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May 6th -- Signals from a very brief but emblematic catastrophe on Wall Street

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ABSTRACT

This essay begins by looking closely at the underlying structural causes of the discontinuity that appeared in the behavior of the U.S. stock market at 2:40pm in the afternoon of 6th May 2010, because the emblematic "catastrophic" aspect of the collapse of equity prices, and their subsequent equally abrupt rebound, renders these events potentially informative about things that can happen in a wider array of dynamical systems or processes – including those with consequences about which there is cause for serious concern. What transpired in those 7 minutes is viewed as being best understood as a hitherto unrecognized "emergent property" of structural conditions in the U.S. national stock market that all the actors in the story collectively had allowed to come into existence largely unremarked upon, through an historical process that was viewed generally as benign and therefore left to follow its own course of evolution unimpeded. The deeper significance of the events of May 6th lies in the attention it directs to the difference between a society being able to create and deploy technical "codes" enabling greatly enhanced connectivity for "exchange networks" - the condition of "hyper-connectivity" among an increasing number of its decentralized sub-systems, and a society that also provides timely mutually compatible institutional regulations and administrative rules for the coherent governance of computer-mediated transactions among "community-like" organizations of human agents. Regulating mechanisms operating to damp volatility and stabilize systems in which there is beneficial positive feedback are considered, as are a variety of circumstances in which their absence results in dysfunctional dynamic behavior. It is suggested that in view of the growing dependence of contemporary society upon on-line human-machine organizations for the performance of vital social and economic functions, continuing to focus resources and creative imagination upon accomplishing the former, while neglecting the latter form of "progress" is a recipe for embarking upon dangerous trajectories that will be characterized by rising systemic hazards of catastrophic events of the non-transient kind.

Keywords: "May 6th market break", price volatility, catastrophe theory, positive feedback, on-line transactions, computer-mediated communities, socio-technical system governance, symmetric regulation, regulatory by-pass, disruptive innovation

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On the morning of May 6th the stock markets on the U.S. East Coast opened with the Dow Jones Industrial Average (DJIA) index at 10,867.80. Uncertainties about the prospective strength of recovery from the recession, heightened by worries about the repercussions of Greece's debt problems, and the impeding release of a U.S. jobs report, weighed upon investors during the ensuing hours of trading, resulting in a gradual downward drift of prices throughout the morning and early afternoon. By 2:00pm (EDT) the average of the 30 securities in the Dow Jones Industrials index was down 161 points – approximately 1.5 percent from its closing level of the previous day. Trading in a number of stocks on the NYSE had been slowed in the preceding half-hour by the exchange's automatic mechanism for suppressing volatility in individual stock price movements, and this condition spread so that during 2:00pm-2:30pm the number of stocks that were similarly affected had increased from 100 to 200.

There then ensued a sudden and extraordinary plunge in prices on the major national exchanges (see Figure 1, *ad fin*). At approximately 2:40pm prices of many stock began falling with extraordinary velocity, taking the Dow Jones Industrials index down to 10,445.84 by 2:42pm, a fall of 3.9 percent. In the next 2 minutes it fell another 573.2 points: the cumulative 998.5 point plunge in the DJIA represented a 9.16 percent fall and was the largest proportional intraday loss recorded by the index since the October 1987 "Market Break." Very much the same downward course was followed by the more broadly based Standard and Poor's 500 index (see Figure 1, *ad fin*). But the fright and pain experienced by investors watching an estimated trillion dollars of market value being thus wiped away during the market's "free-fall" turned out on this occasion to be both short-lived and quite limited. The Dow Jones industrials rebounded with still greater speed from the depths it had touched at 2:47pm, regaining 543 points within 90 seconds, so that the losses for the day had been cut to 4.26 percent by 3:00pm. When trading on the NYSE closed the DJIA stood at only a bit more than 3 percent lower than the level at which it had opened.[1]

The significance of this brief "Wall Street catastrophe" of 6 May does not derive from that episode's immediate or indirect financial repercussions. Rather, it should be seen in the *emblematic* aspects of the story that will be related here in

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[1] The preceding account of the events of 6th May, along with the descriptive details of attendant events subsequently to be related, has been drawn largely from the material found in "Preliminary Findings Regarding the Market Events of May 6, 2010," *Report of the Staffs of the CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues*, May 18, 2010: 149 pp.[Available at: http://www.sec.gov/sec-cftc-prelimreport.pdf];and Mary L. Schapiro (Chairman of the U.S. Securities and Exchange Commission), "Examining the Causes and Lessons of the May 6th Market Plunge," Testimony Before the Subcommittee on Securities, Insurance, and Investment of the United States Senate Committee on Banking, Housing, and Urban Affairs, May 20, 2010. [Available at: http://www.sec.gov/news/testimony/2010/ts052010mls.htm.] See C. Nagi and M. Miller, "Electronic Trading to Blame for Plunge, NYSE Says," *Bloomberg*, May 6, 2010. [Available at: http://www.bloomberg.com/apps/news?pid=20670001&sid=aETiygQQ8Y3g], for the estimate of the market value erased during the plunge in stock prices.

response to the question "What caused this disconcerting free-fall of prices on the U.S. stock market?" To appreciate that quality it is helpful to start from the mathematical rather than the ordinary language meanings conveyed by the term *catastrophe*. For that present purpose it suffices to understand that the field of inquiry known as "catastrophe theory" (introduced by the French mathematician René Thom[2]) is a special branch of the study of *bifurcations*. The latter manifest themselves as sudden shifts, qualitative breaks or *discontinuities* in the behavior of dynamical systems. They are brought about by small, possibly imperceptible alterations in the particular circumstances of non-linear systems, which can cause stable equilibrium dynamics to disappear, or appear at some critical points – where not only the rate of change, but also the rate of change in the rate of change unexpectedly becomes undefined. Catastrophe theory, following Thom's original intentions, provides a general language for conceptualizing and modeling the dynamics of *forms*, rather than a "scientific theory" in the sense of Popper – because languages, like scientific paradigms are not propositions that can be submitted to testing and invalidation, but instead prove themselves to be useful, or not, in particular contexts and for certain purposes.[3]

A commonplace physical illustration of a "catastrophic event" – in this formal sense of the term -- may be experienced by letting your finger trace the surface of a draped fabric until it reaches a point where the surface (the "manifold" as mathematicians would speak of the shawl or cloak's three-dimensional surface) has folded under itself; there gravity will cause your finger's point of contact to drop precipitously from the surface along which it was travelling smoothly – to land upon the lower level of the drapery beyond the fold. That little passage is the "catastrophe." In the present context, what is especially relevant about this conceptualization of the "event" experienced by your finger is its generic nature: catastrophes thus conceived are not phenomena belonging to a category delimited by some size dimension of the system in which they occur, or according to the severity of their sequelae; nor are they to be uniquely associated with processes that that operate only in one or another range of temporal velocities (whether slow, or fast). Instead, the catastrophes to which this essay's title refers are *fractal*, possessing the property of self-similarity.

My premise in what follows is that to look closely at the underlying structural causes of the discontinuity that appeared in the behavior of the U.S. stock market at 2:40pm in the afternoon of 6th May will be worthwhile, because its emblematic

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[2] René Thom, *Stabilité structurelle et morphogénèse*. Reading, MA: W.A. Benjamin, 1972; Paris: InterÉditions, 1977; *Structural Stability and Morphogenesis*, transl. D.H. Fowler. Reading, MA: W.A. Benjamin, 1975.

[3] See the illuminating non-mathematical discussion by David Aubin, "Forms of Explanations in the Catastrophe Theory of René Thom: Topology, Morphogenesis, and Structuralism," in *Growing Explanations: Historical Perspective on the Sciences of Complexity*, ed. M. N. Wise, Durham: Duke University Press, 2004, 95-130. Aubin (pp. 98-99) emphasizes that for Thom the catastrophe theory was a new method of modeling, aimed "to understand natural phenomena by approaching them directly, rather than relying on traditional reductionism. Its main concern was the creation and destruction of forms, but more precisely, as they arise at the mundane level of everyday life. Catastrophe theory posited the existence of a mathematically defined structure responsible for the stability of these forms, which he called the logos of the form. The models built with the help of catastrophe theory were inherently qualitative—not quantitative—and consequently were not suited for action or prediction, but rather aimed at describing, and intelligibly understanding natural phenomena."

"catastrophic" aspect renders it potentially informative about things that can happen in a wider array of dynamical systems or processes – including those with consequences about which there is cause for serious concern. It is fair, however, to give notice in advance that the quest for the cause of that mystifying stock price collapse may be unsatisfying, at least in one respect. Although it is likely that strenuous and persistent inquiries (such as those presently being undertaken by the staffs of the U.S. Securities and Exchange Commission, and the Commodity Futures Trading Commission) eventually will identify a proximate precipitating event in the observable chain of reactions -- one of Aristotle's *causa per accidens*, no actor or actors will be found to have been culpable. What transpired in those 7 minutes will be better understood, instead, to have been a hitherto unrecognized "emergent property" of structural conditions in the U.S. national stock market that all the actors in the story collectively had allowed to come into existence largely unremarked upon, through an historical process that was viewed generally as benign and therefore best left to follow its own course of evolution unimpeded.

My broad contention, then, is that the genesis of this dramatic but transient episode is a reflection -- a small signal but a signal nonetheless – of the damaging potential created by the growing imbalance between two tendencies in modern society. On the one side we have a growing ability and drive to use technical code to build "hyper-connected" systems of dynamic interaction among the participants in novel transactional networks; on the other side, there is the indifferent degree of attention that too often is accorded to furnishing the resulting human and machine organizations with suitable institutionalized norms and regulatory codes. These would serve to damp destabilizing feedback effects that are likely to arise from mimetic behaviors and the relationships of complementary that have been enabled among the ensemble of actors (and *actants*).

If any lesson is to be drawn from the analytical retelling -- the *histoire raisoneé* of this "brief catastrophe on Wall Street," it points to the importance of the difference between computer-mediated "trading networks" or dedicated, special-purpose "exchange networks," on the one hand, and, on the other hand, actual "communities" whose members' transactions can be conducted with greater efficiency "on line." Digital technologies and the architecture of the Internet have greatly expanded possibilities of readily affording "connections" for message generation and transmission between "machines", and among peoples via machines. Unfortunately, however, the Web and its underlying layer of connected sub-networks forming the Internet do not automatically bring into existence functional human-machine organizations that possess the properties of "communities."

