1. INTRODUCTION

Motivation:

The importance of management cannot be over-emphasized. The term has become a household word [1]. The erstwhile days of small-scale, mostly agriculture-based, family-inherited businesses have disappeared into history [2].

Technology explosion, globalization of workforce and international trade development have all improved the quality of lives of employers and employees alike - but it also comes with a price of its own [2, 3]. The management policies that have to be framed for such worldwide enterprises are extremely complex [2, 3].

The present project tries to take ideas from history as to how management policies were framed, and tries to make a humble contribution to the effective framing of policies in such complex organizations. The present era is the era of information technology [4], and the abundance of information of organizations, such as their investment and remuneration policies, their performance in the debt and equity market etc. Such data can be put to good use in framing of management policies [5].

The historical perspective section of this chapter briefly outlines the major categories of management theories and types used thus far in history, also indicating their shortcomings and pitfalls.

Following that, the main motivation for the present project, which is Margaret Wheatley's book titled 'Leadership and the New Science: Discovering Order in a Chaotic World' is reviewed briefly [6].

IBM – The Big Blue:

The organization of focus in my project will be IBM (International Business Machines Pvt. Ltd.) for mainly two reasons:

1. My professional career is defined around this organization.
2. It is a company of high quality.

Not many companies live for more than hundred years. Of these, the ones that maintain a high standard and impeccable reputation are only a handful [7].

What existed as a humble Computing Tabulating Recording Company in 1911 has now grown into a juggernaut [7].

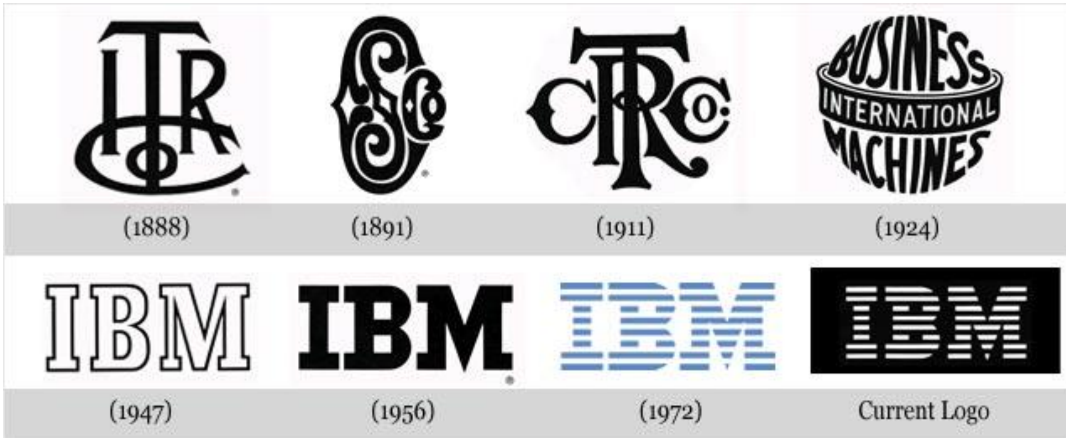


Figure 1 IBM Logos over the years

Yet, there is something unique about IBM that distinguishes it from other juggernauts of the likes of GE, Microsoft, Apple and others.

Cloud Computing, Big Data, Smarter Planet, Sustainable Cocoa, Deep Blue, Cell Broadband Engine, Preservation of culture, spintronics, nanotechnology, copper interconnects, genetic privacy, RISC architecture, Smart energy, DNA transistor, SiGe chips, fractal geometry, e-business, smart healthcare, Apollo space missions, Websphere, Linux, DRAM, FORTRAN, PC, the internet, patents and innovation – what do all these have in common ? All these are the milestones of IBM's 100 Year Historical Glory [7].

Figure 2 Few of IBM's 100 Year Milestones

Yet, the company remains ever so humble and modest, in accordance to the company's motto coined by T.J.Watson – "THINK!".

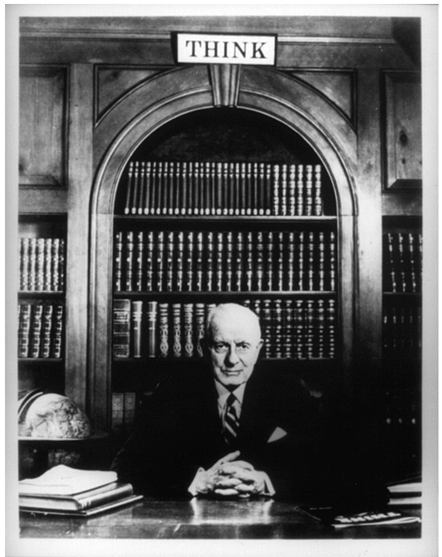


Figure 3 T. J. Watson, Sr. with the THINK Logo

Over the years, the company has never shied away from research and innovation, and the results are for all of us to see. The company invests in one resource – that is people, and the invaluable wealth of knowledge, insight and experience they bring with them [8].

The start of this year – 2014 – saw a dramatic turn of events at IBM offices across the world, but principally in India and the USA – two of its most populous workforces.

A huge layoff amounting to job cuts and weeping faces of 1000's of employees was witnessed [9]. Nobody was spared. Senior management, research engineers, managers, all had to face the axe. Most onlookers construed it as a black mark on the humanity aspect of the business giant.

While the ethics of such an 'out and about' layoff will be debated on company forums and websites for months to come, on the business front, IBM has reinvented itself. In 2013, the image of IBM was that of a business giant possessing a couple of only a few fabrication units across the globe. Come 2015 January, IBM will be seen as an aggressive, risk-taking game player in the emerging fields of cloud computing and big data [10].

Looking at the company's history, it has had many periods of 'reinventing' itself [11]. 2014 will be one of them. Looking at the company's performance in the past, it is likely to emerge with flying colors once again.

It is at this critical juncture that the company's management policies will be a crucial factor. The company is not short of money. It is not short of people either. Thus, a single speck of mismanagement may take the company a long way downhill.

Taking into consideration all these factors, the aim of this project is defined. It makes use one of IBM's biggest assets – big data and information processing – to come up with effective analysis and mapping of company's performance data to important policy announcements such that the company can make more precisely calculated decisions in the future [10].

A historical perspective:

In this section, some of the most prominent theories of management over the past three centuries are reviewed briefly, trying to assess the pitfalls and shortcomings of each. Emphasis is made over the past three centuries, because that is the beginning of when the industrial revolution and colonialism led to the concepts of “global workforce” and “large scale organizations” [3].

Scientific Management (1890-1940)

This was one of the first ‘management’ theories to be developed. As the name indicates, the theory followed a highly routine, mechanized approach to everything in management, including employees. This theory was best suited to large manufacturing and production organizations, where the main factor of consideration was quantity and not quality [12].

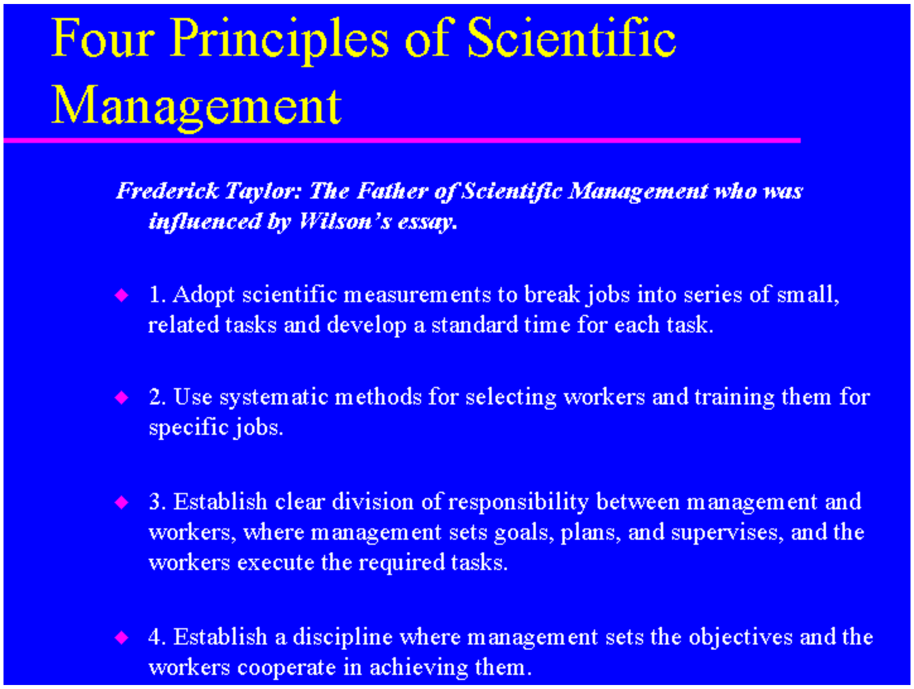


Figure 4 Principles of Scientific Management

Soon, it was to be seen that neither organizations that only produce and manufacture, nor a scientific management theory would last long. As the globalization conditions changed dramatically, organizations had to include more innovation, research and development in their budget. Quality played a major role. Optimizing quality and cost-cutting tradeoffs was purely a thing of strategic innovation [13].

Bureaucratic Management(1930-1950)

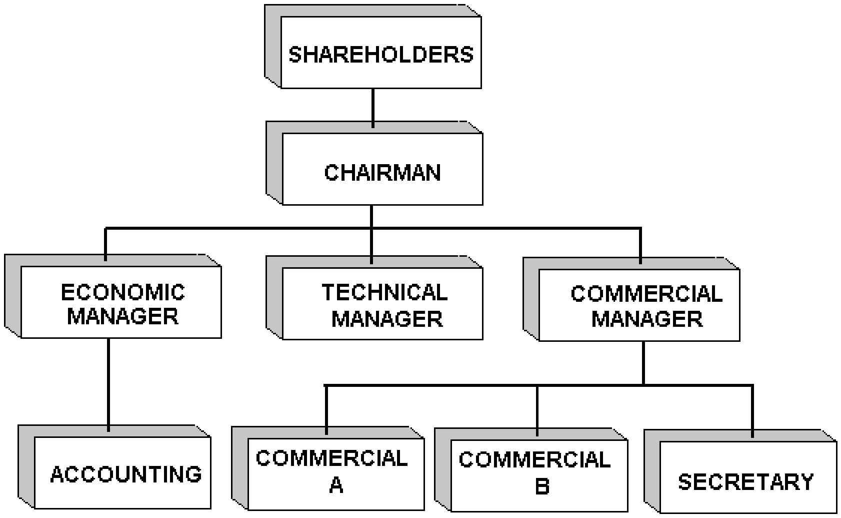


Figure 5 A typical bureaucratic Organization

Taking the concept of scientific management a step further, Max Weber defined Bureaucratic management, with immense emphasis on hierarchy, structure, rules and regulations [14]. While such an approach largely improved productivity and efficiency, it did little to encourage cross hierarchical talk and pooling of innovative ideas that could have become potential breakthroughs for the company. Once again, strategy and innovation took a hit, and this theory collapsed.

Human Relations Management(1950-Today)

"Take my assets-but leave me my organization and in five years I'll have it all back." - Alfred M. Sloan.

At the turn of the 50's, as most of Asia and Africa gained independence, the perspective on global management changed. People were valued as a resource – the most important resource of management. Each employee's uniqueness was highlighted. The value that each employee brought to the organization was understood. Today, Fortune 500 companies like IBM spend extensively on human resource development, training for employees etc. [15].

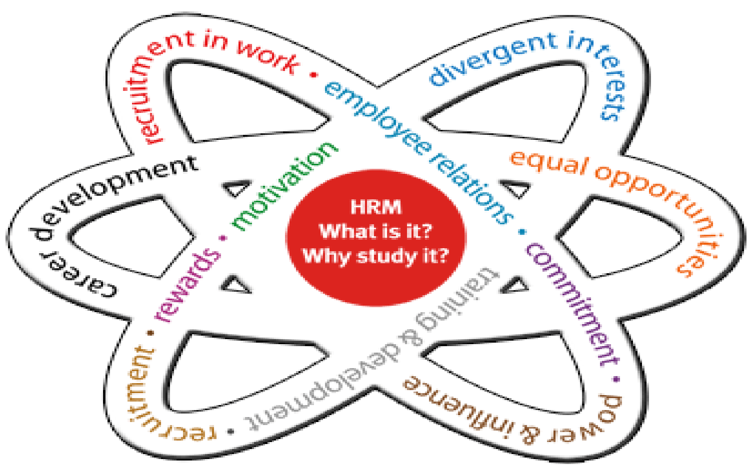


Figure 6 Human Relations Management

While this approach to management has proved to be largely satisfactory, it has its own complexity. Rating of employees, deciding compensation plans, deciding on a career advancement choice that would not adversely affect their family life – these form just the tip of the iceberg.

Contemporary Theories of Management

Among the quantitative vastness of contemporary management theories, three of them stand out:

Contingency Theory:

The Mantra of contingency theory – "It depends". There can be no universal management 'formula' [16]. The situations heavily dictate the type of management and the decisions made thereafter. A variety of leadership options from autocratic to democratic to participative are listed [17].

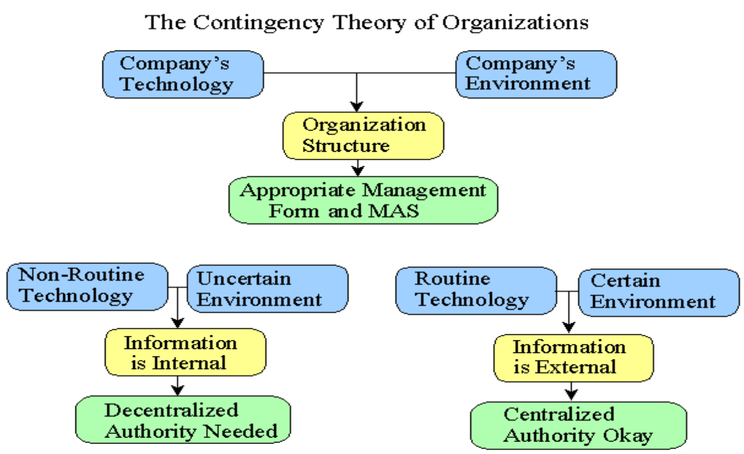


Figure 7 Functionalist Contingency Theory Model

Systems Theory:

Input->Process->Output. Systems theory is essentially a shift of paradigm from the reductionist, structural approach to a more wholesome, broad minded, functional approach. The organization is viewed here as a system, where the removal of even one component has a significant effect on the overall performance [18]. The management as a system consists of the activities of planning, organizing, controlling, coordinating etc [19]. The perception of a company as a system also rings along with it, the concept of feedback, and the notion of minimizing the error between what is desired and what is obtained. Total Quality Management as a course details the aspects and methodologies for quantification of the same [20].

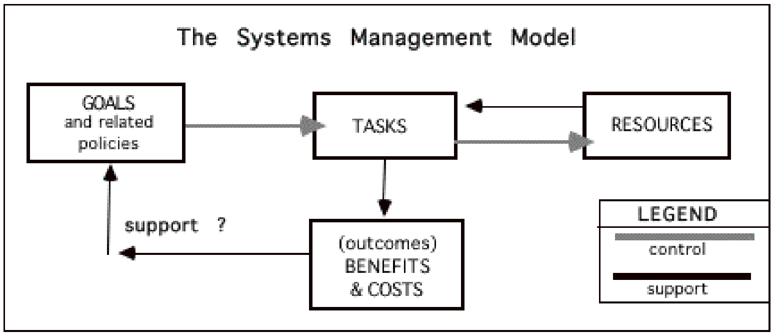


Figure 8 Systems Management

Chaos Theory:

Contrary to the popular negative notion of 'chaos', chaos theory projects chaos as evolution – evolution of complexity [21]. This theory, initially defined in mathematics, subsequently observed in physical sciences, life sciences, weather prediction, art and recently management, outlines how a system starts out as a simple structure, and slowly grows in complexity, sometimes to the point that it appears unruly, though in reality it is not unruly [22]. It is simply sensitive to the initial conditions. From this apparent display of disorder, a pattern starts to emerge. Thus, order to disorder and back to order – this is the rhythmic dance of chaos [23].

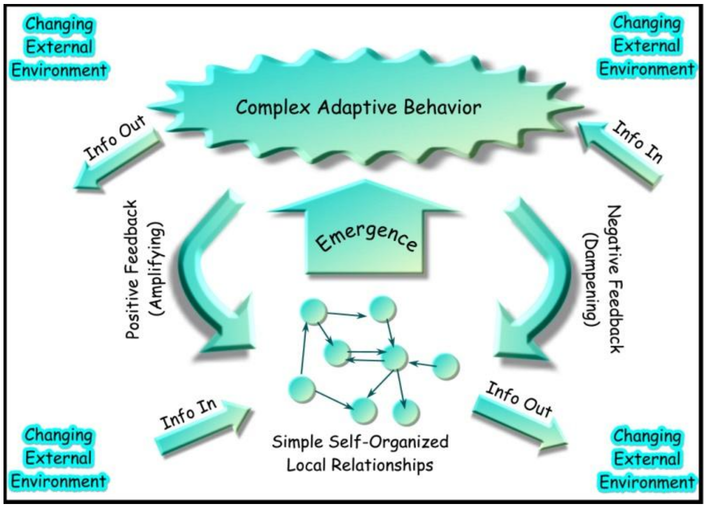


Figure 9 Modeling a Chaotic System

The last two among the above mentioned theories necessitate a shift in perspective. Companies are no longer what they apparently looked few years ago.

In a company like IBM with about 400000 employees, structural approach has little significance [24]. It is the system oriented functionality that matters. Moreover, the patterns arising out of complexity and chaos have to be understood as well. These activities hold the crucial key for effective management in today's era.

Leadership and the New Science: Discovering Order in a Chaotic World

This book, by Margaret Wheatley clearly outlines the concepts of systems theory and chaos theory from a scientific perspective and details how these concepts can be applied to effective management [6].

A Harvard University Doctorate, Margaret Wheatley specializes in Organizational Behavior, Systems Thinking, Theories of Change and Chaos Theory [25,26].

A few important nuggets from the book, relevant to the present project, are outlined below:

1. Management principles have always been derived from science principles, mostly derived from basic physics. Thus, 17th century images of Newtonian physics [27], promising exact predictability and mechanized clockwork motion instilled in us the thought that we could determine anything in this universe. This led to some of the earlier approaches to management – Scientific and Bureaucratic.
2. At the end of the 20th century, Science was reinvented. Quantum theory and chaos theory threw away the deterministic predictable nature of Newton and ushered in randomness, uncertainty, variety and complexity. Scientists described that the very foundations of science that they had been standing on for centuries were being dragged away from under their feet. This definitely calls for a 'reinvention' in management approach as well.
3. "Organizations are living, dynamic systems" – They live; they breathe; they have an identity of their own, apart from that of their stakeholders. They evolve and emerge. They form patterns.
4. "Change is an inherent capacity of living systems" – Organizations too change, they transform. Any effective management theory has to take into account such transformations.
5. "Order is inherent in the universe" – Organizations can be chaotic. They certainly are not noisy. The layoffs of IBM looked like a messy event in February 2014. Six months later, in August, it looks as a catalyst for reinventing the company. Thus, chaos may appear unruly, but underneath the apparent appearance, it has a pattern within. It is orderly. Order is everywhere.
6. "You cannot see order in chaos moment to moment" – Chaos is pattern. Patterns take time to evolve. Micromanagement without understanding the full pattern of the organization can be fatal.
7. "Chaos breeds Self-Organization and Creativity" – A classical explanation for the 2014 layoffs in IBM.

Transformation through Information

1. This is the era of information technology. Terms like Big Data, Information Explosion and Internet of Things are becoming buzzwords. Hence it is no surprise that Big Data and Cloud Computing have become the new focal points of IBM [10,28].
2. Chaos involves complexity. Complexity involves patterns. Patterns are extremely rich in information. By studying few quantifiable parameters of an organization like IBM, the patterns in which the organization evolves can be ascertained. The wealth of information that is uncovered can be used purposefully and constructively to frame effective policies corresponding to various issues such as investment portfolios, internal budget, remuneration policies etc [29].
3. Thus, in essence, the project combines the best features of both of the above mentioned points – information and chaos theory, to come up with an innovative, feasible, simplistic solution to the problem of complex management.

4. Fortunately, the last few years of research in chaos theory by eminent scientists and mathematicians worldwide have resulted in a lot of parameters and metrics that can effectively describe the nature and behavior of the patterns that the system displays while evolving.

Project Flow

In this section, the steps in the project are enumerated:

1. The signals and systems approach to understanding organizations is studied in detail.
2. Special kinds of systems, especially chaotic systems are reviewed.
3. The Share revenue data is considered as the basis data for analysis.
4. An analysis methodology based on chaos theory and various associated parameters is formulated.
5. Few important milestones in IBM policymaking in the recent few years are selected.
6. The formulated analysis methodology is applied to a few case studies pertaining to the milestones.
7. The effect of the policy changes on the pattern evolution is observed and tabulated.
8. This helps to validate the relevance of the formulated analysis methodology.

2. THE SIGNALS AND SYSTEMS APPROACH

In this chapter, the basic concepts of Signals and Systems are outlined, and the concepts are applied to the perspective of organizations. Following this, special kinds of systems including chaotic systems are reviewed, again applying them to the organizational paradigm.

Signal

One of the conventional definitions of a signal is that "A signal is any quantity that varies with time" [30]. Thus almost every variable in the world, such as heart ECG signal, weather data, Foreign exchange market data, employment data, options pricing charts, television viewership rates, variable interest rates are all signals.

Figure 10 IBM Share Price Data

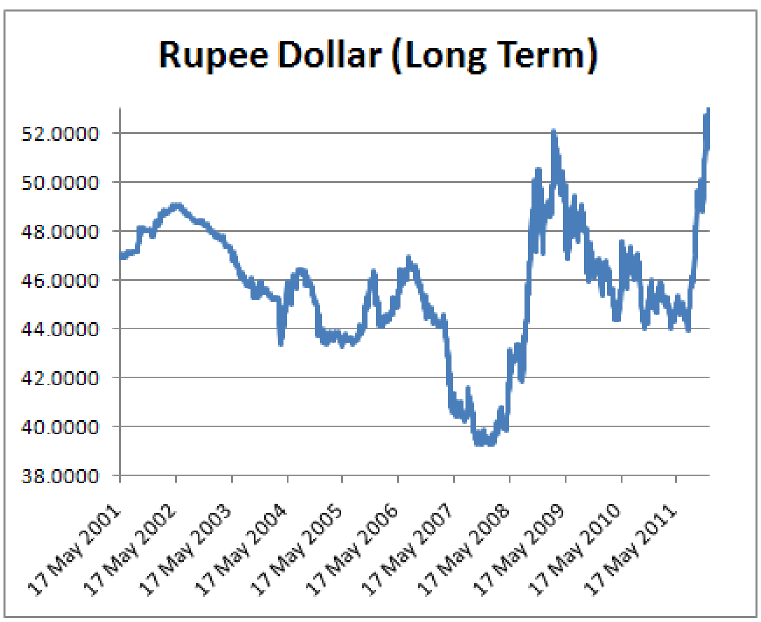
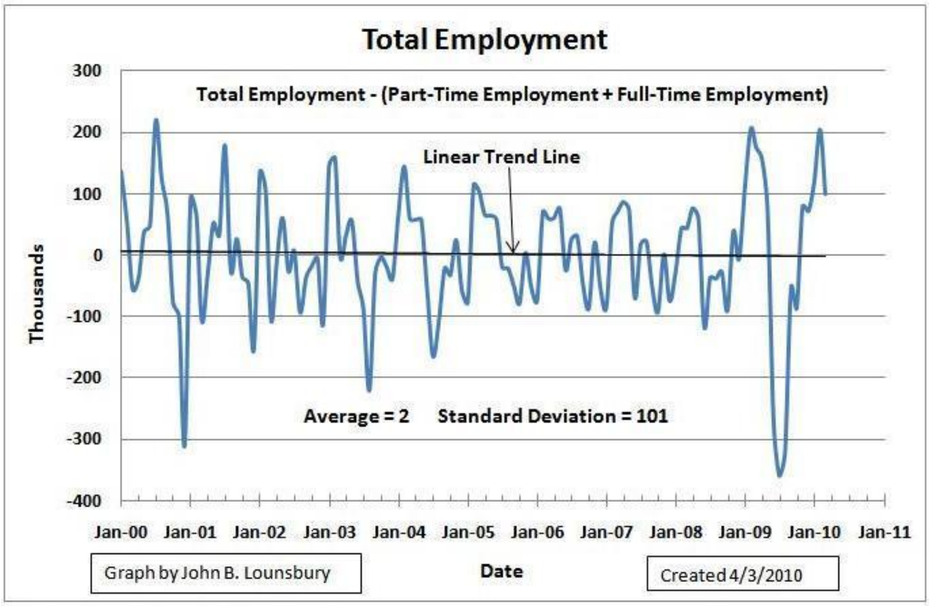


Figure 11 Rupee Dollar Exchange Rate



Data: U.S. Dept. of Labor

Figure 12 Employment Data

Most financial time series such as share revenue data, foreign exchange rates etc belong to a special class of signals called discrete signals [31, 32]. Discrete signals are only defined for certain instants of time. These instants are separated by equal intervals of time.

System

A brief definition of a system is that “A system operates on one or more input signals to yield one or more output signals” [30]. Examples of system include electronic circuits which operate on input and output voltages and currents, information processors and computer that operate on data collected through input devices such as keyboard and mouse, and output information through screen, printer etc.

Figure 13 Block Diagram of a System

Systems can be classified into different types:

1. Linear and Nonlinear systems:

In a linear system, the output is completely proportional to the input. Such systems are seldom found in the real world; but Newtonian Science used linear systems as reasonable approximations of real world systems [30].

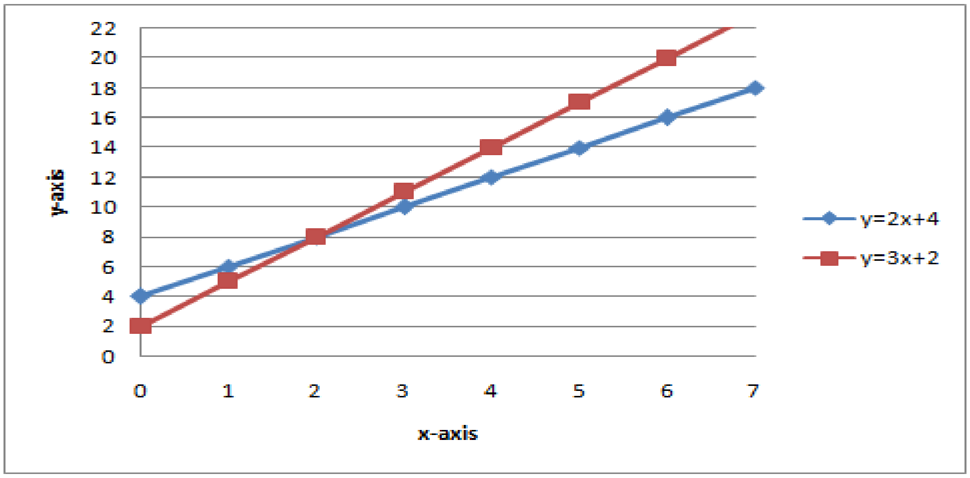


Figure 14 Examples of linear systems

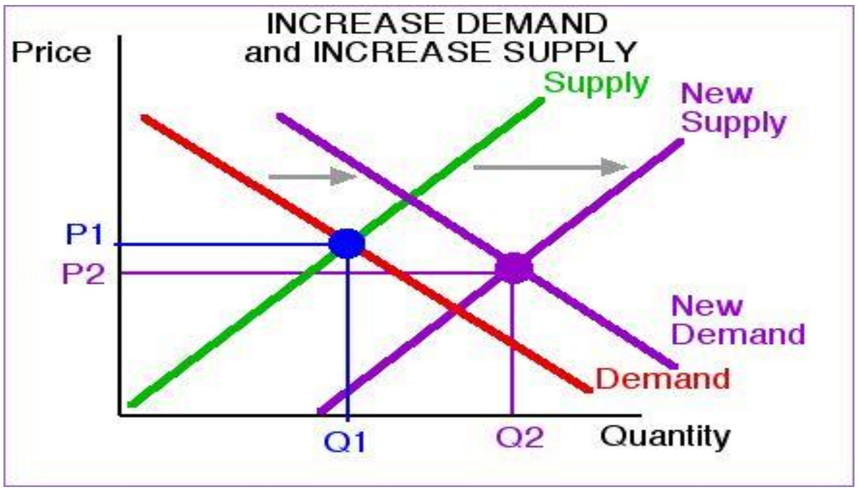


Figure 15 Linear Supply Demand Curve

In a nonlinear system however, the output is seldom proportional to the input. There may be a squared, cubic or even higher order dependence of the output on the input. In other words, nonlinear systems are sensitive to certain values or ranges of values of the input. Thus economic and financial curves such as the risk-return curve and the options pricing curve, which possess break-even points are classic examples of nonlinearity [33, 34].

