A Fractal Statistical Analysis of Enron Stock Prices

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Abstract

This study examined the stock prices of Enron for the periods 1997 to 2002 with the use of fractal statistical analysis. The researchers posited that, since stock prices are products of human decisions, it should follow a fractal distribution. Any deviation from this fractal distribution is deemed to represent interventions and manipulations. Using the fundamental theorem of fractal statistics, the results of the analysis revealed that Enron's stock prices exhibit a hidden fractal dimension that, when uncovered, showed how it reflects the investors' risk exposure in the periods before and after the fraud. The researchers also examined the fractal dimension of the cluster of stock prices found to exhibit a fractal distribution in the pre and post fraud periods. Results of the analysis led to the conclusion that the fractal dimension of stock prices can be an indicator of how close or how far stock prices are to its "natural" behaviour. The farther it moves from this natural state, the higher is the risk associated with it.

Keywords: Enron stock prices, fractal dimension, investor losses, fractal statistics

1.0 Introduction

As early as the seventeenth century, stock markets were officially organized to act as a financial intermediary in helping businessmen and entrepreneurs hasten their asset trading. This avenue allows the traders to gain access to businesses and own a slice of ownership in the company as well as share in its profits. Not only did this increase the investor's worth but more importantly, it greatly contributed to the nation's economy.

The stock market has considerably brought together the buyers and sellers in publicly-traded companies, studied the supply and demand of the stocks in the market and satisfied the optimal reconciliation of both parties. The primary concern of investors pertains to maximization of their savings with sure profit, diverse opportunities, and flexibility. As to the nation concerned, one significant role the stock market fulfils is it serves to gauge the nation's fiscal health. These conform to the functions and responsibilities of a stock market to bundle liquidity by concentrating supply and demand, provide information on prices and volume and most importantly, to ensure the greatest possible transparency for investors.

Due to this, a stock market has a formal structure in place, compliant with laws and regulations set by the government agencies and bureaus. This scheme adds authority and oversight to ensure check and balance among stockholders and businesses with the goal of boosting investor confidence. Regardless of how and where is the stock market formed, there is no definite equation to determine the stock price. However, the variations in causes of its rise and fall have been categorized into three factors, namely: fundamental factors, technical factors and market sentiment. Of these three, the technical factors play the most influential role for it takes into the picture

the external conditions that may modify the supply and demand of the stock. These include exchange rate (Aurangzeb, 2012; Joshua, 2011; Sulaiman et al, 2000; Menike, 2006) and interest rate (Chen, 1986; Menike, 2006; AL-Fayoumi, 2009). Inflation (Chen, 1986; Menike, 2006) and other factors such as consumer price and foreign direct investment are also some of the factors.

On the other hand, the most intriguing trading strategy, commonly labeled as "manipulation", particularly the manipulation of the closing prices, is inseparable when tackling the stock market. Up to now, there is an indefinite impact regarding the extent of how the manipulators can distort the prices (Comerton-forde and Putnis, 2011). One key component in determining the peril brought about by manipulation is the manipulator's incentives. Through his motives, the market is deliberately influenced by buying or selling voluminously to give the impression that the stocks are widely traded. This strategy connotes fraudulent changes in the natural rise and fall of the stocks (Morgenson, 2000).

The United States is considered to have the perfectly competitive market in which an innumerable number of traders meet in its stock exchange markets. This market has been alarmed by the bankruptcy of America's leading energy corporation that once boasted of more than a hundred billion dollars in annual revenue. Interestingly, this chronicle narrates how a firm that reached the peak defied a nauseating failure. By the fall of the year 2000, Enron – a Wall Street Darling – started to crumble under its weight. The company was once highly looked up to in the energy trading industry but is now often discussed in case studies tackling financial manipulation, unethical behaviour, corporate governance, bribery, corruption, politics and greed.

In the year 2000, Enron, a Texas-based company, was the most prominent firm in the energy industry with revenue of US $101 billion. It commenced in 1985 with the merger of Houston Natural Gas and Internorth, both in the business of selling and transporting natural gas. The booming business magnified to commodity banking ranging from natural gas, electricity, Internet broadband, to name a few, which raised the need to generate and become dependent on borrowed cash for its daily operations. This aggressiveness metamorphosed the company from an operating firm to becoming an investment fund (Cunningham and Harris, 2006).