Unlike narrowly purposed exchange networks, "communities" possess developed structures of governance based upon social as well as technical mechanisms. The former require some substantial minimum degree of mutual recognition of the participants' common interest, enough to encourage reflexive identification of individual actors with the group. That, in turn, is likely to induce among the latter a measure of compliance with norms and mechanisms of social control sufficient to stabilize interactions among the individuals – keeping the ensemble operating within functional bounds. The complementary components of the resulting socio-technical structures, when properly designed and expeditiously implemented, can work together to regulate the dynamic interactions within the

system supported by its underlying communication networks. In so doing it may enormously enhance the collective discretionary intelligence of the system as a whole. But, to achieve this requires giving due attention and resources not only to the technical engineering but to the development of appropriate social mechanisms of "community governance. It is perilous to proceed on the assumption that the essential minimum degree of regulatory compliance on the part of a network's participants will be spontaneously forthcoming, simply because so many are seen to be enthusiastically flocking to enjoy the benefits that hyper-connectivity has provided.

A search for the reasons why

What had happened? For a number of days following this "brief catastrophe," shaken traders, equity investors, and stock exchange executives remained uncertain and increasingly worried by the lack of any clear explanation of the episode, and the consequent possibility that the same phenomenon might soon recur; not to mention the even more worrying possibility that on the next occasion the "rebound" would not come so swiftly, and what would ensue was a descent to still lower and persisting depths in market valuations.

Reports of the inconclusive search for the reason why the market had collapsed filled the daily newspapers, the financial press and web services with initial rumors that pointed to suspected "trading irregularities," raising the specter of a concerted speculative attack on some stocks having been engineered among a cabal of hedge-funds. This soon was dismissed as a paranoid delusion that was wholly lacking in empirical foundations.[4] The field was thus cleared for the next hypothesis: the "fat finger" explanation. Evocatively titled, this posited a human error committed by a yet unidentified trader, who, it was said, had unintentionally submitted a computer instruction to sell $16 *billion* worth of stock futures, instead of a mere $16 million.[5] But inspection of trading records, and interviews with various hedge-fund managers conducted by the Securities and Exchange Commission and other agencies of the U.S. federal government in the days following, all failed to locate any localized action of the magnitude that would make it a plausible candidate for indictment as "the accidental culprit" that had triggered Thursday's shocking cascade of stock values. Attention then shifted to the possible consequences of the interactions between pre-programmed algorithms for high-frequency computer implemented trades in stocks and future equities capable of rapidly executing millions of transactions.[6] Without

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[4] Inasmuch as some paranoids have real enemies, the utter lack of supporting evidence in this case was crucial in quickly quelling repetition of this and similar suspicions in the press and on Internet blogs.

[5] This particular rumor was making the rounds soon after the close of the NYSE on Thursday, May 6th. For example, the following passage appeared in a Associated Press news story by financial writer Mark Paradis, released with that date line and a 11:28 PM time stamp under the headline "Wall Street Roller-Coaster: Stocks fall 10 %": "No one was sure what happened, other than automated orders were activated by erroneous trades. One possibility being investigated was that a trader accidentally placed an order to sell $16 billion, instead of $16 million, worth of futures, and that was enough to trigger sell orders across the market." See, http://finance.yahoo.com/news/Wall-St-rollercoaster-Stocks-apf-892184148.html?x=0

[6] E.g., F. Norris, "Keeping up with the computers." *International Herald Tribune*, May 14, 2010. The theme of this genre of news story harked back to the diagnosis of the causes of the October 1987 "Market Break", which had followed the introduction of computer trading algorithms. High-frequently trading algorithms were cast in the role of the latest technical advance that harbored a renewal of the

human interventions the connections among these could set in motion accelerating spirals of ascending or, as in the case it hand, descending prices.

This effort at explanation, however, was little more than an evocation by financial writers of the common association of the role that was attributed to computer program trading in the Black Monday stock market crash of October 19, 1987, which had seen the DJIA drop by 22 percent. Recollections of that not-so-distant historical experience's association with program trading were revived by the recent attention in the U.S. financial press to the new practices of high-frequency traders -- whose ever-faster on-line computers executed enormous volumes of programmed stock transactions at staggering speeds.[7] But the widely held view that implicated program trading as the main cause of the U.S. 1987 "market break" – even if the concurrent global stock price collapse evidently had other causes -- continued to be recalled in terms that inadequately acknowledged the consensus among financial experts that the heart of the problem at home lay not in the computers, but in the computer implementation of what then was a novel financial strategy known as *portfolio insurance*. Portfolio insurance today is a familiar method of hedging a portfolio of stocks against the risk of a market downturn by short-selling an index of stock futures; whereas in the years preceding Black Monday it was a novel financial technique that involved the use of a relatively new financial derivative -- bets on the future values of an index of average stock prices. Then, as now, this strategy was most frequently deployed by the managers of large institutional equity portfolios in conditions of market uncertainty, and rather less so when expectations are "bullish," because its use limits upside gains.

But what was revealed in the U.S. stock market on Black Monday was that program trading by portfolio insurers in conditions where equity holders' uncertainties suddenly were heightened holds a potential for catastrophic value destruction. Once the stock market began to drop, those who had long positions in stock futures would liquidate them, sending the prices of stock index futures downwards, while portfolio insurers who had sold the index futures short would move to sell their stocks, imparting another down-tick in the derivatives market (the stock future index), that would in turn trigger further stock sales, and so on, driving a continuing equity price cascade.[8] The painful discovery of the existence of that

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same dangers. But, as will be noted below, the implicit line of explanation omitted notice of the "spiral-halting" rules that had been put in place by the New York Stock Exchange and other exchanges in the wake soon after the 1987 "Market Break". On algorithmic trading, see the extensive entry and references in Wikipedia: http://en.wikipedia.org/wiki/Algorithmic_trading.

[7] Program trading had been introduced and quickly adopted in the U.S. during the mid-1980's, but still was not widely diffused abroad at the time of the global 1987 collapse of stock market values. Indeed, that movement had begun on the Hong Kong stock exchange (attaining a proportional amplitude twice that of the subsequent fall in the New York stock market), and it spread rapidly from there to other exchanges in the region where there was little program trading or none at all, as was the case in Australia. Evidently there were other causes at work in the larger episode than the one upon which American observers and analysts had particular reasons for focusing their attention. See U.S. Securities and Exchange Commission, *The October 1987 Market Break*. Washington D.C.:1988; also the Wikipedia entry at http://en.wikipedia.org/wiki/Black_Monday_%281987%29.

[8] Richard Sylla, a leading U.S. economic and financial historian, emphasizes that innovations with index futures and portfolio insurance had a critical role in the stock price cascade of October 19th: "I've seen accounts that maybe roughly half the trading on that day was by a small number of institutions with portfolio insurance. Big guys were dumping their stock. Also, the futures market in Chicago was

potential had prompted the introduction in 1988 of the device of "circuit breakers." These would halt trading on the NYSE when the fall in the average value of a market index reached a pre-specified measure, and this mechanism was extended by subsequent legislation and SEC regulations across the range of registered exchanges.

Preliminary inquiries -- carried out by the Securities Exchange Commission (SEC) and the Commodity Futures Trading Commission (CFTC) into the detailed dynamics of stock and future transactions on May 6th -- however, did not indicate that this particular positive feedback mechanism, involving the interaction between trades in stock index futures and sales of blocks of institutional portfolio-holdings involving stocks traded primarily on the major exchanges, was the source of the market break. The sharp rebound, and the observation that a disproportionately large number of the sales executed at bizarrely low prices had involved exchange traded funds (ETF) pointed in a different direction, because ETFs typically were traded on "thin", low liquidity, satellite markets of the major exchanges. This soon turned the attention of the SEC and the CFTC to examining the possibility that the cause of the market break might be found in unexpected and unusual losses of liquidity that had spread from stock to stock as a result of the interactions among the various "on-line' computer-mediated stock-trading *sub-systems* that form the national market system.[9]

In effect, the search for the reason why prices suddenly plunged and rebounded has brought into salience the little appreciated implications of a transformation that had occurred in the stock market's structure: a multiplicity of sophisticated electronic stock trading venues had come into existence in the preceding decade, forming a distributed system whose parts were not *fully integrated*, in the sense of operating under a symmetrically applied governance structure. The now-favored explanatory narrative of this episode, as I presently construe it, therefore runs along the following lines.

Although the ultimate origins of the precipitating price movement in the early afternoon still remain unidentified, it most probably was generated by computer-trading -- quite possibly of stock futures.[10] But the dynamic process that it precipitated, by triggering the New York Stock Exchange's mechanism for slowing the pace of trading in that venue, is of greater explanatory significance than the particular cause of the initiating shocks felt in some individual stock prices. The NYSE's trading system incorporates a "hybrid" mechanism that is intended to dampen volatility in a

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even lower than the stock market, and people tried to arbitrage that. The proper strategy was to buy futures in Chicago and sell in the New York cash market. It made it hard -- the portfolio insurance people were also trying to sell their stock at the same time." See Annelena Lobb, "Looking Back at Black Monday: A Discussion with Richard Sylla," *The Wall Street Journal Online*. (October 15, 2007) Dow Jones & Company. http://online.wsj.com/article/SB119212671947456234.html?mod=US-Stocks.

[9] See http://www.sec.gov/sec-cftc-prelimreport.pdf, esp. pp.25-33.