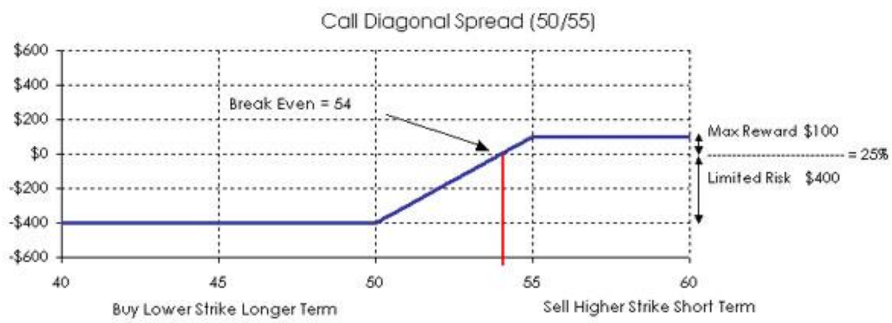


Figure 16 Call Diagonal Spread showing a break even point

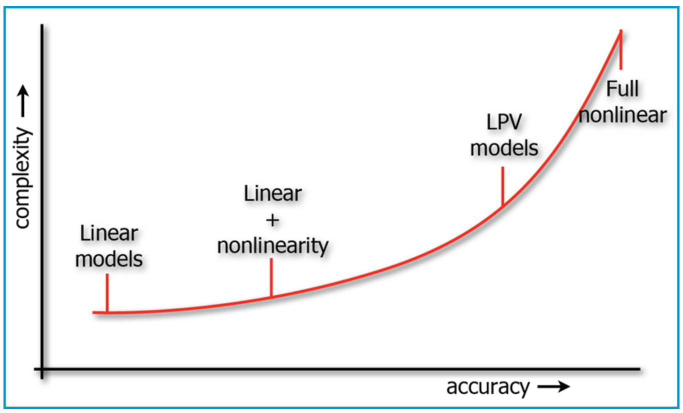


Figure 17 Example of a nonlinear relationship

2. Memory and memoryless systems:

In a memoryless system, past input and output values do not affect the system's present state. Thus, it is totally oblivious to the past occurrences and the effects of such occurrences, and it takes a 'random walk' through the values with little to no correlation to previous outputs. An organization operating in such a pattern is doomed to collapse and what ensues as the output is absolutely noise [30, 33].

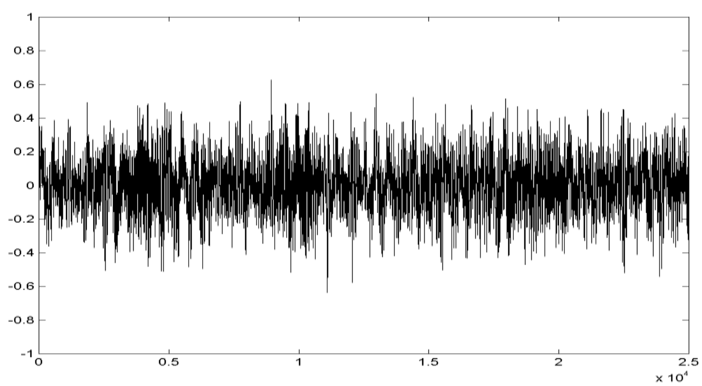


Figure 18 Noisy output signal of a memoryless system

In a memory system, the system's current value is influenced by past values and occurrences. Thus, there is a 'memory' of the system. The memory can be viewed as a predetermined set of rules that the system follows. In other words, it determines how the system evolves. It is this same memory that also decides the complexity of the system. As the memory or the information capacity of a system increases, so does its complexity. The result is that the evolution pattern becomes more rich, more ornamental and more decorative [33].

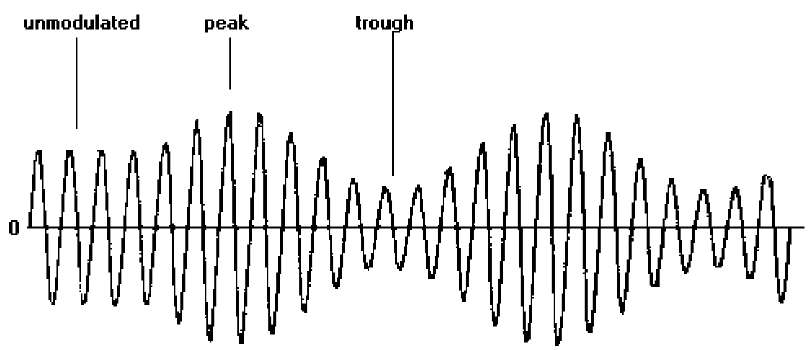


Figure 19 Structured output of a memory system

An organization as a system

One of the key features of the systems theory of management is that the organization is viewed as a system. In this section, this concept will be explored and a signal and system model of IBM will be framed, which will be the basis for the analysis methodology proposed in the next chapter.

A complete system essentially consists of three components: Input, the system itself, and Output. An additional fourth component, feedback is sometimes included.

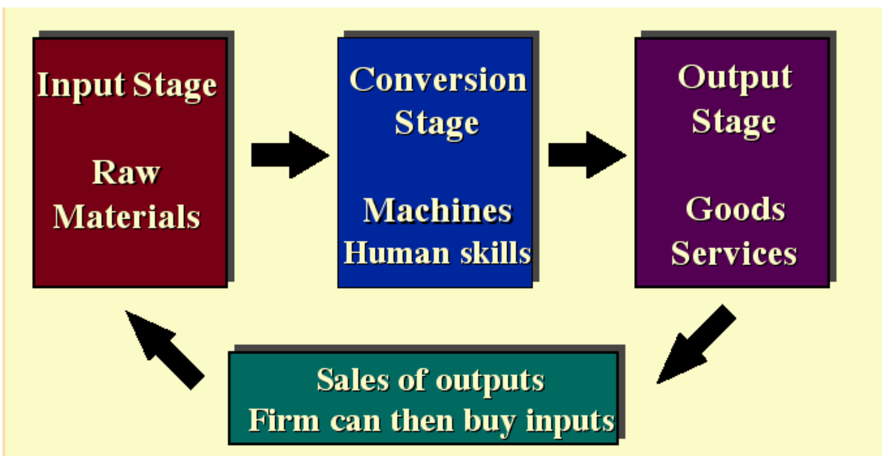


Figure 20 Typical systems theory model of an organization

An organization consists of many components. Traditionally, these are classified as the 6 'M's of management [35].

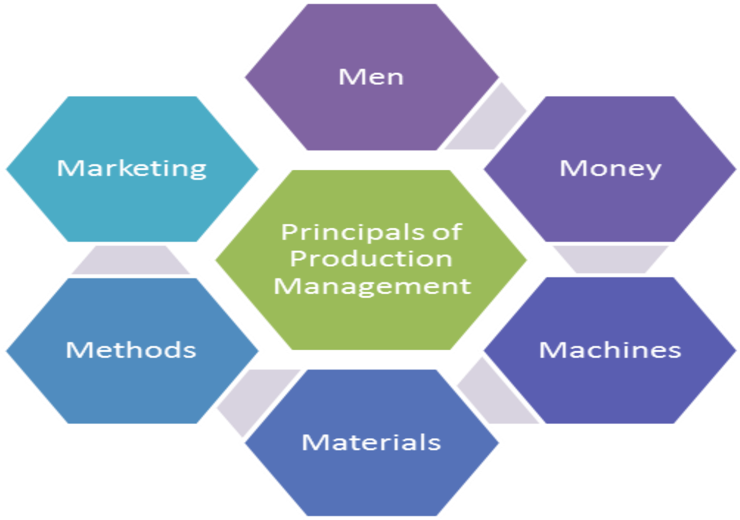


Figure 21 The Six M's of Management

Input is the signal that goes into the system. In other words, input is the external driving force behind the system. For typical multinational companies, inputs could be resources, assets etc. Since traditionally IBM has been a research oriented organization, the principal assets are the employees. Thus, the major investment that IBM makes is the remuneration to these employees. This has reduced greatly, IBM's reliability to natural resources, which is one of the reasons the company has sustained for over 100 years.

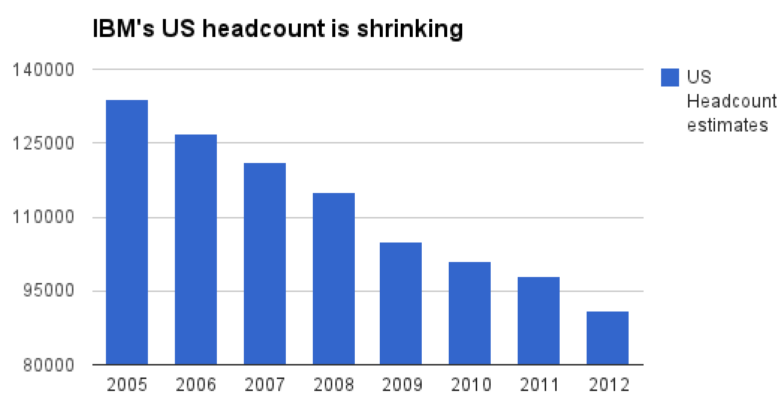
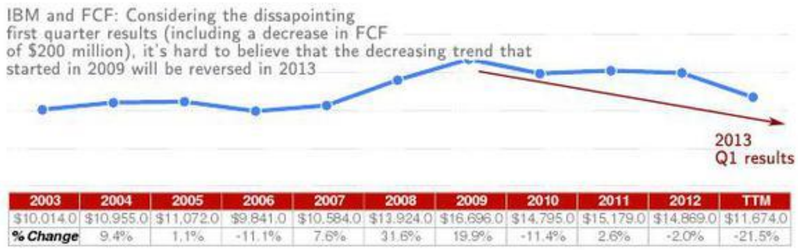


Figure 22 IBM US Headcount

Output is the signal that comes out of the system. It denotes the processed result of the system. Most usually, the output variables are profits and returns, shares purchased etc. For a huge company like IBM, various business units have different outputs. Whereas software product and service based divisions are based on profit, the older Hardware and research based divisions rely on non-tangible output parameters like patents etc [36]. Since IBM is listed on the New York stock exchange (NYSE) [37], the share revenue of the company plays a crucial role, as it depends on both the profits earned by the company as well as the intangible assets like patents and Intellectual Property rights which create confidence in the shareholders.



2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	TTM
$10,014.0	$10,955.0	$11,072.0	$9,841.0	$10,584.0	$13,924.0	$16,696.0	$14,795.0	$15,179.0	$14,869.0	$11,674.0
% Change	9.4%	1.1%	-11.1%	7.6%	31.6%	19.9%	-11.4%	2.6%	-2.0%	-21.5%

Figure 23 IBM Cashflow data

The system, which is the organization itself, is a complex unit consisting of the 6 M's. It is far too complex to model using basic components and units.

The Chaotic System

Chaotic systems can be roughly defined as systems which are clearly distinguished by sensitive dependence on initial conditions and having deterministic evolution even though the phase space appears to be quite random [38].

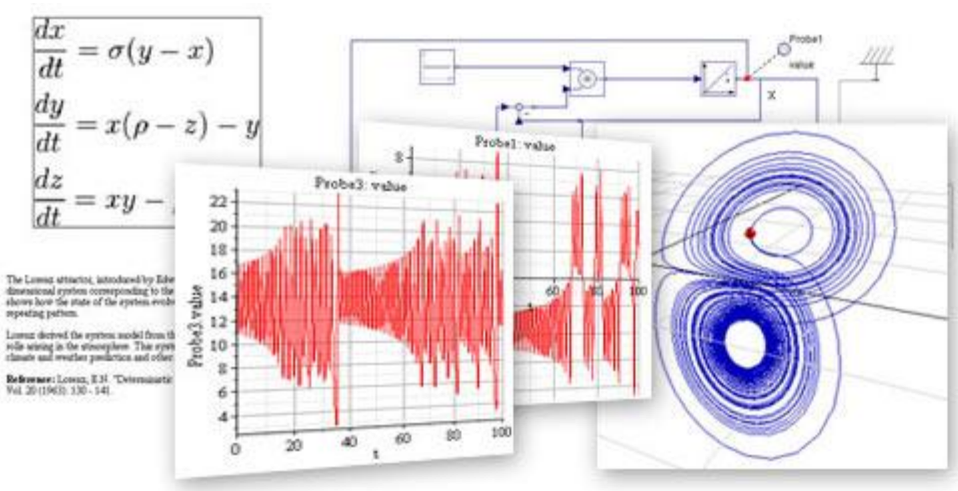


Figure 24 Lorenz system, a typical chaotic system showing equation, output signal and the ornamental evolution pattern

The Chaotic system is a nonlinear, memory system which displays a very unique property:

Sensitive Dependence on initial Conditions

This concept can be explained by a very illustrative quote attributed to Lorenz [39]. "Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?" This has further led to the term "The Butterfly effect". Since chaotic systems are nonlinear, they tend to amplify and exaggerate certain inputs. Also, since they have memory, this causes further spilling over of the results into other areas, and in due course, the trend of the whole system changes drastically [39].

Figure 25 The Butterfly Effect

A typical example of this is that when the India Election results of 2014 were released on May 16th, early trends slightly favored the Narendra Modi led BJP Government. This was immediately reflected as a sharp increase in the SENSEX index.

Figure 26 NIFTY data showing the sharp rise on May 16th 2014

The Need for a Signal and System Approach to analyze patterns in IBM

Now the logical question is: why do we need a signal and system approach to analyze IBM data ? The following points help to clarify:

1. IBM, as mentioned in the first chapter, is a large, continually evolving organization, that repeatedly goes through phases of 'reinventing' itself. Even for such a business giant, the reinventing phases create considerable turmoil and mixed emotions. A bit of introspection into finding out how the market has responded to similar cases in history and the effect that the remuneration and other policies has had on employees will surely go a long way in easing out the framing of policies.
2. The previous section clearly outlines how IBM as an organization can be viewed as a system. The principal asset of IBM (its workforce) and the investment that IBM makes towards them by way of remuneration is the input. The people's opinion of IBM, witnessed as the market dependant share revenue data is the output.

3. Clearly, IBM could be described as a complex, dynamic, evolving system, which satisfies the properties of a chaotic system. There is a wealth of information available for the share revenue data of IBM over the past few years, where certain trends could clearly be identified. A proper signal analysis formulation can clearly bring out the trends and map it to the decisions taken within IBM in the corresponding time duration.

3. FORMULATION OF AN ANALYSIS METHOD

Taking forward from the concepts of signals and systems outlined in the previous chapter, this chapter proposes a signals and systems based analysis methodology using various standards and metrics. A proper explanation, classification and formulation of the various metrics are given. In the end, a sample analysis is given so that the various metrics outlined can be understood more clearly.

Analysis

The following assumptions are made in the analysis of IBM data:

1. IBM is a large, growing and evolving organization, which can be suitably classified as a chaotic system, hence enabling us to apply the principles of contemporary theories of management such as systems theory and chaos theory.
2. The principle investment of IBM is remuneration and thus this is the perfect indicator of the input signal.
3. The share price and revenue data of IBM reflects the market's opinion on the progress of IBM, and is one of the principal sources of revenue for the company. Thus it represents the output signal.
4. Various policy revelations and changes within IBM such as Declaration of dividends and earnings per shares, annual hike announcements, layoffs and retrenchments, and acquisitions clearly reflect in the share revenue data, usually with effects such as the butterfly effect dominant in such trends.
5. Thus, the analysis methodology proposed in this chapter serves to observe the trends and patterns in the share revenue data, try to correlate it with the policy changes and observe the effect that these changes have on IBM employees and the outside market.
6. There are two signals considered for the analysis – daily share price (closing) and share revenue (closing price*volume sold).

The metrics and their respective analyses detailed in this chapter may be grouped broadly into three categories:

1. Temporal Analysis: 'Temporal' is the adjective of time, and temporal analysis refers to the study of how a given signal, such as the IBM share revenue varies with respect to time. Thus, this kind of analysis, apart from giving a glimpse of the 'ups and downs' of a signal, also give other useful results such as the evolution patterns and short term patterns of interest.
2. Spectral Analysis: This pertains to the frequency aspect of a signal. The frequency refers to the rate of change of share variables (i.e. how often it changes values). A signal may have multiple frequency components at the same time. For example, there may be weekly as well as monthly patterns in the variables. Also, the periodicity of the signal can be ascertained using spectral analysis.
3. Nonlinear Analysis: Since the system considered here is nonlinear (chaotic system), nonlinear analysis is required to bring out the true characteristics of the system. These include crucial

aspects such as sensitivity, information capacity of the signal, and the self-repeating nature of the signal.

The results of all three kinds of analyses put together give a complete picture of the output signal and the system it comes from.

Temporal Analysis

The first category of analysis is the temporal analysis. This comprises three components, described as follows:

1. Time Series:

The time series is a representation, a graph of how the share variable varies with respect to time [30, 31, 32, 33, 34]. From this data, the general trend as well as the 'ups and downs' of the signal can be ascertained. For example, the time series of IBM share revenue for a period of two years from 4th February 2012 to 4th February 2014 is plotted as follows:

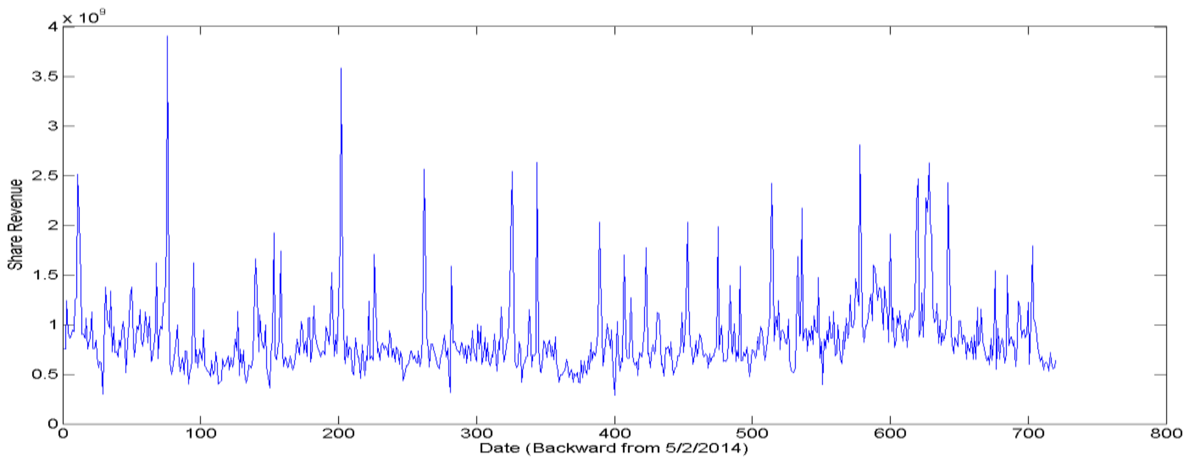


Figure 27 Time series of Share Revenue of IBM

The horizontal (x) axis indicates the number of days going backwards from 04/02/2014 to 04/02/2012. The vertical axis (y) indicates the revenue in dollars (US$).

From the time series, a few inferences become clear:

1. The share revenue is sporadic. While on most days the daily revenue remains in the vicinity of 1 billion dollars, it occasionally shoots up to as much as 4 billion dollars.
2. A certain minimum level is maintained. Very rarely has the revenue fallen below 0.5 billion dollars.
3. By looking at the 'baseline' one sees a dip near 365 days. And on either side of the dip, the baseline slopes up to a gradual 'hillock'. Roughly, this indicates a yearly periodicity in the share revenue.

2. Phase Portrait:

Phase portrait is one of the most valuable analysis results of a chaotic system. It is a qualitative analysis of the evolution of the system. In other words, it shows the path or 'trajectory' that the system follows [40].

The concept of phase portrait originates from mechanics where a 'phase space' was a plot of speed as a function of distance. Generally, the phase plane of a signal is defined as the plot of the signal (v) versus its time derivative (dv/dt) [41].

The following examples help to understand the concept of phase portrait clearly:

Firstly, a normal signal, such as a sine wave is taken. The waveform and phase portrait are shown as follows:

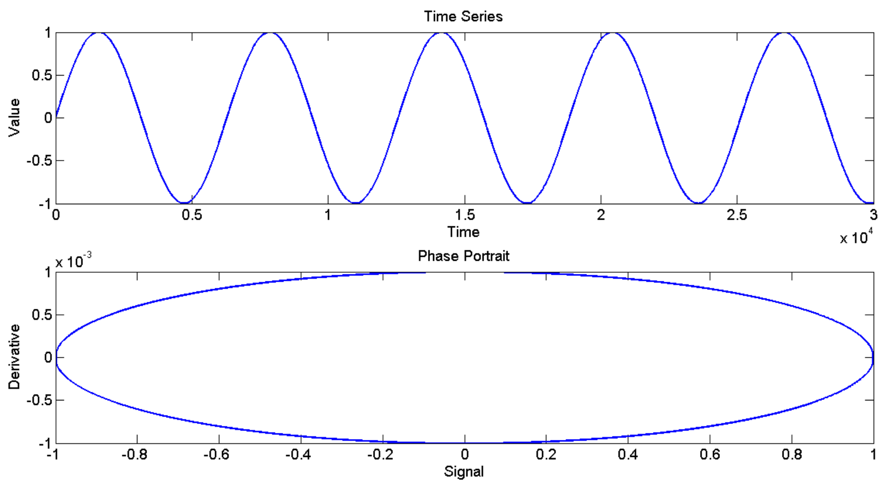


Figure 28 Phase Portrait of a sine wave

As can be seen, the phase portrait of a sine wave is a simple circle/ellipse. This circle describes the path that the signal takes. The signal constantly takes a circular path without changing the radius or the centre. Simple phase portraits such as these come under the category of "very low complexity".

Next, a slightly more complex signal is considered. The signal is a sinusoidal, whose value keeps increasing with respect to time. The signal and phase portrait are as follows:

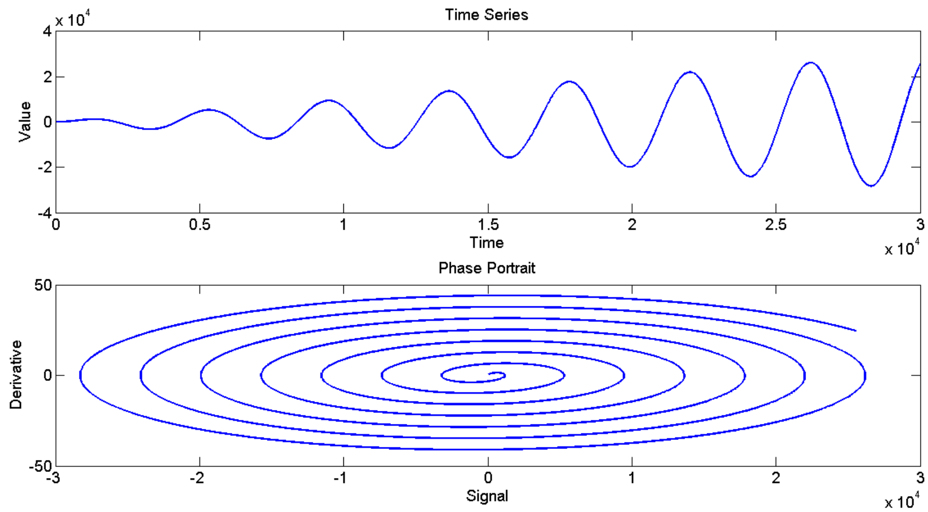


Figure 29 Phase Portrait of a limit cycle

The phase portrait of such a signal is a spiral. A spiral is a circle whose radius keeps increasing with every revolution. In other words, the path traced is a circular path as in the previous case, but moving farther and farther away from the centre. This indicates that the system is unstable since the upper limit of the - signal keeps varying. For this reason, such a phase portrait is called a 'limit cycle' [42].

Next, the complexity is increased even further. This is when the chaotic regime starts [43]. A typical example of a signal and its phase portrait is shown as follows. This signal is obtained by the multiplication of two sine waves of different speeds.

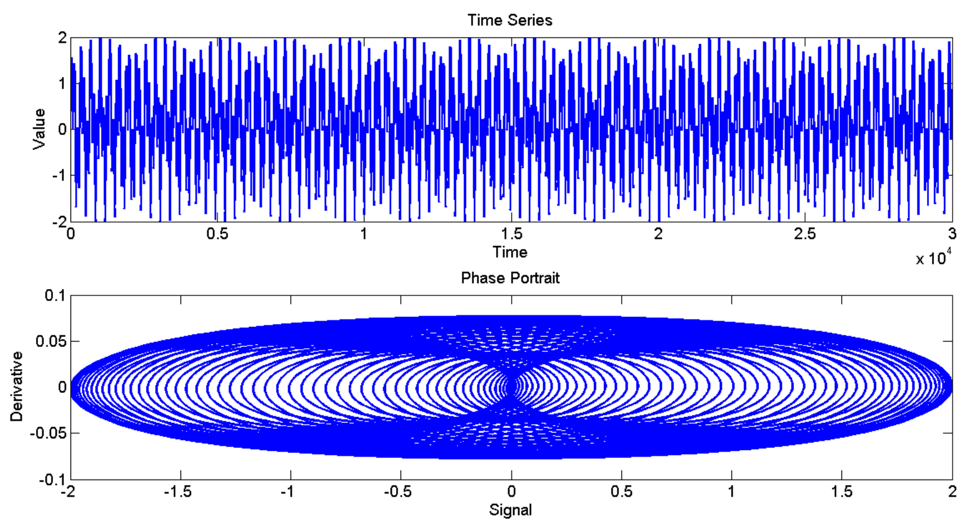


Figure 30 Chaotic Signal Phase Portrait

As can be clearly seen, the signal gives a noisier and more complicated appearance, whereas the phase portrait appears more ornamental. In general, the overall pattern of a phase portrait is called an 'attractor'. Hence, circles, limit cycles, torus etc. are all attractors [22, 38, 40, 42].

There are several popular chaotic systems in literature, in diverse areas such as weather forecasting, electronics, optics, biosystems, power systems, economics, information theory etc [34]. A few such phase portraits are as follows:

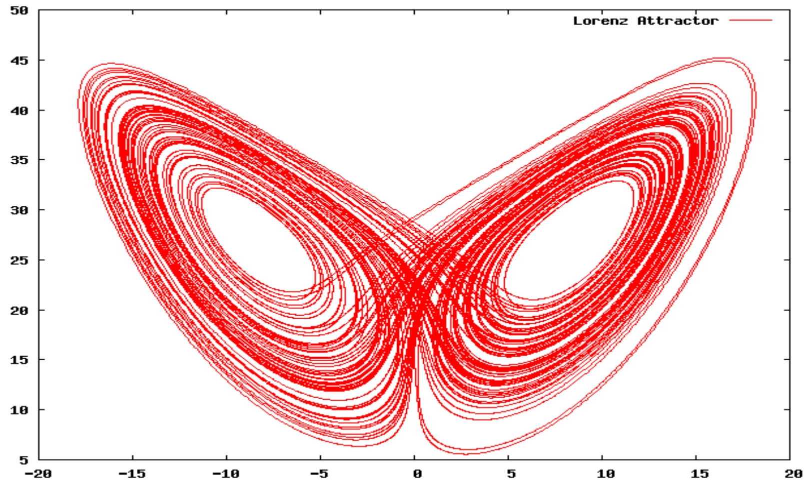


Figure 31 Lorenz Attractor

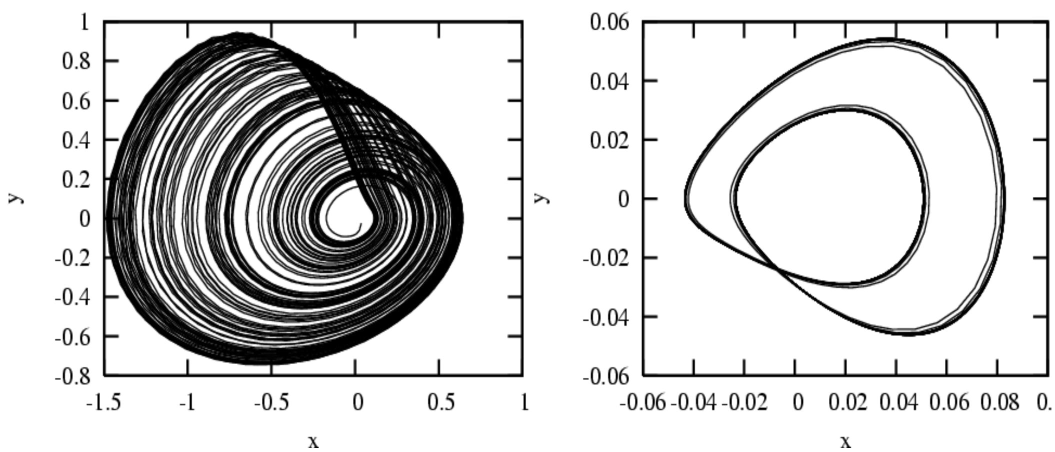


Figure 32 Rossler Attractor

A special case of such attractors is the Tamari attractor which was reported to have described the macroeconomic evolution of Israel during the ruling party change in 1977.

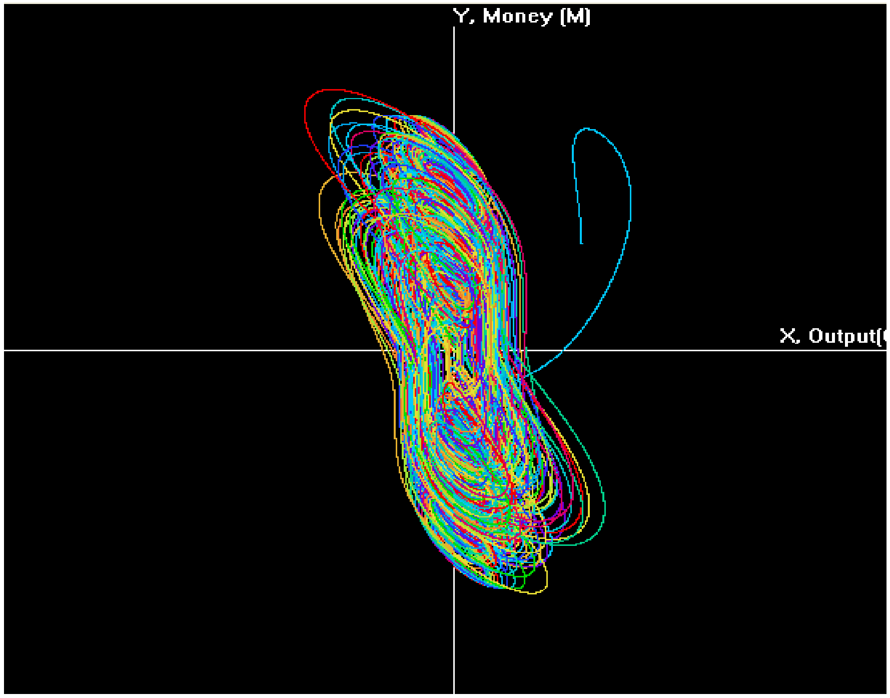


Figure 33 The Tamari Economic Attractor

From the phase portrait, one can understand the following:

1. The degree of complexity in the signal, and hence the system from where it originates.
2. The pattern, and the approximate trend it will take in the future, given its present position in the phase plane. This corresponds to the famous quote on chaos: "When the present determines the future, but the approximate present does not approximately determine the future."

