THE OVER RELIANCE ON EFFICIENT CAPITAL MARKET HYPOTHESIS IN UNDERSTANDING AND REGULATING THE STOCK MARKET: The Need for an Interdisciplinary Approach Appling Chaos Theory

> "On Monday, October 19, 1987 – infamously known as "black Monday" – the Dow fell 508 points, or 22.9%, marking the largest crash in history. Using an analytical approach similar to the one applied to explore heart rates, physicists have discovered some unusual events preceding the crash. These findings may help economists in risk analysis and in predicting inevitable future crashes."[1]

The above quote reveals the importance of new cross disciplinary methods being utilized to help society better understand the nature of the stock market. There is a strong reliance on the Efficient Capital Market Hypothesis ("ECMH") economic model as a basis for our understanding of the stock market[2], its prices, movement, risks, and the rational for its regulation. ECMH is only an economic model attempting to approximate the human interactions within the stock market. I suggest that society overly relies on this approximation, providing it with the same weight as Newtonian physics when compared to Relativity.[3] Though Newtonian physics may have wrong assumptions regarding the nature of our physical world, we will likely not encounter them in our day-to-day lives. However, as relativity shattered Newton's beliefs about time and space, I believe that quantum physics, chaos theory and behavioral finance will do the same for many of the assumptions of ECMH. Furthermore, these scientific revelations will have much more of a significant application in our daily lives.

<u>Overview</u>

I will quickly explain the basics of the Efficient Capital Market Hypothesis, which is the undertone of much of U.S. securities regulations. Then I will address the method of stock market risk analysis used by investors and investment advisors. Next, I will provide evidence of the ineffectiveness of theses theories in accurately describing the nature of the stock market. I will show how scientific advancement has and may continue to explain the nature of the stock market and investment theory, where the traditional theories have failed. Finally, the practical application of the cross disciplinary approach will be evaluated from radical new studies and models to the best future direction of stock market analysis. Ultimately, it is my goal to provide a new vantage point to view stock market dynamics and to challenge the continued reliance on old ideas relating to it.

Efficient Capital Market Hypothesis

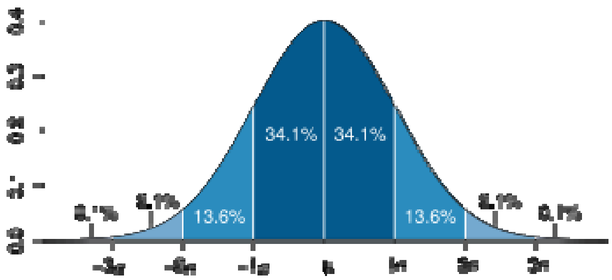
In essence, ECMH states that all investors know the probabilities of returns on stocks, act rationally based on these probabilities and thus stock prices are reflective of this properly interpreted public information.[4] Therefore, stock prices reflect the intrinsic[5] value of their companies.[6] ECMH assumes that the stock market is competitive, information is freely accessible, investors act rationally, the costs of transactions are low and investors only receive above market returns due to chance.[7] As a result, a fundamental principle of ECMH is that it is not possible for investors to "beat the market" on a "risk adjusted basis." Beating the market means consistently achieving returns in excess of other investments, which bear the same level of risk, over a long period of time.[8] The "random walk model" is an outgrowth of ECMH and holds that, though stock prices are based on their intrinsic values, its movement is random.[9] More specifically, this randomness in stock price movement is because prices accurately reflect all public information, so any successive movement in prices is independent of past price movement, and due only to unexpected information recently made public.[10]

The ramifications of the ECMH are staggering. First, using an investment advisor would be pointless.[11] If stock prices reflect all available information about their companies, then they cannot be undervalued or overvalued. [12] Accordingly, attempts to increase profits through the use of fundamental analysis are impossible.[13] Furthermore, if stock movement is random then technical analysis would also be a futile venture.[14] There would be no patterns to identify in past stock price movement.[15] Finally, unless an investor had access to inside information, it would not be possible to "time" the market, because only an insider would know, before the public, when positive or negative information regarding a company would be released.[16] However, under ECMH it would still be important to evaluate the level of risk associated with an array of investments.[17] Therefore, it is important to understand how ECMH has affected investor assessment of investment risk.

<u>How Risk is Assessed</u>

Under traditional market analysis, stock market fluctuation presumably moves in a normal (or bell shaped curve- see Graph 1 below), where the mean, the expected return of the stock market (or an individual investment), is the peak of the curve, and the probability of future price fluctuations is described by the area underneath the decreasing "arms" of the curve.[18] Thus, analysts calculate the probability that a portfolio of investments will be within a finite range by looking at the portfolios standard deviation from its mean (expected return).[19] The standard deviation is based on the past variance of stock prices.[20] Applying the central limit theorem, the probability that stock prices will vary more than three deviations from the mean is less than 3%.[21]

Graph 1: **Normal Distribution**



Dark blue is less than one standard deviation from the mean. For the normal distribution, this accounts for about 68% of the set (dark blue) while two standard deviations from the mean (medium and dark blue) account for about 95% and three standard deviations (light, medium, and dark blue) account for about 99.7%.[22]

The Modern Portfolio Theory ("MPT") is used to insure that an investor picks the optimal portfolio of stocks.[23] MPT is the process of reducing risk through diversification and maximizing an investor's expected return as it relates to their risk.[24] Under this theory there are two forms of risk, market (systematic risk) and asset specific risk (non-systematic risk).[25] Asset specific risk is the risk associated with a specific investment, like an unexpected strike in a company. [26] Therefore, if an investor diversifies their portfolio amongst a large number of stocks, that are not closely correlated, they can eliminate their asset specific risk.[27]

On the other hand, market risk is the risk of events that affect the whole market or a substantial portion of it, such as an unexpected increase in interest rates, war or recession.[28] Because market risks affect all stocks, they cannot be eliminated through diversification. Instead, investors should identify the market risk associated with their individual investments. An investments specific market risk is called its "beta;" which is the measurement of how sensitive an investment's return is to fluctuations in the market.[29] The stock market is set as the average level of risk, so that it has a beta of one, and the closer a stock's beta is to one, the more likely that it will move with the market.[30] Furthermore, it is believed that a high beta risk is correlated with a higher expected return.[31]

The reason that an investor will receive a lower return (or "reward") for lower levels of market risk is explained by the Capital Asset Pricing Model ("CAPM"). Under the CAPM all investments reward-to-risk ratios, their expected return over market risk (beta), are equivalent to that of the overall market.[32] This means that it is not possible (on a risk adjusted basis) to "beat the market," [33] because to increase your expected return you pay the price of more risk (risk premium).[34] In other words, no matter what techniques an investor employs, he cannot get higher returns on his investments than others with the same risk. The proportional increase in expected return to market risk is a linear relationship, which can be graphed on the "security market line."[35] The linear risk to return relationship occurs due to the rational competitive behavior of investors, asserted by the ECMH.[36] Basically, the drive for profit will tend to eliminate any obvious opportunities for abnormal gain" (an imbalance between expected return and risk).[37] Similarly, proponents of ECMH argue that if inefficiency existed in the market, any investment strategy used to capitalize on it would be adopted by other investors, thus eliminating inefficiency.[38]

