

# 11. What Happened May 6, 2010? Anatomy of the Flash Crash

Geoffrey Poitras

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“[R]emarkably fast-growing IT-driven ECNs, MTFs, and other off-exchange trading facilities are giving rise to noticeable issues such as market fragmentation, regulatory discrepancies between markets and free-riding on the self-regulatory functions of incumbent exchanges in the EU and US. In the near future, this trend is also likely to affect Japanese stock markets. The “flash crash” that occurred in the US in May 2010 is an example of a phenomenon arising from these factors.”

*Atsushi Saito, President of CEO, Tokyo Stock Exchange Group*

Despite being a key element in capitalist society, much activity in the stock market happens outside the glare of public scrutiny. In turn, regulation of the stock market is predominantly civil, with criminal sanctions reserved only for the most egregious actions. In the US, the federal stock market regulator, the Securities and Exchange Commission (SEC), is only empowered to impose civil penalties. Criminal prosecution falls within the purview of the Justice Department. Similarly, important instances of historical regulation, such as the 17<sup>th</sup> century Dutch ban on *in blanco* short selling or the 18<sup>th</sup> century English ban on trading of privileges (Poitras 2011), did not involve criminal sanction. Rather, legislation removed the protection of the courts for those involved in such trading. Despite various bans and restrictions, ‘prohibited’ trading continued. Where sanctions associated with trading restrictions were particularly prohibitive, then trading shifts to alternative jurisdictions, e.g., hedge funds domiciled in over shore tax havens use a master-feeder fund structure to avoid public filing requirements in the US. The collapse of the Madoff hedge fund Ponzi scheme in 2008 illustrates that lack of transparency in stock market

dealings continues to the present.

In this opaque milieu of stock market trading, periodic market failures provide situations where the light of public scrutiny reveals detailed information on market activities not regularly available. The bulk of stock market history is compiled from: regular reports of trading by self-regulatory entities, such as the exchanges; legislatively and administratively mandated reports by government regulators; and, the numerous books, pamphlets, periodicals, newspapers and other literature produced by and for market participants. Of these primary sources, the various commissions, government reports and related publications generated by infrequent market failures have been invaluable. Under the public pressure produced by market disruption, information about trading activities that would typically be considered proprietary is revealed. The annals of stock market history are replete with examples of invaluable information from such events, from Isaac Le Maire's 'Memorandum to the Lord Advocate' in January 1609 (Jonker 2009) to the 'Findings Regarding the Market Events of May 6, 2010' by the staffs of the SEC and Commodity Future Trading Commission (CFTC) in September 2010 (SEC 2010). Combined with information obtained from regular public filings by the exchanges and selected companies, SEC (2010, 2010a) provides a robust description of the US stock market landscape at the end of the first decade of the 21<sup>st</sup> century.

### **1. What Happened May 6, 2010?**

A quick sketch of events is provided in SEC (2010, p.1):

On May 6, 2010, the prices of many U.S.-based equity products experienced an extraordinarily rapid decline and recovery. That afternoon, major equity indices in both the futures and securities markets, each already down over 4% from their prior-day close, suddenly plummeted a further 5-6% in a matter of minutes before rebounding almost as

quickly.

Many of the almost 8,000 individual equity securities and exchange traded funds (“ETFs”) traded that day suffered similar price declines and reversals within a short period of time, falling 5%, 10% or even 15% before recovering most, if not all, of their losses. However, some equities experienced even more severe price moves, both up and down. Over 20,000 trades across more than 300 securities were executed at prices more than 60% away from their values just moments before. Moreover, many of these trades were executed at prices of a penny or less, or as high as \$100,000, before prices of those securities returned to their “pre-crash” levels.

By the end of the day, major futures and equities indices “recovered” to close at losses of about 3% from the prior day.

Though SEC (2010) is at pains to avoid the terminology, the stock market events of May 6, 2010 are generally referred to as the ‘flash crash’. This euphemism arises from the perceived importance of high frequency traders in precipitating the disturbing but brief breakdown in the basic price discovery process for certain stocks, e.g., Kirilenko et al. (2010).

Immediate concern about the flash crash in Congress was expressed by: the Senate Committee on Banking, Housing, and Urban Affairs; the Senate Committee on Agriculture, Nutrition and Forestry; and, the House Committee on Financial Services. These committees specifically requested that the staffs of the SEC and CFTC produce a report relating to “the business transactions or market positions of any person that is necessary for a complete and accurate description of the May 6 crash and its causes” (SEC 2010). The result was two reports. A “Preliminary Findings” report delivered May 18, 2010 to the Joint Advisory Committee on Emerging Regulatory Issues (JAC) (SEC 2010a) and a final “Findings” report also delivered to the

JAC on Sept. 30, 2010 (SEC 2010). Armed with the power of the Congress to provide impetus to the investigation, SEC (2010a, 2010) provides unprecedented insights into the workings of the electronic US stock market of the 21<sup>st</sup> century. Historic institutional changes in the stock market have been precipitated by a technological revolution in trading. The changes go beyond exchange demutualization and the demise of the exchange trading floor.

In addition to depth of useful data about the stock market trading landscape, SEC (2010) also reveals the approach of regulators to understanding the changes underway. In particular, the flash crash involved the fragmentation of market liquidity undermining the basic price discovery process for certain stocks. While SEC (2010, 2010a) provides a detailed and helpful description of current trading practices on modern electronic trading networks, it is apparent that “market participants” are in charge of the trading process. Regulators reacted to May 6 events in the stock market by continuing to reverse the direction of previous stock market liberalization rule changes introduced as a reaction to the stock market collapse of 2008-09, e.g., the price limit triggered, short sale price test rule (SEC 2010b). The previous rules had been introduced to facilitate the activities of large stock market participants, including but not limited to high frequency traders. In particular, starting with Reg ATS in 1998 impediments to rapid execution of two-sided trades – such as market circuit breakers, program trading restrictions and the up-tick rule for short sales – were progressively eliminated to facilitate activities such as high frequency trading. The regulatory reaction to the flash crash was to introduce a single stock circuit breaker rule. Despite claims that “the staffs of the CFTC and the SEC are working together with the markets” (SEC 2010, p.6), the regulatory confusion created by having two regulators – the SEC and the CFTC – is more than apparent. Faced with a wide range in public opinion, the regulators are having considerable difficulty in determining what happened and, as a consequence, finding appropriate

regulatory adjustments.