[10] The evidence for this, cited in the Senate sub-committee testimony of SEC Chairman Mary L. Shapiro, on 18th May, is that the precipitous decline in stocks followed very closely the fall in the E-Mini S&P 500 futures index (see Fig 1). The latter tracks the normal relationship between futures and stock prices for the S&P 500, a broader market index. See also the portion of the testimony of CFTC Chairman Gary Gensler, on 11th May, before the a sub-committee of the House of Representatives Committee on Financial Services [http://www.cftc.gov/PressRoom/Events/opaevent_gensler051110.html], dealing with trades in the E-Mini S&P futures contract around the critical period of the market's sell off.

given stock by temporarily converting transactions in that title from an automated (electronic) market to a manual auction market. This action is triggered by the occurrence of proportional change in the price of the stock that exceeds a pre-specified size. The periods during which trading in the stock is thereby slowed are referred to as "liquidity refreshment points" (LRPs), and they can be as brief as one second, or even shorter in duration. The LRP's effect is to provide an opportunity for additional "liquidity" (in the form of buy, or sell orders) to enter the market and moderate the initiating movement of the stock's price. During these intervals, however, an electronic price quotation for the effected stock is displayed by the NYSE, even though it is not immediately accessible and may be by-passed by other trading venues and order routers – although such by-pass is not mandatory.

The NYSE's LRP mechanism, it should be noted, is quite distinct from the total, market wade "trading halts" that are triggered by large price movements in the major exchange averages, namely, those moving the Dow Jones industrials average by -10% or more. The mandated "circuit-breaker" action suspended trading not only on the NYSE but across all the registered stock exchanges and the equity futures markets. Once initiated, such circuit-breaking halts remain in effect for predetermined periods of time -- 30 minutes or longer, depending upon the magnitude of the Dow Jones industrials index's movement and the point in the trading day at which the triggering price change occurs. This system had been imposed by SEC and CFTC regulations in 1988, in the aftermath of the October 19the 1987 ("Black Monday") market break that saw the DJIA drop by 22 percent. It is significant that in approving the introduction of circuit-breakers in 1988, the SEC and CFTC explained that the rules were "an effort by the securities and futures markets to arrive at *a coordinated means to address potentially destabilizing market volatility*" such as recently had been experienced on "Black Monday," and not to prevent markets from reaching new and higher price levels.[11]

In 1998, following another stock market price collapse (that of October 27, 1997) the original rules regarding the magnitude of the absolute price declines required to trigger the circuit-breakers were reformulated in terms of (higher) proportional declines, upon which the duration the halt in trading were made conditional.[12] But, no halt occurred on May 6th, because the afternoon plunge in the DJIA did not reach the smallest (-10%) trigger point for a half-hour halt. Had the original trigger points not been modified by the SEC and CFTC in 1998, when those agencies accepted proposals by the NYSE and the Chicago Mercantile Exchange that specified a larger percentage decline (namely -10%), the May 6th plunge in equity and equity-futures prices would have been stopped by the suspension of trading. Pursuing that counterfactual proposition, however, would open the door to a speculative tale — rather than the one being related here.

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[11] The quotation (with my emphasis) is from http://www.sec.gov/sec-cftc-prelimreport.pdf: p. C-3. See *ibid*., Appendix C for a chronicle of the evolving SEC and CFTC rules governing the use of these so-called "circuit-breakers" that during the period between 19th October and 30th December, 1998.

[12] According to the SEC – CFTC Staffs' Preliminary Report (*op.cit*., p.C-3), in 1988 these agencies "also believed that circuit breakers would help promote stability in the equity and equity-related markets by providing for increased information flows and enhanced opportunity to assess information during times of extreme market movements." This is in essence the rationale of the NYSE's LRP mechanism applied to movements in individual stock prices.

When the NYSE slowed trading in the group of stocks whose prices had dropped, a number of the "market-makers" or "specialist" broker-dealers on that exchange would have found themselves committed to large-sized trades in those stocks for their institutional clients. Disinclined to hold onto this risk, they routed those orders to alternative, satellite electronic exchanges where trading still was ongoing at full speed. The latter venues, however, are not primary locations where under normal circumstances traders hold large order-books involving big blocks of institutional clients' stocks. Rather, they attract smaller retail trade orders that often can find better execution prices (and attention) there than they get on the NYSE or the NASDAQ. In comparison with those iconic stock exchanges these satellite markets are "thin" and at any given moment in the trading day may be quite "illiquid." Consequently, it is to be expected that the execution prices on large-size stock offerings received in those venues would be set at whatever low bids they will have happened to be holding. Were none to be found, the unfilled orders would instantly be forwarded on to other electronic satellites, where the process was likely to be repeated. In this way, further discontinuous drops in equity prices were generated, at a pace accelerated by computer-trading when waves of programmed "stop-loss" orders to sell were able to be executed. That would work to exacerbate the lag of trading on the NYSE behind the declining prices in those active but comparatively illiquid trading venues.

The slowed trading of affected stocks on the NYSE could not automatically have induced a spread of similarly stabilizing reactions across the other exchanges, simply because the "LRP" mechanism of reverting to manual auction trading was *sui generis* to the Wall Street exchange, and algorithms emulating the latter mechanism had not been implemented by satellite stock exchanges and the NASDAQ. In the absence of symmetric damping mechanisms throughout the national stock market system, certain features of the latter structure and trading practices among its participants that had hitherto appeared to be unproblematic, and under normal conditions were unproblematic if not beneficial, unexpectedly began to contribute further positive feedback augmenting the system's destabilizing dynamics.

One of these, noted in SEC Chairman Schapiro's testimony on May 18th before the Senate Sub-Committee,[13] was the interaction between the use of "market orders", "stop loss orders" and "stub quotes" in conjunction with the routing of unfilled orders from the NYSE to satellite exchanges, and transactions in thinly traded securities such as certain exchange traded funds and preferred stocks. A market order is an instruction to buy or sell a stock at the best available current price, and such orders do not require an execution at a specified price or price range. Generally, a market order is assured an execution, but what the execution price may be is not pre-specified. Therefore it is quite plausible to suppose that the use of "stop loss" orders on May 6th further amplified the downward impacts of market orders on prices, because stop loss" orders turn into market orders once the "stop price" of the order has been reached. In a normal market the use of a "stop loss" orders is a strategy that can protect an investor from incurring a major loss, but in the conditions that had developed on the afternoon of May 6th the market orders in conjunction with

[13] See http:www.sec.gov/news/testimony/2010/ts052010mls.htm, "Section 5.Other Factors."

programmed "stop loss" orders had just the opposite effect, leading to executions at absurdly low prices.

This was only worsened by the practice of entering "stub quotes" in program trading algorithms – place-holder orders to buy a given stock at the lowest possible end of the price spectrum: a penny. Again, under normal conditions this practice is benign, since the probability of that price ever being reached for most stocks will be negligible. The practice of "stub quoting," however, has become much more extensive as a consequence of the spread of high-frequency trading: writing a stub order at 1 penny is particularly appreciated by high-frequency traders as a convenient way to be able to measure the round trip order latency period (the time lapse in getting an electronic order into the books) without tying up any material amount of the trading firm's capital. The entry of many lightly capitalized high frequency trading firms in recent years therefore tended to raise the likelihood that minimum stub quotes would be encountered when market orders were forwarded from the NYSE to thin satellite markets when LRP's had slowed transaction on the Wall Street exchange.

A second perverse effect emerged from the behavior of small high-frequency trading firms that had only recently entered the national stock market, and whose activities in normal times was seen as supplying liquidity to it. These firms' normal reactions to the movements of prices quoted for stocks on NYSE and its related electronic market NYSE-arca were altered by the abrupt elevation of the riskiness they now perceived in continuing their pre-programmed trading routines. Finding it increasingly difficult to make sense of the volatile streams of price data their computers were receiving from the major electronic exchanges, some small high frequency trading firms are reported to have worried that the NYSE-arca or the Nasdaq were experiencing technical malfunctions of their electronic trading systems. Were that to be the case in reality, transactions involving exchange originated orders eventually might be cancelled (or "broken") in compliance with the exchanges' policies.[14] That would leave the firm holding those positions when the prices of those securities eventually settled at much lower levels. These firms rarely if ever are "market specialists" and consequently are not under any obligation to continue trading and providing liquidity to the market, and could thus withdraw rather than hold the risk. But, because they were likely to have been (transiently) holding positions in millions of stocks, such decisions to close out their positions would reinforce the downward pressure on prices.[15]

As a result, the prices quoted for hitherto stable, "blue chip" corporate stocks suddenly plummeted --like that of Proctor and Gamble, which, quite inexplicably was

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[14] See e.g., J.Creswell, "In the blink of an eye, trades are made and questions are raised," *International Edition of the New York Times*, May 18, 2010. In the event, many trades on the NYSE and also some on the Nasdaq were cancelled after the event, not because there had been technical problems with the exchanges electronic systems, but exchange policy called for transactions executed at inexplicably deviant prices to be 'broken" to protect investor On "broken trades" and the detailed analysis of the distribution of securities in which these occurred in thinly-traded Exchange Traded Funds, see http://www.sec.gov/sec-cftc-prelimreport.pdf: pp.29-33, 42-44.

[15] On whether some high-frequency trading firms actually went off line after liquidating all their positions, see J. Creswell, *op cit*. Pulling the plug on their program trading activities reportedly was the reaction to bizarre price data from the major exchanges at Tradeworx, a small New Jersey-based trading firm whose founder was interviewed for this newspaper story.

more than halved within a few minutes -- sending understandably alarmed investors heading for exits. The development of this movement after 2:00PM saw a gradually growing number of stocks reaching "lows" in their inter-day values (see Figure 2 (*ad fin*), with the depths of those lows breaching the -20% range by 2:35PM. During the next 5 minutes price drops in the -40% to -100% range were registered for a handful of stocks. There was then a pause in the sale of stocks until 2:45 PM, after which time the bottom abruptly fell out of the market and many, many stocks plunged to inter-day lows in the -40% to -100% range.