Now that we have explored the concepts that the ECMH, related theories and how investors apply those ideas to assess and reduce their risk, we will identify areas in which ECMH has influenced securities regulations. A major goal of acts which regulate securities is disclosure ("the Big D").[39] "The primary purpose of the Securities Act of 1933 [("1933 Act")] is to compel full disclosure of all material facts in public offerings."[40] The Securities Exchange Act of 1934 ("1934 Act") regulates the exchange of outstanding securities requiring issuers to continuously disclose material facts.[41] Through the Securities Acts, Congress hoped to create efficient capital markets, which would accurately reflect all available information and thus restore investor confidence.[42] If investors believed that stocks accurately reflected their intrinsic value, investors would be able to better assess the risk and returns of stocks,[43] and investors would be willing to invest, insuring the growth and stability of our economy.[44]

One of the best known prohibitions of securities fraud is the ban on insider trading. [45] The semi-strong ECMH theory states that only those with insider (non-public) information would be able to beat the market.[46] Thus, these insiders would have an unfair advantage, being able to receive profits from asset specific events, where others would not. An insider would have a higher expected return despite taking a much lower risk and thus would be above the Security Market Line.[47]

Furthermore, under NASDAQ and New York Stock Exchange ("NYSE") suitability rules, a stock broker can only recommend stocks to clients that he/she reasonably believes are appropriate for the customer, based on the client's tolerance for risk; which is assessed through traditional methods, based on EMCH[48] Additionally, banks use traditional risk assessment tools to estimate the value of their market investments because they are required to keep a percentage of their holdings in cash.[49] Therefore, methods of risk assessment become important in aligning a client with investments that provide him/her with the right level of risk as well as in helping banks protect consumer's funds from loss. However, are the current disclosure requirements and penalties for fraud, based on EMCH, sufficient to protect investors from unexpected moves in the market? Do today's regulations and reliance on the ECMH ensure that investors are aware of the risk they are taking on their investments?

<u>Evidence against ECMH: MPT & Normally Distributions</u>

New evidence of the lack of market efficiency is providing support for the growing sentiment against reliance on ECMH. For example, a recent study explained that shares of Shell were trading at a different price in London than in Amsterdam. [50] The only difference between the shares was that in Amsterdam, Shell is called Royal Dutch.[51] This same study showed that mutual funds trade at different prices than the value of the underlining stock.[52] The author argues the application of behavioral finance, which, contrary to EMCH, shows that investors often do act irrationally and that this irrational behavior has a significant long lasting impact on stock prices.[53] This irrational behavior is known as "noise" in stock market prices.[54] Another significant inadequacy of ECMH, which is addressed by behavioral finance, is the inability to explain large market crashes.[55] Under the traditional normal probability distribution model embraced by ECMH, the one day market declines in August of 1998 (of 3.5%, 4.4%, and 6.8%) had a 1 in a 20 million probability of occurring.[56] Even more astounding is that the 29% decline on October 19th, 1987, had a 1 in 50 billion probability of occurring.[57] Therefore, an investor who as assessed their risk under traditional (ECMH related) approach, applying normal distributions, and linear relationships, did not account at all for the possibilities of these crashes. This shows the importance of finding new methods to account for what ECMH cannot.

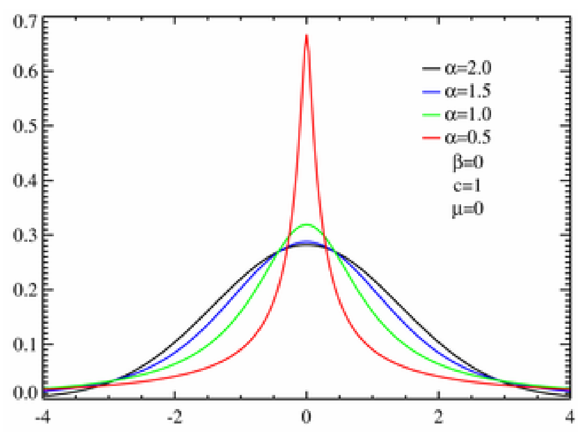
Fat Tails Why Normal Distributions are Wrong

To explain why the ECMH is unable to predict large movements in stock prices, it is helpful to look to its origins, the normal distribution. The normal distribution first gained acceptance after mathematician Carl Gauss applied the concept to estimate the probability of errors in experiments.[58] Using Gauss' method (the normal distribution or Gaussian distribution) scientists could account for random errors and then discount them in their experiments.[59] A good way to understand how a normal distribution works is to think of a coin toss.[60] The probability that on average a coin will turn up heads or tails is 50/50, therefore on average the probability that it will turn up heads more often than tails is zero.[61] This is because each subsequent coin toss is independent or is not affected by the previous toss.[62] However, in tossing a coin, you will sometimes get heads and sometimes tails. [63] Still, the theory states that in the long run random occurrences, like the number of times you get heads over tails will move to zero, or toward equilibrium. [64]

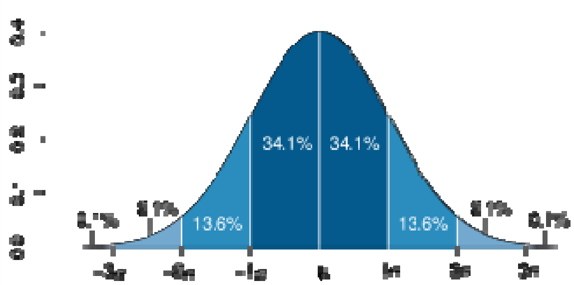
In the early twentieth century, French scientist Louis Bachelier applied the concepts of the diffusion of heat to the movement of bond prices.[65] He found that these changes in prices followed a normal distribution. [66] Therefore, he believed that bond price movement up or down, like the chance that flipping a coin would turn up heads more often than tails, was random. [67] Also, like flipping a coin, past movements in price had no effect on future movement. [68] He reasoned that bond prices must embody all known information, and despite any slight movements bond price on average would move toward the current price. [69] The only thing that would change the probability that prices would move in a specific direction was new information that would make the bonds more appealing to investors. [70] Thus, out of the ideas of what would be ECMH, modern finance was born. [71]