Based on SEC (2010), there is much in the flash crash to digest. Measures of ‘buy-side’ and ‘sell-side’ ‘market liquidity’ are employed together with classifications for traders, such as ‘fundamental sellers’ and ‘fundamental buyers’ defined as “as market participants who are trading to accumulate or reduce a net long or short position. Reasons for fundamental buying and selling include gaining long-term exposure to a market as well as hedging already-existing exposures in related markets” (SEC 2010, p.2). The operative event that triggered the flash crash happened at 2:32 p.m. when “a large fundamental trader (a mutual fund complex) initiated a sell program to sell a total of 75,000 E-Mini [S&P 500 futures] contracts (valued at approximately \$4.1 billion) as a hedge to an existing equity position.” From this point, SEC (2010) traces the process by which this trade was absorbed by the stock market. Other than noting that “only two single-day sell programs of equal or larger size – one of which was by the same large fundamental trader – were executed in the E-Mini in the 12 months prior to May 6”, little attention is paid to the decision process of the large fundamental seller that generated this trade. No substantive mention is made of centuries of regulatory oversight required to deal with disruptive short speculative trades in the stock market

The flash crash involved two inter-related liquidity events: one in the deep market for E-mini index futures and the S&P 500 index ETF (SPY); and, another in the market for individual stocks. The E-mini liquidity event ended almost as abruptly as it started (SEC 2010, p.4):

At 2:45:28 p.m., trading on the E-Mini was paused for five seconds when the Chicago Mercantile Exchange (“CME”) Stop Logic Functionality was triggered in order to prevent a cascade of further price declines. In that short period of time, sell-side pressure in the E-Mini was partly alleviated and buy-side interest increased. When trading resumed at

2:45:33 p.m., prices stabilized and shortly thereafter, the E-Mini began to recover, followed by the SPY.

The Sell Algorithm continued to execute the sell program until about 2:51 p.m. as the prices were rapidly rising in both the E-Mini and SPY.

However, the flash crash did not end with recovery in the E-mini and SPY prices around 2:45 (SEC 2010, p.5):

Even though after 2:45 p.m. prices in the E-Mini and SPY were recovering from their severe declines, sell orders placed for some individual securities and ETFs (including many retail stop-loss orders, triggered by declines in prices of those securities) found reduced buying interest, which led to further price declines in those securities.

The flash crash involving individual securities did not end until around 3:00 p.m. with implications primarily for retail investors (SEC 2010, p.6):

during the 20 minute period between 2:40 p.m. and 3:00 p.m., over 20,000 trades (many based on retail-customer orders) across more than 300 separate securities, including many ETFs, were executed at prices 60% or more away from their 2:40 p.m. prices. After the market closed, the exchanges and FINRA met and jointly agreed to cancel (or break) all such trades under their respective “clearly erroneous” trade rules.<sup>1</sup>

While SEC (2010) observed that “severe dislocations in many securities were fleeting”, such a conclusion masks the serious potential problems that the flash crash represents.

## **2. Historical Antecedents of the Flash Crash**

Referencing the events of May 6, 2010 as ‘the flash crash’ aims to connect the activities of high frequency traders with the disruption of the stock market price discovery function on that date. However, such an interpretation is misguided. This conclusion can be illustrated historically by

considering events surrounding a decidedly similar liquidity event: the stock market crash of 1987. Similarities appear despite a considerable difference in the trading milieu. Though the crash of 1987 did have a technological aspect, a more dramatic revolution in communications and trading technology was still on the horizon. High frequency trading strategies were not available, though various ‘programmed’ trading strategies had progressively been introduced during the decade prior to the 1987 crash. There were also a variety of practical and legal restrictions limiting trading in stock index futures and options. Stock index ETF’s did not appear until the early 1990’s. Despite these differences, the primary regulatory resolution is similar in both events: the use of pricing circuit breakers (e.g., NYSE Rule 80B, Trading Halts Due to Extraordinary Market Volatility). In the case of the flash crash, this solution involved a reworking of the rules to allow the imposition of 5 minute circuit breakers on prices for individual stocks, and not just circuit breakers associated with the market index values implemented following the 1987 crash.

The causes of the stock market crash of October 19-20 1987 have been debated *ad nauseum*. The analysis includes: reports by the exchanges, e.g., the CME and the NYSE; the regulators, e.g., reports by the SEC, the Government Accountability Office, the CFTC and the Brady Commission; and academic studies, e.g., Macey et al. (2009), Edwards (1988), Tosini (1988). For sheer attention and regulatory impact, the crash of 1987 is the disaster of disasters compared to the flash crash. Significant incremental reforms were made to market practices, ranging from the introduction of trading circuit breakers triggered by large market moves to rules impacting the capitalization of specialists on the NYSE trading floor. Physical hardware changes were also made to the execution system for processing orders on the NYSE. Another fallout from the crash was the drastically reduced use of stock markets for dynamic portfolio insurance trading strategies designed to achieve replication of an untraded put option payoff. From the early 1980’s to the

crash of 1987, such schemes had been actively promoted to institutional investors by a number of the leading investment banks and finance academics, including Fischer Black and Mark Rubinstein.<sup>2</sup>

In retrospect, the crash of 1987 still has many lessons for the present, if only these lessons could be adequately understood. As with the flash crash, analysis of the crash by regulators has the flavour of an apology for the current method of oversight. Tosini (1988, p.35), a director at the CFTC at the time of the crash, is an excellent example: “there are many profound, complex and far-reaching issues before the CFTC, as well as other federal agencies and the Congress, concerning stock market and derivative market activities and performance during October ... the call for ‘further research’ has hardly ever been more timely.” The various reports made some key observations, e.g., the Brady Report (Presidential Task Force on Market Mechanisms 1988) recognized that the markets for stocks, stock options and stock index futures were actually one integrated market “linked by financial instruments, trading strategies, market participants and clearing and credit mechanisms.” Despite this integration, the regulatory and institutional structure which was designed for separated markets was unable to deal with “inter-market” pressures. The Brady Commission recommended a number of reforms designed to provide for a more integrated approach to market oversight. These recommendations did little to change the conflicting mandates of regulators overseeing activity in the stock market.