Thus, for a chaotic system, the phase portrait is one of the most valuable tools for a qualitative ascertaining of complexity.

3. Multiscale Analysis:

Most financial variables such as share data vary over different time scales simultaneously. For example, yearly events such as budget announcements and monthly events such as salary pay-days are both influencing factors in the purchasing of shares [43]. In such cases, multiscale analysis becomes a useful tool. A typical multiscale analysis technique is the wavelet analysis [44]. Here, a wavelet is defined as an aperiodic oscillatory signal.

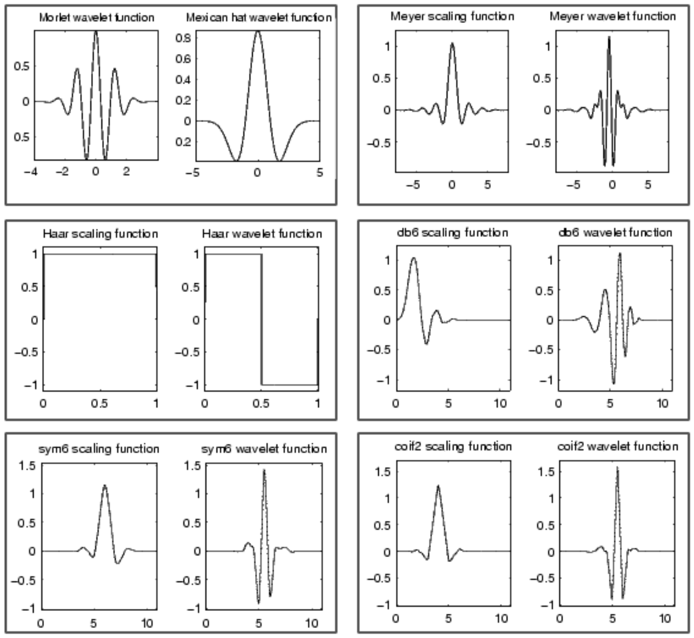


Figure 34 Commonly used wavelets

The multiscale analysis technique involves expanding or contracting the wavelet to different scales and trying to match it with the share data. A strong match indicates that the corresponding scale influence on the share data is present [44].

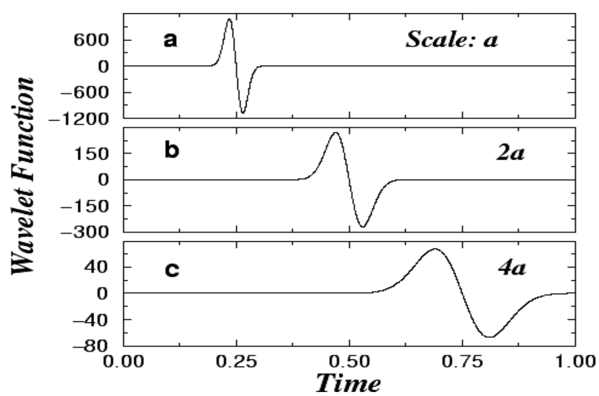


Figure 35 Multiple Scales

As an example of the multiscale analysis, the wavelet analysis of S&P 500 index is shown as follows:

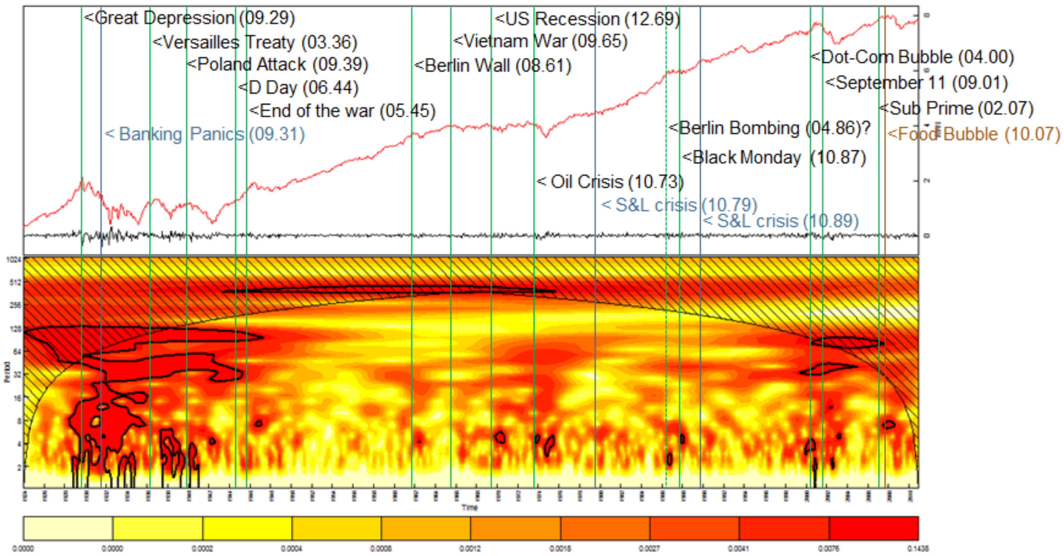


Figure 36 Wavelet Analysis of S&P 500 index

The figure shows the time series of S&P 500 index since 1923, marking important historical events. The colored image is the contour result of the wavelet analysis. Here, the vertical axis indicates the timescale, in days. Darker colours indicate more influence of that time scale on that signal. As can be seen, an event such as the dot com bubble shows a prominent effect on the 30 day time scale (monthly). More serious events such as the D-day of World war 2 signaled larger time scale effects of nearly 500 days.

The wavelet can be any of the commonly used types such as Haar, Daubechies, Morlet etc. The present work uses the Gaussian wavelet which is shown as follows [44].

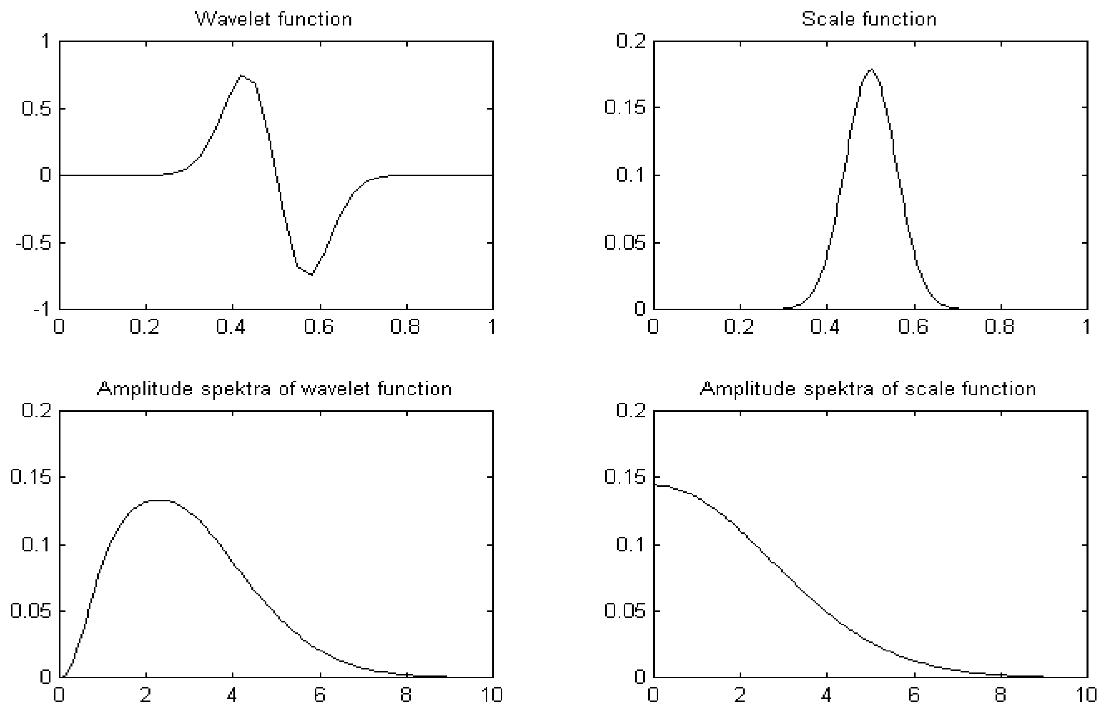


Figure 37 The Gaussian Wavelet Function

The wavelet analysis is most effective when focused in shorter time scales to understand the impact of an event. From the wavelet analysis, both the timescale of influence of that event as well as the duration for which the influence actually existed can be obtained.

Spectral Analysis

The spectral analysis comprises of three components as detailed below.

1. Magnitude Spectrum

Spectrum is a compilation of frequencies. Frequency indicates repeatability, periodicity. Frequency is thus the periodicity of a signal over a particular time scales. Thus, spectrum is the distribution of the periodicity of the share data over different time scales [45].

The magnitude spectrum is numerically calculated by taking a Fourier transform of the signal [45]. The Fourier transform converts time changing signals to frequency distributions.

As an example, the magnitude spectrum of the Euro/USD exchange rate from 2000 to 2006 is considered. The magnitude spectrum of the same is as follows:

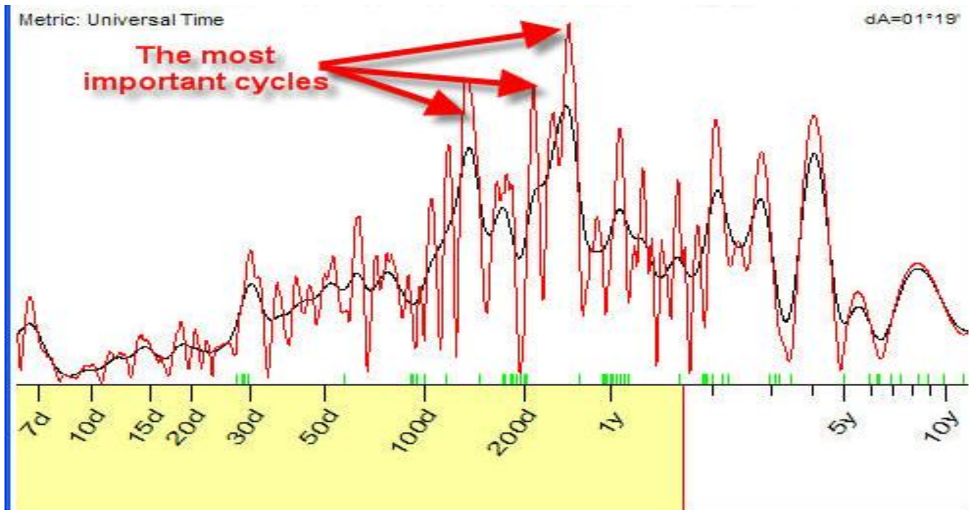


Figure 38 Magnitude Spectrum of the Euro/USD showing prominent time scales

The magnitude spectrum clearly highlights that time scales of 100 days to 1 year are most prominent, thus hinting at yearly repetition of the exchange rate trends.

Thus periodicity distribution can be quantitatively ascertained from magnitude spectrum.

2. Polar Plot

While the magnitude spectrum indicates the periodicity of a signal, it does not indicate the locations of such periodicity. For example, the magnitude spectrum indicates yearly periodicity, but does not indicate which time of the year, the highest rates occur. In sich cases, the polar plot comes in handy.

The polar plot is derived from the polar coordinates [46]. Mathematically, a pair of Cartesian coordinates such as time and value can be converted into polar coordinates – those are magnitude and phase. Phase answers the question which part in the whole (time of the year), and magnitude answers the question how much in that phase.

For example, the polar plot of yearly UK gas consumption for three distinct years is as follows:

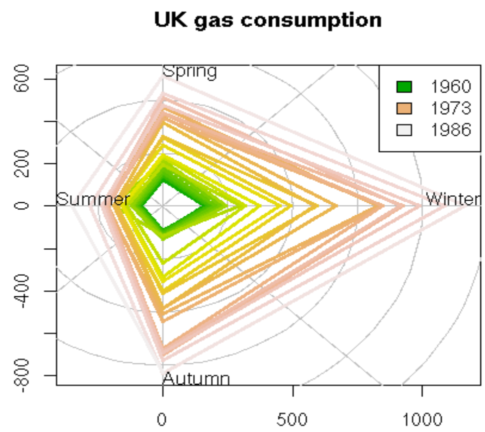


Figure 39 UK Gas Consumption - polar plot

As can be seen, the angle (phase) varies with the four extreme points representing the four seasons. The radius indicates the magnitude. Clearly, gas consumption in the UK shows a periodic trend, with most consumption occurring in the winter of each year, when the weather is the coldest.

3. Spatial Representation

In time series involving very large durations such as 5 years and above, one would like to see how a particular part of the signal 'fits in the bigger picture'. In other words, does a particular event happen periodically? If it does, does its intensity keep increasing or decreasing everytime? In such cases, a spatial representation of multiple 'time segments' is required.

The technique involves taking the concerned share data, splitting it into segments, 'stacking them up', and representing them as pixels on an image [47].

For example, the share revenue of IBM for 2500 days backward from 06/08/14 is represented as an image, with the segment length being 4 months.

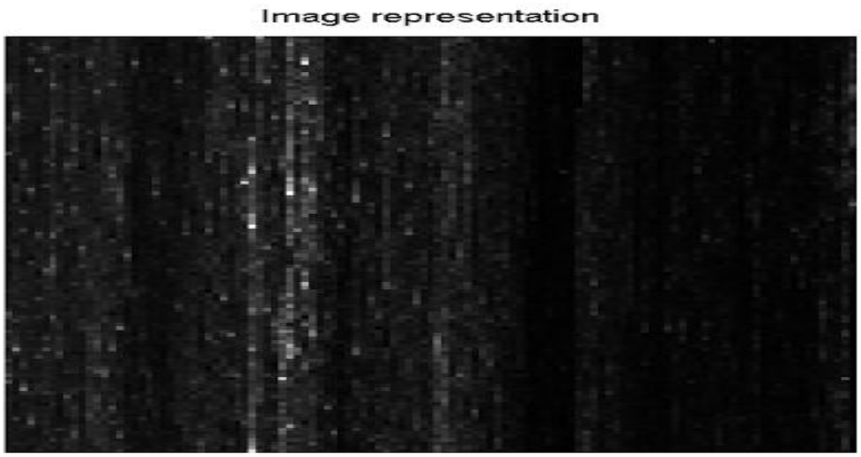


Figure 40 Spatial representation of IBM share revenue

As seen in the figure, the white spots indicate high sales of shares. The overall alignment of the white spots in roughly the same vertical position indicate the periodicity, and the position of any of such white points horizontally reveal how brighter/darker it is in comparison to other such white spots. This indicates how better/worse it is than the previous/next sale.

Nonlinear Analysis

While the temporal and spectral analyses provide an effective qualitative representation of the patterns and trends underlying the IBM share price and revenue data, it is the nonlinear analysis that gives quantitatively assertive information about the nature of the patterns and trends.

1. Largest Lyapunov Exponent (LLE)

The Lyapunov Exponent quantifies "Sensitive dependence on Initial Conditions" [48]. In other words, the Lyapunov exponent quantifies the Butterfly effect [39].

A better understanding of the Lyapunov exponent is obtained by the following figure:

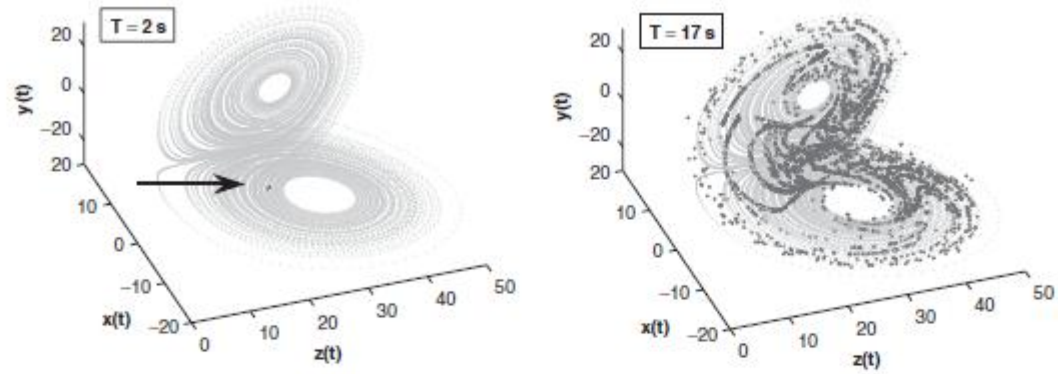


Figure 41 Calculating the Lyapunov Exponent

The above figure shows the Lorenz attractor. In the left pane, the initial time is shown, where a group of very closely separated points are taken. In the right pane, the same points are shown after letting the system evolve for some time.

As can be seen, what were closely separated points in the left pane are scattered wildly in the right pane. The left pane indicates the 'initial condition' and the scattering of the points indicates the sensitivity [48].

The distances between the various points in the right pane are plotted as divergence of nearest trajectories.

The Lyapunov exponents are quantification of these divergences. It is defined as the exponential rate of expansion or contraction of the trajectories in a given direction. It is mathematically given by,

$$\lambda_i = \lim_{t \to \infty} \frac{1}{t} \ln\left(\frac{\|\varepsilon(t)\|}{\|\varepsilon_0\|}\right)$$

Figure 42 Lyapunov Exponent

The largest Lyapunov exponent is the final measure of sensitivity obtained. Though the calculation of Lyapunov exponent requires the actual system to evolve over a period, modern techniques such as the Rosenstein algorithm can be effectively used to obtain the Largest Lyapunov exponent fro the time series directly [49].

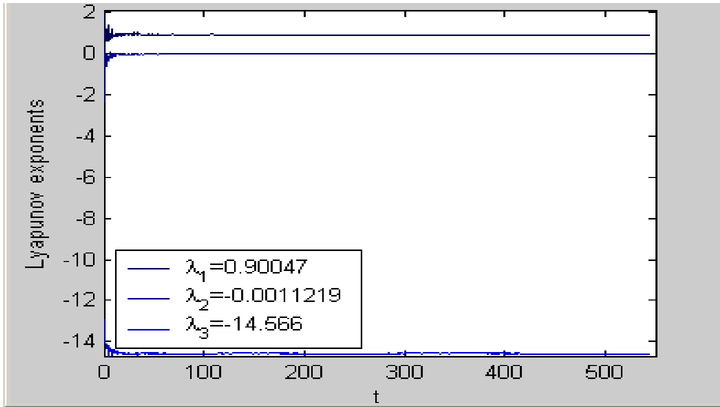


Figure 43 Lyapunov exponents of the Lorenz Attractor

From the largest Lyapunov exponent (LLE) the nature of the system can be inferred as follows:

1. If the LLE is negative, the periodic nature dominates (it may be regarded as a chaotic system with very less complexity).
2. If the LLE is zero, the system is memoryless and noisy.
3. If the LLE is positive, chaotic nature dominates (that is, the complexity of the system is high).
4. The farther the LLE is from zero, the greater is the sensitivity of the system.

2. Fractal Dimension (D2)

A fractal is a system in which, ‘any part of the system resembles the whole’. Most chaotic signals are fractal [50].

A very illustrative insight into fractal nature can be inferred from the Koch fractal [50].

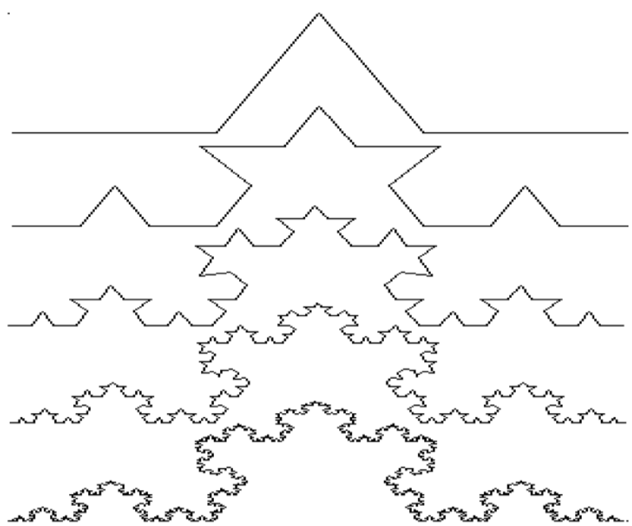


Figure 44 Koch Fractal

Construct a straight horizontal line of any length. Draw an equilateral triangle on the middle one-third and erase the base. Now, we end up with four line segments. In the middle third of each line segment draw equilateral triangles and erase the bases. Now we have sixteen line segments. Repeat the process for each line segment.

After four or five iterations, we end up with a complex and ornamental looking structure. It is called a fractal, since in each iteration, we developed on a fraction (1/3) of the original. The significance of the final pattern is that each part of the final pattern is a miniature version of the whole. This property is known as 'self-similarity' [50].

A few fractal designs in nature are as follows:

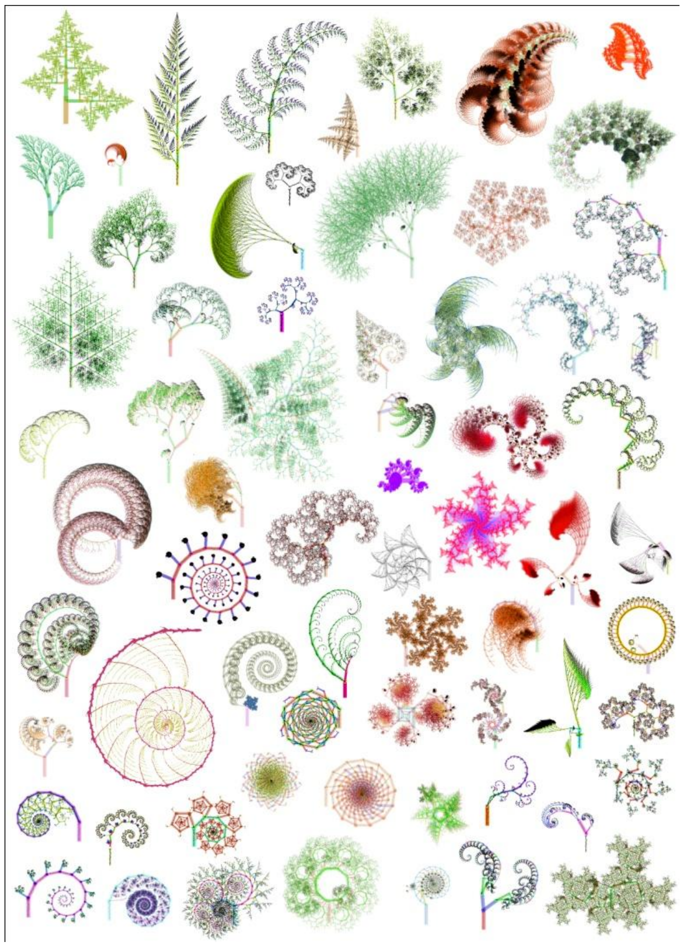


Figure 45 Examples of Fractals in nature

The fractal dimension of a space denotes the degrees of freedom of a particle to move around that space [51]. For instance, a particle in a square can move in two directions: up/down, and left/right. Thus the dimension is two. For fractal structures, since a fraction of the whole is being chewed off every time, the dimension ends up as a fraction such as 0.7 or 0.4.

Thus D2 is a measure of the dimensionality of the signal. A high fractal dimension such as 0.9 or 0.8 indicates more instability than lower dimensions such as 0.6 or 0.4.

Various methods and techniques have been proposed to calculate the fractal dimension of a signal. One of the famous method is the box counting algorithm whose result is called the 'Minkowski Bouligand Dimension' [52, 53].

As an example, the fractal dimension of the Euro-USD conversion is shown as follows:

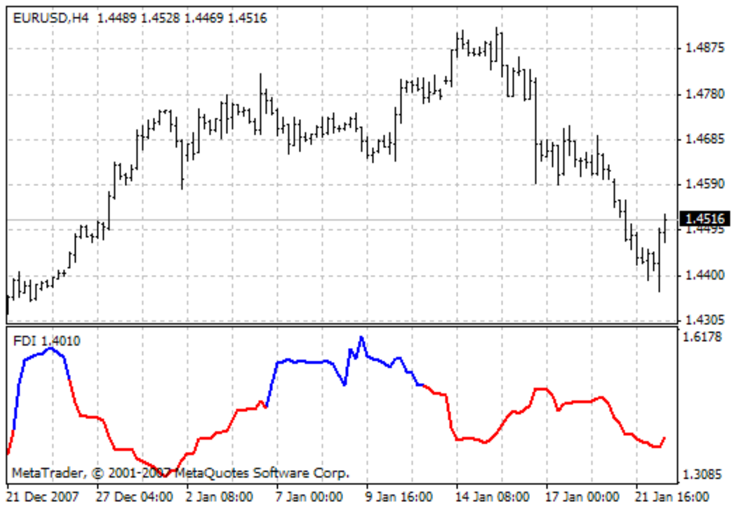


Figure 46 Fractal Dimension of Euro-USD rate

3. Kolmogorov Entropy (K2):

The Kolmogorov entropy is an indicator of the information content of the signal. The concept originated from information theory [54, 55].

The number of times that the time series of a share data crosses a particular value is seen as the empirical probability of that value occurring in the sample space. In other words, the time series of the share data is mapped onto a probability space. Then, the Kolmogorov entropy, denoted as K2 is defined as the uncertainty associated with the probability space.

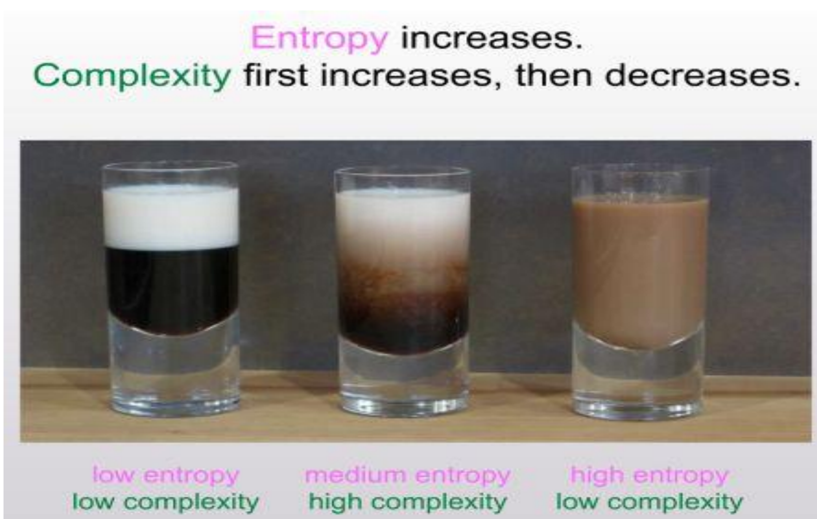


Figure 47 Relation between entropy and complexity

$$K_q = \lim_{\tau\to 0}\lim_{\varepsilon\to 0}\lim_{d\to\infty}\frac{1}{d\tau}\frac{1}{q-1}\ln\sum_{i_1,\ldots,i_d} p^q(i_1,\ldots,i_d)$$

Figure 48 Calculation of Kolmogorov entropy (q=2 for K2)

Maximum uncertainty occurs when all events in the probability space (p(i)) are equi-probable. According to information theory, this is also the case where the information contained in the signal is maximum.

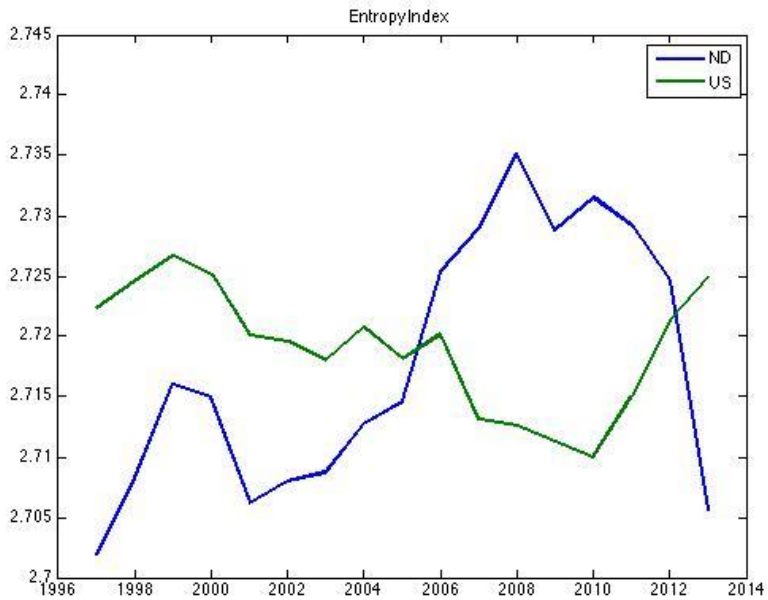


Figure 49 Entropies of economic activity of North Dakota relative to USA

The above figure is the result of calculating the economic activity of North Dakota (ND) relative to its nation (US). A significant rise in the ND entropy shows diversification of economy during that period.

'Information' in the managerial sense can be interpreted as the value that the market sees in a particular share data sample at any instant of time. Hence, more information content can be viewed as potential revelations to the market. The revelation could be related to the internal working of the system that gave rise to the signal (i.e. about the company).

In the present project, K2 is expressed in units of 0.1 nats/symbol, where nat is the natural unit of information. One nat is the information content of an event if the probability of that event occurring is 1/e [56].

Example Analysis

In this section, the metrics used in the above section are used to perform a sample analysis. This will give a clear view of the significance of the various metrics mentioned and the relevance they have to managerial understanding of the market response.