The cascade that pulled down equity values across the "Big Board" and the Nasdaq and most of other electronic exchanges was unsustainable, however, and once it slowed to a halt, the rapid rebound lifted the DJIA by 600 points, allowing it to close the day only 347 points (3.2 percent) below its opening level. Like a forest fire accelerating as it tore through new fuel, it burned itself out -- except that unlike a real fire that stopped when the fuel had been consumed and left a smoldering ruin, in this case much of the rapidly destroyed forest, magically, was quickly regenerated. Of course, there was nothing magical in what happened. Traders who had been short-selling equity futures now held positions that they needed to unwind, and their beginning to doing so initially checked the fall in prices of stock futures and brought buyers into the market for equities. After all, during half-hour of plunging stock prices nothing in the external environment of the securities market had been altered structurally that gave investors grounds to justify the bizarrely low prices at which trades in the stocks of many previously "solid" companies had been executed. As prices on external exchanges stopped falling, the number of LRPs on the NYSE dropped towards more normal levels and trading there began catching up with the movement of prices on the satellite exchanges. A positive feedback process emerged that was driving prices upwards, as market-makers came forward with orders to buy, which in pulling up prices there transmitted a mirroring impulse to the impulse to the equity-futures markets. With the external environment still essentially unaltered, the recovery could continue until stock portfolios had been rebuilt and the accompanying reappearance of portfolio insurance demands stabilized prices of equity-futures, stopping the interactive upward spiral.

A brief catastrophe, "long in the making"

From the foregoing story, it would appear that the brief catastrophe on Wall Street during the afternoon of May 6th actually had been a long time in the making. The structural conditions that were the "root cause" of the transient collapse -- and, more generally of the extreme volatility of stock price movements during this episode – are found in *the imperfect integration of the multiplicity of electronic trading venues* that collectively constitute what is now referred to (by the SEC) as the U.S. "national market system" (NMS). Many electronic exchanges have entered the market during the past decade's climate of deregulation and enthusiastic encouragement of innovation in financial instruments and institutions. Spectacular advances in the technologies of computer-mediated telecommunication were equally, if not more crucial in lowering the barriers to creating networked venues that could cater to the demand for "after-hours trading" in stocks and other securities, particularly the large demands that arise following the release of "news" (including corporate earnings reports, and other announcements) after the main markets have closed. This allowed

the successive entry of small satellite exchanges that collectively grew to be major competitors of the large, long-established stock exchanges.

Once synonymous with the New York Stock Exchange, the Temple of Wall Street has thus become not simply "a virtual place", but the iconic representation of a "national stock market" within which its actual importance as a venue for stock transactions has been dramatically eroded. While the big broker-dealers that make the markets for the "large cap" stocks listed on NYSE's "Big Board" remain active at the historical site, the place has lost its former dominant position as the locus of publicly registered equity transactions. Having handled three-quarters of the volume of stock trades on U.S. exchanges only as recently as 2005, the NYSE's share (comprised mainly of NYSE and the electronic exchange NYSE-arca) had shrunk to approximately 35 percent of the U.S. registered exchanges in 2009, and presently stands at little more than 30 percent (See Figure 3, *ad fin*).

Those statistics leave out of the picture the so-called "dark pools" of private and unregistered equity trading venues, whose existence has only recently become visible to regulatory agencies like the Security and Exchange Commission, where belated concerns have been voiced that the large volumes of high-frequency trades being executed private for banks and hedge funds could destabilize the market. As a result of the loss of volume to its registered and unregistered electronic rivals, and the effect of industry-wide downward pressures on the margins of profits that the NYSE and other exchange operators are accustomed to extracting from the wedge between the prices facing the buyers and those facing the sellers, the profitability of the older established exchanges already had taken a beating well before the onset of the global financial crisis. The value of NYSE EURONext, the corporation that earlier in the decade successfully took the NYSE public (after its two centuries of ownership by the collectivity of private individuals who held seats on the Exchange) has been slashed by more than 75 percent during the past five years.[16]

But the "societal problem," as distinguished from the business problems of competing stock exchanges, resides in the organizational fragmentation of the former stock market that has resulted in a largely unrecognized transformation of the financial landscape. The preceding references to the NMS's "imperfect integration" alluded specifically to the fact that a significant number of the 50 electronically networked exchanges in the U.S. on which equities now are being traded did not follow the NYSE by putting in place mechanisms to damp large movements in stock prices. Nor were the supposed "liquidity-providing" firms that engaged in high-frequency trading obliged to stay in the market, rather than withdrawing when the riskiness of their positions suddenly appeared much greater than normally was perceived.

Consequently, what is of greater import in the current context than the NYSE's shrinking share of the rising volume of market transactions, is how large a

[16] During the year ended December 31, 2009, EURONext operated under two segments: United States Operations and European Operations, providing various services in its United States and European markets. In the U.S. it operates the New York Stock Exchange (NYSE), NYSE Arca and a number of small satellites domestic exchanges including NYSE Alternext, NYSE Amex, NYSE Liffe US, LLC (NYSE Liffe US), NYSE Technologies, Inc (NYSE Technologies) and SmartPool. See Figure 3 *ad fin*, and http://topics.nytimes.com/top/news/business/companies/nyse-euronext/index.html]

proportion of the potentially active traders in the market throughout the course of the ordinary trading day typically are attentive primarily to what is seen to be happening in that iconic venue rather than in the other exchanges. The relative number of regular traders, regardless of the size of the orders they place is likely to have remained much more concentrated on the NYSE (and perhaps a few other salient exchanges) than the volume of trades. That situation would have had a part among the conditions that gave rise of the dynamics that unfolded on May 6th, as it implies that a large number of potential traders were left lagging behind the ever-lower "bargain" prices being set on satellite exchanges – because their attention remained focused on the major, iconic NYSE. Under slowed condition of trading that obtained there as LRP's affect a widening array of listed stocks, a comparatively small number of broker-dealers pushing large blocks of orders onto the thinner satellite venues contributed to individual stock prices breaking through previous "lows" and feeding back quotations to the NYSE that increased the volatility of price movements in the market as a whole.

The behavior of those traders who continued to fixate on the movements of shares on the NYSE and were slow to see what was happening in the less salient satellite exchange might have been simply a matter of previously formed habit, or a well calculated routine – since on-line monitoring has an opportunity cost because it competes for an individual's attention implementing transactions. But even were one to suppose that the persistence of many traders in following the NYSE too closely was simply a path dependent routine, it is rather less reasonable to assume the same style of explanation for the persistence of so many of the satellite exchange operators in not following the NYSE's decision to moderate the short-run volatility of stock-price movements.

Inaction in this one critical respect on the part of the electronic exchanges that had emerged as the NYSE rivals, patently was collectively destructive of the "public good" properties of liquidity and continuous adjustment that had formerly characterized the post-1987 U.S. stock market, and otherwise might have continued in a large network of electronically connected exchanges that were furnished symmetrically with volatility-moderating trading algorithms. In the aftermath of the surprising collapse on May 6th, it has struck many observers as quite – not to say inexcusably stupid -- that the newly registered electronic exchanges bothered to take the same precautions as those that had been in place on the NYSE, even as they were shrinking the latter's share of national stock market transactions. Was it sheer indolence, or tunnel vision on the part of the new enterprises' managers in adopting such collective measures that should bear the blame for the resulting "fragmentation" of the U.S. equity market's governance structure, or negligent hesitancy on the part of the SEC and the CFTC to impose needed precautionary technology upon the growing number of registered exchanges?

To pose the issue in those terms, however, is to miss the point although high volatility in the prices and equities and equity futures has decidedly dysfunctional effects at the systemic, social level, greater price volatility hardly was perceived in those terms by all the new players that were entering the NMS. Rather, the business models of the operators of new electronic exchanges, like those of the small high-frequency trading firms aligned their respective private interests with the perpetuation of conditions of high price volatility that are characteristic of unregulated "thin markets." Larger price moments created greater opportunities for profitably exploiting

technical advantages vis-à-vis other traders that high-speed programmed execution of large volume transactions in anticipation of the buying, or selling actions of others in the market. In that asynchronous form of temporal arbitrage, more abrupt price movements make for bigger profits. Not surprisingly, then, one hears from industry sources that "What all high-frequency traders love is volatility—lots of it."[17]

The answer to the question of why an asymmetric governance regime arose and persisted in the national stock market remains to be thoroughly researched, but surely it is pertinent to have posed it here, in the context of seeking to understand the micro-mechanisms implicated in the May 6th "market break." One striking implication of fragmentation of the governance structure of the U.S. stock market (a phenomenon that has not left the major stock markets of other countries, and their historic exchanges and bourses untouched) is that it rendered exchange stabilization measures of the sort that the NYSE had introduced not merely ineffectual, but likely to function *perversely* and thereby contribute to destabilizing stock price movements in the market as a whole.

To grasp the logic of that unintended but nonetheless bizarre outcome, consider what happens when trading a salient exchange like the NYSE is slowed during an episode of widening and more pronounced price fall. The net effect works to nullify potential bids from substantial "specialist" traders and market-makers in that venue. Those agents, having seen prices dropping to such aberrantly low levels that they would be moved to take a "long" position on their own account, find themselves delayed in executing the required purchase orders. In other words, with prices falling on satellite exchanges, the "speed bumps" that were slowing trading activity on the NYSE actually have the effect of inhibiting ("short-circuiting") the very reactions that otherwise should have worked to check the downward spiral of individual stocks' prices.

It is true that some investors and speculative traders have access to brokers who can deploy online tools in many alternative markets, allowing them to act rapidly upon expectations of a turn-around when prices have dropped to implausibly low levels. In principle then, their reactions should be able to work to halt a price collapse and thereby set the stage for a rebound -- without having to engage the help of the mass of retail traders whose reactions via the NYSE also were delayed by the slower action of manual auctions. But, there is a hitch in that scenario: the greater likelihood is that many of the sophisticated participants in the market that are in a position to quickly avail themselves of the services of well-equipped brokers and high-speed trading programs would be focused on the very highly volatile movements occurring

[17] The quotation is from Creswell, *op.cit*. (2010), in a passage reporting an interview with a small high-frequency trading company, which continues: 'It was like shooting fish in the barrel in 2008,' said Majou Narang, the founder of Tradeworx. 'Any dummy who tried to do a high-frequency strategy back then could make money.'" When reading such comments it is relevant to note that beginning in the fall of 2007 and continuing throughout 2008, indicators of daily expected volatility in stock prices were elevated above the level that was characteristic throughout the preceding years, at least back as far as the beginning of 2005. That was the case, moreover, even before the November-May 2008 period of spectacularly high volatility. See the time-series of the daily values of the Chicago Board Options Exchange SPX Volatility Index ("VIX"), which uses options prices to construct a measure of the expected volatility of the S&P 500 stock price index, available at http://www.sec.gov/sec-cftc-prelimreport.pdf:p.12 (Figure 2).

on the smaller and less liquid satellite exchanges. What they would have seen there during the critical "free-fall" phase would either induced them eventually to withdraw from trading entirely, as happened in some instances involving small firms, or left them more inclined to wait until the downward cascade of values began to slow -- sufficiently that the mass of other trader could be expected to soon take notice. Reaching that point would present sophisticated high-frequency traders with their opportunity to jump in ahead of the rest, and take their profits when the herd's arrival was driving the market's rebound. Yet, their waiting for the signal of that opportunity to become visible amidst the chaotic price movements emitted from the variety of illiquid satellite exchanges actually was allowing the free-fall to continue and thus postpone the onset of the market's eventual rebound.