Both the crash of 1987 and the flash crash speak directly to the problems raised by the systemic change in financial markets brought on by the historical resurgence in speculative exchange trading of equity derivatives. Various events have since been replayed because some lessons were not fully understood. This happened because analysis of the crashes, on the whole, focussed on the specific events that occurred during the crash and did not adequately distinguish between

the singularity and the commonality of the specific events. Poitras (2002, p.52-8) details the chain of events in the crash of 1987. As measured by the Dow Jones Industrial Average (DJIA), the US equity market had achieved a peak of 2722 in August of 1987. P/E ratios for the S&P 500 were averaging 23, relatively high considering the potential for negative market sentiment. In modern parlance, the equity market was due for a correction. On Wed. Oct. 15, 1987 there was a news release reporting an unexpectedly large US trade deficit, banks raised prime rates and there was considerable downward pressure on equity prices. The S&P 500 fell from over 314 to below 306. Despite a calming statement by Treasury Secretary Baker on the Thursday, the S&P 500 fell again to 298. When some negative PPI and industrial production numbers hit the market at the open on Friday, the stage was set. Significantly, even though things were gloomy, none of this was a shadow of events about to unfold. This leads to a key observation about the crash: it was an severe event that was not associated with a correspondingly severe negative information inflow to the market.

The crash actually started on Friday October 17, 1987. In the face of the somewhat negative sentiment, the DJIA fell a record 108 points. The S&P 500 started the day at 298 and fell to around 282. These were significant market moves that, all things considered, may have presented some buying opportunities. Over the weekend, there was some chatter about a dispute between the US and Germany over interest rates, leading to speculation that the US might let the dollar fall, an event which would be negative for US equities. There was the usual carry over on foreign markets, such as Tokyo and Australia, though the wave of intense selling had not yet hit international markets. The New York market opening was confronted with rumours in the news that the US had attacked Iranian oil platforms in the Persian gulf, which almost surely added to the rush of sell orders. At the open the DJIA was down 67 points. The S&P 500 futures contract on

the CME fell 18 points at the open. At a time when 100 million share volumes were uncommonly large, the NYSE processed 50 million shares in the first half hour. Despite the market turbulence, a 10 am meeting of NYSE officials and major brokerage houses did not feel a trading halt was needed.

The sequence of events which was to follow was structured around two institutional procedures. The first concerns the method of executing stocks on the NYSE. Historically, stocks trades on the NYSE involved a floor broker for a member firm having to walk the order to an NYSE trading post for that stock and execute the trade directly with the specialist or with another broker using open outcry. At the time of the 1987 crash, this was still the case for block trades involving 10,000 or more shares. This manual method of trading was inefficient and costly for trades involving large bundles of stocks which have to be sold at once. Such trades were not only being done by index arbitragers, but also by a wide range of market participants. To improve market performance for these traders, the NYSE introduced the Designated Order Turnaround (DOT) in 1976. This system permitted the computerized execution of small trades. Effectively, brokers with member firms could enter trades into a computerized order system, permitting trades to be entered in brokers' offices. Upon receiving the order, the DOT system would automatically route the trade to the appropriate NYSE specialist, where it would be executed. The whole process could be completed in a matter of minutes.

The success of the DOT system led to a new and improved version, the Super-Dot, being implemented in 1984. This new DOT system further enhanced execution times and access. This remarkable progress in information technology created its own demand from a growing legion of program traders. This category includes a range of trading strategies, including portfolio insurance and index arbitrage. Program traders could enter the exact weights for a portfolio of

stocks which could be executed simultaneously by computer entry. Prior DOT execution risk in such strategies was an important deterrent. Yet, the interaction between the progress in information technology and the trading of newly introduced financial engineering products was not well understood at the time and, as illustrated in the flash crash, continues to the present. Hints of the crash of October 1987 were observed on Sept. 11-12, 1986 and on Jan. 23, 1987 when 'excessive' stock market volatility was observed. These preliminary tremors attracted some attention, and efforts were made to track the activities of program traders through the DOT system. A poll by NYSE of specialists and floor traders found that, almost without exception, program trading was done through the DOT. On average, in the year leading up to the crash, DOT orders from program traders were found to average around 18% of all DOT trades with over 28% of all orders on Oct. 19, 1987 being due to program traders.

In addition to the DOT, the other essential institutional feature to consider in evaluating the crash of 1987 is the short sale rule, e.g., Macey et al. (1989). More precisely, from 1938 until 2004, Section 10(a) of the Securities Exchange Act regulated short sales of stocks registered on a national securities exchange. The rule has historical roots in the concentrated short selling that precipitated the market break of 1937. The SEC adopted Rule 10(a)-1 in 1938 to restrict short selling in a declining market. More precisely, Rule 10(a)-1 prohibited short selling of securities, except when the short sale either: takes place above the last sale price of that security; or, at the last price, if that price is above the preceding price. The idea is that the rule prevents excessive and accelerating downward pressure on prices during a market downturn and provides preferential treatment for traders that are long stock and want to exit positions. However, there is no such rule on futures markets. As such, dynamic portfolio insurance strategies could be implemented by shorting stock index futures, instead of attempting to short the underlying stocks in the cash

market. In addition, the single digit percentage margins on futures contracts were only a small fraction of the 50% margins on stocks.<sup>3</sup>

These substantive differences across cash and derivative security markets for stocks can be attributed to regulatory competition between the CFTC, which regulates commodity futures contracts and futures exchanges, and the SEC, which regulates stock markets and stock exchanges. The effects of this competition continue to the present.<sup>4</sup> The roots of this two regulator system can be traced to Depression era reforms which were well suited to markets where commodities were traded separately from trading of financial securities. Along with the Securities Act (1933) and the Securities Exchange Act (1934) to deal with stock market reform, the Grain Futures Act (1922) was amended and renamed the Commodity Exchange Act (CEA) (1936). With various amendments and updates over the years, the CEA is still the centrepiece of US commodities regulation. The CEA (1936) extended the government's control of futures trading considerably: authority over speculative limits was established; registration requirements were imposed on floor brokers and futures commission merchants; cheating, fraud and market manipulation were made specific criminal offenses; and, restrictions were imposed on options trading. For more than seven decades, the CEA has provided a successful model for sustainable speculative exchange trading of commodities.

By 1974, the growth in both volume of trade and the number of new contracts (over which the CEA gave little effective control to regulators) brought a thorough reform. The CEA was amended to include the Commodity Futures Trading Act which forms the basis of current U.S. government commodities regulation. The CEA (1974) empowered the Commodity Futures Trading Commission (CFTC). This marks a technical beginning to the competition between the futures industry, centred in Chicago and regulated by the CFTC, and the stock markets, centred in

New York and regulated by the SEC. The CFTC is an "independent" five member commission appointed by the president, with authority to regulate all US futures trading and exchange activity. Included in the CFTC's mandate was the right to approve both the introduction of new contracts and changes in exchange bylaws. Together with these powers, the CFTC also has considerable emergency authority, e.g., assessment of large civil fines; cease and desist orders. In 1978, several amendments were made to the Act dealing with the issue of jurisdiction. In opposition to the position of both the SEC and the US Treasury, the CFTC was given exclusive jurisdiction over all future contracts, including the newly emerging financial futures contracts. Subsequent and ongoing legislative action has focussed on clarifying jurisdiction over increasingly complicated overlaps between the two regulators, e.g., options on stock index futures contracts; commodity ETF's that are traded on stock markets and use futures contracts to capture the commodity price exposure.