Today, "organizational researchers [like economists and stock analysts] presume Gaussian (normal) distributions, with stable means and finite variances, with appropriate statistics to match."[72] The problem with assuming that stock prices are random and follow a normal distribution is that this does not account for probability of large price movements, of big crashes or surges in the market.[73] These extreme probabilities are called "fat tails," because distributions that take into account these extreme events when graphed have a larger area under the tails of their distribution than the normal distribution (compare graph 3 and graph 4 below).[74] Normal distributions discount these events as outliners. For example, under traditional statistical analysis, "financial market drops of 10 percent in one day should occur once every 500 years."[75] In reality market crashes happen approximately every five years. [76] In an attempt to rescue the normal distribution, the GARCH[77] distribution was introduced.[78] In the GARCH the "bell" curve (of a normal distribution) vibrates. As volatility in the market increases, the normal distribution increases to allow for greater variance in stock prices and when volatility decreases it shrinks back down.[79] However, even with this adaptive method, 90% of extreme movements are not accounted for.[80] The persistent problem is that these distributions (and ECMH) are anchored in the false idea, that the stock market is a linear system.[81] Therefore, stock price movement is independent from past movement (random), investors are rational and perfectly competitive, eliminating any investment or strategy that would allow one to beat the market.[82] Recall that the MPT and CAPM dictate a linear relationship between expected profit and risk: the level of return varies in proportion to the level of risk taken on. Also, that all market information is processed by investors linearly, information about stock prices become public and people act rationally, and the information causes a proportional effect on stock prices.

Graph 3 Levy "Fait Tail" Distribution



Graph 4 Normal Distribution



According to chaos theory and fractal geometry, the future movement of stock prices are dependent on the past movement of stocks.[83]

Non-Linearity and Chaos Theory

However, contrary to the belief under MPT and CAPM, the stock market is a dynamic (or non-linear) system. [84] Chaos theory is the study of these dynamic systems.[85] Many systems in life are dynamic, such as the beat of your heart, evolution, and even the structure of your brain.[86] Unlike linear systems, dynamic systems do not react proportionally to changes.[87] Additionally, there is no one simple cause for the changes in a dynamic system. For example, counter to ECMH, relevant new public information is not the *only* factor that affects stock prices. Current changes in dynamic systems, such as movement in stock prices, are dependant on past changes, like past stock price movement. [88] An underlying principle of chaos theory is the concept Sensitive Dependence on Initial Condition (a.k.a. the "Butterfly Effect"). [89] Sensitive Dependence on Initial Condition states that the smallest change in the initial state of a dynamic system has a drastic effect on its future behavior.[90] This explains Bachelier and later economists' belief that stock prices moved in a random walk. The slightest miscalculation of what affects stock prices would cause any long-term predictions to be widely inaccurate making the movement of prices look totally random.[91] For example, the scientist who discovered this phenomenon, Edward Lorenz, attempted to use computer models to predict weather patterns. [92] He found that when he changed the initial input into his model by .0001 the prediction of the model was widely different than the previous prediction (see graph 5 below). [93] Therefore, it seems that it is impossible to accurately predict the changes in dynamic systems like the stock market, as we cannot accurately account for all the factors that effect stock price movement. [94] However, chaos theory stands for the idea that that we can find an underlying order to apparently random and difficult to predict dynamic systems. [95]

Graph 5: The beginning of Lorenz's graph remained the same, but drastically changed its path overtime. Imagine if this was a prediction on stock prices. Investors would invest when the market was about to crash instead of boom.

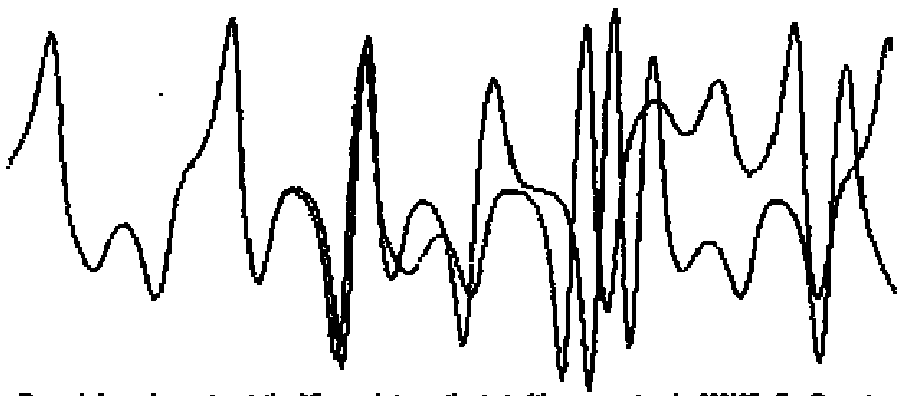


Figure 1: Lorenz's experiment: the difference between the start of these curves is only .000127. (Ian Stewart, Does God Play Dice? The Mathematics of Chaos, pg. 141)

Basically, the application of chaos theory to the stock market suggests that movement in the market is not random, but like other dynamic systems, is self similar. Self similarity states that dynamic systems have repeating patterns when viewed from different scales, called fractals.[96] In the stock market if you look at the fluctuation of prices for the right period of time, for example one day, or one month, the movement over this period of time may be a scaled down version of how the market as a whole will move over a longer period of time.[97] For example, while studying the movement of cotton prices, the father of fractal geometry, Benoit Mandelbrot, found that:

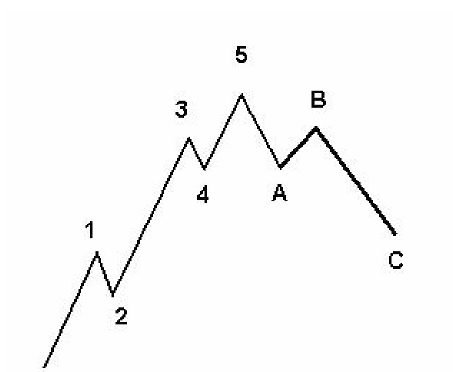
> The numbers that produced aberrations from the point of view of normal distribution produced symmetry from the point of view of scaling. Each particular price change was random and unpredictable. But the sequence of changes was independent on scale: curves for daily price changes and monthly price changes matched perfectly. Incredibly, analyzed Mandelbrot's way, the degree of variation had remained constant over a tumultuous sixty-year period that saw two World Wars and a depression.[98]

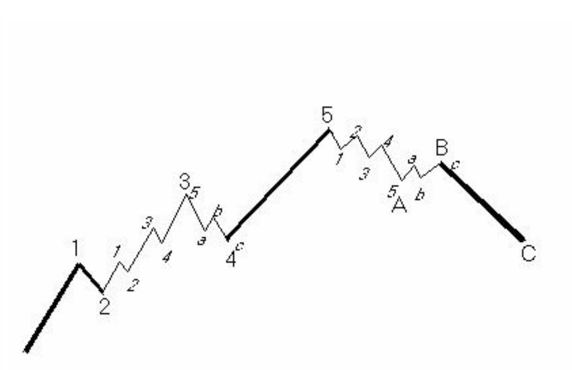
Therefore, self similarity creates the amazing possibility that complex systems like the stock market,[99] or even the human body may be governed by simple rules or equations.[100]