Choice of Data

The share data selected for the sample analysis is the daily share revenue of IBM as listed on the NYSE, for a period starting from 06/08/2014 going backwards till 01/09/2004.

Share revenue is calculated as the product of closing share price and volume of shares sold, and is expressed in US$.

Temporal Analysis

The time series of the IBM share revenue is plotted as follows:

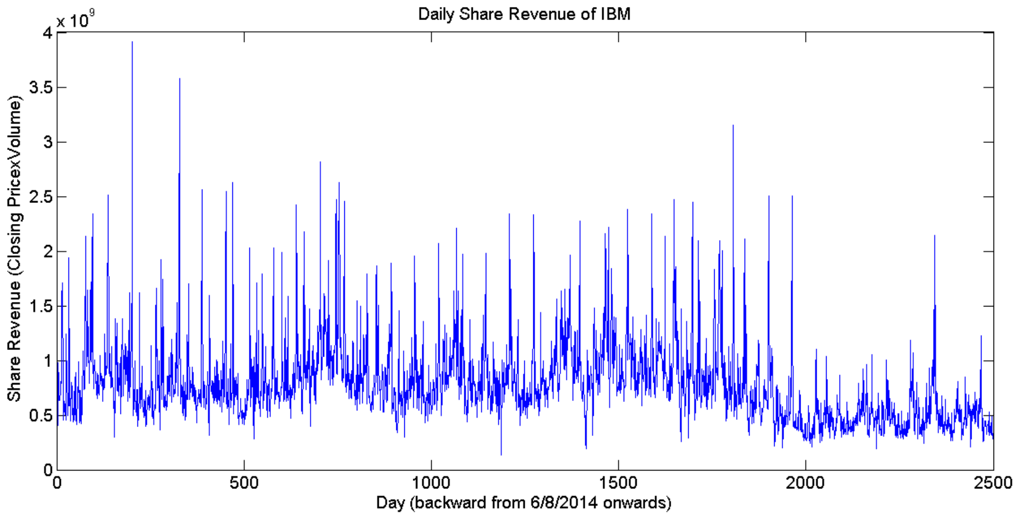


Figure 50 Time Series

The time series shows the sporadic nature of the share revenue. It also shows how the baseline value has risen gradually over the years. Also, the number of days revenues of over 3 billion dollars have been earned are also on the increase in later years.

The corresponding phase portrait is obtained as follows:

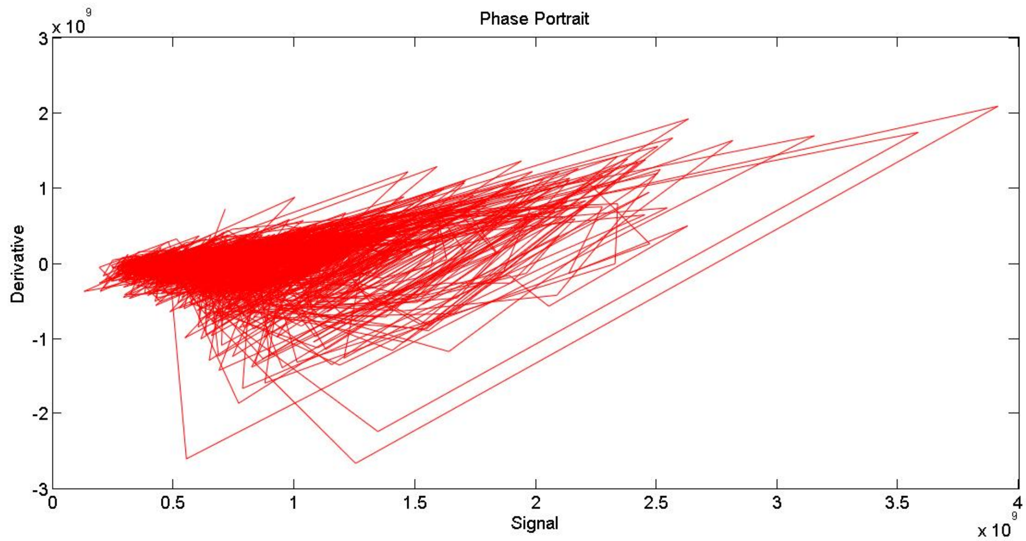


Figure 51 Phase Portrait

The phase portrait shows reasonable degree of complexity. The recurring triangular theme can be easily inferred. Roughly, it resembles the Tamari economic attractor mentioned earlier in this chapter.

The multiscale analysis for this period is shown as follows:

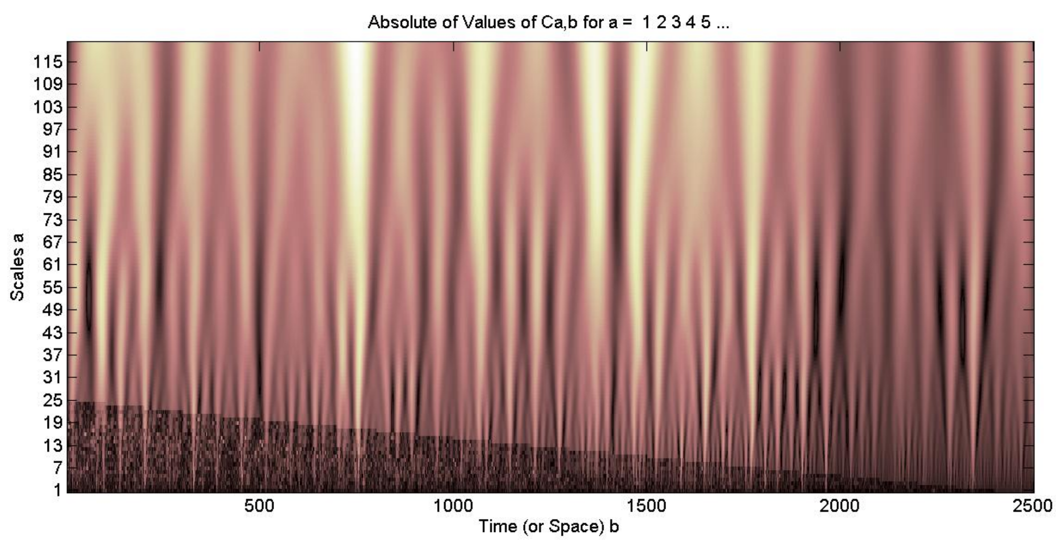


Figure 52 Multiscale Analysis

Here brighter colors indicate higher values. In smaller scales of upto about 25, numerous patterns are seen throughout the time axis. As the time scale increases, at a time scale of 90 days and above (Quarterly), the most prominent and relatively long-lasting patterns alone are seen. The almost symmetrical ‘whites’ and ‘blacks’ on either side of 1400 cannot be missed.

Spectral Analysis

The magnitude spectrum for the IBM share data is plotted as follows:

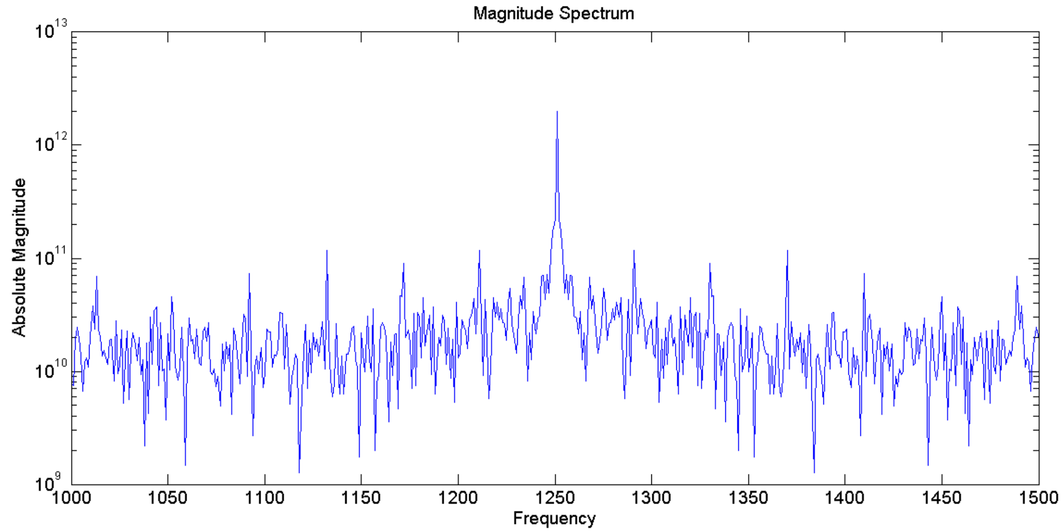


Figure 53 Magnitude Spectrum

The magnitude spectrum clearly shows the presence of multiple peaks distributed over a wide range on either side of the central value of 1250. Thus the presence of periodicities at all levels such as weekly, monthly, quarterly, half-yearly and annually can be seen.

The polar plot plotted for a monthly period is seen as follows:

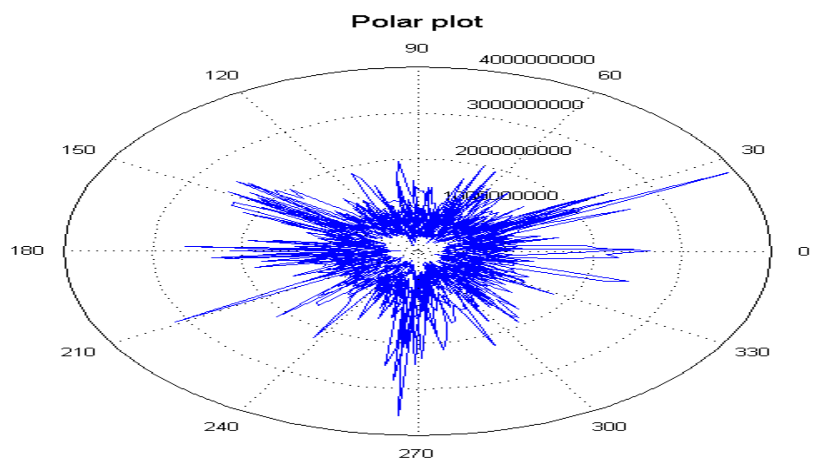


Figure 54 Polar Plot

The polar plot shows prominent peaks corresponding to angles of 30, 150 and 270. These correspond roughly to three days in a month with 10 day interval between each pair. The high peak at 30 shows the large volume of shares purchased near the beginning of each month, probably when the salaries have been released.

The spatial representation of the share data is as shown below:

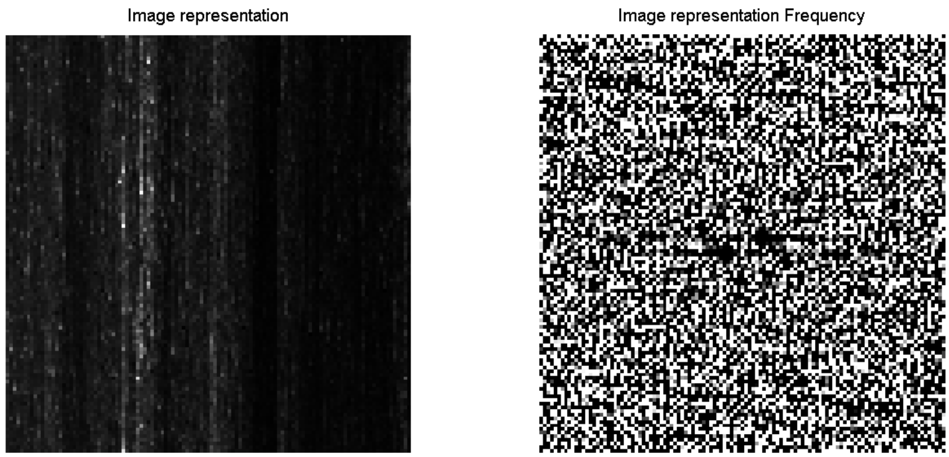


Figure 55 Spatial Representation

The spatial distribution of the share revenue data, plotted as an image clearly shows periodicities near the left one-third of each horizontal row. The period is chosen as one quarter. The right pane of the above figure shows the spatial spectrum of the image data. This frequency spectrum acts like a unique bar code that captures all the dynamics of the spatial representation displayed in the left pane.

Nonlinear Analysis

The Lyapunov exponent for the IBM share revenue data is computed using the Rosenstein algorithm, and is obtained as follows, with the divergence of nearest trajectories.

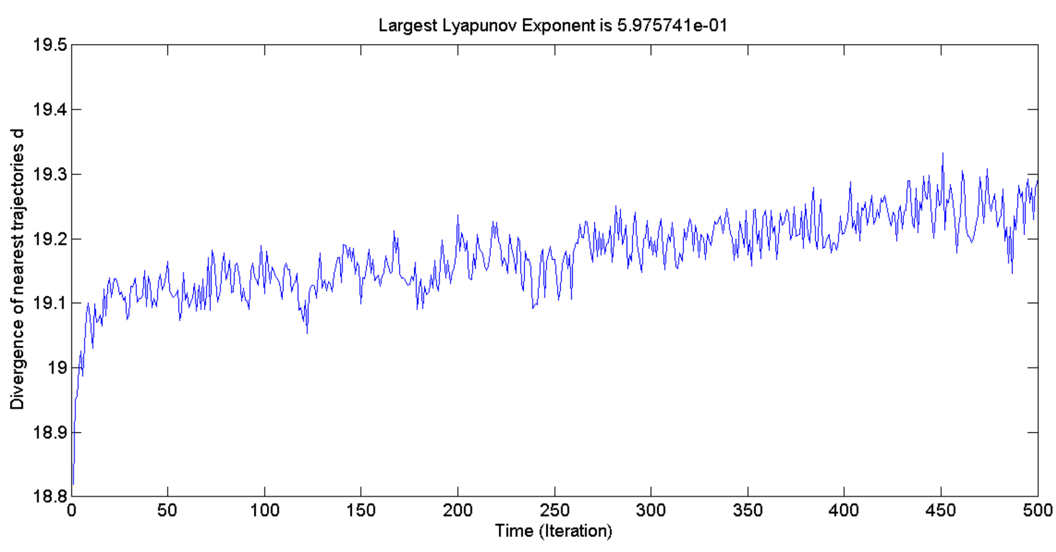


Figure 56 Lyapunov Exponent

A Lyapunov exponent of 0.59 indicates reasonable complexity but relatively low sensitivity.

The Fractal dimension and Kolmogorov entropy are obtained as follows, along with the results of the box counting algorithm.

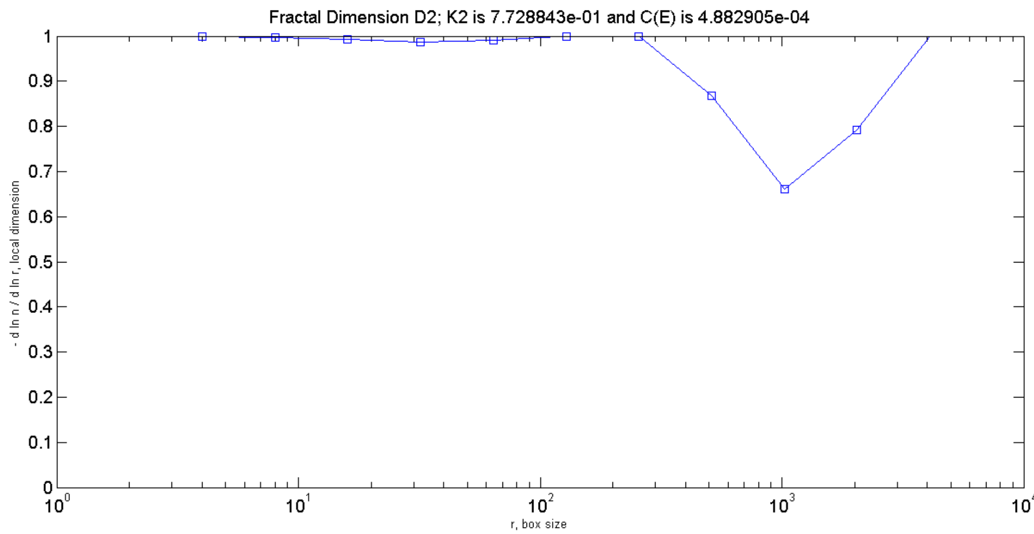


Figure 57 K2 and D2 values

A D2 value of 0.661 clearly indicates fractal nature, with a reasonable amount of instability. A K2 value of 7.728 is quite high, indicating uncertainty and hence significant information contained in the signal.

4. CASE STUDIES - ANALYSES AND DISCUSSIONS

The various concepts and metrics discussed in the previous chapters are put to effective use in this chapter.

This chapter considers four particularly significant events in the recent history of IBM:

1. Acquisition of Business Analytics Software Firm Cognos in 2007.
2. Announcement of hikes of the likes of 20-25% for IBM India employees in 2011.
3. Layoff and retrenchment in Q1 2014.
4. Annual declaration of dividends and earnings per shares in Q1 2013.

In each case, the policy implications of the events are qualitatively assessed. Then, suitable time durations are defined before and after the event. For both time durations, the temporal, spectral and nonlinear analyses are performed, first using share revenue data, and then using share price data. The various plots and graphs are presented. Finally, the inferences and discussions from such analyses are detailed.

The four case studies and analyses according to the above mentioned procedure form the next four sections of this chapter.

1. Acquisition of Cognos

Cognos Incorporated was a company in Ontario, Canada, dealing with business intelligence (BI) software [57]. It became a public company in 1986, listed under the Toronto Stock Exchange. Business Intelligence essentially refers to the effective harnessing of useful information from raw data [58]. Designing of strategies from such business intelligence can go a long way in providing a competitive market advantage.

On November 9th, 2007, IBM announced that it would be acquiring Cognos. The deal was finally settled in January 2008. The acquisition of BI giant Cognos put IBM in the elite league of a BI 'megavendor' with competitors such as Oracle, Microsoft and SAP.

Also, the easy access to BI software induced IBM to think in terms of effective data management. Soon, IBM came up with radically new concepts such as "Smarter Planet", "Big Data" and "Cloud Computing" [10, 28, 59], each bringing immense value to the future. With the decision to sell the microelectronic fabrication unit [60], IBM expects to focus big time on data and BI, and capture a huge share of the market.

To understand the implications of the acquisition of Cognos, two time durations are selected.

1. Before Acquisition announcement: September 18th 2006 to November 9th 2007.
2. After Acquisition announcement: November 10th 2007 to 2nd January 2009.

The Share revenue data analysis followed by share price data analysis will be presented.

A. Temporal Analysis

Time Series

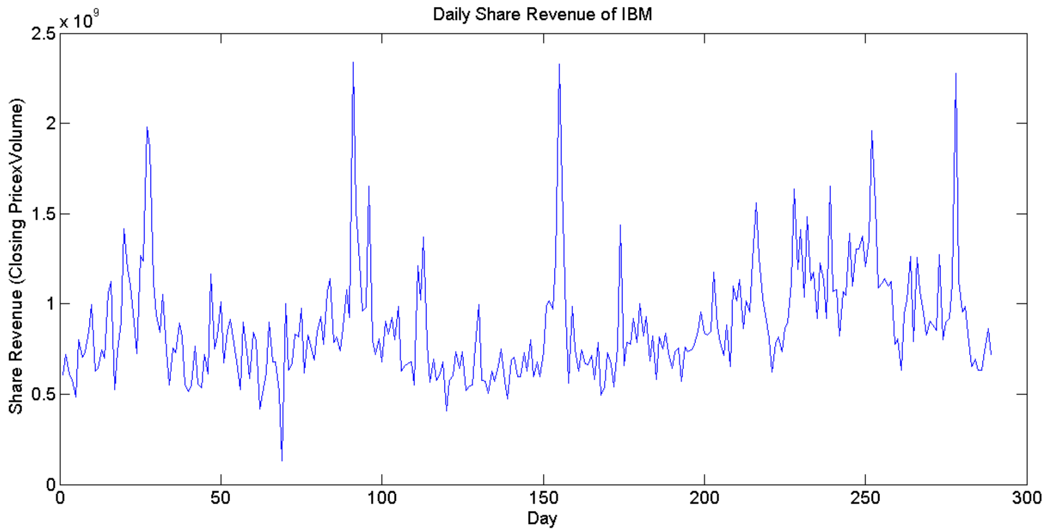


Figure 58 Revenue Time Series before

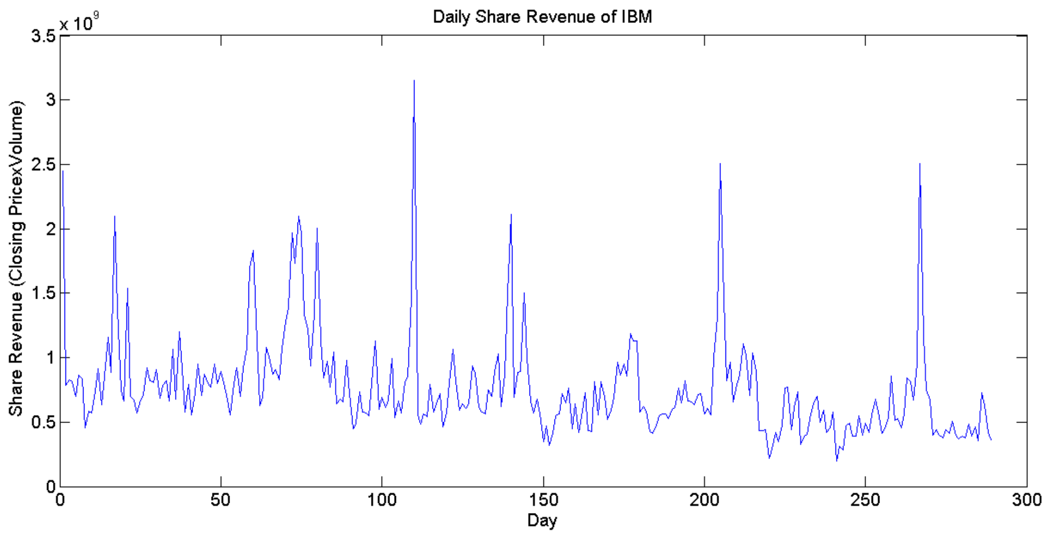


Figure 59 Revenue Time Series after

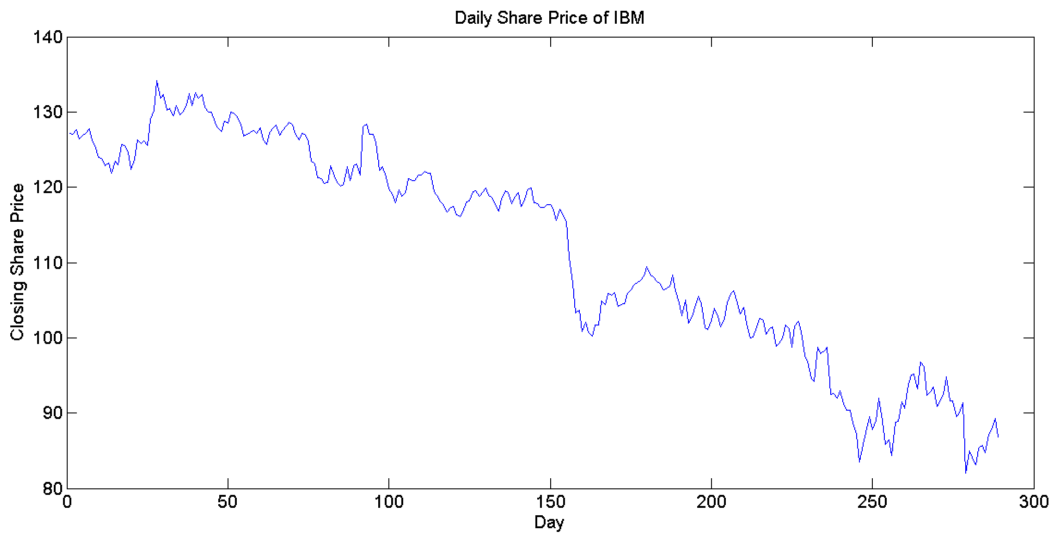


Figure 60 Price Time Series before

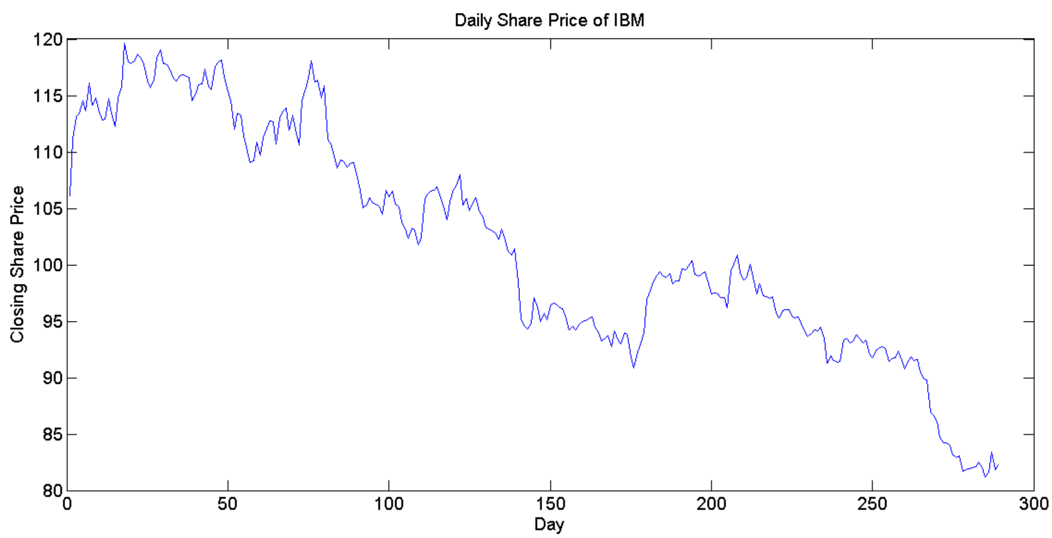


Figure 61 Price Time Series after

The revenue time series show that the peaks in revenue have gone up after the acquisition announcement, with peak revenues of over 3 billion dollar being reported. On the other hand, the peak share price has gone down from about $130 to $120.

Phase Portrait

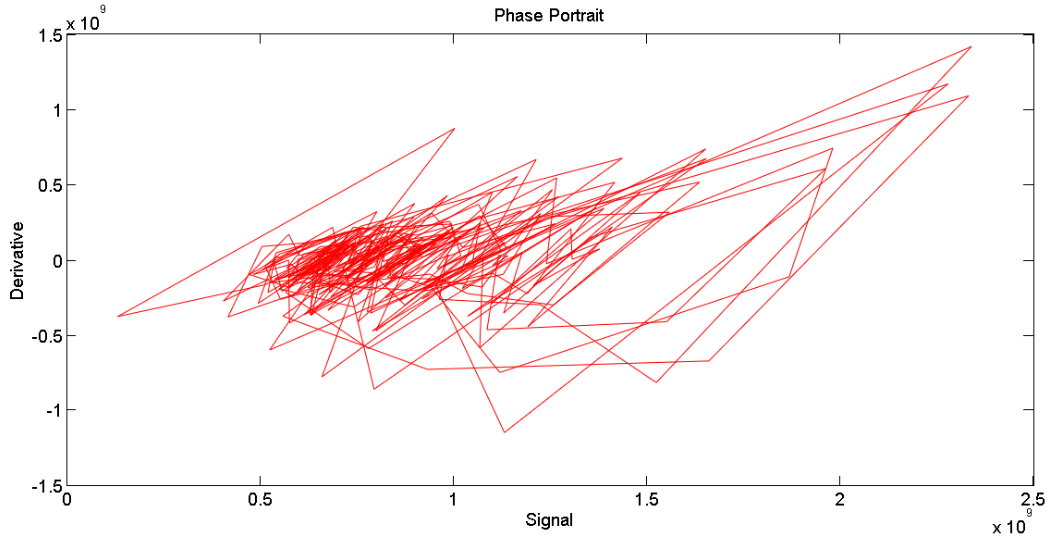


Figure 62 Revenue phase plane before

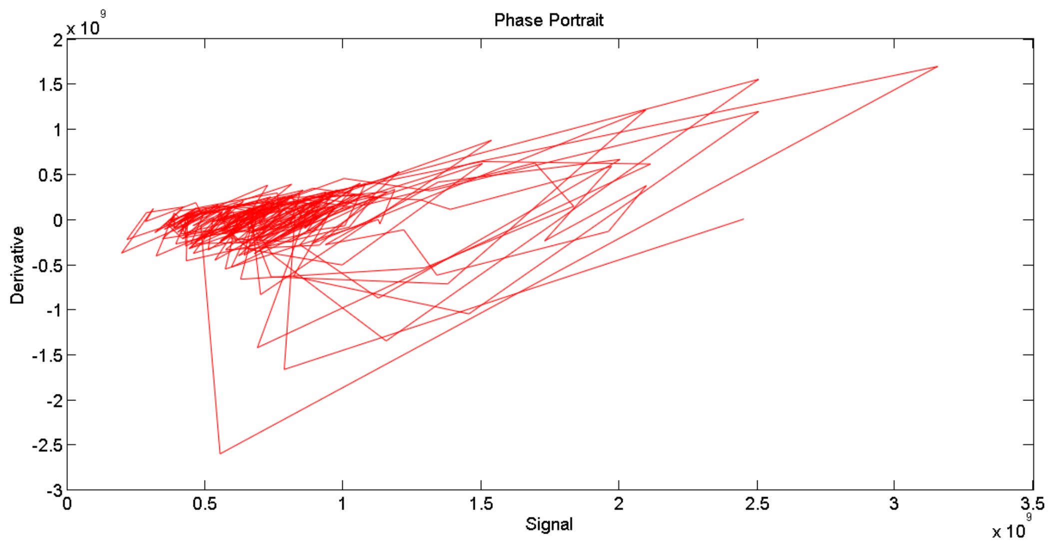


Figure 63 Revenue Phase plane after

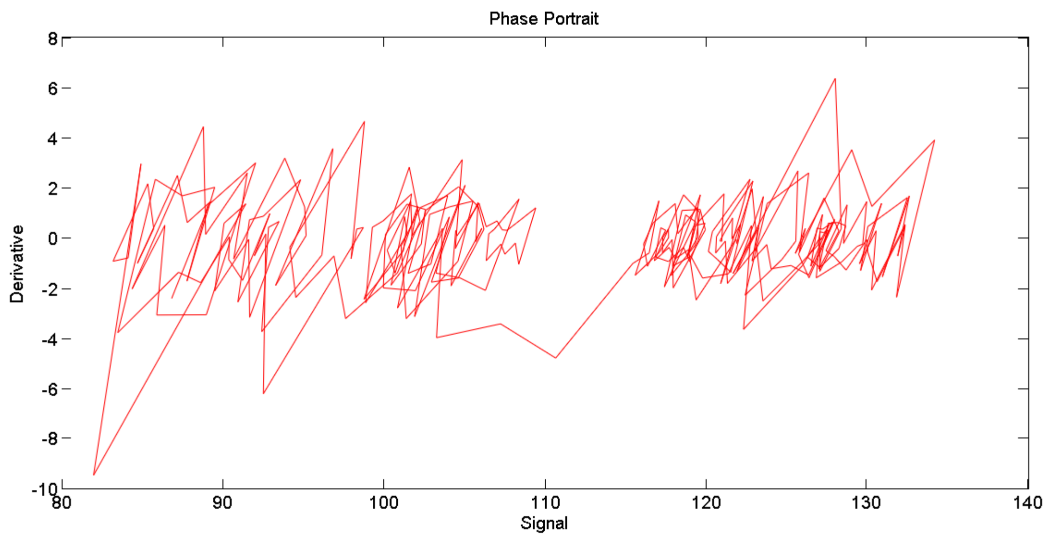


Figure 64 Price Phase Plane before

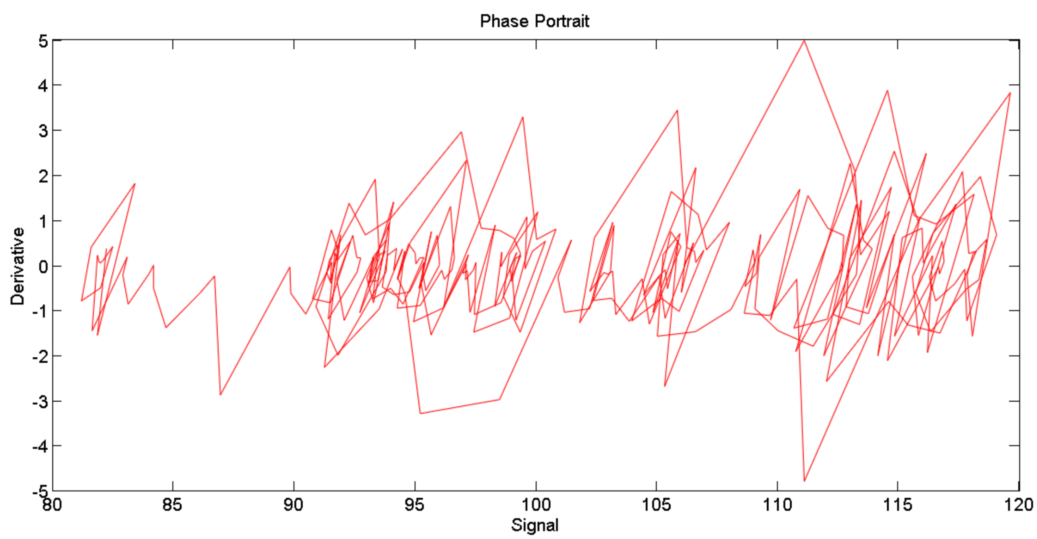


Figure 65 Price Phase Plane after

Both the revenue phase portraits show considerable degree of complexity, though after acquisition, longer phase paths become more dominant. These indicate larger variation of share revenue. The phase portrait of the share price has changed from an almost bistable state (two stable points corresponding to signal values of below 105 and above 115) to a more unstable state.