Portfolio insurance includes a range of trading strategies that fall within the overlapping jurisdictions of the SEC and CFTC. One important strategy involves dynamically trading stock index futures in order to replicate the payoff on a portfolio composed of the underlying cash stock index and a put option. The reason that dynamic trading was so attractive in the period leading to the crash of 1987 is associated with the relatively limited array of path independent option products that were available. Exchange traded option maturities were a maximum 9 months, not all stocks had traded options, index options were relatively illiquid and the OTC market lacked sufficient liquidity to provide options with the exercise price variation and longer term maturity dates that many institutional investors desired. Even though absence of arbitrage requires that cash-and-carry arbitrage conditions apply to the spot and futures markets, the sheer volume of trading on Oct. 19 meant that a wide spread between the stock index futures and the underlying

cash market stock index was seemingly inevitable. What emerged was much worse: an information technology breakdown. The rush of sell orders effectively crashed the DOT system. At 11:45 am the ticker was approximately 1 hour behind and a number of stocks had yet to open because of the lack of an orderly market. By 2 pm volume had reached 400 million. The final numbers for Oct. 19 were 603 million shares traded, with a drop of 508 points (23%) on the Dow and 80.75 points on the S&P 500, a loss of nearly 30%. At the bell the ticker was approximately 130 minutes behind.

This slaughter on the stock exchanges led to a flurry of overnight activities. As the US market collapse spread overseas, there was complete or almost complete trading halts on the Tokyo and Hong Kong stock exchanges. There was an unprecedented drop on the London FT Index. The opening of the New York market was preceded by reassuring statements and actions from the Federal Reserve Board (FRB), major banks were lowering prime rates and the NYSE shut down the DOT system to prevent the execution of program trades. A temporary and partial trading halt was implemented just after 11 am as the market approached 180 on the S&P futures, while the cash market was trading just below 220. This seemed to spell the end of the crash. Prices recovered and by 2 pm the spread between cash and futures narrowed close to normal levels, though the spread did widen as the close approached. At the end of the day, the DJIA was up 102 points on volume of 608 million shares. Due to actions taken to combat the crash, there was strong recovery of the dollar and a decline in interest rates. The low prices combined with the sudden brightening of the economic picture led to a buying spree, both in the US and offshore. By the close Thurs. Oct. 20, the market had recovered about half of what was lost on Monday.

The crash of 1987 was an unprecedented security market event. It exposed serious weaknesses in a regulatory system that was designed to fight the battles arising from old technology.

Problems originated from an inability to assess and structure the rapid changes in the stock market. This was a debacle which was created by a well intentioned need to innovate, to improve portfolio management of large financial institutions and investment companies. As it turns out, the portfolio insurance programs based on dynamic trading were generally unable to deliver the protection which was claimed *ex ante*. The situation for which the insurance was most important, the protection of losses in the event of a market collapse, led to preconditions which prevented the outcome from being achieved. The programs could only get so big and it was not possible for more than a small fraction of market participants to successfully pursue such dynamic trading strategies. In addition, there are numerous untold stories of other strategies, such as delta hedging by option traders, which also contributed to the crash. Undoubtedly, such traders also contributed to the selling via both the DOT and floor trading which only added to the downward pressure on prices.

### **3. High Frequency Trading and the Flash Crash**

SEC (2010) identifies an unusually large (75,000 = \$4.1 billion in equity value) short trade in the E-mini contract by a mutual fund complex as the proximate cause of the liquidity event that produced the flash crash.<sup>5</sup> No further information is given about the identity of the trader or the reason for engaging in the large short trade. As a reaction to the negative market sentiment that preceded this trade on May 6, it is possible that the trade was a crude attempt at ‘legitimate hedging activity’:

By 2:30 p.m., the S&P 500 volatility index (“VIX”) was up 22.5 percent from the opening level, yields of ten-year Treasuries fell as investors engaged in a “flight to quality,” and selling pressure had pushed the Dow Jones Industrial Average (“DJIA”) down about 2.5%.

There is evidence that the same mutual fund complex had placed one similar sized trade in the

previous year that was subsequently closed in a single day, but no further information is given about the motivation for these trades. Such a pattern of trading is not consistent with execution of a dynamic portfolio insurance strategy. Consistent with the arguments supporting short selling in SEC (2010b), there is implicit acceptance by SEC (2010) of short seller rights to engage in ‘legitimate hedging activity’. However, absent any further information, the short trades by the “large mutual fund complex” would appear to be yet another instance of aggressive and disruptive short side speculative exchange trading, e.g., Poitras (2011).<sup>6</sup>

Given the implicit assumption of SEC (2010) that such aggressive short trading is acceptable, attention focuses on the trading mechanics of the failure to provide sufficient stock market liquidity to clear the trade. The trade was submitted at a time of the day when the circuit breakers in the cash market that were in place at the time would not be triggered. Consistent with typical trading activity (SEC 2010, p.3) “sell pressure was initially absorbed by:

- high frequency traders (‘HFTs’) and other intermediaries in the futures market;
- fundamental buyers in the futures market;

and

- cross-market arbitrageurs who transferred this sell pressure to the equities markets by opportunistically buying E-Mini contracts and simultaneously selling products like SPY, or selling individual equities in the S&P 500 Index.”

The role of some HFTs as high tech ‘scalpers’ is apparent in the stock market process of transforming the large speculative E-mini short trade:

HFTs accumulated a net long position of about 3,300 contracts. However, between 2:41 p.m. and 2:44 p.m., HFTs aggressively sold about 2,000 E-Mini contracts in order to reduce their temporary long positions. At the same time, HFTs traded nearly 140,000

E-Mini contracts or over 33% of the total trading volume. This is consistent with the HFTs' typical practice of trading a very large number of contracts, but not accumulating an aggregate inventory beyond three to four thousand contracts in either direction.