An accomplice to this fraudulent scheme, Arthur Andersen, was once among the most reputable international accounting firms in the world. In its audit of Enron, financial reporting issues that floated include mark-to-market accounting, financial reporting for Special Purpose Entities (SPEs) and reporting of outstanding shares. As to the first issue, there is an aggressive assumption of interest rates and demand which overstated the earnings of the company. What is worse is that the estimated earnings dawdled far behind from the actual income. This unfortunate financial event necessitated the recognition for a loss, but Andersen discernibly ignored the need to examine the values assigned to the contracts and strategies to conceal the losses.

In several articles published in New York Times during 2002, Enron officers relayed to its employees that the company's stock price would not cease rising despite other officials' skepticism on the company's financial stability. Further, it is to be noted that issues are already raised by the Wall Street analysts upon seeing the "red flags". It is even unexpected that they still rated the company as a "strong buy" on November 8, 2001, the same day Enron acknowledged it had overstated profits by $600 million. Alan P. Warnick, Enron's Vice President for Organization Development and Training, in his interview with Vance and Madsen

(2009), stated that Enron's downfall is synonymous to Napoleon's collapse. In an article by Kroll et al. (2000), it depicted leadership lessons on hubris and arrogance. The factors that led to the latter are the same reasons leading to the unethical behaviour and subsequent downfall of the former.

According to Cummings et al (2002), the Enron saga is depicting a perplexing array of dramas. It pictures out investors faltering of losses from a stock price that dwindled from $36 to less than a dollar in just one quarter. The most compelling question would point to Enron executives using inside information to time sales of company stock and putting millions of dollars into their pockets (Kranhold et al., 2002). Government officials and the company's officers, including their friends and colleagues, were accused of selling their stocks between 1999 and 2001 based on the information derived from Enron executives detailing its financial problems. In fact, several officers earned more than hundred million dollars in selling their stocks but significantly denied allegations of wrongdoing, particularly insider trading.Ma and Huey-Lian (1998) enumerated the reasons for insider trading which include portfolio diversification and corporate control.

While there is an abundance of chronicles and studies made on what caused Enron's downfall, there is a dearth of literature that examined Enron's stock prices in light of the fraud. This study aims to fill this gap by scrutinizing the stock prices of Enron in the years that lead to its downfall, taking into consideration the role that fractals play in financial markets.

2.0 Conceptual Framework

The behaviour of stock prices is as impulsive and enigmatic as it is spontaneous and playful. The seeming unpredictability of the movement of stock prices has earned it the interest of many scholars and researchers. For example, the world has seen the advent of concepts such as the Efficient Market Hypothesis (Fama, 1964) and the Random Walk Theory (Malkiel, 1999). The Elliot Wave Model and Hurst exponent (Hurst, 1951) are also significant concepts. In addition, fundamental and technical analysts have debated time and again which of the philosophy above is better. This arbitrariness of the changes in stock prices has added to the growing chant echoed all over the financial markets. It calls the need for more information and new ways of trying to get ahead of the game of chance in the stock markets.

Imperative in any study of the stock market behaviour, however, is that human beings' knowledge of stock prices (and eventually the stock price behaviour) shape their decisions. As such, stock prices are ultimately spurred the same way human beings think. This occurrence makes the stock price behaviour a product of a "natural" phenomenon. The central thesis of this paper, then, is that stock prices follow a fractal distribution. Any intervention or manipulation is integrated into this expected behaviour, resulting in an altered distribution. Accordingly, unaltered stock prices are fractal while stock prices affected by manipulation and intervention deviate from this. With this in mind, the researchers propose to view stock prices using a fractal approach.

In the year 1975, the world was introduced to the word fractal by the mathematician Benoit Mandelbrot. Derived from a Latin word that means fractured, fractals have since then taken the world in awe, allowing everyone to see the hidden configuration of all things made by nature. The appreciation of fractals has never been clearer than in the field of geometry, often being associated with concrete images of beautiful shapes and breath-taking pictures. This relatively new science of fractals, however, extends even to the realm of the abstract --- that of mathematics and, more relevantly, to financial markets.

The field of finance is no stranger to fractals. Peters (1994) advocated the concept of a Fractal Market Hypothesis. An alternative to the Efficient Market Hypothesis, the Fractal Market Hypothesis takes into account liquidity in addition to detecting fractality or multifractality of stock price behaviour. A Multi Fractal Market Hypothesis posited by Corazza and Mallari (2002) was statí in their study of foreign currency markets. Los and Yalamova (2004) also used multifractal analysis in the examination of the 1987 market crash. The examination of the trends in technical analysis, the "five waves up, three waves down" of the Elliot Wave Model, and the application of the Hurst exponents are also some of the many applications of fractals in financial markets.