Multiscale Analysis

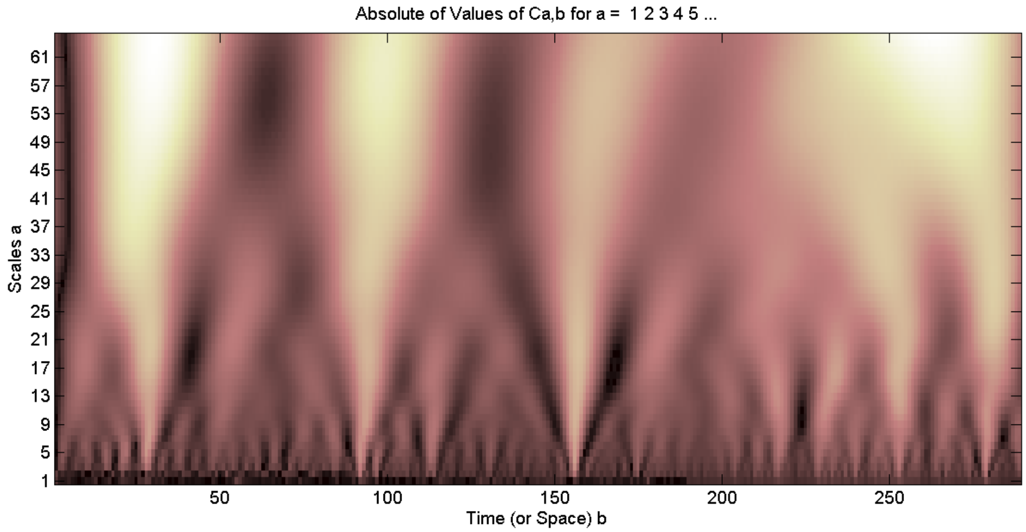


Figure 66 Revenue Multiscale Analysis Before

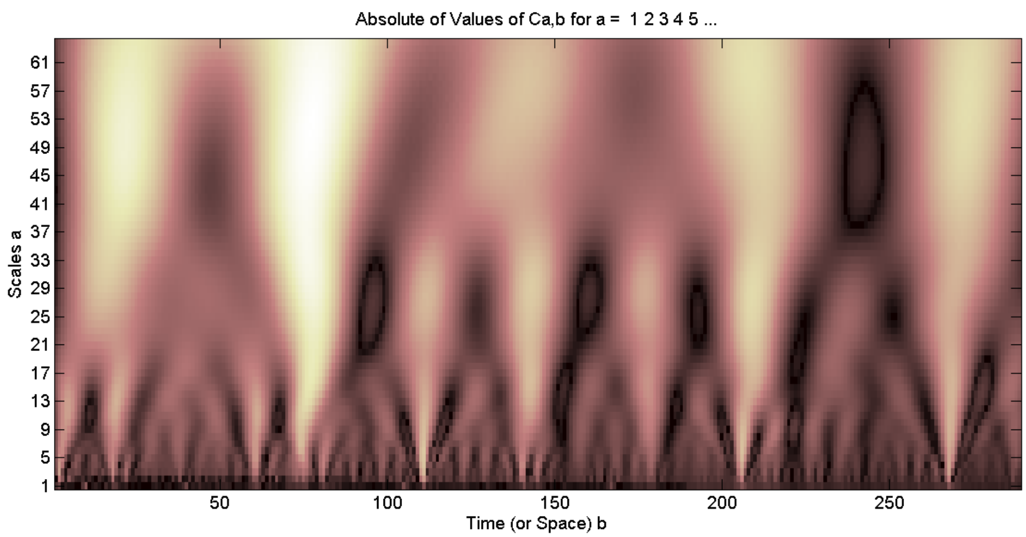


Figure 67 Revenue Multiscale Analysis after

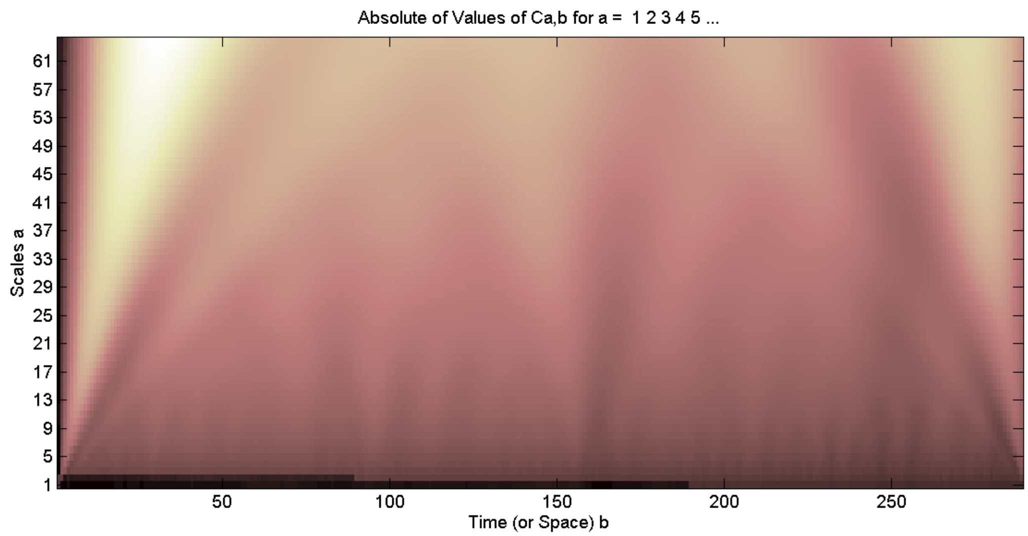


Figure 68 Price multiscale analysis before

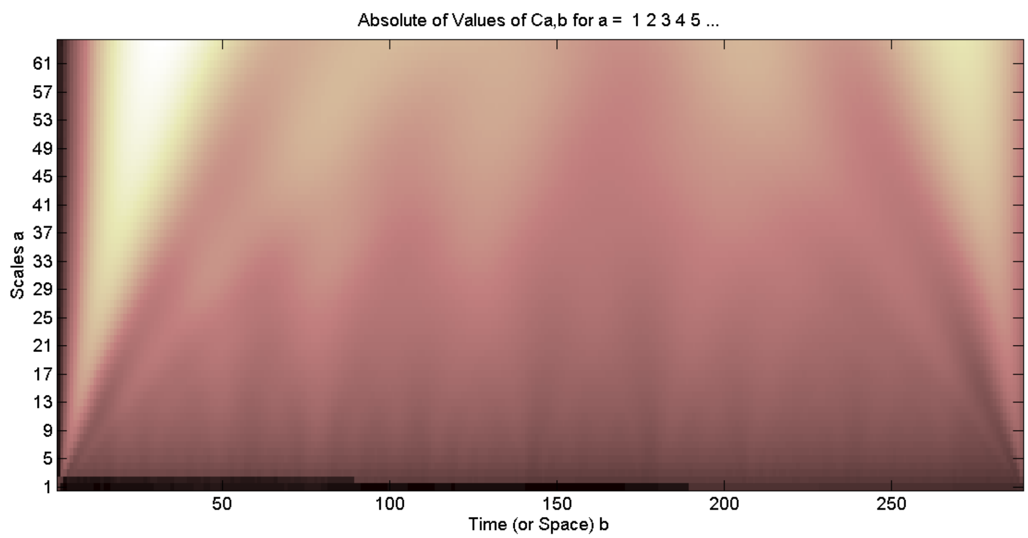


Figure 69 Price Multiscale analysis after

The multiscale analysis of the revenue data after the acquisition announcement reveal a lot of ‘black spots’ indicating long term contrasting patterns of low revenue, in the time scales of around 30 days and 45 days. The major black spot at the time value of around 250 indicates a major dip in the share revenue. This occurs at around January 2008, precisely at the time when the acquisition was executed. By paying out to the employees of the former Cognos in shares and share value, this was a time when a major share rearrangement took place.

B. Spectral Analysis

Magnitude Spectrum

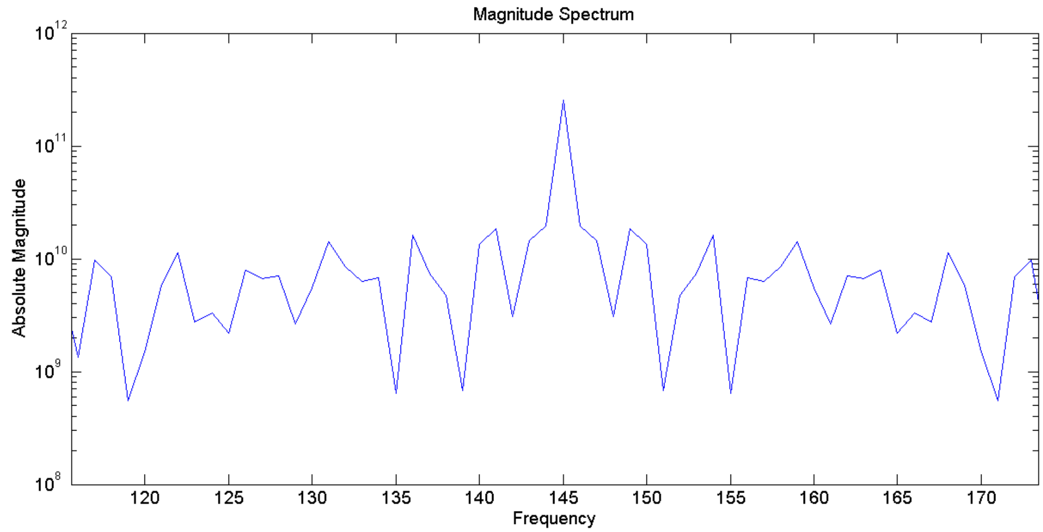


Figure 70 Revenue spectrum before

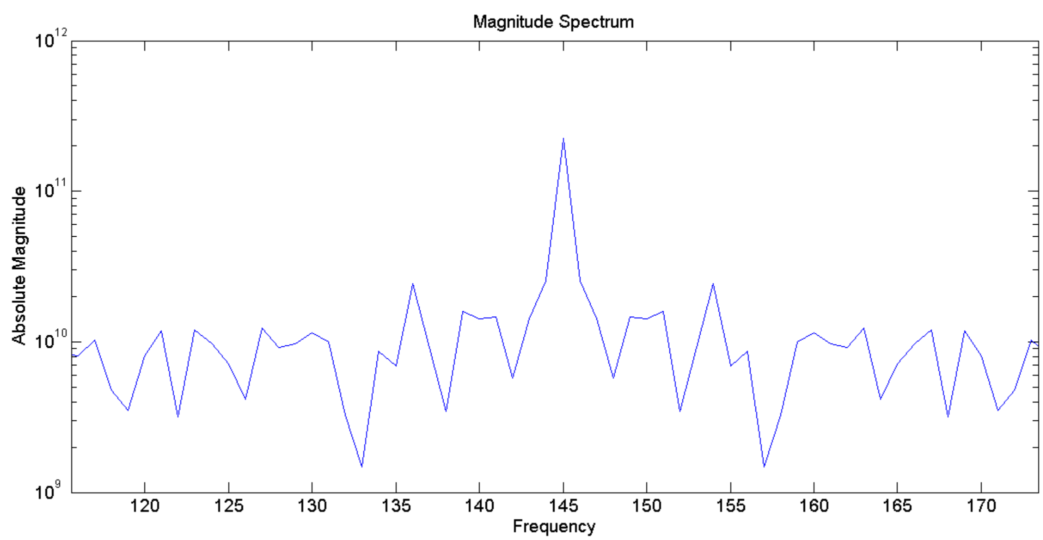


Figure 71 Revenue spectrum after

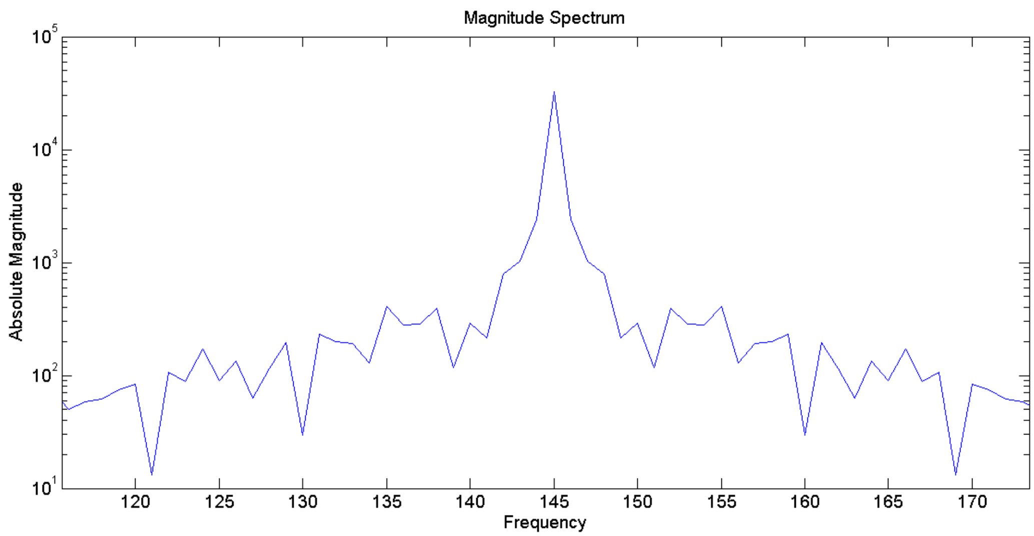


Figure 72 Price spectrum before

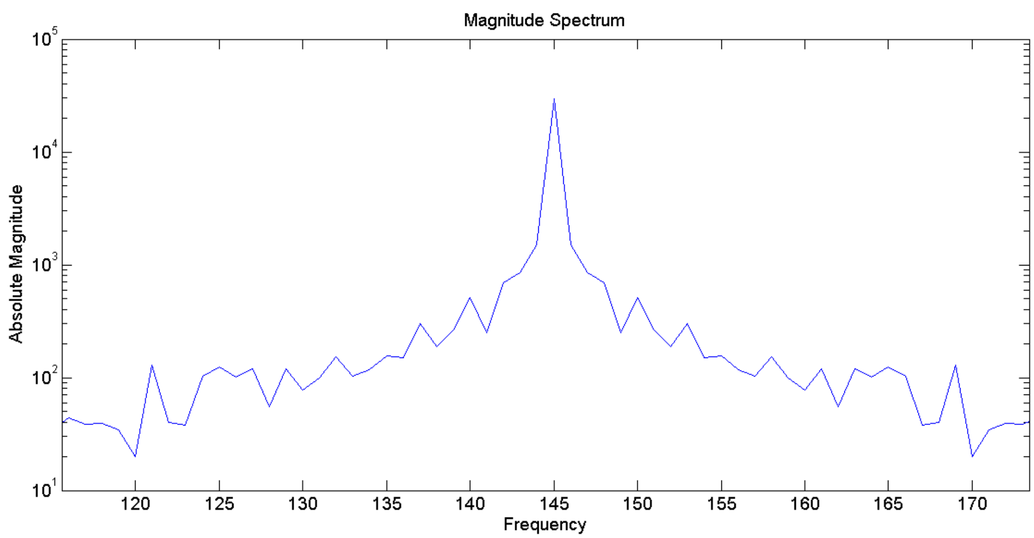


Figure 73 Price spectrum after

The almost similar spectra for both revenue and price before and after the acquisition announcement indicate that no major change in the periodicity distribution has been observed.

Polar Plot

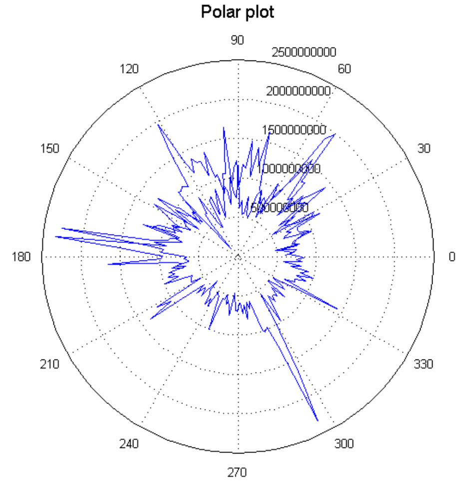


Figure 74 Revenue Polar plot before

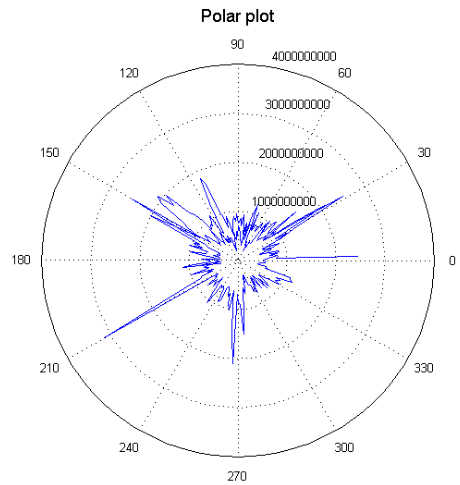


Figure 75 Revenue Polar plot after

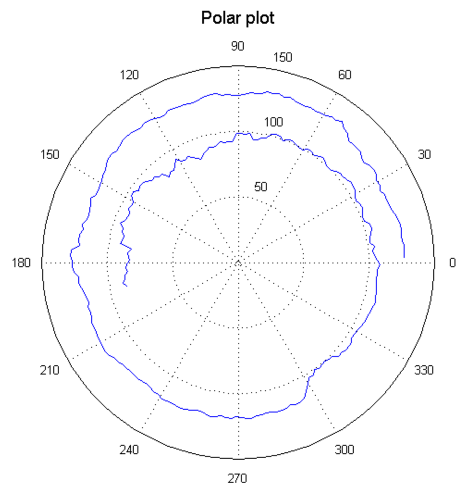


Figure 76 Price polar plot before

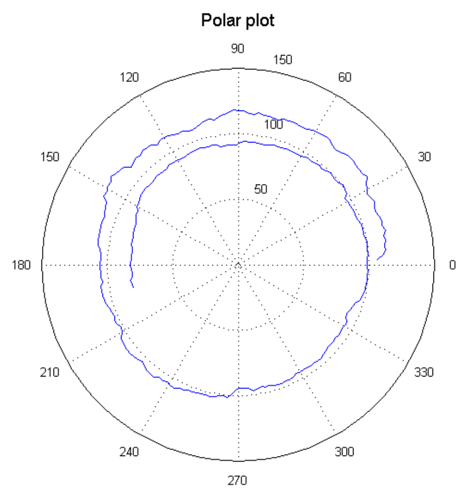


Figure 77 Price Polar plot after

The revenue polar plots show a major redistribution in the monthly share purchase pattern from a 'mid-month' approach to more of a 'month beginning and month end' approach. There aren't much changes in the price polar plots, however.

C. Nonlinear Analysis

Lyapunov Exponent

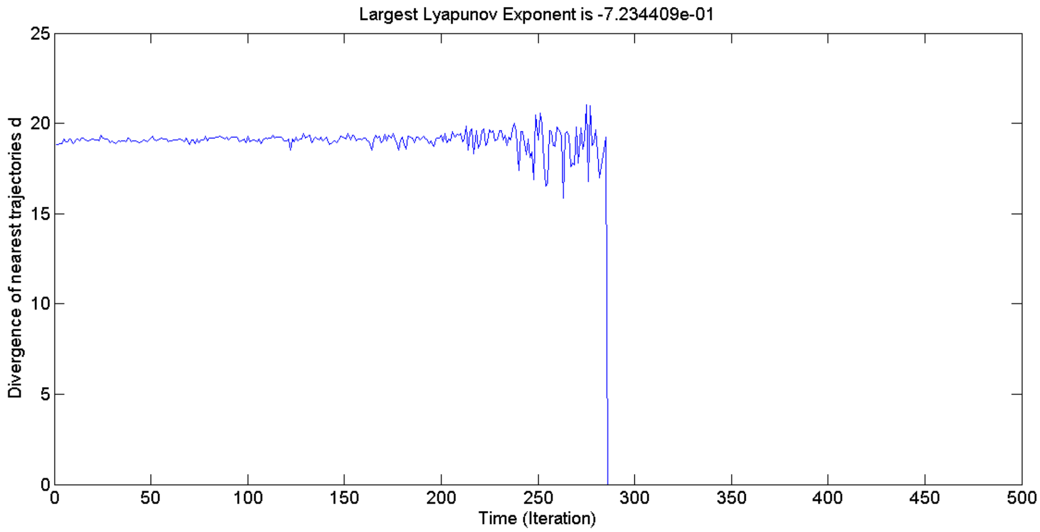


Figure 78 Revenue LLE before

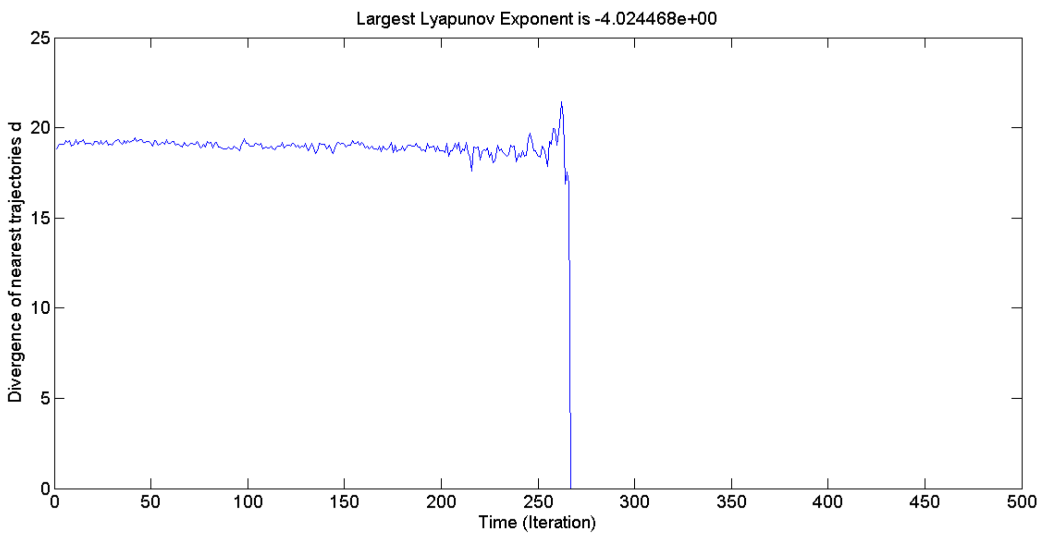


Figure 79 Revenue LLE after

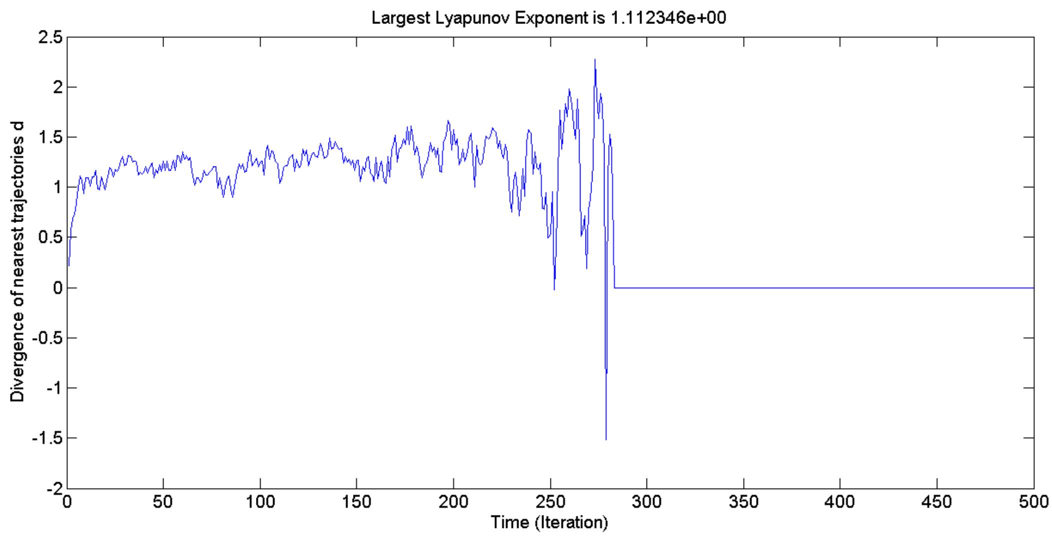


Figure 80 Price LLE before

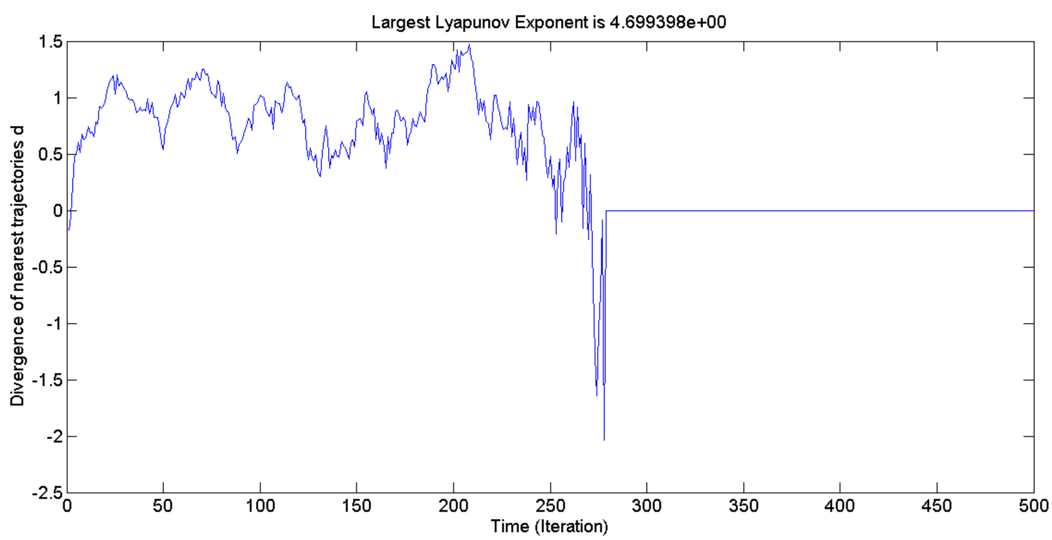


Figure 81 Price LLE after

In revenue data, a sharp LLE increase 0.723 to 4.022 shows a dramatic increase in sensitivity and complexity of the market response. The same can be observed from the steep increase in LLE of price from 1.112 to 4.699.