As such, attributing the crash to scalping activities by HFTs is misguided. However, HFTs are involved in a much wider range of activities than high tech scalping. The key factors producing the crash are to be found elsewhere:

As with the crash of 1987, the flash crash is yet another instance where speculative trading of stocks using futures exchanges conflicts with the stability of the price discovery process in the cash market for stocks. More precisely, pricing stability in the cash market for stocks has historically depended on the speculative hypothecation demand – leveraged purchases using margin and other sources of borrowing – being offset with speculative cash market short selling – using borrowed securities that will be later repurchased and returned to the lender. The availability of stock for lending on the short sale provides an effective limit on speculative short selling. Stock index futures contracts do not face such a physical constraint. Cross market arbitrage trading is the transmission mechanism that translates the speculative short selling in the futures market into the cash market. The implication of this in the flash crash is apparent in the following:

In the four-and-one-half minutes from 2:41 p.m. through 2:45:27 p.m., prices of the E-Mini had fallen by more than 5% and prices of SPY suffered a decline of over 6%. According to interviews with cross-market trading firms, at this time they were purchasing the E-Mini and selling either SPY, baskets of individual securities, or other index products.

While the E-mini and the SPY recovered quickly from the temporary liquidity shortage, it was cross market arbitraging using less liquid stocks and, especially, ETFs that created the 20,000 broken trades, with retail investors on one side of the of the bulk of these trades -- more than 2/3 of

these broken trades were ETFs.

Despite avoiding reference to a ‘flash crash’, SEC (2010, II.2.d, p.45-48) does provide a useful, if incomplete, examination of “Equity-Based High Frequency Traders” activities on May 6. The problems confronting stock market regulators addressing disruptive trading behaviour is apparent in the description (p.45): “HFTs are proprietary trading firms”. In effect, the precise trading strategies used by these firms are outside the purview of the regulator. However, there is sufficient information to provide a general functional description:

HFTs are proprietary trading firms that use high speed systems to monitor market data and submit large numbers of orders to the markets. HFTs utilize quantitative and algorithmic methodologies to maximize the speed of their market access and trading strategies. Some HFTs are hybrids, acting as both proprietary traders and as market makers. In addition, some HFT strategies may take “delta-neutral” approaches to the market (ending each trading day in a flat position), while others are not delta-neutral and sometimes acquire net long and net short positions.

The recognition that HFT strategies can involve both proprietary trading and market making is a decided improvement over SEC (2010a) where a functional definition for proprietary HFT firms focuses on market making:

(1) the use of high-speed and sophisticated computer programs for generating, routing, and executing orders; (2) use of co-location services and individual data feeds offered by exchanges and others to minimize network and other types of latencies; (3) very short time-frames for establishing and liquidating positions; (4) the submission of numerous orders that are cancelled shortly after submission; and (5) ending the trading day in as close to a flat position as possible (that is, not carrying significant, unhedged positions overnight)

The definitional transition from the ‘Preliminary Report’ of May 18 to the ‘Final Report’ of September 30 reflects learning on the part of the regulator precipitated by the Congressional authority given to investigate the market disruption of May 6. However, even armed with such authority, not all activities of proprietary HFT trading firms were exposed to the glare of public scrutiny.

The primary data sources for the SEC (2010) examination of proprietary HFT trading were: minute by minute FINRA Equity Trade Journal data covering less than half of aggregate stock market volume; 15 minute interval data covering trading on all major US stock exchanges by executing broker-dealers; and, direct interviews with HFT firms that were “identified by FINRA as either engaging in high frequency trading strategies (such as electronic market making or statistical arbitrage), or providing trading access to other HFT firms” (p.45). Significantly, the “audit trail data” provided by FINRA only:

includes trades reported by Nasdaq, reported to the Nasdaq TRF, and the ADF. It does not include trades executed on any other exchanges, including the NYSE, NYSE Arca, and BATS, or reported to any other exchange’s trade reporting facility. Accordingly, the data encompasses less than half of the trading volume during the most volatile period on May 6. Moreover, HFTs generally are understood to be less active in the OTC market than in exchange markets.

In effect, even backed with the power of Congressional investigative authority, SEC (2010) is unable to obtain even half the information on the trading activities of participants central to stock market activity during a crucial time period. This sustains a conclusion (SEC 2010, p.7):

the events of May 6 clearly demonstrate the importance of data in today’s world of fully-automated trading strategies and systems. This is further complicated by the many

sources of data that must be aggregated in order to form a complete picture of the markets upon which decisions to trade can be based. Varied data conventions, differing methods of communication, the sheer volume of quotes, orders, and trades produced each second, and even inherent time lags based on the laws of physics add yet more complexity.

This conclusion begs the question: if the data is so important, why is SEC (2010) only able to obtain less than half the minute-by-minute trading activity of the ‘proprietary HFT trading firms’ that may have been the source of transmitting disruptive short speculations into the broader stock market?

Despite these limitations, SEC (2010) is able to obtain remarkable results about trading activities of ‘proprietary trading firms’ using HFT methods. In the end, 12 HFTs, responsible for 46% of the trades on the FINRA Equity Trade Journal were identified and interviewed for SEC (2010, p.45):

Of the HFTs we interviewed, we did not find uniformity in response to market conditions on May 6. Although some HFTs exited the market for reasons similar to other market participants, such as the triggering of their internal risk parameters due to rapid price moves and subsequent data-integrity concerns, other HFTs continued to trade actively. Among those HFTs that continued to trade, motivations varied, but were in part based on whether they thought their algorithms would be able to operate successfully (profitably) under the extreme market conditions observed that afternoon.

Further breakdown of HFT activities based on closer examination of the FINRA audit trail is illuminating:

we found that 6 of the 12 HFTs scaled back their trading during some point after the broad indices hit their lows at about 2:45 p.m. Two HFTs largely stopped trading at about 2:47

p.m. and remained inactive through the rest of the day. Four other HFTs appear to have each significantly curtailed trading for a short period of time, ranging from as little as one minute (from 2:46 p.m. to 2:47 p.m.) to as long as 21 minutes (from 2:57 p.m. to 3:18 p.m.).

It seems that some of the purely ‘market making’ HFTs stopped market making, leaving proprietary HFTs to dominate the trading results during the most important time period.

[A]ggregate trading activity of these 12 HFTs picked up just after 2:30 p.m. and increased significantly during the period in which the broad indices were rapidly declining from 2:43 p.m. through 2:46 p.m. ... HFT trading activity during those three minutes increased by over 250% for NYSE Arca-listed securities, which we note are predominately ETFs.