This paper, however, would like to use a relatively novel fractal application known as Fractal Statistical Analysis (Padua, 2015). An essential tenet of this approach is that the "natural" state of things may differ from what is considered its current "normal" state. Banking on the idea that nature is abundant with fractals, Fractal Statistical Analysis (FSA) posits that the natural state, then, is fractal. Man's interventions & manipulations of the things and circumstances around him alter this natural state. Accordingly, the altered natural processes of nature reveal a normal, rather than a fractal, state. Thus, it is possible for data sets that exhibit a normal distribution to have been sourced from a fractal distribution, only that it has been altered owing to man's interventions.

The fundamental theorem of fractal statistics (Padua, 2015) is that a given data set (x) is fractal if and only if $\log\left(\frac{x}{\theta}\right)$ has an exponential distribution with rate parameter $\beta = \lambda - 1$. The theorem is graphically explained by Figure 1 below.

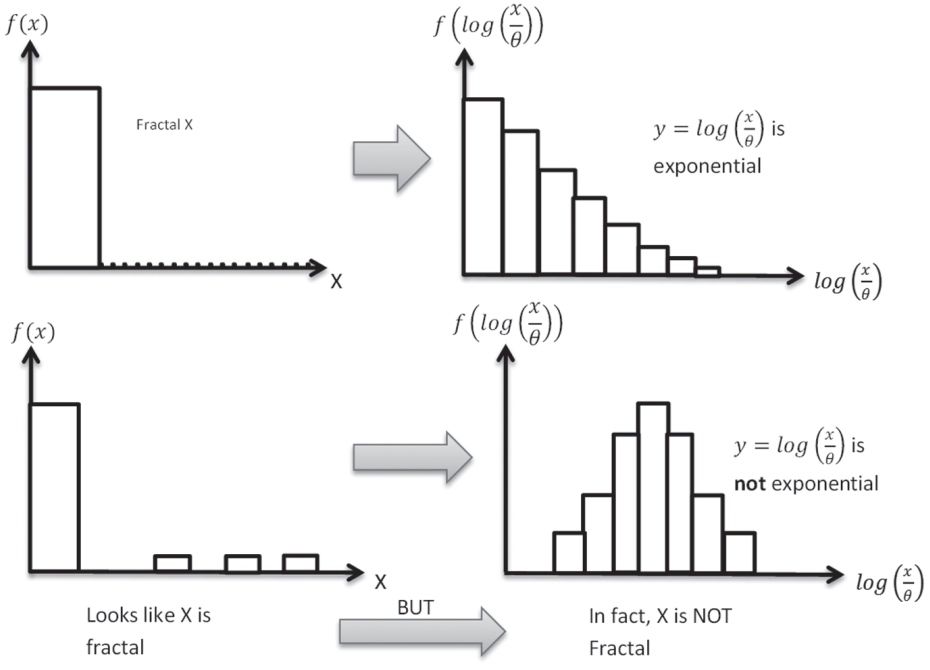


Figure 1: Illustration of the Fundamental Theorem of Fractal Statistics (Padua, 2015)

As shown in Figure 1, for a phenomenon to qualify for Fractal Statistical Analysis, it must satisfy two things: (1) the raw data, represented by x, must exhibit a fractal distribution, and (2) the $\log\left(\frac{x}{\theta}\right)$, represented by y, must display an exponential distribution. These two requirements are initially satisfied by a visual assessment of the histograms pertinent to such. To reinforce this, a test for exponentiality and regression analysis was done.

However, it must be noted that as per the previous discussion, there are some data whose fractal dimension has been altered by human intervention and, as such, will not exhibit the required distributions above. In this, case, one must search for the fractal distribution by trimming the data until it arrives at the required distribution. The interventions or manipulations are represented by the trimmed data.

3.0 Presentation, Analysis, and Interpretation of Data

The researchers obtained the closing stock prices of Enron Corporation for the period covering January 2, 1997 to December 31, 2002. There were a total of 1,508 observations. In order to ascertain if the data satisfies the fundamental theorem, generation of the histograms of the closing stock prices (x) and the $\log\left(\frac{x}{\theta}\right)$, represented as y, were shown in Figures 2 and 3 below.