> Researchers discovered a simple set of three equations that graphed a fern. This started a new idea - perhaps DNA encodes not exactly where the leaves grow, but a formula that controls their distribution. DNA, even though it holds an amazing amount of data, could not hold all of the data necessary to determine where every cell of the human body goes. However, by using fractal formulas to control how the blood vessels branch out and the nerve fibers get created. [101]

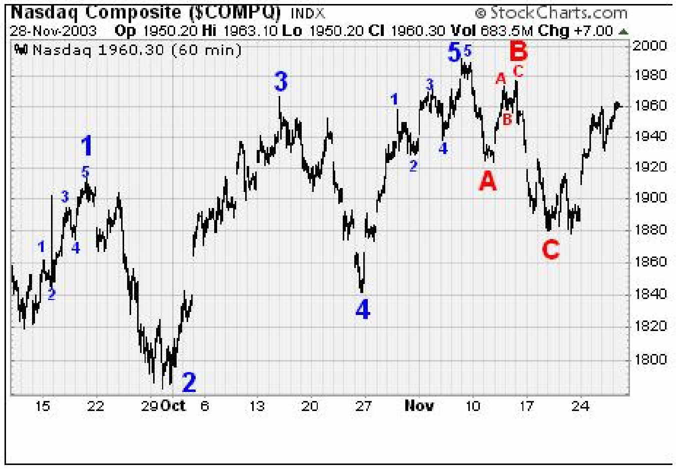
Though precisely predicting stock movement using chaos theory is impossible, it may help us to identify patterns that emerge at critical times and equations to identify the limits of stock market movement.[102] In fact, even the Golden Ratio (based on phi) and the Fibonacci Sequence have been used to predict market movement.[103] For example, in the 1930s Ralph Elliot used the Fibonacci Sequence to form his theory that market prices move in waves, "five waves up and three waves down."[104] Further, more that these waves are self similar in that, embedded in the five-three large movements in stock price, was the same movement on a smaller scale (see graphs 6 & 7 below).[105] Elliot believed that people mimicked each other's investment behavior ("crowd behavior"), causing stock prices to move in clusters or waves. [106] Though some are skeptical of the accuracy of Elliot's Wave theory, it shows how the ideas of chaos theory can be used to identify predictive patterns in the market and how these patterns may be explained by investors' irrational behaviors.[107]

Graph 6: Elliot's Large Waves[108] **Graph 7: Waves embedded in Larger Waves**[109]





Graph 7: Elliot's Waves- NASDAQ Composite during 2003[110]



In the 1980's, a pair of scientists, Doyne Farmer and Norman Packard, used chaos theory not to predict how the market would move, but where a roulette ball would land.[111] Doyne Farmer and Norman Packard used mini computers hidden in their shoes to identify the probabilities that the roulette ball would land on each number. [112] The mini-computes would apply algorithms, based on chaos theory, to change the odds in roulette in their favor. [113] They soon realized that they could make a much more lucrative career by applying chaos theory to predict stock market movement. [114] So they hired additional scientists and started the Prediction Company. [115] The Prediction Company uses theories of chaos and evolution to create "complex adaptive ecosystem models" that are not constrained by the ideals of ECMH, but are more inline with the numerous and ever changing factors that effect market movement.[116] Since the company was established they have been successfully managing the funds of big banks as well as that of high wealth individuals and institutional investors. [117]

Another group of scientists from the University of Tokyo believe that by using chaos theory they have identified predictive patterns in the fluctuations of stock prices preceding the 1987 crash in the S&P 500.[118] A year before the 1987 crash, the stock market no longer seemed to be moving randomly, but became scale invariant (self similar).[119]

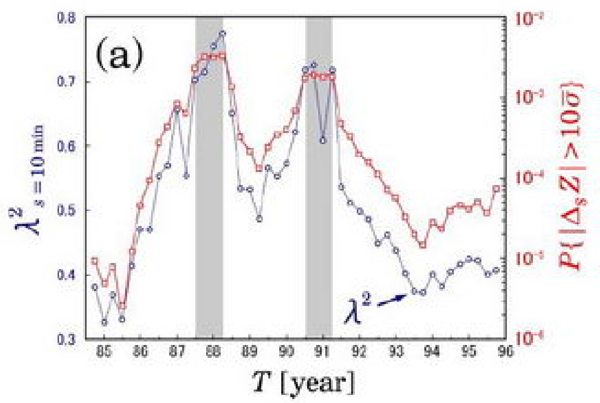
Thus, the probabilities associated with large price fluctuations of stock prices, over a ten minute period, reflected that of the market over longer periods of time.[120] In other words, the probable movement of the stock market remained constant regardless if one looked at market fluctuations over ten minutes or say ten days.[121] Furthermore, when applying a non-normal probability analysis that assumed fat tails, the scientists realized that as October 19th, 1987 approached, the probability of a large market crash increased.[122] Thus, the market was moving toward a critical point (Black Monday) at which the market would crash.[123] By applying a non-normal probability distribution over the traditional normal distribution demanded by ECMH and portfolio theory, investors may be able to better assess their risk levels, accounting for extreme price movement.

The scientists believe that a possible reason for the 1987 crash was the large price fluctuations over small periods of time (like ten minutes).[124] These small scale fluctuations "rapidly grew through internal interactions in the stock market" and caused "highly clustered behavior of traders" all selling at the same time.[125] Therefore, the movement of the market itself could have dictated investment decisions. This result is considered impossible under the ECMH because it has nothing to do with the intrinsic value of the stocks themselves and the price movement was not random but it mirrored and lead to later market movement. Furthermore, this gives credence to trend analysis and market timing, which may have been able to identify the pattern of increased price volatility and the invariance of that volatility.

Furthermore, these patterns may be used to identify when the stock market is reaching a "critical point" and thus help to predict and prevent market crashes and better assess portfolio risk.[126] These predictive patterns could be used to establish early warning systems or better controls to prevent or reduce an impending crash.

However, an interesting qualification of these patterns is that they are only predictive of when the stock market is reaching a critical point internally. [127] External factors like war or economic crashes in other countries may cause a “phase shift,” thus eliminating the predictive pattern in the market. [128] For example, fluctuations similar to those that suggested the crash of 1987 were evident in 1990, but a phase shift occurred due to Desert Storm, and a crash did not occur; instead of reaching a critical point the market only slowed (see Graph 8 below). [129]

Graph 8: Showing the 1987 Crash & 1990 near Crash[130]



“This graph shows the probability of 10-minute price variations during 1984-1995. The significant increase in 1987 resulted in black Monday, and the increase in 1990 did not result in a crash, likely because of the influence of the Iraq-Kuwait and Gulf wars causing sluggish stock activity.”[131]

Therefore, I believe that events that cause drops in the market and slow market advances, may provide an important tool to prevent larger sustained crashes. These events may act as positive corrections, by dampening speculation in a bull market and thus prevent a bear market.[132] The resulting market drop may act as a negative feed back loop,[133] because it would reduce investors herding behavior, by reducing overconfidence in the market. Thus, irrational investment will decrease and the market will slow and become stabilized. On the other hand, negative events that over correct may cause a herding behavior in a negative direction (like the crash in 1987) and may lead to a bear market. Finally, an insufficient correction may be followed by rallies that continue over speculation and lead to a massive crash.