Consequently, in the absence of a supervening regulatory authority willing to curtail the profitability of financial enterprises in the part of the market where the volume of stock transactions was growing most vigorously, there was little call for the introduction of stabilizing safe-guards. In any case, to provide cross-exchange stabilization of individual stock prices, the SEC would have had to break with precedent by extending its domain of its regulatory activity and require registered exchanges to install the algorithms needed to emulate the NYSE LRP system to provide cross-exchange stabilization of individual stock prices.[18] Such a regulatory initiative, moreover, would have had to be pursued in the face of presumptive claims that high-frequency traders were on balance net suppliers of liquidity to the market – a contention that is rather easier support when their actions' effects are being considered against a background of "normal" market conditions.[19] Nevertheless, the passivity of the SEC in this matter is made all-the-more striking by its contrast with the actions taken to protect against extreme swings of contract prices in the market for stock index futures. There, an array of automatic price-stabilizing control mechanisms that have been introduced by the Chicago Mercantile Exchange (CME) and the International Commodity Exchange (ICE), the two major exchanges on which the E-Mini S&P 500 futures and other stock index derivative are traded.[20]

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[18] Such a step would have gone beyond the precedent set by the SEC in mandating the successive introduction (beginning in March 2007) of "penny-pricing" of exchange-traded stock options – starting with a selected group of electronic equity-options exchanges and eventually extending to all of them. The SEC justified imposing penny-pricing as beneficial for investors, and had to contend with the perception by some brokers in the exchange-traded stock options market that it would so narrow their margins and could only be in their interests if the volume of transactions rose sufficiently on all the exchanges. For the background of this innovation-diffusing action by the SEC. and its consequences for the brokers and the exchanges, see Elizabeth Stone, "The SEC and Electronic Options Trading, 1998-2008." Economics Department Seminar Paper, Stanford University, March 24, 2009.

[19] In the wake of the revelation of the consequences of not having cross-market volatility suppressing safe-guards in place, it might be reasonable to anticipate there now would be a voluntary movement toward symmetrically equipping all the registered exchanges with LRP-emulating programs and common regulations for their activation. On the other hand, the positive private business reasons for preserving volatility that have been identified could very well re-surface, engendering recalcitrance if not active resistance on the part of the new electronic exchanges and high-frequency traders – thwarting remedial regulatory reform of that kind.

[20] On both the CME and ICE, automatic rejection of orders falling outside of the pre-specified "reasonable" price ranges, and maximum size-limits on orders, as well as required lower limits for the execution of stop orders," all serve as protection against errors in entry orders, and endogenously generated extreme swings in prices. In addition, the CME Globex's "Stop Spike Functionality" automatically pauses trading for pre-specified intervals in order to protect against cascading "stop loss"

Reading the story of May 6th as a parable for our times

The deeper significance of May 6th's "brief catastrophe on Wall Street" – which is to say, its emblematic value – consists in the attention it directs to the difference between a society being able to create and deploy technical "codes" enabling greatly enhanced connectivity, the condition of "hyper-connectivity" among an increasing number of its decentralized sub-systems, and a society that also provides timely mutually compatible institutional regulations and administrative rules for the coherent governance of transactions among the human and machine agents throughout the multiplicity of the sub-systems upon which it vitally depends. Being far more able to accomplish the former than the latter form of "progress" is a recipe for a society moving onto dangerous trajectories characterized by rising systemic hazards of catastrophic events of the non-transient kind.[21]

The analogy been "digital code" and legal regulations (or more generally institutionalized social procedures and social "norms") governing human transactions, and the potential problems of permitting the former to be substituted for the latter on the Internet was influentially articulated more than a decade by Lawrence Lessig. The focus of the concerns originally animating Lessig's 1999 book, *Code* (now available in its 2nd Edition, 2009), was the transfer of rule-setting from the open political area, where a range of societal values might be reflected, to the province of a self-appointed technical cadre. The technocracy might not be so different from the politician in serving their own personal interests or conveniences or those of others who were animated by private commercial goals, but, more troublingly, were able to do so in a far less transparent manner without being held publicly responsible for the consequences. In a similar fashion, the continuing advancements in digital information technology not only permit but make it commercially attractive to go only pursuing greater degrees of technical connectivity, thereby facilitating interactions among human and machine subsystems that can form technically interoperable "exchange systems" without attaining socio-technical compatibility." This state of affairs implies that a rising portion of the digital information transactions upon which modern societies are growing to depend are subject to dynamic processes with non-transparent properties, yet remain ungoverned by social and technical norms that are

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orders. Further details of these practices are given in CFTC Chairman Gensler's testimony before the House sub-committee [http://www.cftc.gov/PressRoom/Events/opaevent_gensler051110.html].

[21] As tempting as it is at this point to draw the connection between the present discussion of the case for institutionalized as well as purely technological measures to control self-reinforcing, positive-feedback driven market dynamics, and the grave challenges posed by similar processes at work in global warming, that digression to a far more complicated to subject must be resisted firmly. I have not been able, however, to exercise the same measure of self-restraint on other, previous occasions: see P. A. David, "From the Economics of QWERTY to the Millennium Bug, and Beyond: *Just-in-Time* for Y2K, and Next…For Irreversible Global Warming and Environmental Catastrophe?," presented at the Conference on *Historical Approaches in Economics*, held in Honor of Gavin Wright. Stanford Institute for Economic Policy Research, Stanford University, 27-28 September 2008; K.J. Arrow, L. Cohen, P.A. David, et al. "A Statement on the Appropriate Role for Research and Development in Climate Policy," *The Economists' Voice*, 6 (1):Article 6, March 2008 [DOI: 10.2202/1553-3832.1518. Available at: http://www.bepress.com/ev/vol6/iss1/art6.]; P.A. David, C. Huang, L. Soete, and A. van Zon, "Towards a Global Science and Technology Policy Agenda for Sustainable Development," *UNU Policy Brief No.2*, November 2009. [Available at: http://www.merit.unu.edu/publications/briefs.php].

regularly adjusted to maintain predictable functional stability compatible with the sustainability of the whole system.

The nub of the problem here is that IT innovation is being driven in part by attractive private incentives for entrepreneurial agents seeking ways to escape the constraints that socio-political regulations impose upon their profit-seeking activities -- when the latter are construed with reference to the exploitation of pre-existing structures of technological knowledge. One recourse open to those in that position is to seize opportunities to enter expanded "exchange systems" some aspects of which naturally, or by design extend beyond the pre-defined scope of existing regulatory controls – thereby altering the rules of the game to which they will be subject. Novel telecommunications technologies that create unfamiliar transactional networks, and especially those that can be connected with other subsystems to create new "hybrids" – by means of technical interface devises, or communication protocols, and intermediating agents – frequently have been especially doubly attractive, in offering both superior technical capacities and the prospect of being able to exploit these when liberated from the regulatory restraints that have come to be placed on long-established modes of production and forms of business organization. Indeed, it is in part because the participants entering a novel pure "exchange system" generally are not obliged to submit to a universal set of regulations that "standardize" their behavioral norms and technical practices, that the formation of such systems – which also offer opportunities for specialization and trade, agglomeration externalities, and arbitrage – have proved so attractive in the history of human societies.

This being the case, in the absence of external interventions by super-ordinate regulatory authorities, or the exercise of greater bargaining power by the sub-system (or network) with which the member of other subsystems (networks) seek to establish communications, the components forming exchange systems are likely to remain substantially differentiated in their internal workings. When interactions among them are dominantly complementary, so that the effect of exchanges is beneficial and consequently self-reinforcing for each of the subsystems, it is likely that some if not all of the subsystems will be exposed to what for them will be unprecedentedly strong positive feedback, self-reinforcing impulses that overwhelm whatever damping regulatory constraints or social norms had formerly been in within each of them. As a result, those enjoying substantial net advantages of having gained the requisite degree of "network connectivity" sufficient to support "exchange," or those entering such a system with relatively less effective stabilizing norms, are most likely to become the drivers of positive-feedback effects. That will only render the behavior of the emerging exchange system "predictably more uncertain" – in the sense of being less stable, or "excessively volatile" than that experienced formerly by each of its constituent elements. What is created is a world where there is less "safety in numbers," because heterogeneity among the connected actors tends to rise with their numbers, so that even though diversity may promote creativity within the system, unregulated innovations bring growing and non-transparent systemic risks.

It is useful, then, to see in the explanation of the recent minor episode on Wall Street a little parable, and perhaps also an instructive signal – if we are attuned to receive it – of that much bigger story. The moral I would have us draw from that tale is that the sheer pace of advance in digital information technologies has posed a species of governance problem to which polities and will have to learn to cope, or be

more and more frequently beset by catastrophic collapses in the functions of the socio-technical information systems upon which the world's population has become increasing dependent.

The parable taken farther afield, across the spectrum of unwelcome 'emergences'

The problems of the unexpected emergence of volatile market behaviors with which the foregoing pages have been occupied, should by now be understood to have the potential to appear where-ever hyper-connectivity -- in the sense of dense highly efficient communications that facilitate exchange transactions among agents (humans and/or machines) -- allows the formation of a "system" to be technically enabled. But, destructive *sequelae* other than those that have been the center of the discussion thus far can be seen to issue from structural circumstances that produce "run-a-way" dynamical systems. Although some among these manifest themselves at the microcosmic level of personal interaction processes, the features they share with the sources of macroeconomic and financial instability are striking. A good parable is a highly elastic thing, in that it may be usefully stretched to fit the scale of large events that play themselves out over prolonged time-spans, or, as in the fleeting stock market break just examined, are compressed within the span of an hour. To put this point somewhat differently, one may say that the structural conditions permitting the self-referential inflation of "bubbles" until they no longer can be deflated and therefore must burst, are fractal. Accordingly they can generate analogous dynamical behaviors in a wide variety of circumstances, and at both the high-frequency and low-frequency ends of the narrative spectrum.