Recalling that more than 2/3 of broken trades were in ETFs, SEC (2010, p.47) draws the following conclusion from the FINRA audit trail:

The data suggests that for at least the period from 2:00 p.m. through 2:40 p.m. on May 6, HFTs were relatively more active in ETFs (listed primarily NYSE Arca) than corporate stocks (listed primarily on NYSE and Nasdaq). Furthermore, their reduced participation in NYSE Arca-securities with broken trades reveals that they too were part of the general withdrawal of liquidity seen in those products.

The final significant result from the FINRA data was: “HFTs were primarily sellers of securities on May 6.”

Because the flash crash was a ‘downside’ liquidity event, SEC (2010, p.47-8) also:

examined a data set obtained from the largest public quoting markets on May 6 – each of the equities exchanges and Direct Edge (EDGA and EDGX). This data included total dollar volume on those markets across all securities by 15-minute increments, and was

further categorized according to liquidity-taking and liquidity-providing buys and sells. This 15 minute interval data covers a different range of stock trading activity where identification of specific HFT firms was not directly possible, though the executing broker-dealer was identified. To address this problem:

Specific participant data was also provided for each executing broker-dealer that was among the top 20 aggressive sellers on each market during the rapid price decline on May 6. From this list of aggressive sellers, we aggregated data for 17 executing broker-dealers that appear to be primarily associated with HFT firms in order to compare trading patterns of these firms with the rest of the market.

For the 6 business days prior to May 6, “these 17 HFT averaged 43.8% of total dollar volume on the public quoting markets”. Closer examination of this trading data provides the ‘smoking gun’ of the flash crash:

As a percentage of total market dollar volume, the activity for these 17 HFT firms increased in the period from 2:00 p.m. through 2:45 p.m. to a high of 50.3%, before sharply falling to 36.6% in the period from 2:46 through 3:00 p.m. This pattern is consistent with some HFT firms reducing or pausing trading during that time. Notably, *the 17 HFT firms escalated their aggressive selling more significantly (reaching a total of \$9.3 billion) than any other category of trading during the rapid price decline in the period ending 2:45 p.m.* (emphasis added)

The associated conclusion is: “In general ... it appears that *the 17 HFT firms traded with the price trend on May 6 and, on both an absolute and net basis, removed significant buy liquidity from the public quoting markets during the downturn*” (emphasis added). Less kind words could classify the net activities of these proprietary HFT firms as ‘predatory’ or ‘abusive’ short selling.

#### **4. The Flash Crash and the SEC Market Initiatives**

The dozen years following the introduction of Regulation ATS in 1998 have witnessed changes in the stock market regulatory environment rivalling the sweeping changes of the Depression era. In 2005, these changes culminated in Regulation NMS and Regulation SHO. Regulation ATS “increased competition with traditional exchanges by establishing a regulatory framework for alternative trading systems (ATSs) to trade listed securities without registering as exchanges” (Kramer and Corcoran 2010, p.295). In turn, by giving trade-through protection to automated quotations but not manual quotations, Regulation NMS facilitated the transition to electronic trading, further encouraging the development of high-frequency trading strategies and the dispersion of trading activity across a variety of market trading platforms. The passage of amendments to Regulation SHO in July 2007 that eliminated the price test for short sales – both Rule 10(a)-1 for exchange listed securities and the related NASDAQ bid test rule – marks the last of the major stock market liberalization initiatives by the SEC. The fallout from the financial collapse of 2008-9 has precipitated a process of retrenchment that includes: the introduction of Rule 201 of Regulation SHO which reinstates a form of short sale price tests; and, the introduction of single stock circuit breakers in response to the flash crash.

Crashes represent severe downside disruptions in the price discovery process. The aftermath of the discontinuous fall in prices inevitably leads to intense focus on the activities of stock market short sellers. While there were crash elements in the financial collapse of 2008-9, the systemic problems in the stock market were more pronounced and the downside movement in prices more ongoing. Release No. 34-61595 “Amendments to Regulation SHO” (SEC 2010b) is the regulatory response to the relatively unrestricted short selling during the time period associated with the financial collapse. Being prepared so soon after the implementation of Regulation SHO

amendment in 2007, SEC (2010b) is an historical curiosity. The stock market regulator is being forced by events to backtrack on a substantive market structure initiative. As is evident in the tone of the discussion in SEC (2010, esp. II.D), the implementation of Regulation SHO in 2007 was well founded in empirical evidence and regulatory procedure. The regulatory change did not restore Rule 10(a)-1 that applied to all stocks. Instead, Rule 201 only imposes the price test on individual stocks experiencing price declines greater than a fixed value. Significantly, Rule 201(d) provides important exceptions for inter-market arbitrage that undermine the ability to address the disruptive aspects of short selling.<sup>7</sup>

It is difficult to be critical of market structure and liberalization initiatives by the SEC. Some type of regulatory change was needed in response to changes in trading technology. It is natural and expected for the SEC to actively involve those players directly involved at the centre of stock market trading: large broker dealers; specialized trading firms; and, the exchanges and other self-regulatory organizations. Public comment periods and advisory panels are typically dominated by contributions from these players and the rule making process dictates that careful consideration be given to such input. It is difficult enough to balance the often disparate views of these players. As a consequence, formulation of regulatory rules that protect the activities of 'proprietary trading firms' is not surprising, even if such rules lead to destabilizing outcomes. Rules that impinge on the profitability of large broker dealers or require significant changes in market trading practices are likely to face fierce resistance. As with the crash of 1987, the flash crash illustrates that the problem of large players driving the process of regulatory change is exacerbated where the trading firms are operating in both cash and futures markets and subject to the differing regulators.

For centuries, inter-market arbitrage has been an important source of profitability for dealers in

financial markets. In medieval times, Venetian and Florentine bankers arbitrated exchange rates across fairs in different geographical locations. Inter-market arbitrage in the stock market achieved modern characteristics during the 19<sup>th</sup> century. There was ‘shunting’ between London and the regional stock exchanges and ‘arbitraging’ between London and foreign markets, e.g., Michie (1986); Haupt (1870). The introduction of trading in stock index futures contracts and other derivatives created another opportunity for inter-market arbitrage, in this case between the cash and futures markets. While this variant of inter-market arbitrage was novel for the stock market, such trading is well developed in the commodity markets where the liquidity provided by speculative exchange trading enhances the stability of the price discovery process. Previous to the severe restrictions on trading time contracts and other derivative securities imposed during Depression era stock market reforms, such trading was conducted in the same venue as cash market trading.