Consequently, the importance of predictive stock patterns, like those found by the Tokyo scientists, are not only that they may help predict crashes, but also identify positive correction from negative ones. Those corrections that cause a phase shift, where the pattern predicting a market crash is no longer present, would be positive and those that do not eliminate the pattern would be negative. Either way, these patterns would be invaluable to identify future large movements in the market.

However, collars, circuit breakers and any newly developed market control based on predictive patterns may actually prevent a positive correction and thus lead to a crash. On the other hand, if a pattern is truly predictive then we should be able to ascertain if our market controls prevented a crash, because the pattern would disappear. Then again, what effect could our observation of patterns that predict the movement of the stock market and our subsequent control and other actions have on the market? Quantum physics may shine some light on these questions. A fundamental idea in quantum physics is Heisenberg's uncertainty principle. The uncertainty principle provides that a person's mere act of observing something will change its outcome.[134] Though the uncertainty principle has been applied to explain the movement of particles and other quantum events, it may also cross over into the macroscopic world of the stock market, because "quantum mechanics is the language of all matter and energy, not only at the level of atoms."[135] Therefore, the mere observation of a pattern predicting a crash could prevent its occurrence or change its magnitude or timing.

A Better Approach: Complex Adaptive System Model

Now that the ECMH has been removed from its position as doctrine and we have identified how chaos theory and other methods can be helpful in studying the non-linear stock market, the question still remains what new approach should replace ECMH. I suggest a new model called the Complex Adaptive System Model may be the solution (CASM). CASM is a non-linear interdisciplinary model, embracing the new world of Econophysics. It applies chaos theory, physics and biology and is more in line with the actual behavior of the stock market and investors. The model attempts to explain investor interactions, or agents in the model, understanding that all investors are not the same (homogeneous) but sometimes act "irrational[ly], operating with incomplete information, and relying on varying decision rules."[136] CASM holds that though individual interactions may be simple to explain, the aggregate of these straightforward interactions creates a complex and adapting or changing system.[137] In other words, the parts are more complex than the whole; this is called "self-organized criticality."[138] The author provides a good analogy to explain the important ramifications of the self-organized criticality of the stock market:

> Start to sprinkle sand on a flat surface and the grains settle pretty much where they fall; the process can be modeled with classical physics. After a modest pile is created, the action picks up, with small sand slides. Once the pile is of sufficient size, the system becomes "out of balance," and little disturbances can cause full-fledged avalanches. We cannot understand these large changes by studying the individual grains. Rather, the system itself gains properties that we must consider separately from the individual pieces.[139]

Thus, like the sand pile, the stock market and its movements must be studied as whole and not only the individual actions of its agents.[140] Investors take information from their environment and put it through the filter of there own interactions with the market and derive investment strategies (a.k.a. decision rules).[141] These strategies compete in the market and like natural selection some are eliminated and others adapt taking on the advantages of other strategies.[142]

Furthermore, CASM embraces the idea of non-linearity, realizing that there is no one cause for stock market movement, but that there is an interaction effect creating feedback loops where variables interact with one another reinforcing, exaggerating and canceling each other out.[143] Thus, the stock market is not seen as the independent and random byproduct of the ECMH, but as a dynamic system prone to fat tails of booms and crashes.[144] Thus, CASM abandons the normal distribution for one with fat tails.[145] At the same time, the model takes into consideration that often market prices will follow the traditional random walk model, but also holds that trends do persist and that the market does have a lasting memory; in other words past prices have a lasting effect on future prices.[146]

This long memory in the market is explained in part by viewing investors as inductive decision makers, often irrational, and having heterogeneous expectations.[147] Thus, investors can cumulatively make errors in the value of stock prices, by applying similar strategies creating self-reinforcing trends and over speculation.[148] In this way the CAPM and its purely competitive market, which is solely dependent on the linear relationship between risk and reward, is no longer doctrine.[149] In fact, investors are increasingly placing their investment decisions in the hands of common predetermined program strategies, executed instantly by computers. For example, the NYSE reported that just over April 2nd-6th "program trading amounted to 32.3 percent of NYSE average daily."[150] The CASM shows the importance of this lack of diversity, because just as a species needs diversity to survive, so does the stability of the stock market.

As the true potential for instability becoming more apparent, through chaos theory, there is a growing need to apply more realistic models to help demystify the market. Thus, scientists at the Santa Fe Institute are using the CASM to create a computer generated simulation of the market that mimics the behavior of the actual market.[151] Through these types of models they hope to better understand the nature of the market, predict its movements and provide a better measurement of risk.[152] Ultimately, the hope is that by using models like CASM, we can establish simple equations and rules that will help to explain the market as its own living entity. Just as DNA may rely on a specific set of rules that through continuous iteration is able to manifest the complex development of our bodies, the stock market may also be governed by such specific rules.

By better understanding these rules, the nature of the market and associated risks, we will be better equipped to promulgate new securities regulations, providing sufficient protection to investors while maximizing economic growth. At the very least, it is clear that we must move away from our orthodox reliance on ECMH, MPT and the CAPM, and account for the true dynamic and fat tailed risk associated with the stock market.

EPILOGUE

A concern that may be raised by many is whether computer models can approximate the dynamic nature of the stock market and the complex math of chaos theory? Interestingly enough, we may find the answer in quantum physics and genetics. Recently, the first commercial quantum computer was announced.[153] Quantum computers can greatly increase our computational ability.[154] This is because where traditional computers use bits to process information, switching between 1 and 0, quantum computers use quantum bits "which can be both a 1 and a 0… at the same time."[155] This applies the quantum physics idea of superposition, which would allow a quantum bit to be in all possible states at once (1 and 0) and then collapse into one reality upon observation.[156] Thus, quantum computers are able to carry out multiple calculations at the same time, whereas traditional computers can carry out computations only in a sequence.[157] In fact, the company that claims to have developed the first quantum computer states that its computer can compute 64,000 simultaneous calculations.[158]

On the software side, using neural networks, non-linear computer systems that adapt to their environment, can help to better approximate investor interactions.[159] In fact, neural networks are themselves based on "the network of neurons in the brain."[160] Also, genetic algorithms and evolutionary programming can help improve computer models.[161] Genetic algorithms learn and adapt to meet the complexity of the real world by imitating how living beings mutate and change through evolution.[162] Thus, econophysicists can apply these new technologies to cope with the complex and ever changing nature of the stock market.