An initial examination of Figure 2 shows that it did not readily exhibit a fractal distribution. However, a closer inspection and a more in-depth analysis revealed that the first three bars seem to resemble the said fractal distribution. As such the researchers decided to trim the data subsequent to those data points. The bars inside the red dotted sphere are subject for trimming. Interestingly, the untrimmed data set mostly represent the stock prices of Enron in the year after it filed for Chapter 11 bankruptcy.

Figure 3, on the other hand, also did not readily reveal an exponential distribution. Nonetheless, the researchers identified a possible exponential distribution in the last few clusters of data. The manipulations hide the characteristics of the fractality. The researchers thus decided to remove all the data points prior to the said cluster. The data to be trimmed are the bars inside the blue dotted sphere. Surprisingly, a closer inspection of the data subject for removal showed that these represent the years when Enron's manipulations started to crumble.

Considering that the two histograms reveal two different circumstances, the researchers deemed it best to take a two-part analysis. Part 1 will be an analysis of Enron Corporation after to the peak of the fraud as sourced from Figure 2, and Part 2 will be prior to the peak of the fraud as anchored in Figure 3.

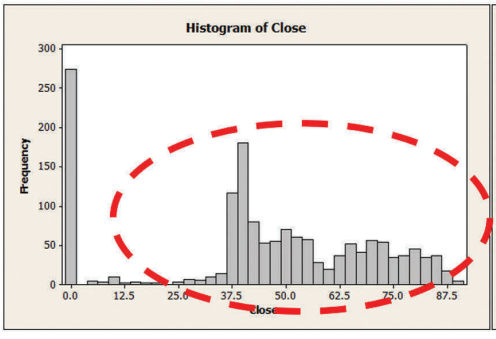


Figure 2: Histogram of x (1997 – 2002)

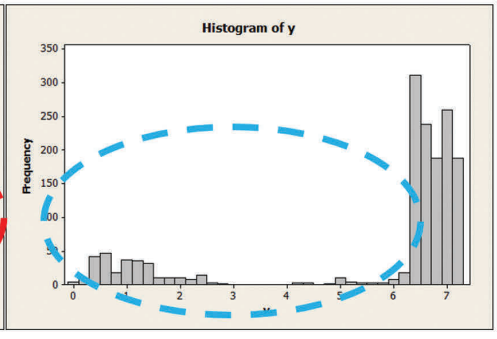


Figure 3: Histogram of y (1997 – 2002)

Part 1: Enron Post-Fraud

From the original data of closing stock prices, the researchers proceeded to remove the data identified in Figure 2. After trimming the data, the histogram of the remaining closing prices was generated. See Figure 4.

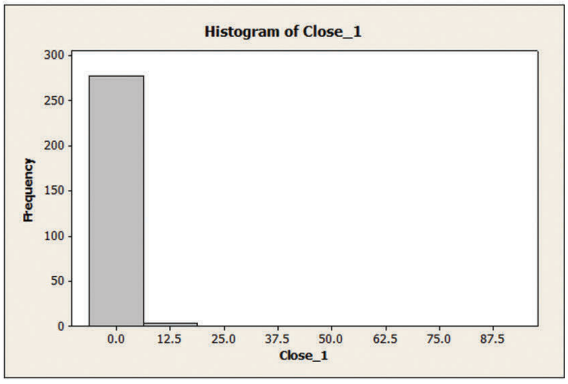


Figure 4: Histogram of Closing Prices after Data Trimming

As shown in Figure 4, the remaining data now resembles a fractal distribution. As such, the researchers proceeded to calculate y to determine if it followed an exponential distribution. Generating the theoretical exponential distribution serves as a guide in determining whether an exponential distribution occurred. These theoretical y-values are randomly generated and correspond to the same number of observations as well as the same mean of the actual y-values. In order to numerically determine its fit, the theoretical data was plotted against y.

Figure 5 above shows that the remaining y seemingly followed an exponential distribution. This result further supports the semblance it has on Figure 6 and the fitted line plot. The researchers then performed regression analysis. The analysis resulted in a regression equation of sort y1= 0.3270 + 0.7061 sort t1, and an R-Sq (adj) of 96.9%.