Sustainable speculative exchange trading of commodity futures contracts depends on characteristics of the underlying cash market. The history of futures trading is replete with examples of contracts that were introduced and failed due to lack connection with the cash market. For example, the first interest rate futures contracts, the GNMA and GMNA II, failed due to difficulties in arbitraging the cash and futures markets. The relationship between futures prices for different delivery dates and between futures prices and spot prices varies with each commodity depending on the specifics of the associated short and long cash-and-carry arbitrages.<sup>8</sup> As a group, financial futures have prices that are tightly bound by the short and long arbitrages. In contrast, various physical commodities have a marked difference between the short and long arbitrages due to limitations on the ability to short sell the spot commodity. In addition, arbitrages for physical commodities are impacted by considerations of storability, seasonality and other

factors affecting the convenience yield. As a consequence, over time physical commodities can exhibit both backwardation and contango in the term structure of futures prices due to factors other than the relationship between the pecuniary carry cost and carry return, which determine the term structure for financial futures prices.

For financial futures, ease of short arbitrage execution depends on the availability of the spot commodity for short selling. Eurodollars futures have the desirable characteristic that both the spot commodity and the borrowing instrument are the same, funds are both borrowed and lent in the Eurodollar deposit market. Similarly, currency futures involve borrowing and lending in the Euro- currency deposit market. Other financial futures involve different markets for the cash market borrowing and lending involved in the notional arbitrage. For example, the notional short arbitrage in Tbond futures involves borrowing a deliverable Tbond that is sold in the cash market using a term repurchase agreement (RP), with a simultaneous long position established in Tbond futures to reacquire the Tbond to deliver on the short, using the funds from the maturing RP. The notional short arbitrage in stock index futures involves borrowing the stock index ETF, selling in the cash market and investing the proceeds in the broker call loan market, simultaneously taking a long position in stock index futures – using the funds from the maturing broker call loan to settle the delivery on the future purchase that returns the index ETF to the lender on the short.<sup>9</sup>

Notional arbitrages are theoretical constructs that assume, for example, simultaneous transactions. Actual execution of the arbitrage can differ. Ultimately, arbitragers will chose the trading strategy that produces the most profit. For financial futures, this involves minimizing transaction costs and execution time. In the stock market, the SEC market structure initiatives have created a windfall for the large proprietary trading firms engaged in inter-market arbitrage. Even in Rule 201 on short sale price test restrictions, Rule 201(d) provides specific exemptions for

certain domestic and international arbitrage transactions. Maintaining arbitrage equality between cash and futures prices has become a hallmark of SEC policy, particularly in the period since Regulation ATS. The domination of ‘proprietary HFT firms’ in inter-market arbitrage of stock index futures contracts is more than apparent in SEC (2010). The activities of these firms provide an almost instantaneous conduit for uncollateralized speculative short sales in the futures market to be transmitted into the cash market. The futures short is only secured by the margin deposit ensuring marking to market requirements are met.

The actual cash and carry arbitrage for stock futures is impacted by the necessity of allowing sales of stock by traders not in possession of the stock at the time it is being sold. For example, such provisions are essential to market makers where the objective is to balance long and short cash positions by the end of the trading day. Recognizing that the proprietary trading desks of broker-dealers can be involved in arbitrage activity, there is a subtle difference between such inter-market arbitrage short selling and the naked short selling prohibited by Regulation SHO. A ‘naked’ short sale arises when “the seller does not borrow or arrange to borrow the securities in time to make delivery to the buyer within the standard three day settlement period. As a result, the seller fails to deliver securities to the buyer when delivery is due; this is known as a ‘failure to deliver’”.<sup>10</sup> This leads to the concept of ‘threshold securities’ specified in Regulation SHO where short selling is curtailed in a stock which exceeds the threshold for allowable failures to deliver in a given time frame. Yet, through the exemptions provided for inter-market arbitrage, a *de facto* naked short sale can be placed using stock index futures contracts. The collateral constraint imposed in the cash market is the responsibility of the inter-market arbitrage firm, the stock market traders best able to avoid ‘failure to deliver’ sanctions.

The removal of short sale price test restrictions in July 2007 exposed the weakness of the

collateral constraint on the unrestricted cash market short selling associated with speculative exchange trading of futures contracts. The SEC has chosen to deal with these difficulties using an evolution of circuit breaker rules and restricted price tests that complicate but do not substantively restrict inter-market arbitrage activity. In the absence of restrictions on leveraged purchasing of stock, including long purchases in the futures market and with borrowed funds in the cash market, there is an understandable reluctance to impose overly stringent restrictions on short selling. Disruptions to the price discovery process from leveraged stock purchases often precipitate the predatory short selling that characterizes market crashes. Balancing of long and short speculative demands along the time path is needed to ensure accurate price discovery. In the absence of inter-market arbitrage transmitting stock index futures speculation into the cash market, the supply of collateral available for short sales (i.e., stock available for lending) provides an effective mechanism for achieving this balance. Because leveraged margin purchases at broker-dealers are eligible sources of short sale collateral, increases in leveraged speculation simultaneously increases the ability to do collateralized short sales.

It is a commonplace to observe that the evolution of the stock market embodied in the SEC market structure and liberalization initiatives was precipitated by the revolution in trading and communications technology. Despite the potential and realized benefits of these technological advances, no attention was given to the over two century old tradition of the 3 day settlement lag that facilitates various facets of disruptive short selling. In the middle of the 19<sup>th</sup> century, three day settlement was considered to be the shortest time practical to affect the delivery of the stock certificate. Market makers that had sold a security not owned at the time of sale needed the time to locate stock for delivery. With the trading technology of modern markets, a system of accounting for collateral available for short sales is not only possible but necessary. Instead of

potentially ineffective and inefficient circuit breakers and price tests, a requirement that all short sales on a given trading day locate collateral by the opening of business for the next trading day is not only feasible but desirable. More stringently, short sales could be required to locate collateral prior to the trade.

Cash market short selling based on collateral available for lending is the convention in commodity markets. For example, in the gold market central banks often lend to short sellers charging a short sale fee that depends on market conditions. Tightening collateral requirements on short selling in the stock market would provide an increased incentive for firms to locate stock needed for the short sale. Instead of a market characterized by firms specializing in locating stocks to avoid failure to delivery, technological advances could permit the creation of collateral depositories that would provide access to stock available for lending to short sellers for a nominal fee. Periods of heigten leveraged purchases would provide simultaneous increases in collateral available for short sales. Similarly, collateral constraints in periods of excessive short selling would result in increased costs for increasingly limited collateral. Most importantly, the inter-market arbitrage trading that transmits unconstrained short selling with futures to the cash market would be dampened by the collateral constraint. As a consequence, stock index futures prices would not mirror cash market prices as closely. Instead, futures prices would be impacted by the costs of collateral. Excessive short futures selling would cause futures to sell at a discount to cash, increasing the incentive to purchase in the futures market and reducing the generation of short sales in the cash market. Similarly, excessive long futures purchases would result in leveraged purchases of stock increasing the supply of collateral available for short selling in the cash market.