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[1] Lisa Zyga, Physicists Predict Stock Market Crashes, PhysOrg.com (2006), http://www.physorg.com/news11164.html. *See also* Kiyono et. al., *Criticality and Phase Transition in Stock-Price Fluctuation*, Physical Review Letters 96, 068701 (2006).

[2] For the purposes of this paper, "stock market" will refer to highly organized, regulated and competitive markets, such as the New York Stock Exchange and underlying indices such as the SP 500 and NASDAQ. They are most inline with the assumptions of the ECMH.

[3]Craig Lambert, *The Marketplace of Perceptions*, Harvard Magazine, (March-April 2006 (quoting Dr. Laibson, in explaining the over reliance on the idea of rational decision makers:

> To be fair, the naysayers would have agreed that the rational model only *approximates* human cognition—"just as Newtonian physics is an approximation to Einstein's physics," Laibson explains. "Although there are differences, when walking along the surface of this planet, you'll never encounter them. If I want to build a bridge, pass a car, or hit a baseball, Newtonian physics will suffice. But the psychologists said, 'No, it's *not* sufficient, we're *not* just playing around at the margins, making small change. There are *big* behavioral regularities that include things like imperfect self-control and social preferences, as opposed to pure selfishness. We care about people outside our families and give up resources to help them—those affected by Hurricane Katrina, for example.)

[4] *See* Eugene F. Fama, *The Behavior of Stock-Market Prices*, 38 Journal of Business 1, 36 (University of Chicago Press 1965).

[5] By intrinsic value I mean that a stock's value derives solely from the worth of the company it represents; the assets, liabilities and potential risk associated with that company. A company's risk of failures and successes are based on internal factors and external factors (i.e. politics and the economy). *See* F. Fama, *The Behavior of Stock-Market Prices*, 38 Journal of Business 1, 36 (University of Chicago Press 1965).

[6] Eugene F. Fama,*The Behavior of Stock-Market Prices*, 38 J. BUS. 1, 36 (1965).

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[7] Charles J. Corrado and Bradford D. Jordan, FUNDAMENTALS OF INVESTMENT VALUATIONS AND MANAGEMENT 408-10 (3rd ed., 2005).
[8] *Id.*
[9] Simon M. Keane, STOCK MARKET EFFICIENCY THEORY EVIDENCE AND IMPLICATIONS, 12 (P. Allen ed., Deddington Oxford 1983).
[10] *Id.*
[11] *See* Charles J. Corrado and Bradford D. Jordan, FUNDAMENTALS OF INVESTMENT VALUATIONS AND MANAGEMENT, 269 (3rd ed., 2005).
[12] *Id.*
[13] *Id.*
[14] *Id.*
[15] *Id.*
[16] *See* Charles J. Corrado and Bradford D. Jordan, FUNDAMENTALS OF INVESTMENT VALUATIONS AND MANAGEMENT, 269 (3rd ed., 2005).
[17] *Id.*
[18] *Id.*,Lisa Zyga, *Physicists Predict Stock Market Crashes*, PhysOrg.com (2006), http://www.physorg.com/news11164.html; *see also* http://www.childrens-mercy.org/stats/definitions/norm_dist.htm; Additionally, the "*Central Limit Theorem* which states that if the sum of the variables has a finite variance, then it will be approximately normally distributed (i.e. following a normal or Gaussian distribution)." However the variables must be random, independent and identically-distributed . *See* Central Limit Theorem, http://en.wikipedia.org/wiki/Central_Limit_Theorem.
[19]*See* Charles J. Corrado and Bradford D. Jordan, FUNDAMENTALS OF INVESTMENT VALUATIONS AND MANAGEMENT 439 (3rd ed., 52005). However, popular opinion is moving away from the belief that stock market movement is normally or lognormally distributed. *See* Normal Distribution: Financial Variables, http://en.wikipedia.org/wiki/Normal_distribution.
[20] *See Normal Distribution,*, http://mathworld.wolfram.com/NormalDistribution.html; *see aslo* Wikipedia, *Normal Distribution*, Financial Variables, http://en.wikipedia.org/wiki/Normal_distribution.
[21]*See Standard Deviation*, http://mathworld.wolfram.com/StandardDeviation.html; *see also* Wikipedia, *Normal Distribution*, Standard Deviation, http://en.wikipedia.org/wiki/Normal_distribution.
[22] Wikipedia, *Normal Distribution*, Standard Deviation, http://en.wikipedia.org/wiki/Normal_distribution; *see also Normal Distribution*,, http://mathworld.wolfram.com/NormalDistribution.html;
[23] Modern Portfolio Theory is part of the Capital Asset Pricing Model ("CAPM"), which is used not only by investors and analysts in making investment decisions, but also the CFOs of America's biggest companies. *See* Benoit B. Mandelbrot and Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD 59 (Basic Books 2004) (explaining that in a survey done by Duke University that 73.5% of nearly 400 America's companies use CAPM when making big financial decisions, such as whether to issue stocks, bonds or take on debt, and even what companies to acquire).
[24] Modern Portfolio Theory, Investopedia, http://www.investopedia.com/terms/m/modernportfoliotheory.asp
[25] Charles J. Corrado and Bradford D. Jordan, FUNDAMENTALS OF INVESTMENT VALUATIONS AND MANAGEMENT , 400 (3rd ed., 2005).
[26] *Id.*
[27] *Id.*
[28] *Id*. at *398.*
[29] *Id.* at *401.* A stocks volatility is the measure of its deviation from its expected return, over time.
[30] *Id.*
[31] *See Id.* This will become important later in our discussion of chaos theory.
[32] *Id.* at 408-10 The difference between a stock's "expected excess return on the security and the actual return," is its alpha. Campbell R. Harvey, *Asset Pricing and Risk Management*, lecture transcript (1995). The CAPM assumes that a stock's alpha is zero. *Id.*
[33] *Id.*
[34] *Id.*at 408-10.
[35] *Id.* at 410.
[36] *Id.* at 408.