Fractal Dimension and Kolmogorov Entropy

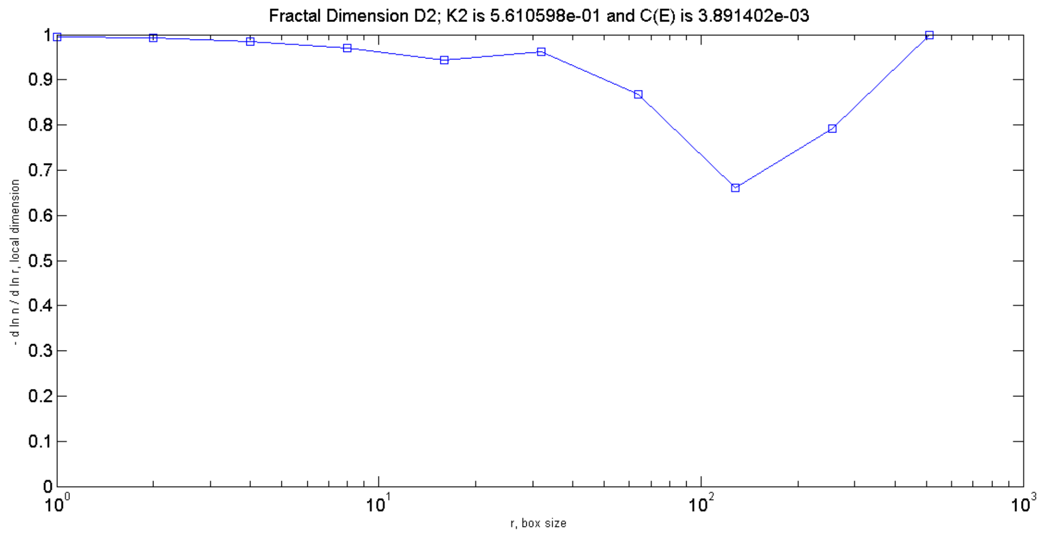


Figure 82 Revenue K2D2 before

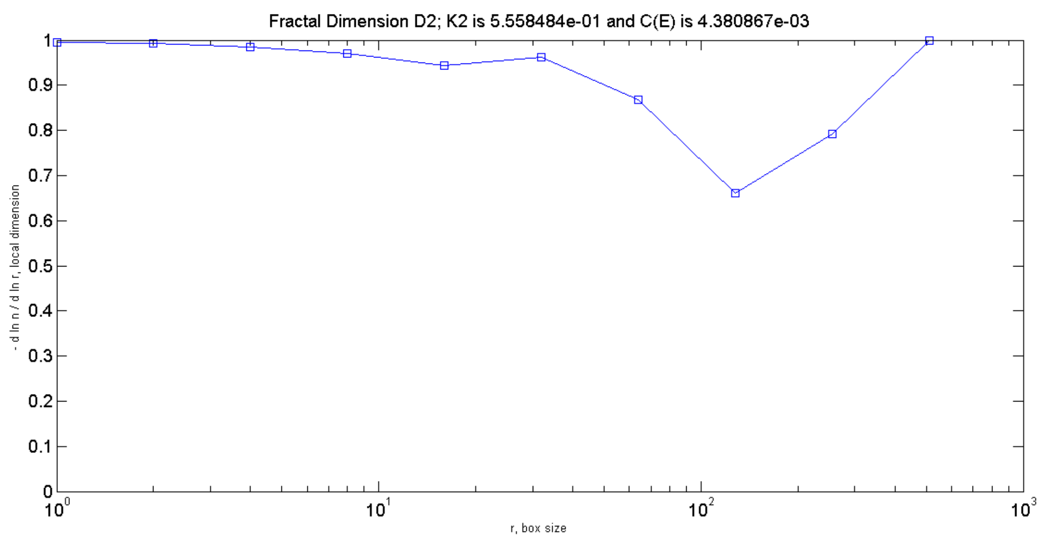


Figure 83 Revenue K2D2 after

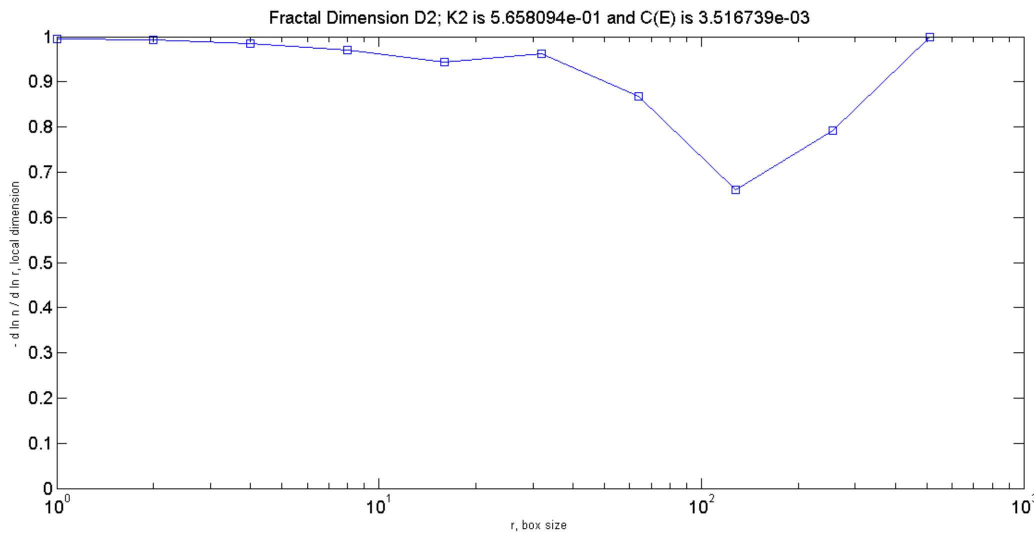


Figure 84 Price K2D2 before

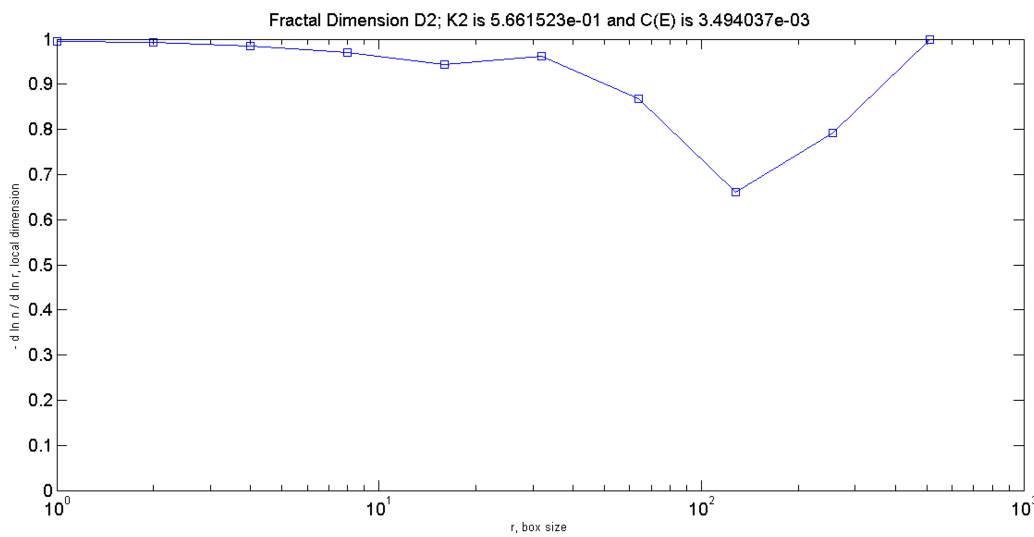


Figure 85 Price K2D2 after

The constant fractal dimension (D2) of 0.661 for both revenue and price indicates that the stability of the system is not affected by the acquisition announcement. Revenue data entropy decreased slightly from 5.61 to 5.55, and price data increased slightly from 5.658 to 5.661. The decrease in the revenue entropy can be attributed to the sharper contrast in share revenue due to the share rearrangement.

D. Interpretation and Discussion

The above analysis reveal key trends in the share market performance of IBM caused due to the acquisition of Cognos BI. An increased sensitivity, as witnessed by the LLE increase is seen. Thus the slight decrease in K2, signifying lesser information content, meant that the market did not have a clear understanding of which way the Cognos acquisition would turn IBM's fortunes. Hence there were differences of opinion, and while optimistic buyers went bullish, pessimistic buyers went bearish. Hence, a sharp contrast in the share revenue data is seen, as witnessed by the multiscale analysis. This also affected the share price data, as the variation in the prices as well as the maximum price went down.

2. Announcement of hikes in IBM India in 2011

2010-2011 was one of the happier years for IBM. Just a year away from celebrating its centenary [7], this was the year IBM reached and relished several milestones. The SmartCloud [61], the smarter planet initiative, a lot of business awards at the global level were the hallmarks of the year.

In India too, similar trends were seen. While the software departments were recruiting from premier institutes all over India such as IITs, IIITs and NITs by tens and hundreds, the systems and research departments were aggressively hiring interns. Productivity reached a new high, and the annual hike announcement during July 2011 was a happy occasion. Average employees were promised atleast 15% hike, whereas excellent performers would be earning hikes as much as 25%.

While this may seem to be a totally internal affair, the announcement of hikes clearly affected the share market performance of IBM.

To understand these implications, two time durations are selected.

1. Before hike announcement: July 20th 2010 to July 20th 2011.
2. After hike announcement: July 20th 2011 to July 20th 2012.

The Share revenue data analysis followed by share price data analysis will be presented.

A. Temporal Analysis

Time Series

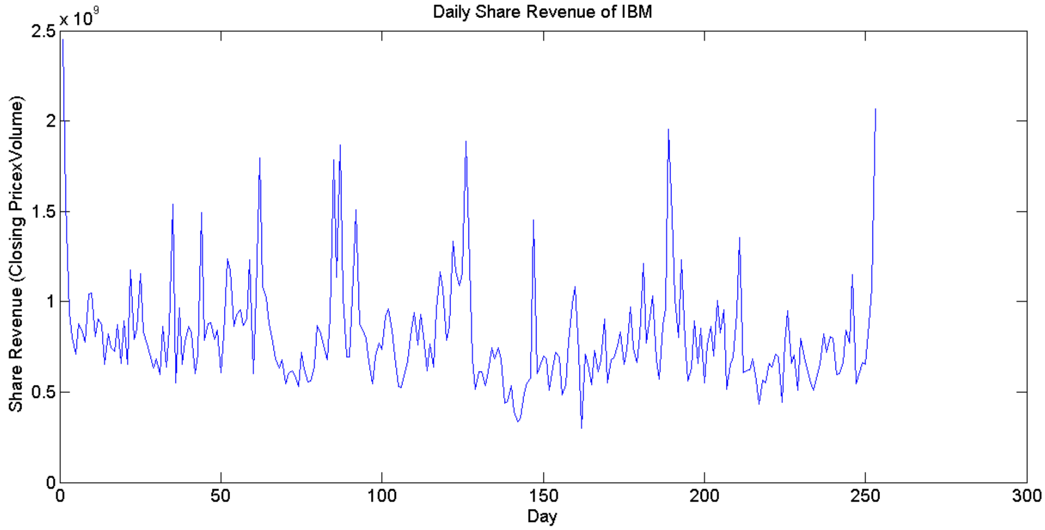


Figure 86 Revenue time series before

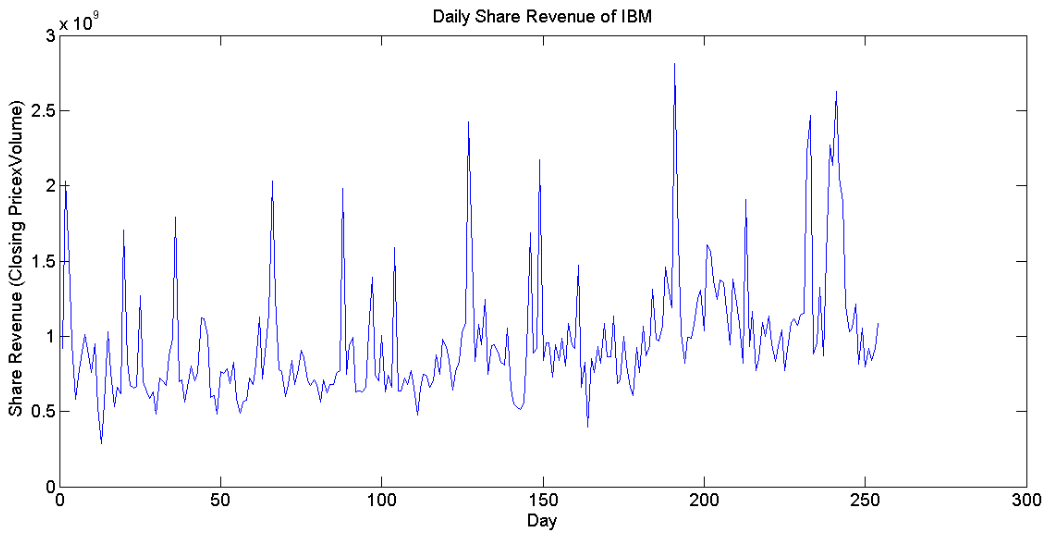


Figure 87 Revenue time series after

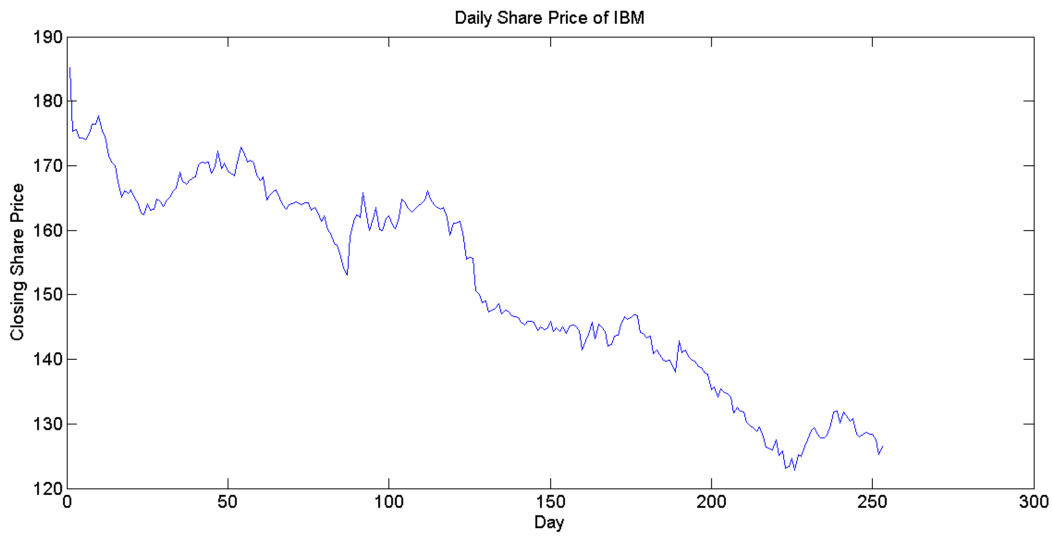


Figure 88 Price time series before

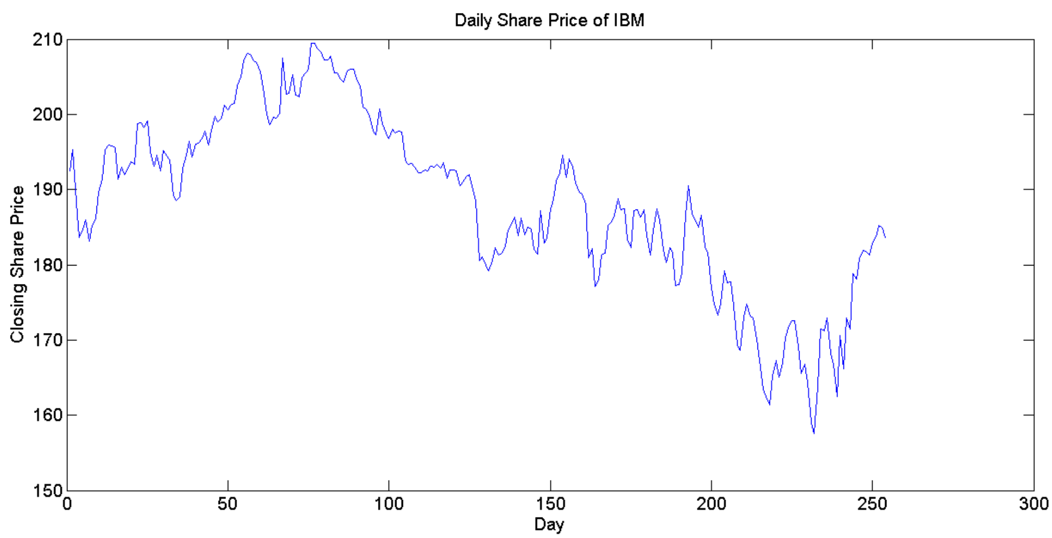


Figure 89 Price time series after

The revenue time series show that the hike announcement caused a temporary rise of the baseline from around $0.75b to almost %1b for about two months, before going back to the former value. The price time series show that the general range of share price has increased from a low of $120 to a low of almost $160.

Phase Portrait

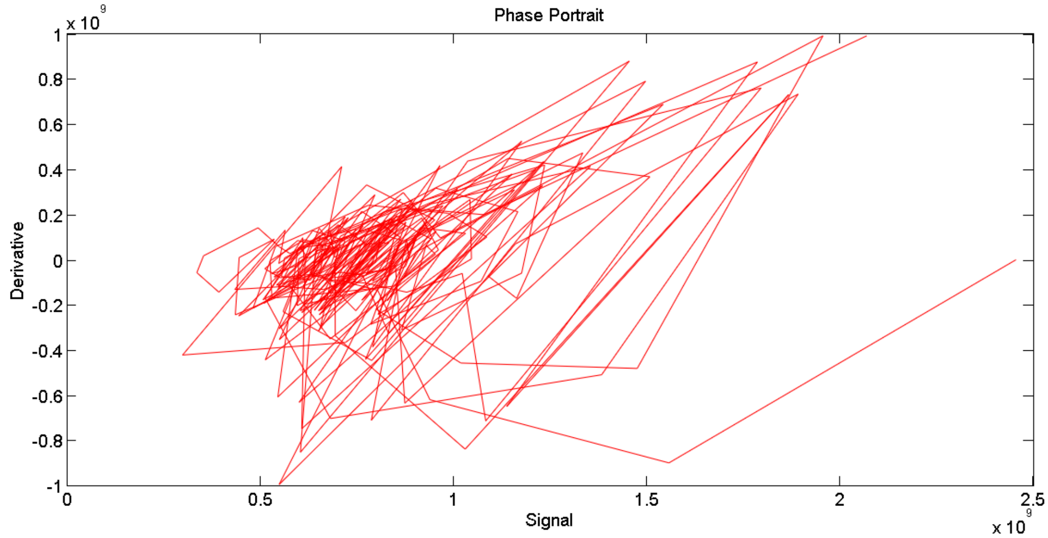


Figure 90 Revenue phase plane before

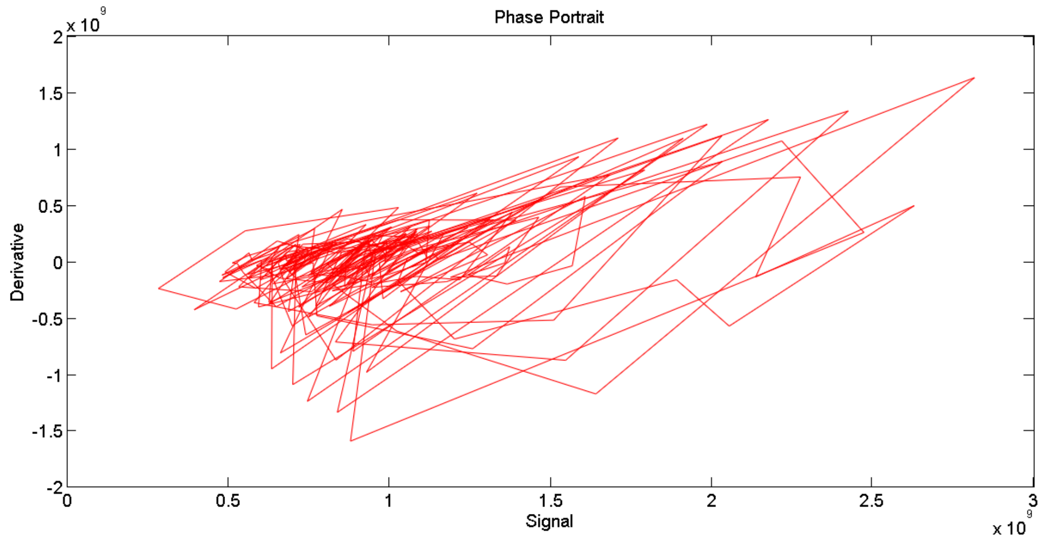


Figure 91 Revenue phase plane after

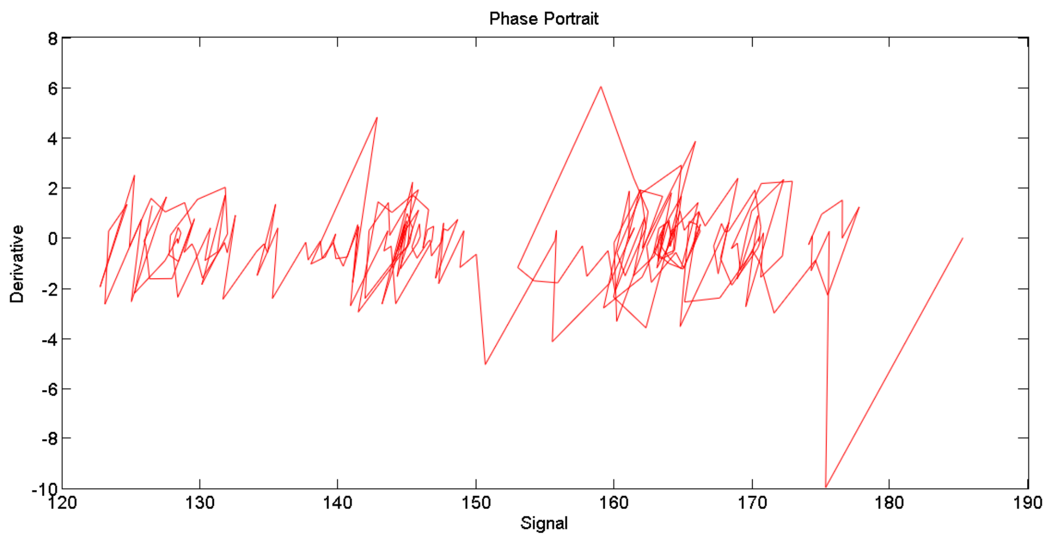


Figure 92 Price phase plane before

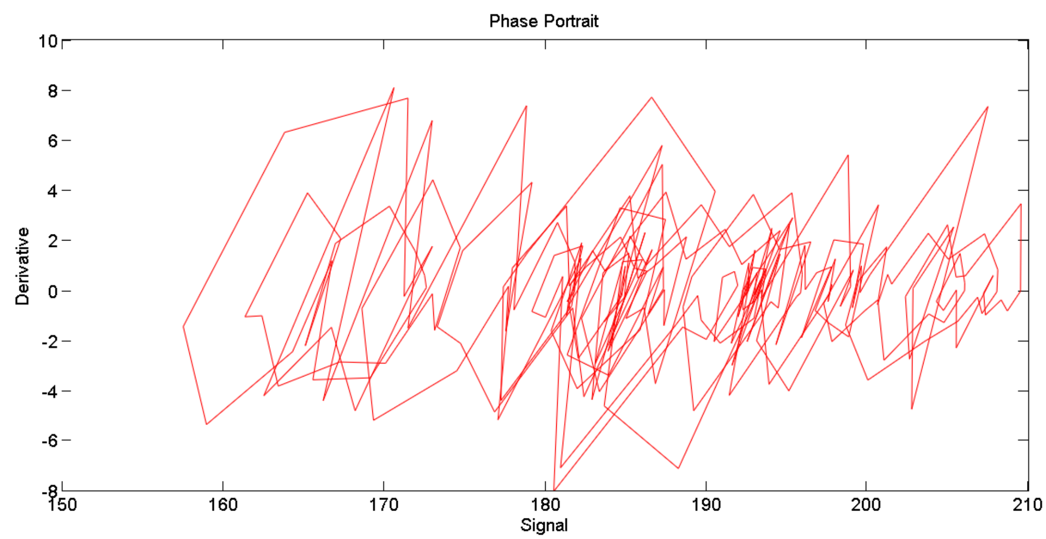


Figure 93 Price phase plane after

The overall complexity of the system seems to have been preserved with respect to both price and revenue. Whereas the price phase portrait was a bistable affair between $145 and $165, the hike announcement forced it to change shape, and the result is a more oscillatory nature above and below $175. This indicates a major upward trend in the share price.

Multiscale Analysis

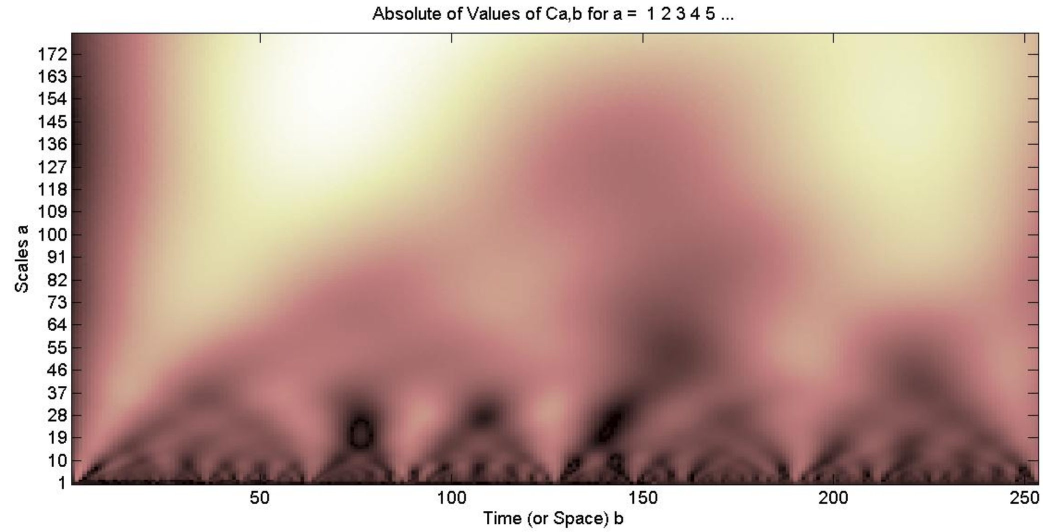


Figure 94 Revenue Multiscale analysis before

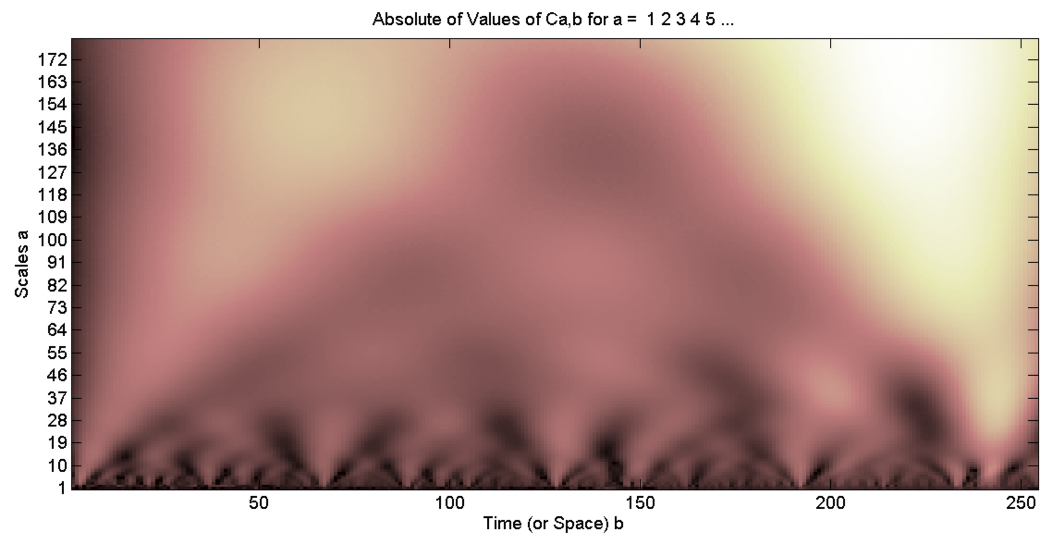


Figure 95 Revenue multiscale analysis after

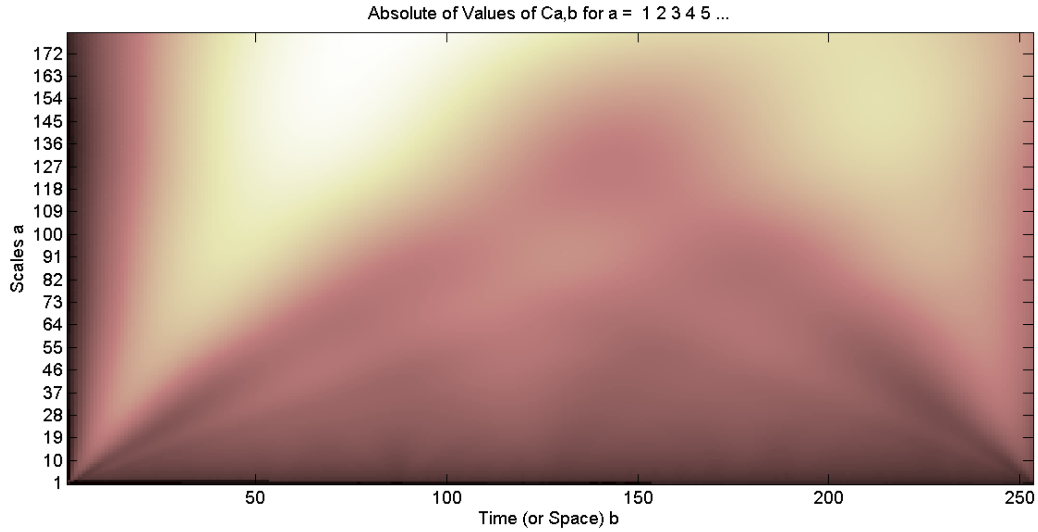


Figure 96Price multiscale analysis before

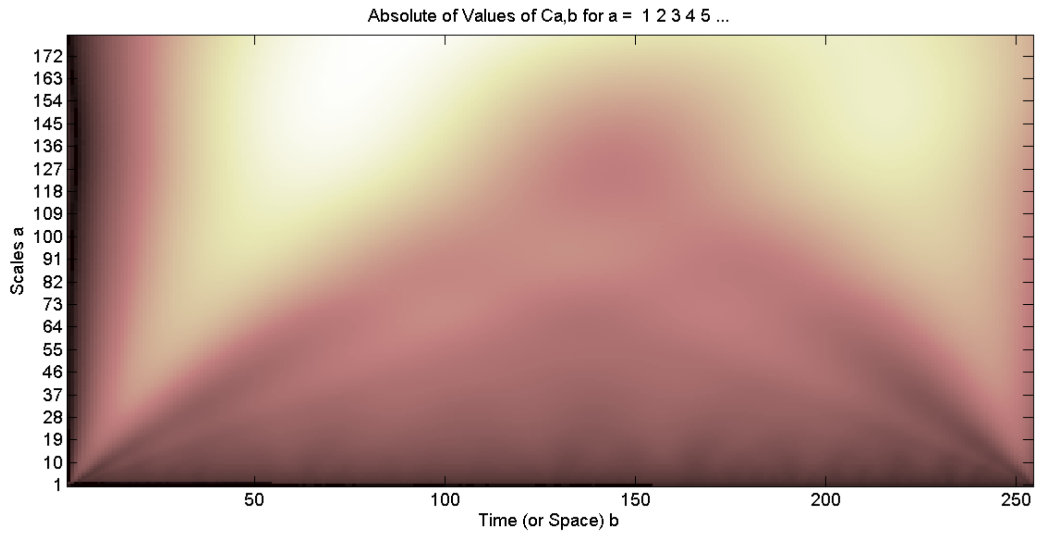


Figure 97 Price multiscale analysis after

The revenue multiscale analyses indicate that the periodic 20-day timescale contrasts before the hike announcement are visibly reduced after the announcement. The contrasts seem to have 'evened out'. Noteworthy is the white 'flash' at around 250 time duration. This signifies the increase in the baseline value of the shares. The price data show no interesting multiscale observations.