## 5. Conclusion

Like other stock market crashes, the brief flash crash of May 6, 2010 involved a severe downside disruption in the price discovery process. The aftermath of any such discontinuous fall in prices inevitably leads to intense focus on the activities of stock market short sellers. The regulatory response to the flash crash, SEC (2010, 2010a), provides a fascinating glimpse into the stock market at the end of the first decade of the 21<sup>st</sup> century. Combined with the amendments to Regulation SHO introduced to address short selling during the financial collapse of 2008-9, the SEC has opted to employ a combination of single stock circuit breakers and restricted price tests to deal with disruptive short selling. While such restrictions on short selling are a decided improvement over unrestricted short selling, this paper argues that the most effective route to dealing with disruptive short selling originating from futures markets is to significantly tighten the requirements associated with locating stock available for short sale. From the beginning of trade in stocks in the early 17<sup>th</sup> century, the *in blanco* sale of stock has met with regulatory restrictions. Only in the last few decades has the progress of technology instilled the modern hubris that such restrictions are unnecessary.

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## NOTES

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<sup>1</sup>. FINRA is the Financial Industry Regulatory Authority, the largest independent self regulatory authority for securities firms doing business in the United States. FINRA oversees nearly 4,580 brokerage firms, about 162,850 branch offices and approximately 630,695 registered securities representatives. FINRA is involved with: registering and educating industry participants; examining securities firms; writing and enforcement of rules and ensuring compliance with federal securities laws; information and education for the investing public; providing trade reporting and other activities for the securities industry; and, administration of a dispute resolution forum for investors and registered firms. FINRA performs market regulation functions under contract for the major U.S. stock markets, including the NYSE, NYSE Arca, NYSE Amex, NASDAQ and the International Securities Exchange. FINRA has approximately 3,000 employees located in Washington, DC, and New York, with an additional 20 regional offices. More information can be found at <http://www.finra.org>.

<sup>2</sup>. A partial listing of key players implementing portfolio insurance strategies for large institutional investors during the period leading to the crash of 1987 includes: Leland O'Brien Rubinstein Associates, Aetna Life and Casualty, Putnam Adversary Co., Chase Investors Mgmt., JP Morgan Investment Mgmt., Wells Fargo Investment Advisors, and Bankers Trust Co. This list does not include the wannabes at Goldman Sachs, Salomon Bros., Nomura and other firms seeking to gain status in this area. Goldman Sachs was the firm which employed Fischer Black at this time.

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<sup>3</sup>. US regulations for margin involve a number of different regulators, including the Federal Reserve Board, FINRA and, indirectly, the FDIC and the SEC. Regulation T administered by the Federal Reserve governs the extension of credit by securities brokers and dealers in the United States and applies to margin requirements for stocks bought with funds received from the broker dealer. Since 1974, initial margin for stock purchases is 50% and maintenance margin is 25%. FINRA also establishes minimum margin requirements. In general, margin describes necessary collateral to: purchase new securities; sell securities short; writing options and other derivatives contracts; or withdraw cash without selling securities.

<sup>4</sup>. One particularly significant instance involved the CFTC's 1998 attempt to extend regulatory authority to OTC derivative trading that failed in the face of dissent from the Federal Reserve, the SEC and the Treasury. Such trading in credit default swaps and related derivatives was at the core of the sub-prime mortgage crisis that precipitated the financial collapse of 2008-9.

<sup>5</sup>. Position limits in the E-mini contract traded on the CME are set in conjunction with the S&P 500 contract which is 20,000 net short or long. Given that the E-mini is 1/5 of the S&P contract, a position done completely in the E-mini would have 100,000 contract limit. For the S&P 500 index at 1200, the value of the position limit is \$6 billion. By comparison, the important Eurodollar futures contract has no position limit. Agricultural futures contracts, such as wheat and corn, work with limits on price moves instead of speculative position limits.

<sup>6</sup>. The approach suggested in SEC (2010) is to define the short trade by the mutual fund complex as 'legitimate hedging activity' and, as a consequence, is an activity that requires support and encouragement. Poitras (2002, esp. p.132-5) details the difficulties that can arise with distinguishing hedging activity from speculation. Conventionally, a trader actively engaged in

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the cash market is considered a hedger in the futures market. However, such a definition ignores situations where the ‘hedger’ engages in futures trading activities that are purely speculative. Falloon (1998, ch.8) details a classical illustration of the distinction: the Cargill corn case of 1936-7. SEC (2010) provides no information about the trading motives of the ‘large mutual fund complex’. However, a trading strategy of placing a \$4.1 billion short trade in one day that is unwound, say, a month later in one day would appear to be a speculation on market price movement, i.e., a trade placed solely to benefit from price changes is ‘speculation’ by definition.

<sup>7</sup>. From SEC (2010b, p.129): “bona fide arbitrage transactions promote market efficiency because they equalize prices at an instant in time in different markets or between relatively equivalent securities.”

<sup>8</sup>. Long and short refer to the cash position in the arbitrage. The long arbitrage involves borrowing the funds to purchase the spot commodity that is simultaneously sold for future delivery. This arbitrage bounds the futures price above. The short arbitrage involves borrowing the spot commodity, investing the proceeds from the short sale and purchasing the commodity for future delivery. This arbitrage bounds the futures price from below. Financial futures as a group have tight bounds around the futures price because both the short and long arbitrages are readily executed. In Eurodollars futures, for example, the short (long) arbitrage involves borrowing (lending) for T days in the Eurodollar deposit market and using the funds to purchase (from borrowing with) a 3 month + T day Eurodollar, simultaneously undertaking a Eurodollar futures contract to issue (purchase) a 3 month Eurodollar purchase in T days.

<sup>9</sup>. Such notional arbitrages are discussed in conventional textbooks on derivative securities, e.g., Poitras (2002, ch.4). The arbitrage descriptions are only illustrative. For example, most stock

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index futures contracts are cash settled. In this case, the gain or loss on the futures position would offset the costs of buying the ETF in the cash market to return to the short. In addition, short positions have to return any pecuniary return earned during the time the short is in place. For example, the short Tbond position would owe the coupon that accrues.

<sup>10</sup>. This quote was obtained from the SEC at: <http://www.sec.gov/answers/nakedshortsale.htm>.