[37] Simon M. Keane, STOCK MARKET EFFICIENCY THEORY EVIDENCE AND IMPLICATIONS 13 (P. Allen ed., Deddington Oxford 1983).
[38] *Id.* (This process is referred to as the market's ability to "learn").
[39] *See* Niels B. Schaumann, SECURITIES REGULATION 11 (Gilbert Law Summaries 2002).
[40] *Id.*
[41] *Id.*
[42] *Id.* at 2. However, the concept of the markets actually being efficient was solidified in the 1950s. Gibbons Burke, *Chaos Theory to Investment and Economics (Book Reviews),* Futures (Cedar Falls, Iowa) (1994) ("Since its introduction in 1953 by Maurice Kendall, what came to be called the Efficient Market Hypothesis (EMH) assumed the mantle of religious orthodoxy -- anyone who suggested the markets might behave otherwise was often labeled a quack.")
[43] *See* Niels B. Schaumann, SECURITIES REGULATION, 1-2 (Gilbert Law Summaries 2002).
[44] *Id.*
[45] Securities Exchange Act of 1934, 15 U.S.C. § 10b-5 (West, 2007); *see also SEC v. Texas Gulf Sulphur Co.; United States v. O'Hagan,* 521 U.S. 642, 655 (1997) (misappropriation theory of insider trading).

[46] Charles J. Corrado and Bradford D. Jordan, *Fundamentals of Investments Valuations And Management*, 264 (3rd ed., 2005).
[47] *See Id.*
[48] *Id.* For similar requirements regarding investment advisors see the Investment Adviser Act of 1940 §§204, 204A, 205 & 206. *Questions Advisers Should Ask While Establishing or Reviewing Their Compliance Programs*, SEC website (2006), http://www.sec.gov/info/cco/adviser_compliance_questions.htm.
[49] Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD, 248 (Basic Books, 2004).
[50] Craig Lambert, The Marketplace of Perceptions, Harvard Magazine (March-April 2006) (citing Sendhil Mullainathan & Summers, *The Noise Trader Approach to Finance* (1990))*, also available at* http://www.harvardmagazine.com/print/030640.html.
[51] Craig Lambert, *The Marketplace of Perceptions,* Harvard Magazine (March-April 2006) (citing Sendhil Mullainathan & Summers, *The Noise Trader Approach to Finance* (1990))*, also available at* http://www.harvardmagazine.com/print/030640.html.
[52] *Id.*
[53] *Id.* Behavioral finance "focuses on the psychology and behavior of individual economic agents, and explores the implications for asset pricing, regulation and management. It is, by its nature, interdisciplinary and relies on psychologists, sociologists, behavioral decision theorists, marketing researchers, financial economics, macroeconomists and accounting researchers, among others." Behavioral Finance Research Initiative, The International Center for Finance at the Yale School of Management, http://icf.som.yale.edu/research/behav_finance.shtml. For more information regarding behavioral finance and a subset of it neuroeconomics *see* Mathew Baltierra, Silly *Monkeys With Money: How Irrational Behavior Affects the Stock Market*, Advance Securities Paper (Working Paper 2007) (explaining how behavioral finance and neuroeconomics effect stock market prices).
[54] Craig Lambert, *The Marketplace of Perceptions,* Harvard Magazine (March-April 2006) (citing Sendhil Mullainathan & Summers, *The Noise Trader Approach to Finance* (1990))*, also available at* http://www.harvardmagazine.com/print/030640.html.
[55] *Id.*
[56] Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD, 3 (Basic Books, 2004).
[57] *Id.* at 4.
[58] *Id.* at 31-42.
[59] *Id,*
[60] *Id.*
[61] Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD, 31-42 (Basic Books, 2004).
[62] *Id.*

[63] *Id.*
[64] *Id.*
[65] *Id.*
[66] Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD, 31-42 (Basic Books, 2004)..
[67] *Id.*
[68] *Id.*
[69] *Id.*
[70] *Id.*
[71] Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD, 31-42 (Basic Books, 2004).
[72] Bill McKeley & Plerpaolo Andriani, *Why Gaussian Statistics are Mostly Wrong for Strategic Organization*, Vol 3(2) Strategic Organization 219, 219 (2005), *also available at* http://soq.sagepub.com.
[73] *See* Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD, 247-48 (Basic Books, 2004).
[74] Bill McKeley, Plerpaolo Andriani, *Why Gaussian Statistics are Mostly Wrong for Strategic Organization*, Vol 3(2) Strategic Organization 219, 222 (2005), *also available at* http://soq.sagepub.com;
[75] *Id*.
[76] *Id.*
[77] Generalized Auto-Tregressive Conditional Heteroskedasticity.
[78] *See* Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD,, 222 (Basic Books, 2004).
[79] *Id.*
[80] McKeley, *supra* note 73.
[81] *See Id.*
[82] *See Id.*
[83]*Normal Distribution*, http://en.wikipedia.org/wiki/Normal_distribution; *see aslo* Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD, 228-29, xxii (Basic Books, 2004).
[84] McKeley, *supra* note 73.
[85] *Chaos Theory: A Brief Introduction*, www.imho.com/grae/chaos/chaos.html.
[86] McKeley, *supra* note 73.
[87] *Id.*
[88] *Id.*
[89] *Chaos Theory: A Brief Introduction*, http://www.imho.com/grae/chaos/chaos.html.

> The flapping of a single butterfly's wing today produces a tiny change in the state of the atmosphere. Over a period of time, what the atmosphere actually does diverges from what it would have done. So, in a month's time, a tornado that would have devastated the Indonesian coast doesn't happen. Or maybe one that wasn't going to happen, does.

Id.
[90] *Chaos Theory*, http://www.imho.com/grae/chaos/chaos.html.
[91] *Id.*
[92] *Id.*
[93] *Id.*
[94] *Id.*
[95] *Chaos Theory*, http://www.imho.com/grae/chaos/chaos.html.
[96] *Id*.
[97] *Chaos Theory*, http://www.imho.com/grae/chaos/chaos.html. This self similarity means that dynamic systems are often governed by power laws. Thus, the frequency of an event is inversely proportional to its strength. For example, the larger the crash or surge in the stock market the less likely it is to occur. However, power laws suggest scale invariance. Thus, the portion of small to medium price changes are equal to that of large to massive price changes. *See* Wolfgang Paul & Jorg Baschnagel, STOCHASTIC PROCESSES FROM PHYSICS TO FINANCE(Spriger-Verlag, Berlin

1999); *see also* Benoit B. Mandelbrot & Richard L. Hudson, THE (MIS) BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN AND REWARD 164 (Basic Books 2004).

[98] *Chaos Theory: A Brief Introduction*, http://www.imho.com/grae/chaos/chaos.html (citing James Gleick, *Chaos - Making a New Science*, pg. 86).

[99] For example: "Wolfram long ago learned enough about these rules to prove his case about the potential role of cellular automata as a universal computer capable of producing patterns for everything from quasars to bumblebees, hurricanes, stock markets, and rose petals." Michael S. Malone , *God, Stephen Wolfram, and Everything Else*, Forbes.com, 6 (November, 2000), http://members.forbes.com/asap/2000/1127/162.html.

[100] *Chaos Theory: A Brief Introduction*, http://www.imho.com/grae/chaos/chaos.html.

[101] *Chaos Theory*, http://www.imho.com/grae/chaos/chaos.html.

[102] *Chaos Theory*, http://www.imho.com/grae/chaos/chaos.html.