In addition, the researchers also computed for the β of the data. It was found to be 0.858601. The fractal dimension λ on the other hand was

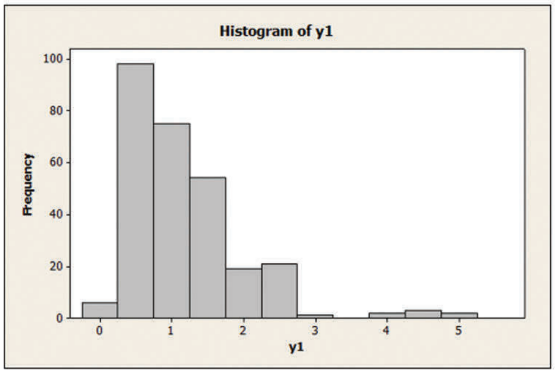


Figure 5: Histogram of y after 1st trimming

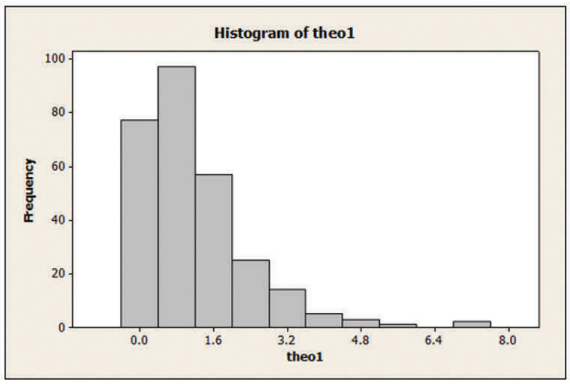


Figure 6: Histogram of theoretical exponential distribution

1.858601. Analysis of these was done together with the results from the second part of the analysis.

Part 2: Enron Pre-Fraud

In order to depict the movement of Enron's daily closing stock price during the "pre-fraud period", the researchers plotted the y values of the closing prices for the period January 2, 1997 to December 31, 2002. It can be recalled that Figure 3above shows this histogram.

Stock prices with a y-value of 0 to 6 comprise a majority of the data. These are the data to be removed in this analysis. In this regard, one must recall that according to the fundamental theorem of fractal statistics, whatever data eliminated in

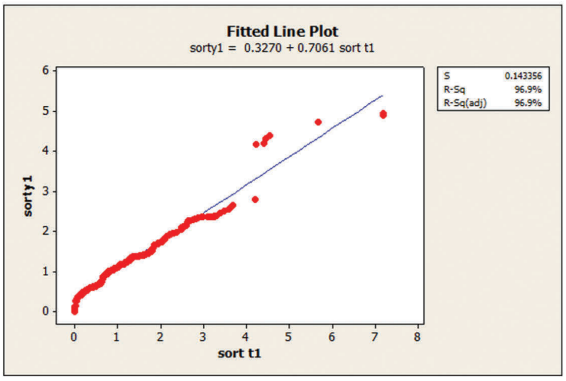


Figure 7: Fitted Line Plot

the process of searching for the hidden fractal dimension are to be analysed as these reflect man's interventions or manipulations. True enough, a thorough inspection of these clusters shows that these prices pertain to the years 2001 and 2002 where significant events happened to Enron. What is remarkable is that in the early part of 2001, during the company's quarterly analyst conference call, the management is highly enthusiastic about the bullish movement of its stocks. This event convinced the stock analysts that the company is doing an excellent job in the securities market. Ironically, in mid-2001, the company's Chief Executive Officer resigned due to personal reasons. This event sparked to a more interesting issue pointing to the time when one of the firm's executives warned his successor that a series of questionable accounting practices would lead to Enron's implosion.

On the last quarter of the year, the scandals were gradually uncovered. On November 8, 2001, the company admitted that they have overstated profits by $600 million, dating back to 1997. What is worse is in the same month, the company also reported $618 million loss due to the Special Purpose Entities run by the company's CFO. At mid-November, there raised a hope for Enron to recover as Dynegy Inc., a Texas-based electric utility company, agreed to buy Enron at $8 million in stock. Unfortunately, 21 days after the agreement, Enron's stock price plunged below $1 with Dynegy aborting the deal. These led the company filing a Chapter 11 bankruptcy claim on December 2, 2001, the largest in the US history. Eventually, the Securities and Exchange Commission investigation not only scrutinized Enron but also extended its investigation to include the company's auditing firm, Arthur Andersen. The latter is charged for shredding the audit documents and for falsely providing a reasonable assurance that the company's financial accounts are free from material misstatements. This crisis did not only have an adverse impact to Enron and Andersen, but the former's employees felt the greatest disadvantage. They were miserable upon seeing their retirement, health insurance and means of livelihood wiped out due to Enron's bankruptcy.Figure 2 presents the histogram of the trimmed data, after the first iteration.