To explore this a bit more specifically, one may briefly turn to the sphere of quotidian and short-lived human communications facilitated by advanced (digital) telecommunications, and consider the congruence between the conditions seen to underlie the behavior of prices in the U.S. stock market on May 6th, and the phenomenon known in email forums on the Internet as "flaming." An episode of "flaming" refers to a behavioral break in the course of a discussion or negotiation conducted by email – via a "forum', subscription list, wiki, or game servers such as XBoxLive. Typically such incidents are marked by one of the participants descending precipitously into hostile, abusive commentary directed at another, or several others. These outbursts sometimes are reciprocated rather than remaining one-sided, and they are reported now also as occurring in the course of instant messaging exchanges and video-sharing websites. Going still farther afield, one might include as part of the same broader phenomenon the recent reemergence on the Web of an nastier, digitally implemented version of what in a former time were called "slam books": that being a reference to the medium in which teen-age school children (girls mostly) inscribed and circulated anonymous remarks about each others' perceived personal defects.

In the latter cases of quite corrosive exchanges, which proceed rapidly from disparagement to highly abusive comment, total anonymity of the parties seems the essential condition for sudden departures from civil intercourse between class-mates and ostensible friends; whereas, in other circumstances it is the parties' quasi-isolation from each other that seems to remove inhibitions on verbal aggression; either that, or the reduced likelihood of their unwelcome messages electing prompt negative

feedbacks in the form of physical retaliation by the recipients.[22] Isolation, of course, is simply the extreme state of low dimensionality channels of communication with others -- such as speaking to a person without being able to see their facial expressions or "body language," exchanging scripts without hearing the other party's intonations or involuntary utterances that usually are sufficient to cue adjustments in the tenor of human conversations; or, again, "texting" under symbolic restrictions that tightly limit the conveying of qualifications and nuanced expressions. In the latter case we have a tidy instance of an inexpensively effected "connectivity" producing exchange networks whose technically efficient performance is achieved by attenuating the affordances that contribute to the experience of "community."

Fortunately, these may turn out to be largely transient problems of the early Internet era, inasmuch as the availability of greater bandwidth at reduced costs could mitigate the "distancing" effect of text communications conducted with minimal grammar and vocabulary. But comparatively narrow bandwidth of greatly cheapened new communication media affording connectivity among geographically dispersed and anonymous parties do no not promise those salutary, mitigating effects and they bring reduced expectations of retaliation for disseminating hurtful messages. In this domain, however, unlike those involving pure machine organizations, it is *the anticipation* of negative feedback that serves as an important regulator, or volatility-moderating mechanism to limit damaging interactions among incompletely communicative parties.

More generally, even though humans are socialized from infancy to recognize precursory signals of adverse reaction by other to their behavior (such as shifts in facial express, oral tone, etc.), their interactions undergo perceptible transformations when they are insulated from the full range of their actions' adverse effects upon one another – either by spatial separation that limits the possibilities of physical retaliation, or by low-dimensionality and high latency in the channels afforded form message exchanges. Misunderstood messages that could be construed as hurtful are more likely to elicit responses in kind, rather than requests for clarification. There is thus a tendency to allow ourselves more scope to provoke those with whom we find ourselves exchanging messages, and in turn to reciprocate others' provocations. Liberated from the automatic triggering of "dampers," the back-and-forth process of verbal or symbolic messaging thus can, and often does proceed with escalating ferocity until the parties are separated.

There is a striking resemblance between this aspect of human social interactions -- when the actors can be connected to exchange messages without having to fully internalize the effects of those messages on the correspondent parties, and

[22] See, e.g., N. A. Johnson, "Anger and flaming in computer-mediated negotiations among strangers," *Decision Support Systems* 46, (2009): 660-672, in which the conditions promoting this phenomenon are distinguished from those of computer communication *per se*, and contrasted with those in which computer-mediation reinforces a sense of community among the participants. "The literature suggests that, compared to face-to-face, the increased incidence of flaming when using computer-mediated communication is due to reductions in the transfer of social cues, which decrease individuals' concern for social evaluation and fear of social sanctions or reprisals. When social identity and ingroup status are salient, computer mediation can decrease flaming because individuals focus their attention on the social context (and associated norms) rather than themselves."

micro-biologists' observations on the evolution of virulence in microbial pathogens.[23] Comparison of viral, bacterial and protozoal agents of human diseases has shown that vector-borne pathogens have greater per-infection lethality than pathogens directly transmitted by contact with hosts. This is found to account for the severity of malaria, yellow fever, dengue, sleeping sickness and other insect-borne diseases being much greater that most of the respiratory-tract infections in humans. Pathogenic microbes (such as *Mycobacterium tuberculosis* – originally referred to as the "the "tubercle bacillus") that are transmitted directly by contacts between mobile human hosts have evolved in the direction of reduced virulence. Consistent with this observation, it is found experimentally that among pathogens that when human subjects are exposed to a strain of the yellow fever virus that has cycled between humans and mosquitoes (its vector), the effects are much less severe than those produced by exposing a human subject to a strain of the virus carried by vectors that have not been in prior contact with humans. Like vector-borne pathogens, water-borne bacteria typically evolve more virulent strains than those that are transmitted by skin contacts with infected humans (and consequently loose their transport when their human hosts become immobilized. Thus, the virulence of diarrheal bacteria is observed to vary positively with extent to which they are waterborne: the proportion of severe strains among *Shigella*, for example, is found to be higher in geographic locales where there are opportunities for water-borne transmission.

The mechanism driving this differential behavior in microbial populations is the conditions of transport that permit, or prevent engagement of negative feedback from the pathogen's debilitating impacts upon their host. More virulent organisms' reproductive potentialities will be diminished relative to that of the others as a consequence of their destructive interactions with the hosts upon which they depend not only for nutrition, but for transport to other sites from which they and their progeny can draw sustaining resources – as does the *Mycobacterium tuberculosis* in consuming iron from the blood of its human host. Not so in the case of micro-pathogens (or "macro-parasites") that form no symbiotic "communities of dependence" with the medium that conveys them from one source of necessary resources to the next. The latter's replication therefore will not be impeded by genetic mutations and interactions with immobile hosts that result in the expression of greater virulence – which is to say, in correspondingly more debilitating or lethal effects upon the organisms with which they come into contact.

Now we consider the parable stretched in the other direction, by applying it to comprehend larger social systems – though not necessarily ones whose consequences for human societies are less damaging than the evolution of increasingly virulent microbial pathogens. This exercise can make its point by focusing on the outline resemblance between the foregoing stories of un-damped systems of social interaction in miniature, and the terms in which economists and economic policy analysts have come to explain the genesis and cataclysmic unfolding of the of the global banking and finance crisis of 2007-2008. Like the minor and transient episode of May 6th, the remarkable "bubble" that developed in U.S. house-prices, and the contemporaneous

[23] See P. W. Ewald, "Host-Parasite Relations, Vectors, and the Evolution of Disease Severity," *Annual Review of Ecology and Systematics*, 14, (November) 1983:pp. 465-485. [Available as: doi: 10.1146/annurev.es.14.110183.002341]; P. W. Ewald, "Evolution of Virulence," Infectious Disease Clinics of North America, 18, 2004: pp.1-15; P. W. Ewald, "Evolution of Infectious Disease, New York: Oxford University Press, 1994.

rise in degree of "leverage" attained by financial institution during this period, were phenomena "a long time in the making." So too as was the largely unnoticed evolution of a "shadow banking and financial system" that not only facilitated but drove these developments inexorably forward.

Crucial in that slower approach to the "edge of the manifold" beyond which lay monetary crisis and descent into widespread business failures and unemployment, was the gradually quickening emergence of novel financial intermediaries that operated outside the purview of supervisory agencies and regulatory codes that were supposed to reduce the prudential risks associated with moral hazard. The latter also were thought to be adequate restraints on the degree of systemic risks to which widespread illiquidity among banks and financial intermediaries could expose the "real" economy. These intermediaries deployed innovative financial instruments that soon connected new and long-established banks and investment houses alike in webs of contingent contractual claims, each one presumably of direct commercial benefit to the parties --if only because the novelty of their forms allow those using them to operate outside the domain of existing regulations and close governmental oversight.[24] Credit default swaps (CDSs) ostensibly were a useful means of hedging against the risk of other companies defaulting on bonds that had been issued against collateralized debt obligations (CDOs), some of which were backed by mortgages of varying qualities – still another instrument that created an opaque structure of entanglements). But, CDSs turned out to have quite different system-level properties when they were created and deployed without restraint as a mode of betting on the likelihood of adverse business outcomes being suffered by third parties. They succeeded in enmeshing the counterparties in web of contracts characterized by increasingly correlated risks of mutual default, thereby obviously vitiating their ostensible usefulness as a means of diversifying against prudential and systemic risk.

The scope for banking and financial intermediaries to explore how they best could provide their customers and clients with these new and intriguingly lucrative "services" was expanding steadily in the U.S. throughout most of the 20th century's closing quarter – without drawing much general notice. This transformation of a previously staid and stolid branch of business, often disparaged by outsiders as "necessary but boring", had been accomplished incrementally by successive legislative steps that modified and blurred the sharp separation of commercial banking from investment banking activities – a separation that had been imposed in the U.S. by the passage of the Glass-Steagall Act during the Great Depression. The ultimate repeal of Glass-Steagall during the final year of the Clinton Administration therefore was largely symbolic, for by then most of the work of deconstruction had already been accomplished – certainly as far as concerned the operations of the large commercial banks.[25]

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[24] This shared aspect of financial and technological innovations is developed further, below, in the concluding section.