[103] Bill Williams, TRADING CHAOS: APPLYING EXPERT TECHNIQUES TO MAXIMIZE YOUR PROFITS 265 (John Wiley & Sons 1995).

[104] http://www.trade2win.com/traderpedia/Elliot_wave.

[105] http://www.trade2win.com/traderpedia/Elliot_wave. Elliot believed that there were many cycles of both impulse and corrective waves, and he based the cycles on the Fibonacci series of numbers " 1, 2, 3, 5, 8, 13 etc. The [cycle] names are: 1.Grand supercycle, 2. Supercycle, 3. Cycle, 4. Primary, 5. Intermediate, 6. Minor, 7. Minute, 8. Minuette, 9. Sub-minuette." *Id; see also* Bill Williams, TRADING CHAOS: APPLYING EXPERT TECHNIQUES TO MAXIMIZE YOUR PROFITS 265 (John Wiley & Sons 1995) (explaining that "Bill Williams (a PhD in psychology) claims discovery of the underlying fractal nature of Elliott waves.").

[106] http://www.trade2win.com/traderpedia/Elliot_wave.

[107] Bill Williams, TRADING CHAOS: APPLYING EXPERT TECHNIQUES TO MAXIMIZE YOUR PROFITS 265 (John Wiley & Sons, 1995).

[108] http://www.trade2win.com/traderpedia/Elliot_wave.

[109] *Id.*

[110] *Id.*

[111] Gary Weiss, *Using Chaos to Make a Bundle*, BusinessWeek.com, http://www.businessweek.com/1999/99_51/b3660094.htm.

[112] *Id.*

[113] *Id.*

[114] *Id*.

[115] *Id.*

[116] Seth Lloyd, *Complex Systems: Review*, Massachusetts Institute of Technology Engineering Systems Division, p. 8, (2002), http://esd.mit.edu/WPS/ESD%20Internal%20Symposium%20Docs/ESD-WP-2003-01.16-ESD%20Internal%20Symposium.pdf.

[117] Weiss, *supra* note 112.

[118] Lisa Zyga, *Physicists Predict Stock Market Crashes*, PhysOrg.com (2006), http://www.physorg.com/news11164.html.

> While analyzing stock-price fluctuations based on critical dynamics and phase transitions… the team found that the probability of large price fluctuations increased unexpectedly ("non-Gaussian" behavior), as if approaching a critical point signifying a major change. At the critical point – or day of the crash – an abrupt phase transition did indeed occur as the probability model changed from being scale dependent to scale invariant. Scale invariance, which in this case meant that the prices no longer depended on the time scale, is characteristic behavior observed at a critical point.

[119] Lisa Zyga, *Physicists Predict Stock Market Crashes*, PhysOrg.com (2006), http://www.physorg.com/news11164.html.

[120] Kiyono et. la., *Criticality and Phase Transition in Stock-Price Fluctuation*, Physical Review Letters 96, 068701-1 (2006), *also available at* http://link.aps.org/abstract/PRL/v96/e068701.

[121] *Id.*

[122] *Id.*

[123] *See Id.*

[124] *Id.*

[125] Kiyono et. la., *Criticality and Phase Transition in Stock-Price Fluctuation*, Physical Review Letters 96, 068701-1 (2006), *also available at* http://link.aps.org/abstract/PRL/v96/e068701.
[126] *See Id.*
[127] *Id.*.
[128] *Id.*.
[129] Kiyono et. la., *Criticality and Phase Transition in Stock-Price Fluctuation*, Physical Review Letters 96, 068701-1 (2006), *also available at* http://link.aps.org/abstract/PRL/v96/e068701.
[130] *Id.*.
[131] Lisa Zyga, *Physicists Predict Stock Market Crashes*, PhysOrg.com (2006), http://www.physorg.com/news11164.html.
[132] A correction is a downward movement in a rallying market of 10%-15%, www.investopidea.com.
[133] *See* Wolfgang Paul & Jorg Baschnagel, STOCHASTIC PROCESSES FROM PHYSICS TO FINANCE (Spriger-Verlag, Berlin 1999) (explaining that negative feedback loops are "Processes that tend to counteract, or cancel out, deviations from a current system state.").
[134] http://theory.uwinnipeg.ca/physics/quant/node7.html.; s*ee also* www.myspace.com/advancedsecurities, video: Double Slit Test (The Double slit test shows the wave-particle duality, how the observation of photons, particles of light, affects its movement and its nature).
[135] Bryan Gardiner , *D-Wave Demonstrates First Quantum Computer*, Extremetech.com (2007), http://www.extremetech.com/article2/0,1697,2094849,00.asp. The article continues to explain that "The problem is that while the scientific community has learned a great deal about this fundamental language of nature—even constructed an alphabet of characters and written it down—it still hasn't figured out how to read that alphabet in any meaningful way." *Id.* The article seems to be identifying the problem of combining the quantum mechanic laws that are apparent in the subatomic world and the more classical/relivistic laws that apply to the macroscopic world that we interact with. The most promising theory to unify these to fields, the microscope and the macroscopic, is String Theory (a.k.a. Super String Theory or M-Theory). String theory is hoped to be the unifying theory and may be the key to not only understanding our physical world, but also the nature of other complex systems like the stock market.
[136] Michael J. Mauboussin, *Revisiting Market Efficiency: The Stock Market as a Complex Adaptive System*, Credit Journal of Applied Corporate Finance, Volume 14 Number 4, p. 8 (Winter 2002).
[137] *Id.*
[138] *Id.*.
[139] *Id*.
[140] *Id*.
[141] Mauboussin, *supra* note 137.
[142] *Id.*
[143] *Id.*
[144] *Id.*
[145] *Id.*
[146] Mauboussin, *supra* note 137.
[147] *Id.*
[148] *Id.*
[149] *Id.*
[150] http://www.nyse.com/press/1176373638959.html. However, in reaction to large crashes and the increased dependence of program trading, the NYSE implemented Rule 60B, as a "collar" to help prevent drastic drops in the stock market. NYSE, Rule 60B (West 2007). The modern collar is triggered if the Dow Jones falls below set levels, and stops trading for set periods of time. *Id.*
[151] Mauboussin, *supra* note 137.
[152] *Id.*
[153] Bryan Gardiner, *D-Wave Demonstrates First Quantum Computer (*February 14, 2007), http://www.extremetech.com/article2/0,1697,2094849,00.asp.
[154] *Id.*
[155] *Id.*
[156] *Id.*

[157] *Id.*

[158] Bryan Gardiner, *D-Wave Demonstrates First Quantum Computer (*February 14, 2007), http://www.extremetech.com/article2/0,1697,2094849,00.asp.

[159] Lloyd, *supra* note 117.

[160] *Id.*

[161] *Id.*

[162] *Id.*