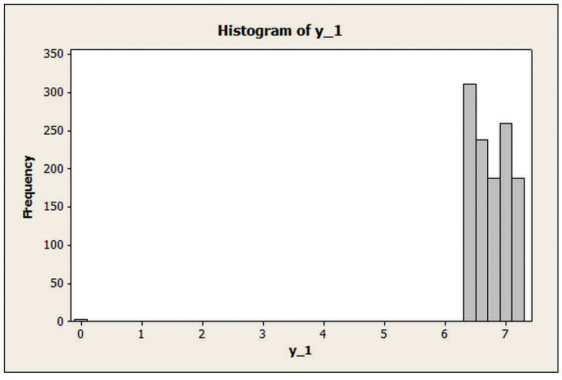


Figure 8: Histogram of y after 1st trimming

After the first trimming, what remained are the data for the years 1997 to 2000, considered the "pre-fraud" years of Enron. However, further data need to be trimmed to arrive at an exponential distribution. The researchers performed 16 iterations for this purpose, resulting in data being removed. The data eliminated can be traced back to

the years 1997 to 1999 where the Special Purpose Entities (SPEs) were created, the brainchild of the company's CFO. These companies are primarily established to conceal debt and inflate profits which unknowingly, and was the first step that led to the business' downfall. On 1999, the company also manipulated the California energy industry causing the electricity prices to rise by creating congestion on power lines. These schemes proved advantageous to Enron, as depicted in August 2000, where the stock price hit an all-time high of $90.56. Further, Enron Online was also established, handling $335 billion in online commodity trades. Despite the significant increase of energy prices in California, frequent electric emergencies and rolling black-outs are noticeable at this period. These manipulative schemes triggered the investigation of government agencies, particularly the Federal Energy Regulatory Commission, in discovering the factors affecting the competitive pricing and reliability of the company's service.

Figure 8 depicts the y-values after the 16 iterations – majority of which are the stock prices during 1997, with only 17 units from the early part of 1998. An inventory of these 17 units would show that 14 pertains to the month of January and 3 from the month of February. The researchers also generated a theoretical exponential distribution in order to have a gauge of the exponentiality of the distribution of the y-values.

A simple visual appreciation of Figures 9 and 10 would not readily show the fit of the actual y-values to the theoretical exponential data. As such, the researchers performed regression analysis and generated the fitted line plot. Figure 11 presents the said plot.

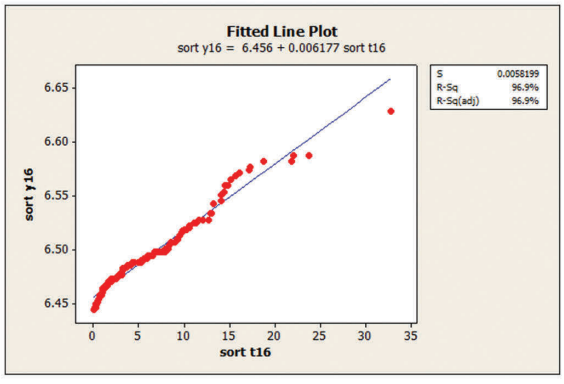


Figure 11: Fitted line plot (16th iteration)

Results of the fitted line plot and regression analysis show an R-squared or coefficient of determination at 96.9% implying that the relationship between the stock price and the theoretical values is fitted to the regression line. The less than 100% R-squared is attributed to the reason that on the year 1997, this is still considered

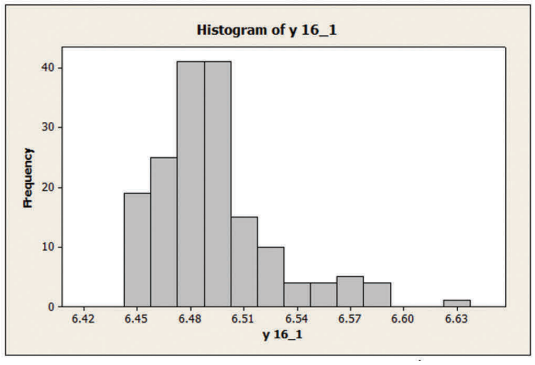
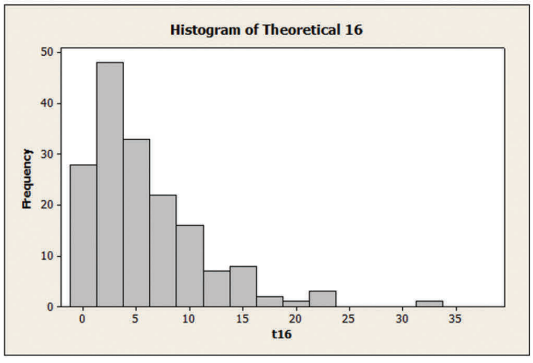