B. Spectral Analysis

Magnitude Spectrum

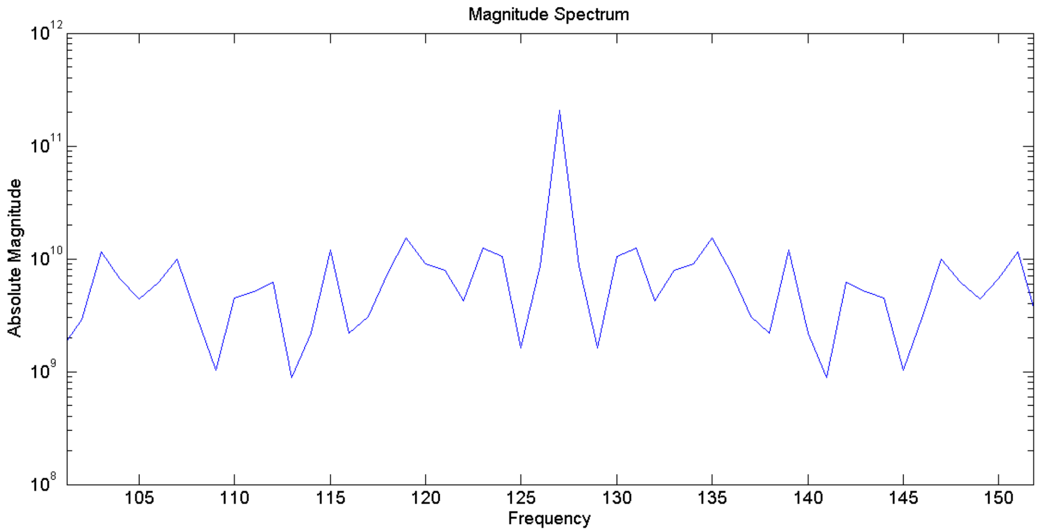


Figure 98 Revenue spectrum before

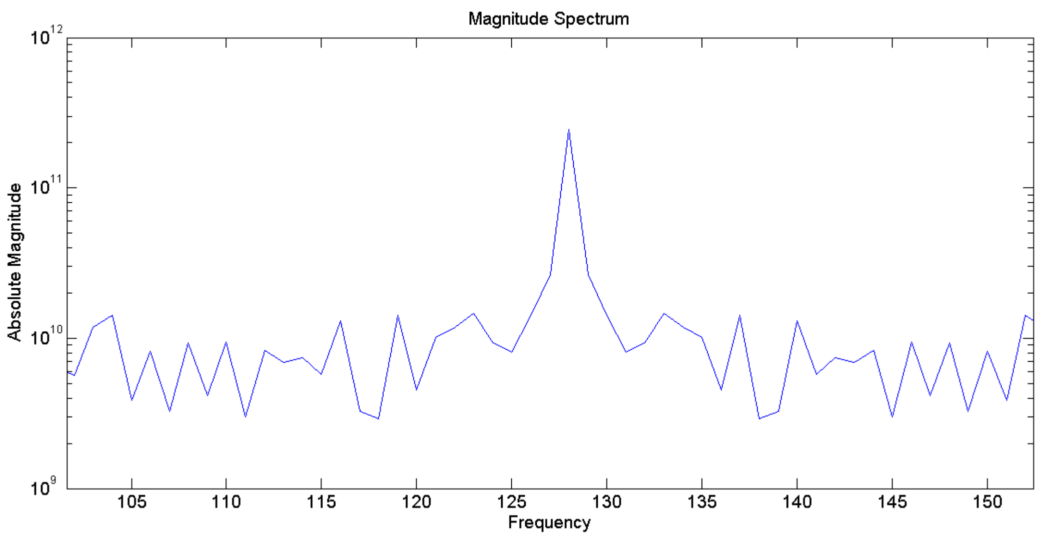


Figure 99 Revenue spectrum after

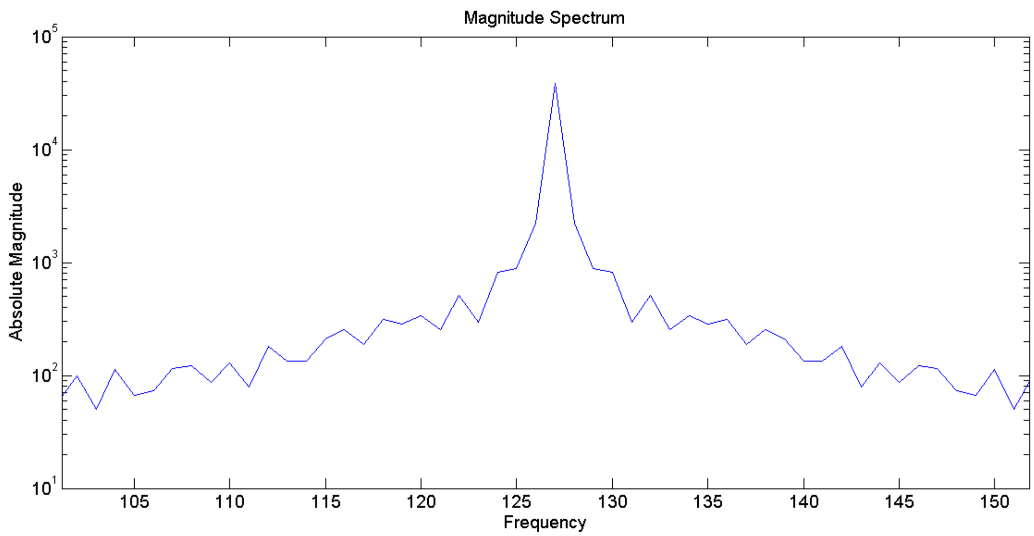


Figure 100 Price spectrum before

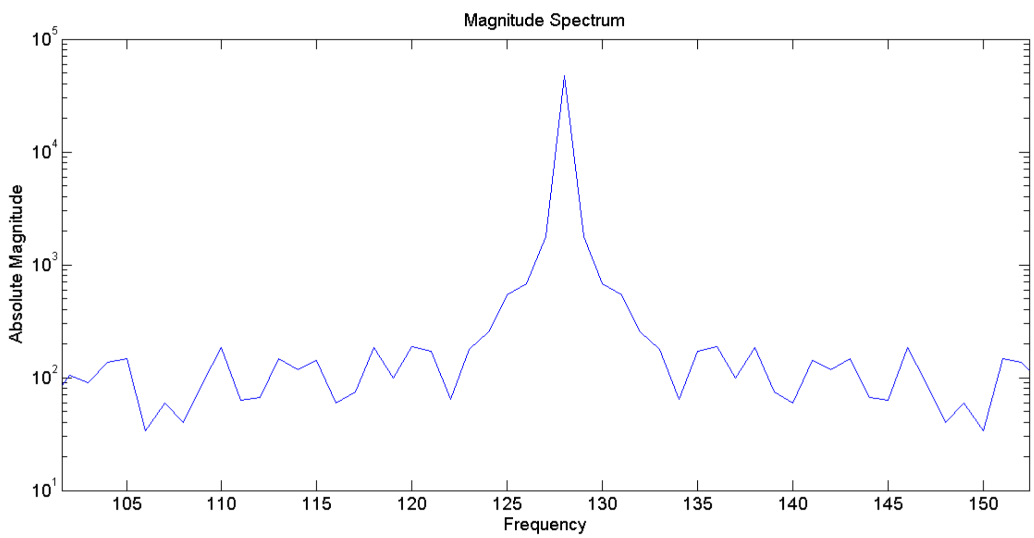


Figure 101 Price Spectrum After

There aren't any noteworthy changes in the magnitude spectrum of either share revenue or share price.

Polar Plot

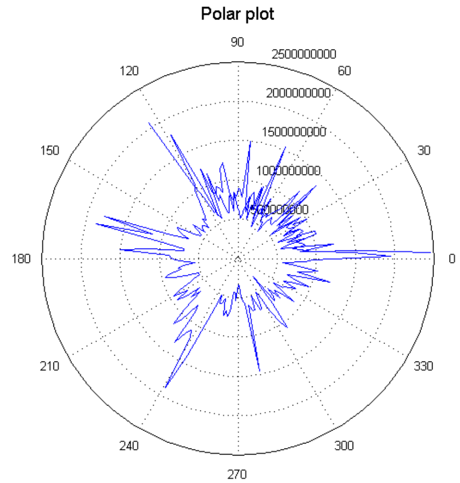


Figure 102 Revenue polar plot before

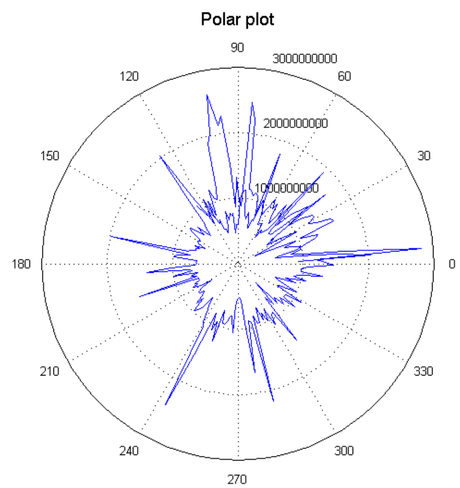


Figure 103 Revenue polar plot after

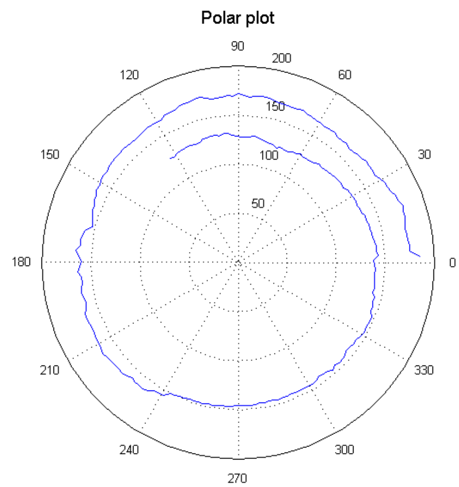


Figure 104 Price polar plot before

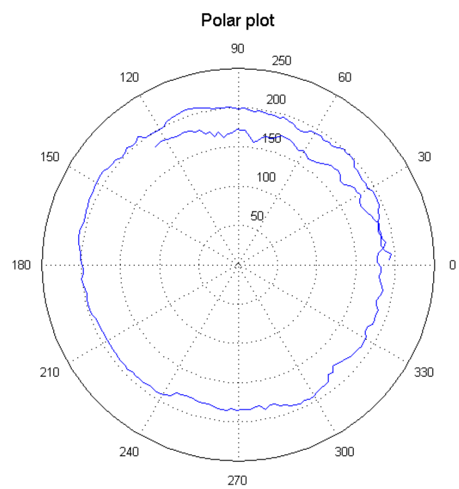


Figure 105 Price polar plot after

The revenue polar plot before the hike announcement shows fairly evenly distributed share purchases over the month, whereas, after the hike announcement, the purchasing pattern of shares seems to have turned a wild turn. This affected both the periodicity and the purchasing patterns of shares over the days of a month.

C. Nonlinear Analysis

Lyapunov Exponent

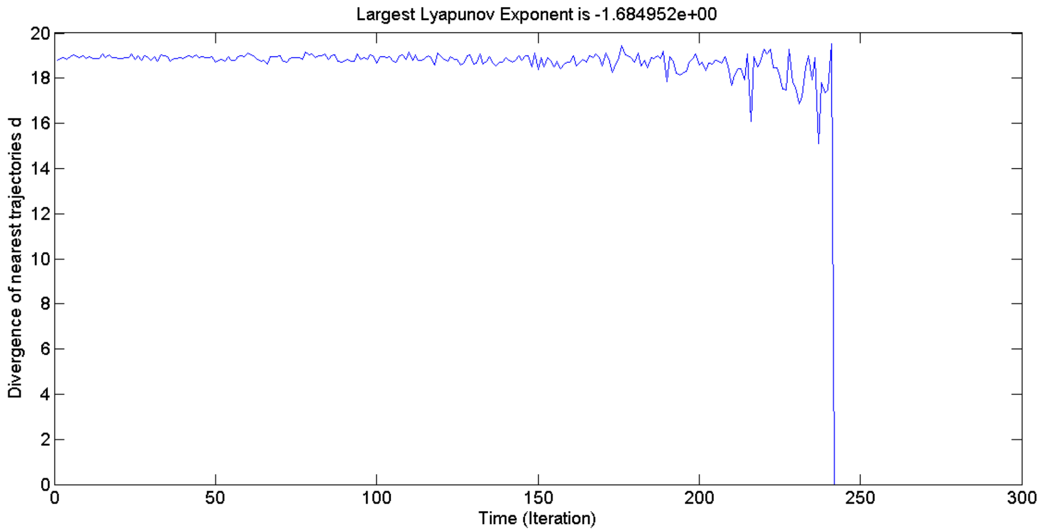


Figure 106 Revenue LLE before

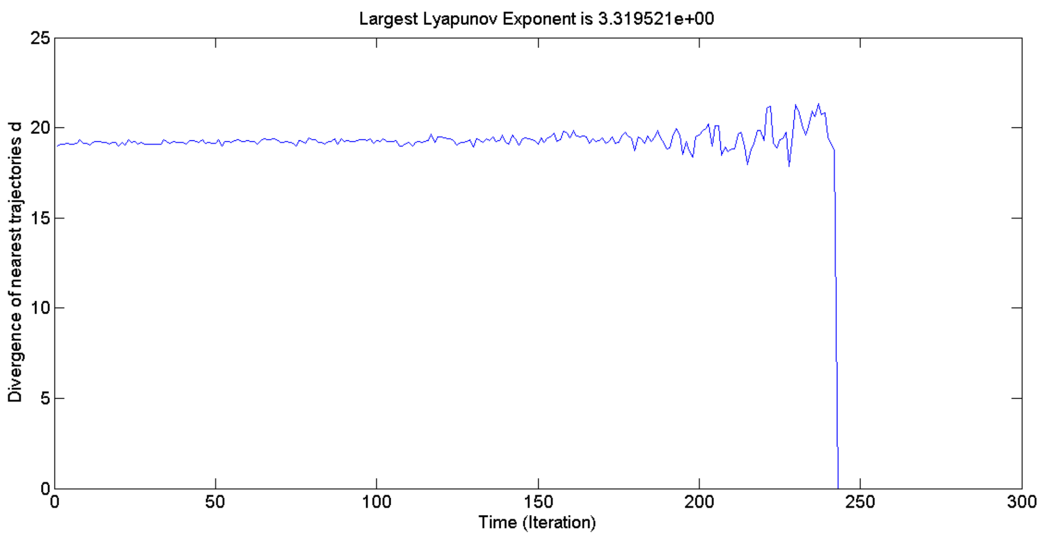


Figure 107 Revenue LLE after

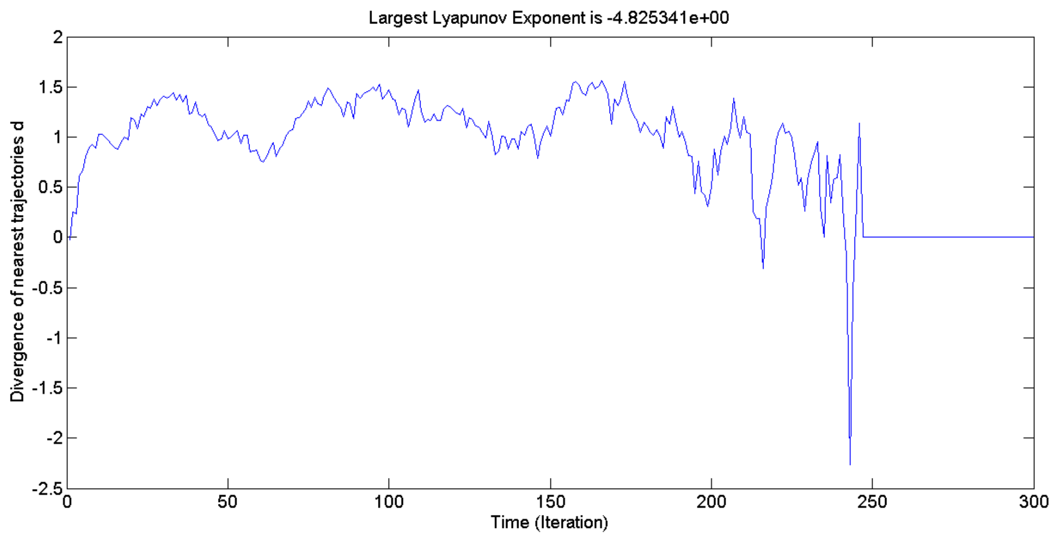


Figure 108 Price LLE before

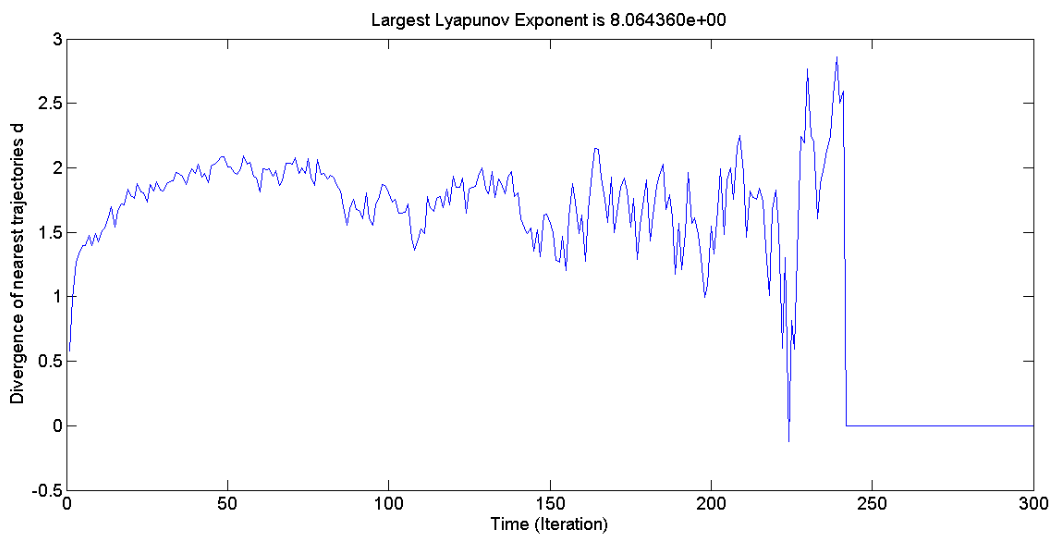


Figure 109 Price LLE after

The revenue LLE rose from -1.68 to 3.31. This signifies two things. Firstly, the system has transformed from a periodic to a more chaotic nature. Secondly, the sensitivity has increased. The same trend is observed for the price LLE which rose from -4.82 to 8.064.

Fractal Dimension and Kolmogorov Entropy

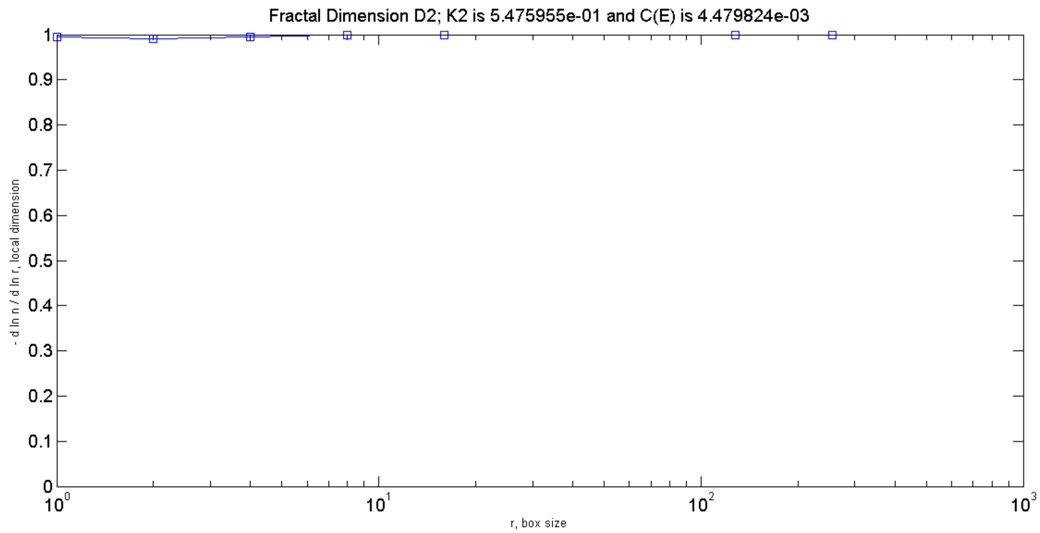


Figure 110 Revenue K2D2 before

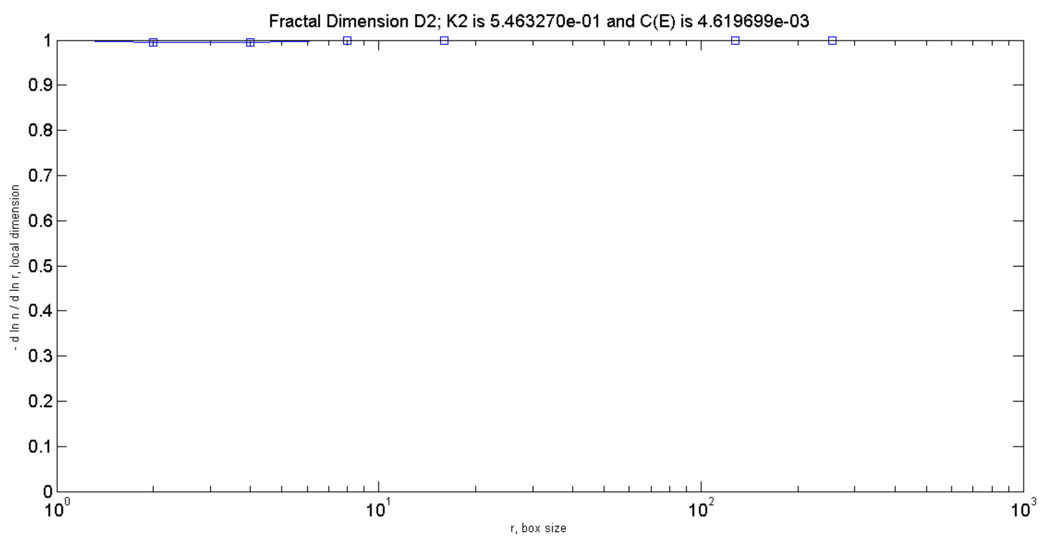


Figure 111 Revenue K2D2 after

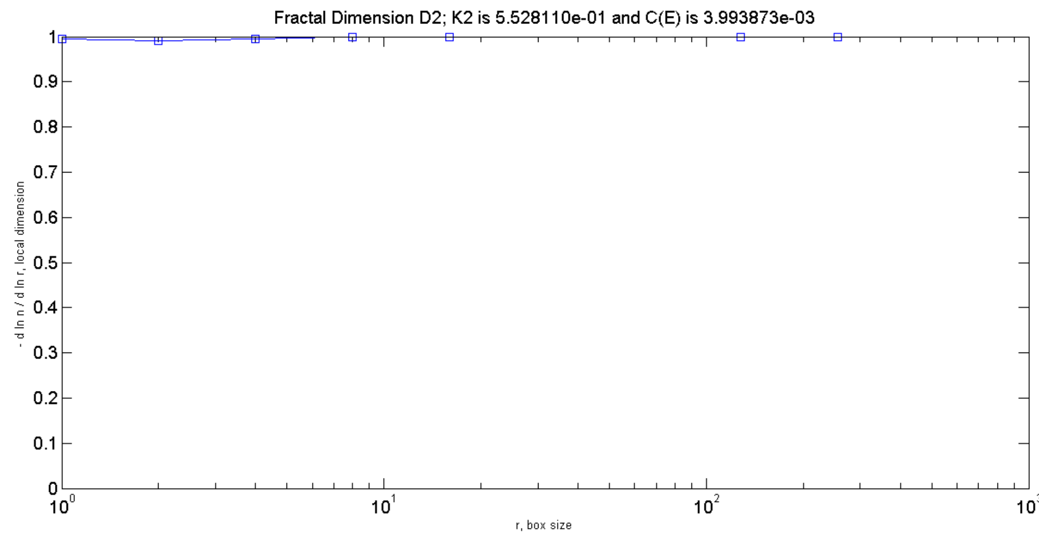


Figure 112 Price K2D2 before

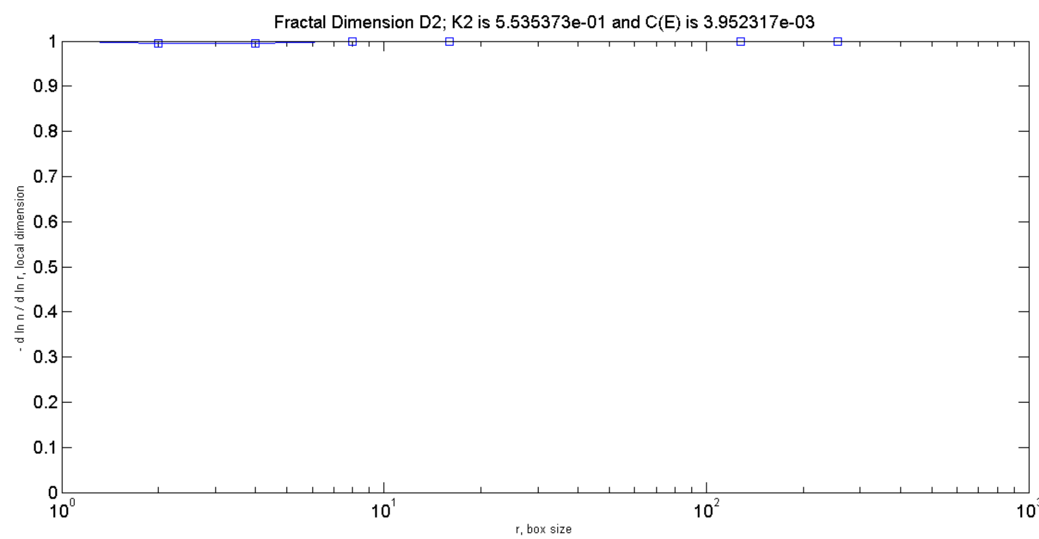


Figure 113 Price K2D2 after

For both revenue and price data, the fractal dimension remains constant at 0.98 indicating a constant stats of system instability. In revenue data, K2 decreased slightly from 5.475 to 5.463, whereas K2 in price increased from 5.528 to 5.535.

D. Interpretation and Discussion

The initial couple of months after the hike announcement saw a marked increase in the share revenue baseline. This could indicate a generally bullish trend. This also helped to even out the contrasts caused before the hike announcement. But, the purchasing patterns of shares varied greatly. Rather than a systematic approach towards buying shares every week or every ten days, the polar plot indicates a less coordinated approach. This drove the system from a periodic one to a chaotic one, as witnessed by the Lyapunov exponent. All these results point towards an improving yet chaotic trend in the share performance of IBM. AS the company turned 100 in 2011, mixed opinions across India as well as the US prevailed, and more people joined in the share purchasing fray. Though synchronization took a hit, the overall results turned favorable for the company, encouraging it to set sail for yet another 100 years.

