

Much of this course has focused on the financial, social and political conditions that created a market crash or series of crashes, and their effects on the localized and global financial world. This kind of contextualization is key and informs the way we assess any kind of major historical event. In the case of the Flash Crash, there is one small twist on this that is different from the rest of this course. The 2010 Flash Crash is unique in that there is no major overspill; rather, there is the situation of it being subsumed within a broader economic decline, the Great Recession. Thus, when we view the 2010 Flash Crash, it would make sense to view it alongside the conditions highlighted in Module 5.

Furthermore, the complications of blame are thought to be clearer and the cause of the Flash Crash is often (and controversially) laid at the door of Navinder Sarao and his 'spoofing' algorithms. However, the purpose of this series of notes is more to assess the ability of any individual – like Sarao – or a group of individuals to attack the system from within and reap benefits. In the case of 2010, for example, it is easy to simply blame program trading, whereas it was the clever use of computer-input methods that tricked the system that was subject to influence. This change, in turn, would allow for people to make wagers on trajectory, and knowing – or deciding – the trajectory of the price or index value would serve their purposes. Insider trading has been common since the inception of stock exchanges and governing bodies and financial institutions have tried to either use or control this kind of market manipulation to their advantage. In the case of the 2010 Flash Crash, when looking at the spillover, the fluctuations in share value became part of the tapestry of the Great Recession and acted in many cases as a wake-up call that encouraged new regulations in banks, stock exchanges and other financial institutions.



## Fixing the tap, not the bucket

The American government saw the critical need to fix the problem: the way in which the stock market could be manipulated, and the ongoing struggle to prevent the financial realm from wrecking the economy of the world in one fell swoop. Though there had been attempts at regulation that aimed to stem the conditions that created crisis moments, the Flash Crash specifically highlighted this issue more than any before.

The core of the attempts began with more assertive federal and local investigations into price manipulation, program trading and investor wagering. Hearings by both Houses of Congress under the Subcommittee on Capital Markets and Government-Sponsored Enterprises looked into the issue of how fluctuations in the market were not controlled and despite technical guidelines and floor protocol that dictated how free-falling stock share value must addressed, a rapid slump and rise occurred. Notably, it was established that several notable exchanges were not complying with existing regulations that ensured that stocks and securities must be bought at the most reasonable available price, and that stub quotes – penny price requests that effectively booked the stock or security until the investor was able to afford it, blocking anyone from accessing it – were commonly used and unregulated. This, however, can easily be manipulated by careful decision-making practices that could cause fluctuations that investors could ride in the pursuit of profit.

The decision by the committee and the federal regulatory bodies was to implement trading curbs and measures that aimed to protect the manipulation of times of fluctuation. A **trading curb** is a measure implemented in the interest of preventing market crashes, and effectively stops trading for a short period of time in order to stabilize the market values and gain as much data on the collapsing or rising exchange values, so that the powers that be can intervene and prevent a surge in trades commonly occurring during market crashes. Any index that registers a radical short-term change in its overall share value will have to suspend trading and alert the authorities, and most trading curbs are specific to securities and stocks trading, making the ability to ride out the system more difficult if sales are suspended. What this effectively did for the NYSE and other American indices and exchanges was prevent high frequency trading from affecting the stability of the financial system, making it possible to track down and remove toxic orders or traders in time.

There has been criticism of the response to the 2010 Flash Crash, hence the controversy mentioned above. First, the indictment and arrest of Sarao as an individual among many in the investment pool

that arguably exacerbated the Flash Crash is a point of frustration to many, especially considering he was extradited to America rather than being tried in the native United Kingdom, where he resided. One individual, it has been argued, cannot be the sole recipient of blame in a financial world that is so diverse and complicated and where so many conditions – like the Greek debt crisis and the ongoing conditions of the global financial crisis – are at play. Furthermore, though regulations were placed on the markets, there still remains the possibility of volatility on currency markets, securities trading and other critical components of financial sector development that are either unaccounted for. Crashes have occurred since 2010 and will continue should similar conditions of global or localized financial uncertainty continue to feed the greed of individuals or groups willing to try and manipulate the financial system.

The complex and unpredictable nature of financial markets mean that any investor has to accept a certain level of risk with any trade. Various algorithms that might help make sense of the market, don't always produce the best result. As with regulators like the Office of Thrift Supervision and credit ratings agencies that we saw in Module 5, some of the factors that were intended to reduce risk actually amplified it. Market spoofing manipulated the various algorithms that were intended to gauge the market, fooling traders into believing false signals of high and low demand. And, even with regulation, bad actors can have a significant impact on even global markets. Even major players like Barclays, UBS, and JP Morgan manipulated the American derivatives market in the Libor scandal. Paradoxically, however, the Flash Crash may also be a story about the durability of the financial system. A temporary crisis gave way to a learning opportunity, and most certainly a valuable lesson that rapid fluctuations in value are not always what they seem.



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