[25] Charles C. Wang and Y. David Wang, in a recent paper ("Explaining the Glass-Steagall Inertia", Department of Economics, Stanford University July 20, 2009) show that that pressure for sweeping reform or repeal of the Glass Stegall Act in the early post-WWII era had been alleviated by the exploitation of loopholes in the 1933 statute. These limited the effectiveness of the Act's separation of investment banking from commercial banking, while leaving unaffected Senator Glass's long-sought objective of instituting federal bank deposit insurance. The effect of the former was to reduce the intensity of lobbying for the statute's repeal by the large commercial banks, whereas that of the latter

Yet, that symbolism heralded the onset of a still more permissive, deregulatory impulse in both the Congress and the agencies of the federal government under the administration of President Bush. The resolute "economic liberalism" animating Chairman Greenspan's resistance to exercising the supervisory powers and regulatory authority of the Federal Reserve System over innovative financial instruments and banking practices was paralleled by the recalcitrance of the Securities and Exchange Commission to subject investment banks to controls that would disadvantage "New York" in competition with the City of London and other international financial centers.

Thus released from externally imposed checks on the impulse to seek greater profit through greater "leverage," positive feedback effects in the interactions among financial institutions were able to grow in power: they rushed to follow one another into new and riskier practices – finding reassurance about their comparative competitive vigor, and the illusion of "safety in numbers" in striving to maintain parity with their rivals and peers in their pursuit of ever more dubious lending practices. The magnitude of the destructive social consequences that can issue from allowing explosive economic processes of this sort to take hold of substantial claims on a "hyper-connected" system's assets are now only too familiar.

Closing reflections on the fraying nexus between financial instability and real economic growth in the 21st century

The excesses of the recent financial boom in the West and the ensuing global credit crises are not really new developments in the history of market economies, as Reinhart and Rogoff, and others before them have noticed.[26] One aspect, however, may be seen to be a signal of novel things to come while manifesting the familiar susceptibility of capitalist systems to this form of macro-instability. Nothing about that should be regarded as paradoxical: the discontinuous advent of novelties such as speciation in biological evolution is rooted in the continuity of mutant organisms' genetic endowments with that of their ancestors.

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maintained a congressional base of support for the Glass-Steagall Act's perpetuation – particularly among representatives of the interests of the country's less capitalized unit banks and the communities they served. As information technologies facilitating financial transactions and securities trading improved during the 60s to the 80s, however, changes in the competitive landscape marginalized U.S. commercial banks' relevance while weakening their ability to compete both at home and abroad. The wave of technological and regulatory changes that responded to that threat, being designed to improve the commercial banks' revenue growth and relative profitability, combined with repeated failures of more radical legislative proposals to find broad political support in the Congress during the 1980's and 1990s, allowed the Act's continuing survival in the statute-books. Wang and Wang argue that the eventual repeal of Glass-Steagall by the Gramm-Leach-Bliley Act of 1999 was the resultant of an essentially extraneous occurrence during the euphoria of the emerging Internet boom: the merger between Citicorp and Travelers Insurance in 1998, and the widespread perception that the latter would be a smashing business success, created sufficient political enthusiasm to overwhelm the factional conflicts that had doomed previous legislative efforts at reform.

[26] See C. M. Reinhart and K. S. Rogoff, *This Time Is Different: Eight Centuries of Financial Folly*. Princeton, NJ: Princeton University Press, 2010. This work is discussed in P. Krugman and R. Wells, "Our Giant Banking Crisis," The New York Review of Books, LVII(8), May 13, 2010:pp.11-13. Also, see, e.g., C.P. Kindleberger, *Manias, Panics and Crashes: A History of Financial Crises* 4th Edition. Hoboken, NJ: John Wiley & Sons., 2000. C.P. Kindleberger and R. Z. Aliber, *Manias, Panics and Crashes: A History of Financial Crises*, 6th Edition, forthcoming from the same publisher in 2010.

What we have recently experienced in the confined, high-frequency dynamical behavior of the U.S. national stock market on 6th May, and also in the property-finance-and-derivatives boom and crisis, are resultants of innovations that have affected and thereby disrupted both the sphere of technical affordances and the sphere of institutionalized regulatory structures. The synchronicity of the latter disruptions in each case, and in still others, is not entirely accidental.

Rapid advances in digital technologies, accelerated by the "connection-less" architecture of the Internet have enormously expanded possibilities of effecting conditions of hyper-connectivity in specific forms of transactions among human agents and machines ('things'). That modern society's augmented facilities in these respects have tended to outrun its capabilities for creating networked *communities* (in the particular sense of the term that has been invoked here) is neither a mere coincidence nor the product of concurrent independent processes one of which inherently moves at a slower pace than the other. Technological innovations engender positive private forces that contribute that the observed lag response in "governance," as has already been noticed. The business models of the operators of new electronic stock exchanges, like those of the small high-frequency trading firms that flocked into the national stock market, were aligned with and so worked to perpetuate the condition of high price volatility that normally is found in "thin" unregulated markets.

Thus, proximate reasons for the absence of mechanisms that would slow trading on the satellite electronic exchanges (paralleling the mandated cross-exchange "circuit breaker" regulations) can be found in the institutional consequences of the technical novelties that were driving alterations in the NMS's structure. Much of the volume of trading came to lie beyond the established ambit of the regulatory agencies, even though the registered equity and equity futures exchanges remained in other respects well within the jurisdictions of the SEC and the CFTC. Therefore, even if one leaves out of the picture the growing importance in the NMS of the unregistered "dark pools", there is a striking parallel between this aspect of the genesis of the May 6th "market break" and the failed regulatory supervision of the "shadow banking" system that had expanded quickly following the Glass-Steagall Act's repeal and the introduction of loosely regulated innovative financial instruments such as the CDOs and CDSs.

The riskiness of the CDOs would have been difficult for the rating agencies to establish accurately, even had they stronger incentives to do so, because the underlying packages of variegated mortgages were not like the usual assets against which corporate and government debentures conventionally were issued. As for the CDSs, being a form of insurance that deviated from conventional insurance contracts sufficiently for the firms writing them to make the case that they really were not insurance of the kind that called for the issuers to hold capital commensurate with the obligations they represented. Freed from the restraints that would otherwise have been placed upon their use within the regulatory jurisdiction of both the SEC and State commissions responsible for regulating the insurance industry, these devices for increasing "leverage" multiplied until they represented obligations far greater than even the most optimistic valuations of the assets they ostensibly were supposed to be insuring.

Situations of this sort occur repeatedly, in large part because established governance procedures and regulatory structures affecting transportation, communication or other network industries, and the contractual networks of banking and finance, historically have tended to be specified with reference to specific, widely-deployed technical or legal modes of transaction. They pertain not to generic functions, but specifically to the uses of railways, airplanes, and motor trucks, or telegraphy, telephones, radio and television systems, and to specific types of businesses (deposit banks, investment banks, and mutual saving associations) or to particular, classes of financial securities and contractual agreements. Legislative statutes addressing problems encountered with particular practices, especially technical practices, thus tend to confine themselves to dealing with the identified specific context of perceived dysfunctional outcomes. Rarely does social "rule-writing" for these domains tackle the generic goal, aiming to establish procedures that would achieve and maintain acceptable *standards of performance* for larger classes of socio-technical systems – including those who imminent emergence can be envisaged.

Rapid technological innovation, however, by creating novel and more effective means of connectivity, and permitting or inducing experimentation with new business models and other social practices (e.g., summoning "flash mobs") thus is able to have doubly disruptive effects, whether intended or not. In addition to their impacts upon the users of established technical practices, they induce the introduction of novel "forms" that more readily can escape the confines of the polity's legislative and administrative spaces. "Regulatory by-pass," permitting the formation of incompletely regulated or socially uncontrolled new businesses and technological systems can be an unplanned consequence of innovative activity. But the prospective profits to be reaped from successful regulatory by-pass also may be one of the strategic drivers of private investment in the deliberate design and implementation of system-disrupting innovations.

Modern societies, through their rush to create innovations in digital communication technologies and information processes, therefore may be creating a future multitude of emerging "networked exchanges" for which they continually will be failing to provide timely structures of governance, and passively encouraging fragmentation of previously integrated communities whose once functional interactions were sustainable but are becoming less so. This tendency might be tolerable as the regrettable cost of continuing economic dynamism. Indeed, some may be inclined to hail the consequences of the race in which innovation always stays a step ahead of governance and thus forms liberated spaces for the growth of profitable productive enterprises – portraying this process as the essential feature of "creative destruction" seen by Joseph Schumpeter to be inherent in capitalist economies' growth and development.

A judgement of that kind risks taking optimism to the limit of blindness, or denial of the possibility that we may no longer be living in the world that Schumpeter saw. Having highlighted salient historical continuities in the structural formations that are likely eventually to manifest themselves in transient market malfunctions and more profound financial crises that implicate real economies' abilities to fully utilize their productive capacities, it is necessary to conclude by drawing attention to a worrisome new departure in the workings of market capitalism that has become more obtrusive in recent years. Schumpeter's theory of economic development, one should

recall, integrated real and monetary dynamics by assigning a central role to the financial accommodation of investments directed toward industries that would supply new products, or to the production of familiar goods and services by radically novel technologies. Credit-fuelled investment "manias" that involved experimentation with the use of novel financial instruments as well as reliance on familiar practices in banking and finance, were a recurring feature of the capital formation booms that figured in Schumpeter's schema; these movements were "excessive" in the sense that they were likely to outrun the expansion of consumption demand required to fully utilize the productive capacity that was being brought into existence.

The ensuing collapse of the final wave of real but nonetheless "speculative" investments, and the ending of the mania in a financial crash, thus are closely coupled events in the Schumpeterian business cycle model. Nevertheless, the manias' latent function -- a modern sociological construct that Schumpeter did not employ-- could be seen to have been that of effecting temporal coordination in the undertaking of many infrastructure investment projects whose "lumpiness" and complementary relationships made the commercial viability of each project interdependent with that of the others. None of those enterprises might have been successfully launched, but for the unreasoned optimism that had simultaneously animated their promoters and overwhelmed dispassionate recognition of the hazards of undertaking any one of them with without assurances of the others' being completed.