Figure 9: Histogram of y after 16th trimming



10: Histogram of theoretical y-values after 16th trimming

the "planning phase" of a greater fraud to be laid out by Enron. During this period, the stock prices were not yet thoroughly manipulated by the "intelligent gamblers" composed mainly of the company's executives whose goal is to please Wall Street and keep its stock price afloat.

In addition, the researchers also computed for the β of the data. It was found to be 0.154047. The fractal dimension λ on the other hand was 1.154047.

Analysis of β and λ

After Parts 1 and 2 have been completed, the researchers compared the computed β and λ of Enron prior and after the peak of the fraud. See Table 1 for the results.

Table1: Comparison of Enron's beta and lambda

	PRE-fraud	POST-fraud
Beta (β)	0.154047	0.858601
Lambda (λ)	1.154047	1.858601

Table 1 shows the comparison of Enron's beta and lambda in the two periods examined. The researchers interpret the beta as the risk exposure of Enron's investors and creditors. This means that, prior to the peak of the fraud, investors and creditors could expect to recover about 85% of their investment should Enron decide to liquidate, pegging the risk exposure at the beta of 15%. On the other hand, Enron stakeholders after the peak of the fraud can only expect to recover about 15% of their investment since the risk exposure is about 85%. This interpretation is supported by Enron's liquidation settlement distribution. In the light of Enron's bankruptcy and liquidation, the United States Securities and Exchange Commission conducted in-depth investigations that eventually led to several proceedings aimed at recovering investor losses. Owing to this is the creation of the Enron Victim Trust and the establishment of the corresponding Fair Fund. As of October 1, 2014, it was reported that the distribution of the Enron Victim Trust has been completed, and approximately $450 million had been paid in settlements. There was also a class action settlement administered by Gilardi& Co. LLC. The said class action case recovered about $7.2 billion for Enron investors. As a result, it can then be said that the investors recovered roughly $7.65 billion out of the over $60 billion in losses. This recovery rate is about 13%.

The researchers interpreted the fractal dimension (lambda) to reflect how close the stock prices to its "natural" state are. Considering that the post-fraud lambda is higher, it can then be posited that the stock prices on these dates more likely exhibit a behaviour that is considered "natural" for stock prices. This trend is attributable to the discovery and subsequent investigation of the fraud. Since regulatory agencies have stepped in, Enron's executives are no longer able to execute their fraudulent schemes and as such, stock prices behaved "naturally". The lambda prior to the peak of the fraud, however, shows a smaller lambda. Quite expectedly, this was the period when the fraud was about to reach its peak. As such, it is expected that mechanisms must have been slowly put in motion to facilitate the fraud and eventually, manipulate the stock prices.

4.0 Conclusion

Fractals is the language by which nature speaks to us. Stock price behavior, being intrinsically products of man's fractal thought processes, can then be viewed through this fractality. This paper was able to show that the stock prices of a corporation that has been known to have engaged in massive fraud through "creative" accounting

show different fractal dimensions in the periods before and after the peak of the fraud. These fractal dimensions spelled how natural or unnatural the stocks' behaviors were.

A basic foundation of any human intervention is traceable to man's desire to do whatever can be done in order to secure an advantage over the results of natural processes. As these interventions alter the fractal state of things, one must acknowledge that deviations from what is considered natural carry with it the corresponding risks and rewards.

Since the stock prices are expected to exhibit fractal behaviour, it is then posited that the more a stock deviates from its natural state, the less fractal it becomes. The less fractal a series of stock prices are, the higher is the risk associated with it. This risk may come in the form of exposure to losses, as in the case of Enron where human interventions were in the form of fraud intended to deceive its stakeholders while unjustly magnifying the wealth of the perpetrators. On the other hand, risk, may also come in the form of rewards. This is to be the case when the interventions made are legitimate and effective.

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