That the new capital structures erected in those episodes of over-investment were tangible and durable was a crucial analytical supposition of this analytical scheme, and it was an equally important premise for Schumpeter's sanguine normative stance regarding the cyclical instability of the macroeconomic growth process. He saw successive waves of temporarily "excessive" investment as having each left in its aftermath more efficient systems of production and distribution whose expanded capacity was available for more intensive exploitation during the ensuing phases of recovery. Indeed, their eventual utilization in the post-crisis phase of recovery was the source of the secular upward course of real income and wealth in those societies from the Industrial Revolution of the late 18th century onwards. In this account of capitalist development, the positive trend is inextricably connected with the phenomenon of cyclical instability.

But it has become harder to see such a dynamic at work in the present century, where the investment manias associated with the "dot.com boom" and the "home mortgage and financial derivatives" bubble are popularly likened to the Tulip Mania of the Netherlands' Golden Age – an arcane topic in the annals of speculation schemes that until lately occupied the attentions of few people other than the social and economic historians studying pre-industrializing and financially interconnected regions of Northern Europe in the 17th century. The common thread tying the Dutch Tulip craze to its early 21st century counterparts -- and distinguishing all of them from the intervening historical succession of investment manias -- is that after they had "crashed" so little in the way of enduring productive assets was left behind.

More disturbing still, the latest episode would seem to have surpassed the turn-of-the-millennium boom in that dubious respect. The latter movement saw the excessive investment exuberance ignited by the Internet's advent become a scramble to subsidize the concentration of web traffic on competing websites and portals, and

eventually animate investments in Internet's infrastructure layer. While it precipitated some spectacular mergers and acquisitions among telecommunications companies, the firms in that industry also were putting into place much new bandwidth predicated on expectations of continued hyper-exponential growth in web traffic. The mass of "dark fibre" that was left behind after 2001 certainly weighed heavily, for a time, upon the fortunes of the telecommunication corporations that owned it. But those real investments subsequently contributed substantially to the failure of the predicted congestion of the Internet to materialize during the years that followed. Viewed against that standard, the most recent episode of reckless mortgage investment in which global banking and financial institutions allowed were allowed, and allowed themselves to be caught up -- for the purposes of housing refinance and residential tract-building in arid regions remote from urban employment centers in California, Nevada and Arizona -- must be judged a largely sterile speculation.

If that is a harbinger of the future, it is a worrisome harbinger of a phase of sterile instability in the dynamics of capitalist "information societies" that focus their people's creative energies and imagination almost exclusively upon enabling new forms of "hyper-connected exchange networks," rather that on the challenge of creating "network communities" that can effectively govern the complex socio-technical systems they have built.

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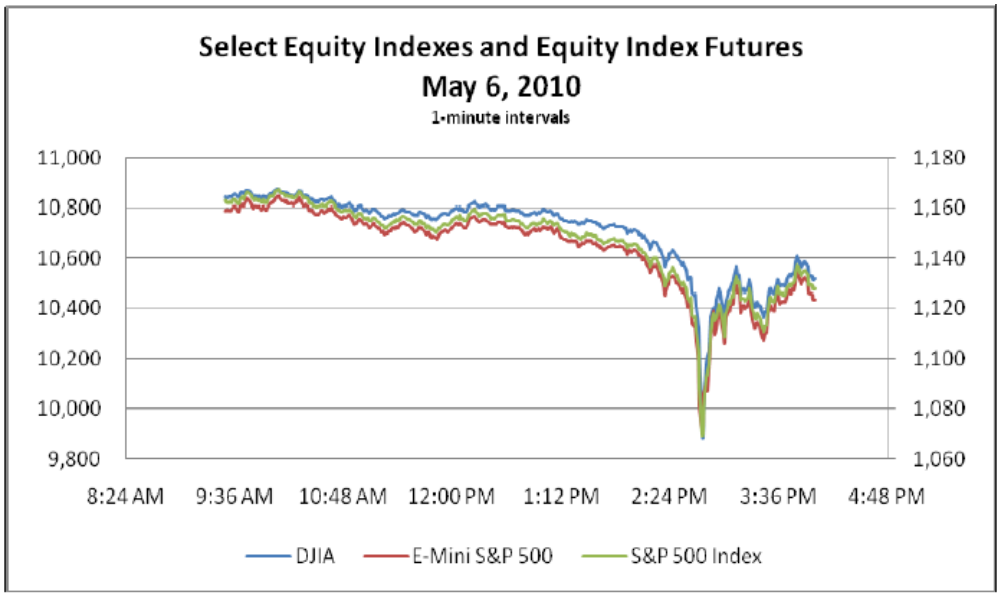

Figure 1

Source: http://www.sec.gov/sec-cftc-prelimreport.pdf:p. 17 (underlying data from *Bloomberg*)

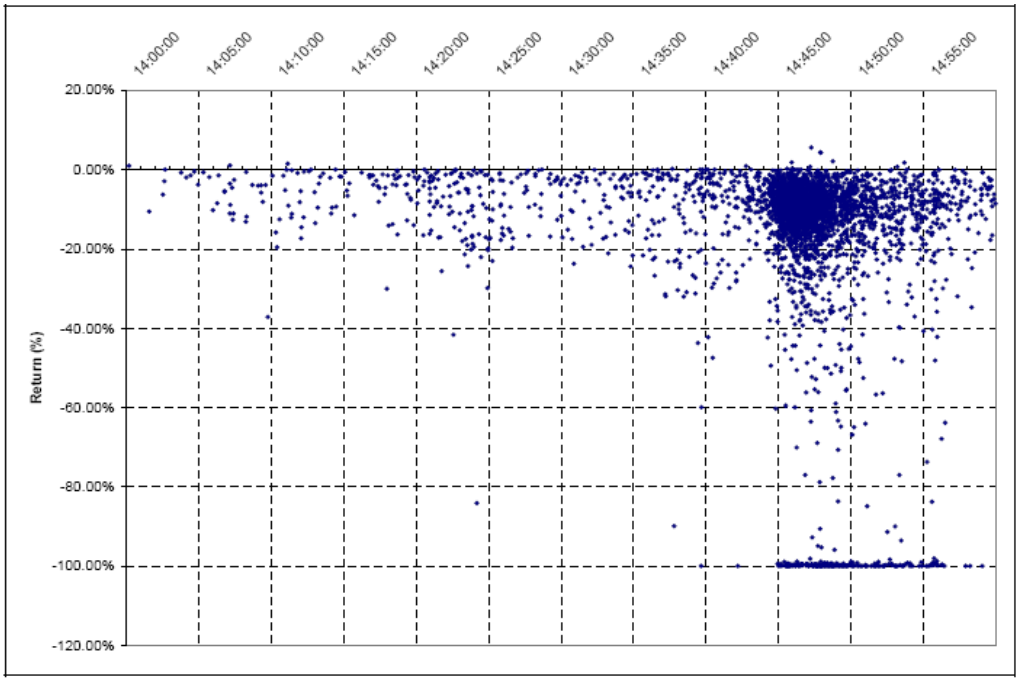

Figure 2

***Notes:* Fig. 2 depicts** e timing of daily lows during the one-hour period from 2:00 p.m. to 3:00 p.m. on May 6. Each point represents the return from the May 5 close to the lowest transaction price on May 6, plotted against the time at which the transaction occurred. Daily lows not occurring during this one-hour interval are not depicted. The figure includes all equity securities (common and preferred) of corporate issuers, exchange-traded products, closed-end funds, and ADRs, traded on major U.S. exchanges, with a share price of more than $3.00 and a market capitalization of at least $10 million as of the May 5 close.

Source: http://www.sec.gov/sec-cftc-prelimreport.pdf: p. 24. (Underlying data from *Thompson Financial Datastream and NYSE Trades and Quotes.*)

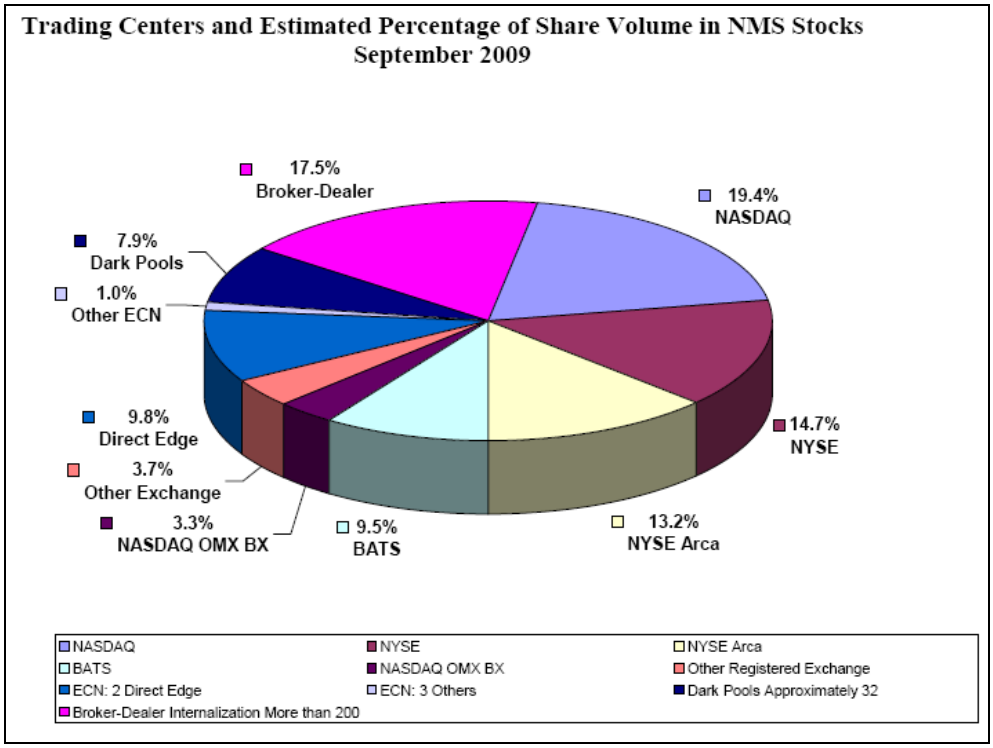

Figure 3

Source: http://www.sec.gov/sec-cftc-prelimreport.pdf Appendix A: p. A-3.