3. Layoffs and Retrenchments of Q1 2014

The decline in the sales of servers and storage systems in 2013 had lead IBM to initiate a “Global Restructuring” program [62], whereby the top executives would forego their bonuses and nearly 15000 job cuts would be seen. This is in part, a measure to pioneer new, high value segments of the IT industry, with the company shifting focus from hardware based areas semiconductor research, mainframes and power processors to information based areas such as cloud computing and big data. While the job cuts started in India, Brazil and European Union soon followed suit. Following that, US based offices such as the Research Triangle Park (RTP) also witnessed job cuts [9].

Following this, on mid-April, IBM announced the Q1 2014 results, with profits and earnings from the systems and technology group (STG) significantly down by almost 11%.

While many long timers knew that this was only a restructuring and shift in focus in IBM, the market did not seem to welcome this change. The layoffs were perceived by many potential shareholders in both India as well as abroad as a decrease in the performance of the company.

To analyse the implications, the following time durations are defined:

1. During the Layoff (Q1): January 2nd 2014 to April 16th 2014
2. After the Layoff (Q2): April 17th 2014 to July 31st 2014

The Share revenue data analysis followed by share price data analysis will be presented.

A. Temporal Analysis

Time Series

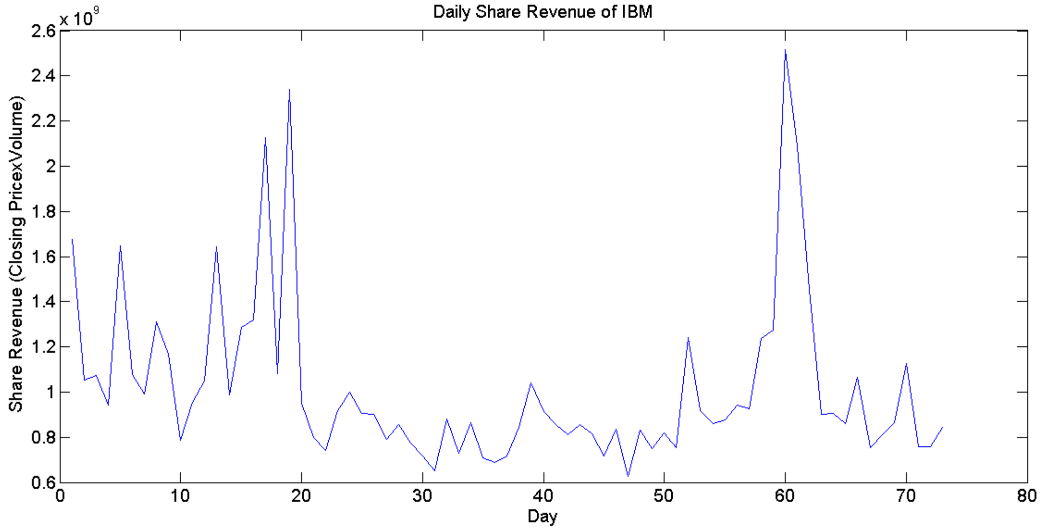


Figure 114 Revenue time series before

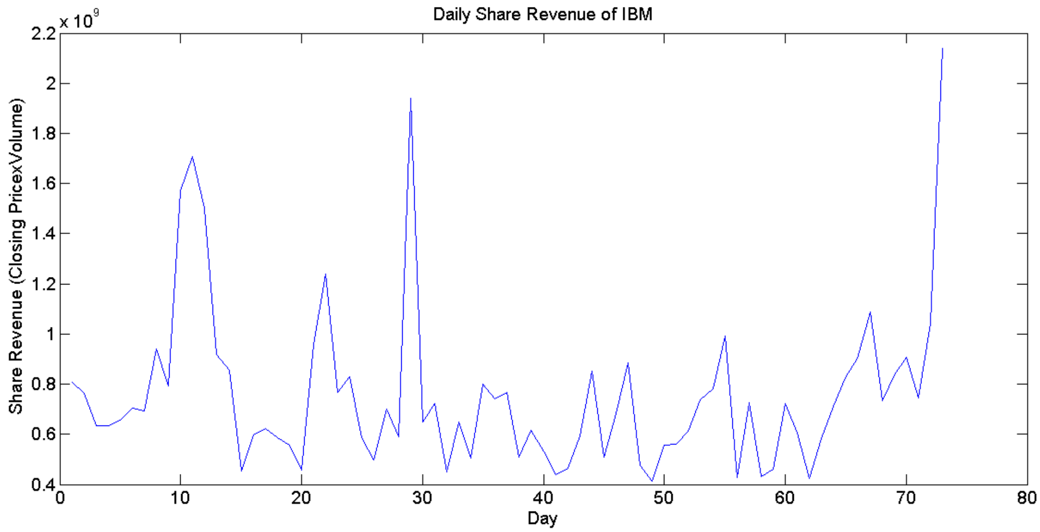


Figure 115 Revenue time series after

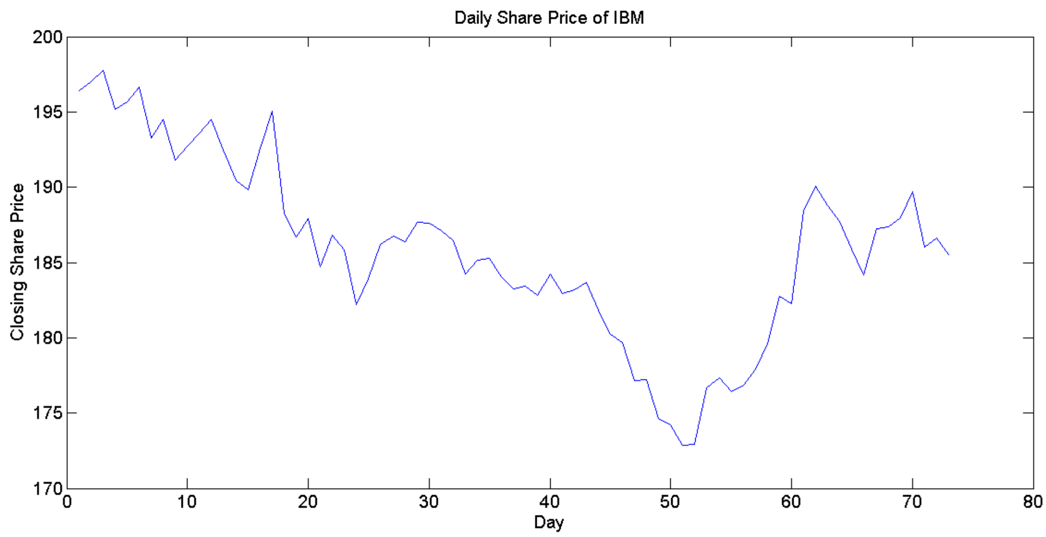


Figure 116 Price time series before

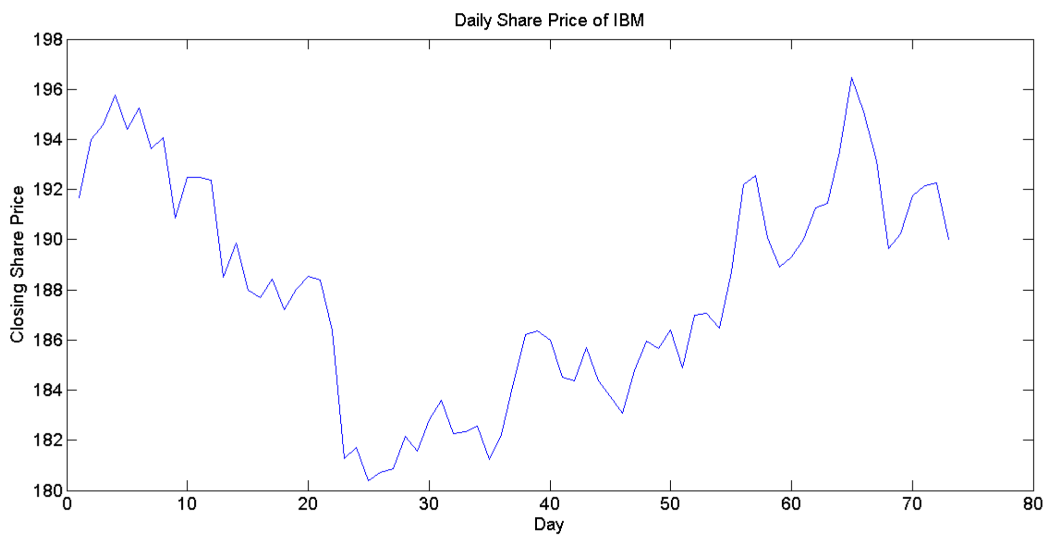


Figure 117 Price time series after

The revenue time series indicate a slight lowering of the baseline from $0.8b in Q1 to $0.6b in Q2. There is not much change in the price time series. The huge lapse of share purchase between 20 and 60 axis value in the Q1 revenue series is noteworthy.

Phase Portrait

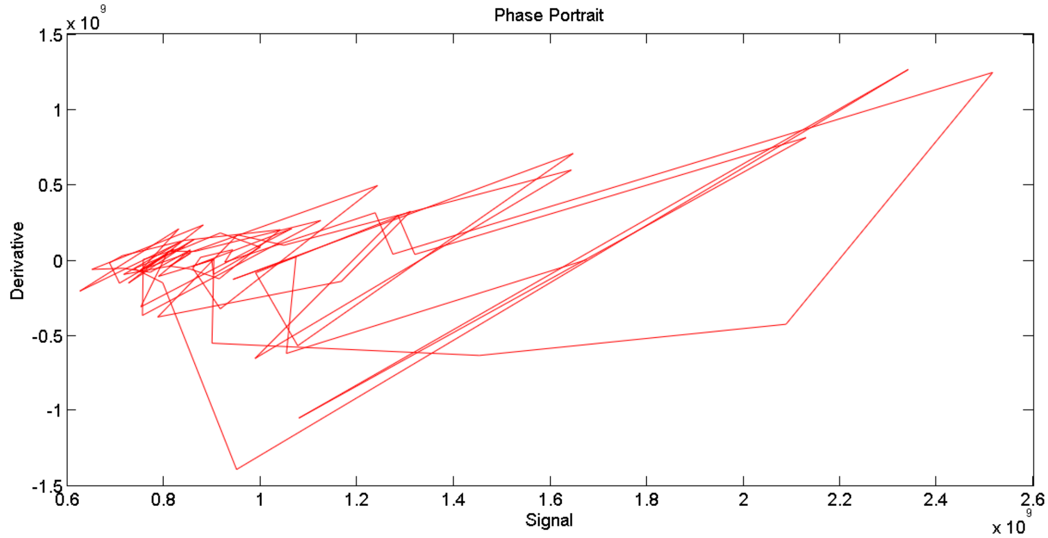


Figure 118 Revenue phase plane before

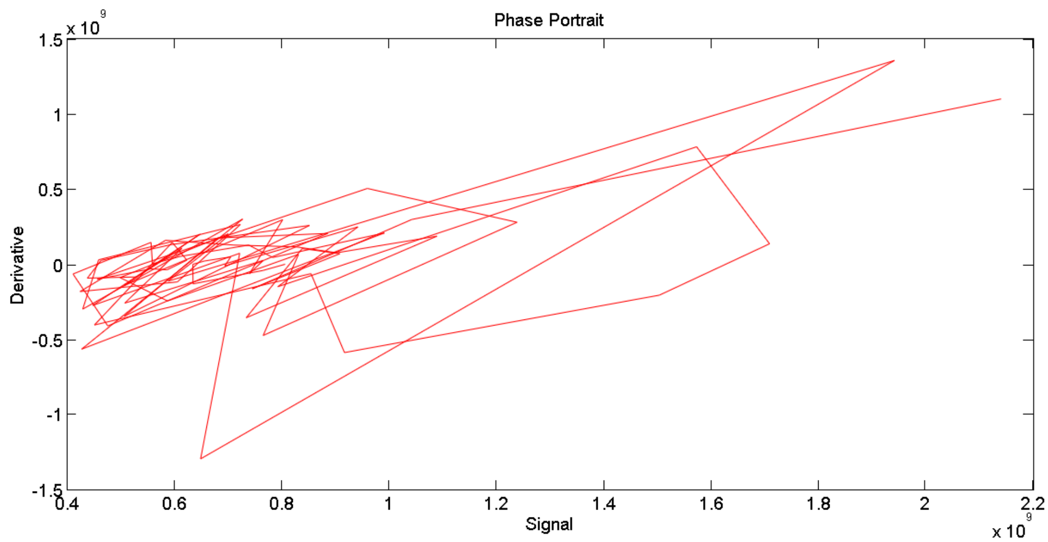


Figure 119 Revenue phase plane after

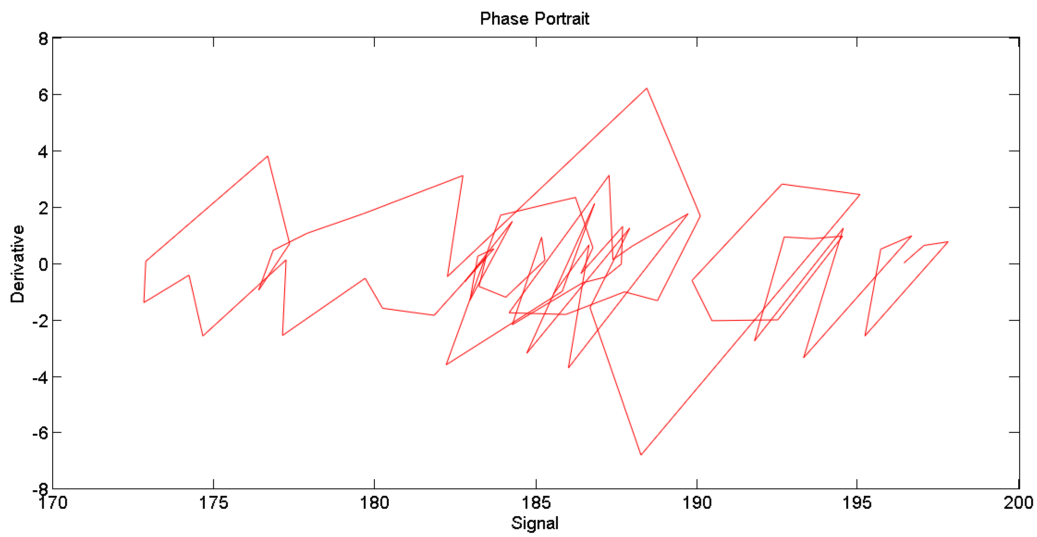


Figure 120 Price phase plane before

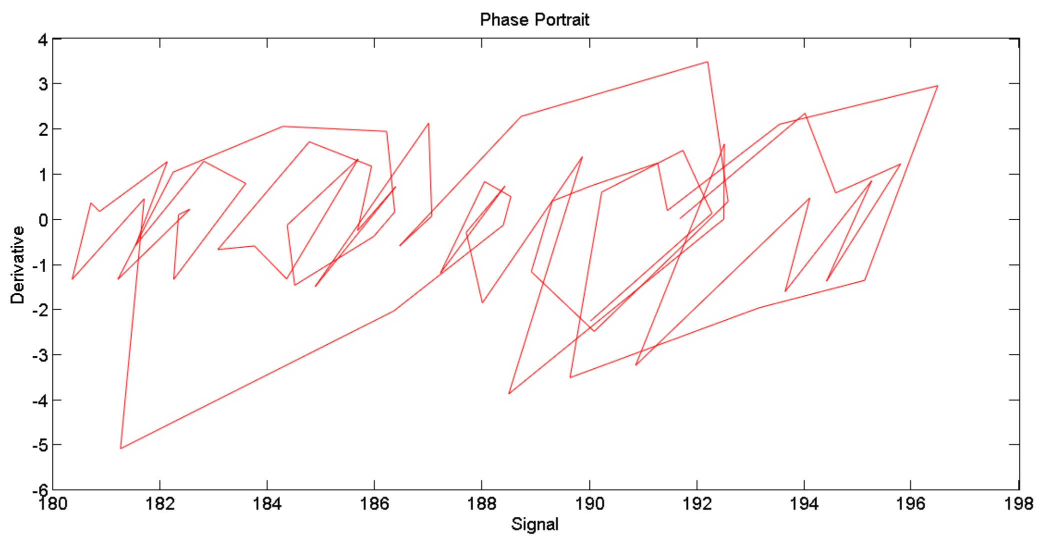


Figure 121 Price phase plane after

The complexity has not changed considerably. Both the price phase portraits indicate an oscillatory nature above and below $188.

Multiscale Analysis

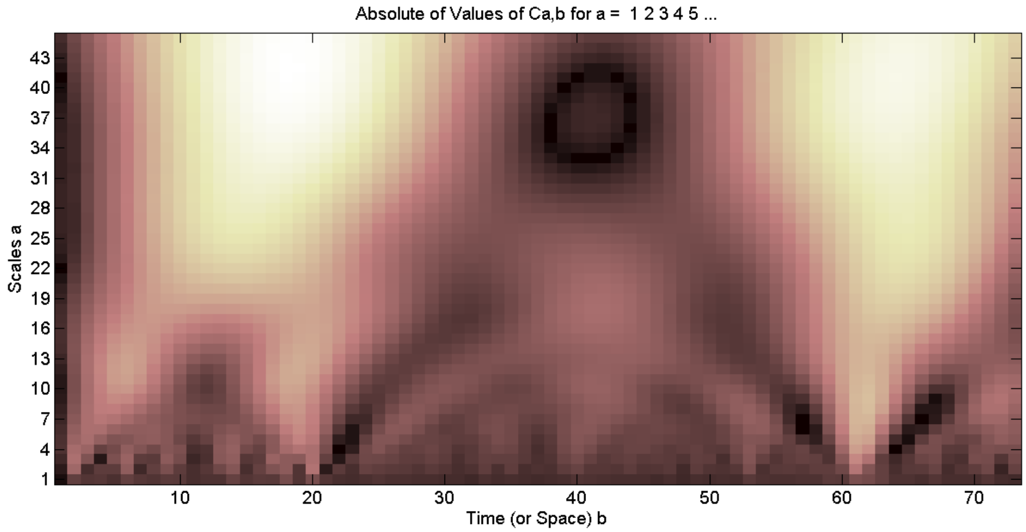


Figure 122 Revenue multiscale analysis before

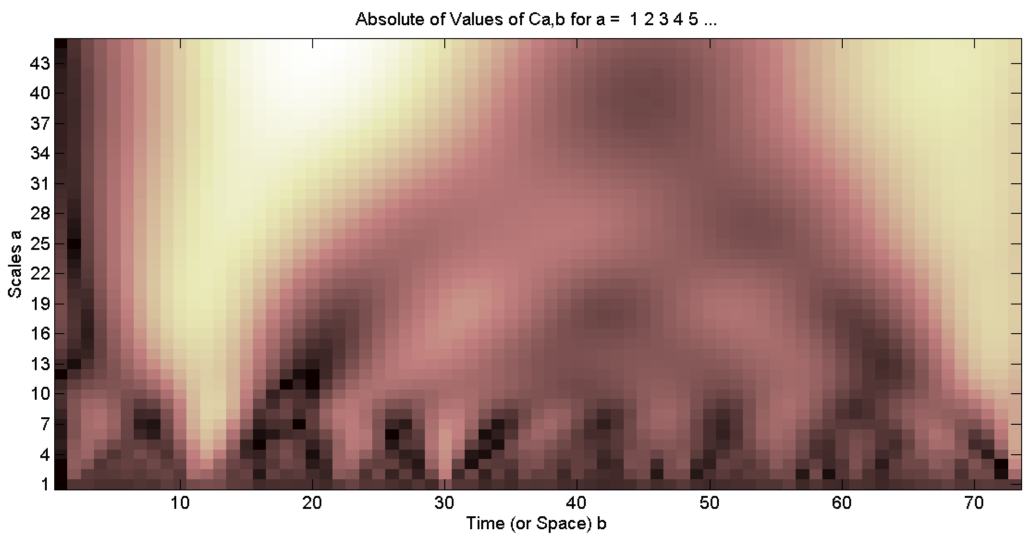


Figure 123 Revenue multiscale analysis after

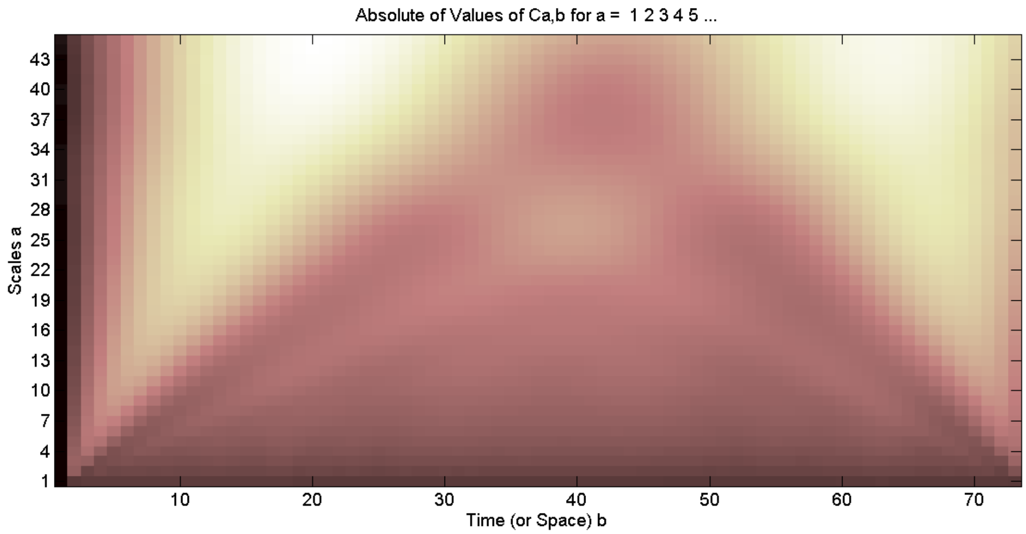


Figure 124 Price multiscale analysis before

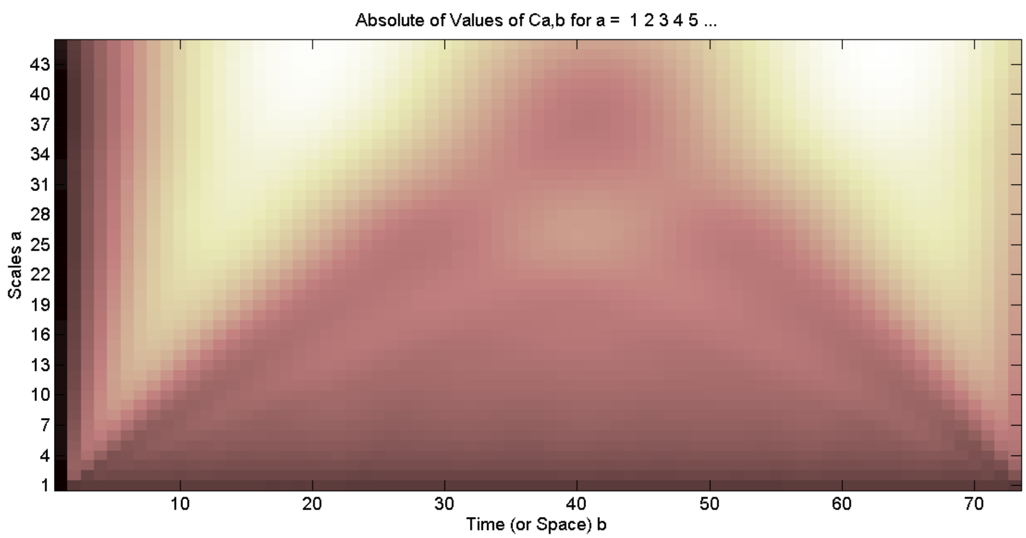


Figure 125 Price mutiscale analysis after

The most noteworthy feature in the multiscale analysis is the “black hole” in the Q1 revenue corresponding to a time value of about 40 and timescale of about 35. This corresponds to the precise date of the layoff. This clearly indicates the drop in the share revenue in that period, also witnessed by the ‘lapse’ in the Q1 revenue time series mentioned earlier.

B. Spectral Analysis

Magnitude Spectrum

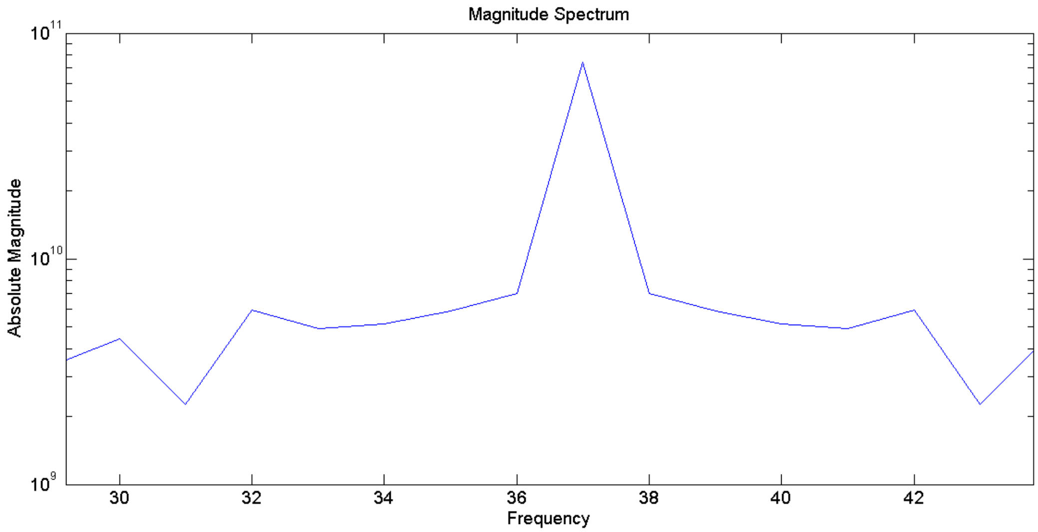


Figure 126 Revenue spectrum before

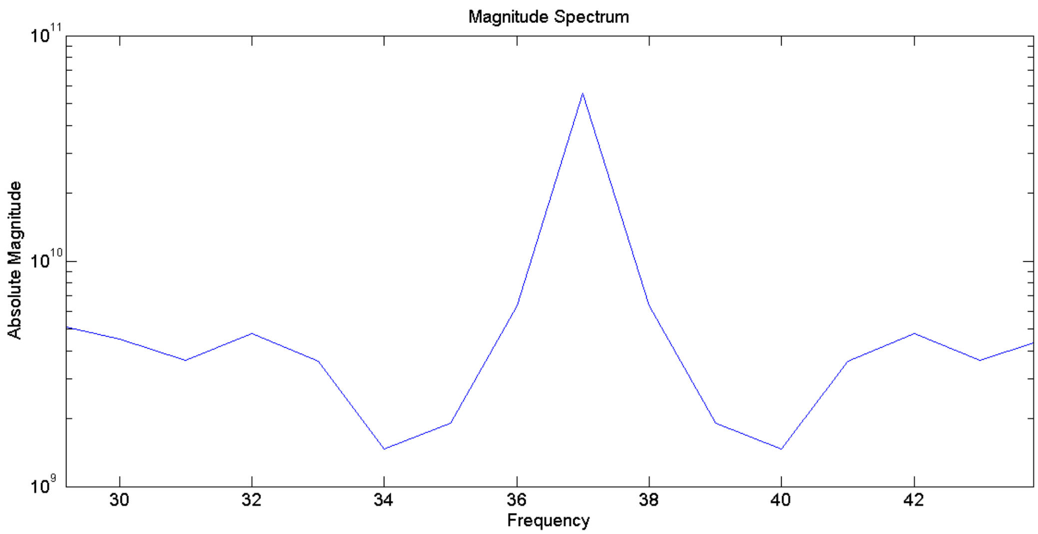


Figure 127 Revenue spectrum after

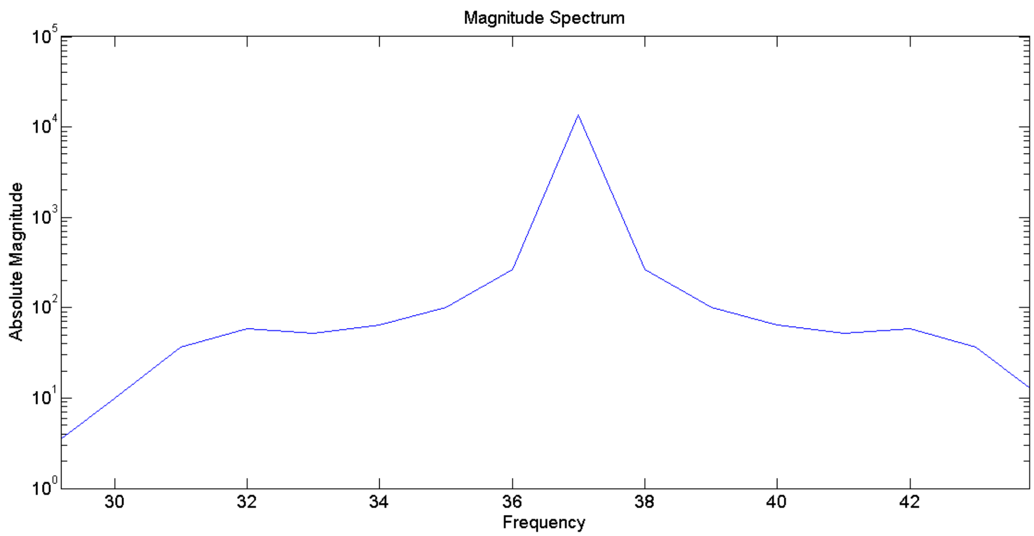


Figure 128 Price spectrum before

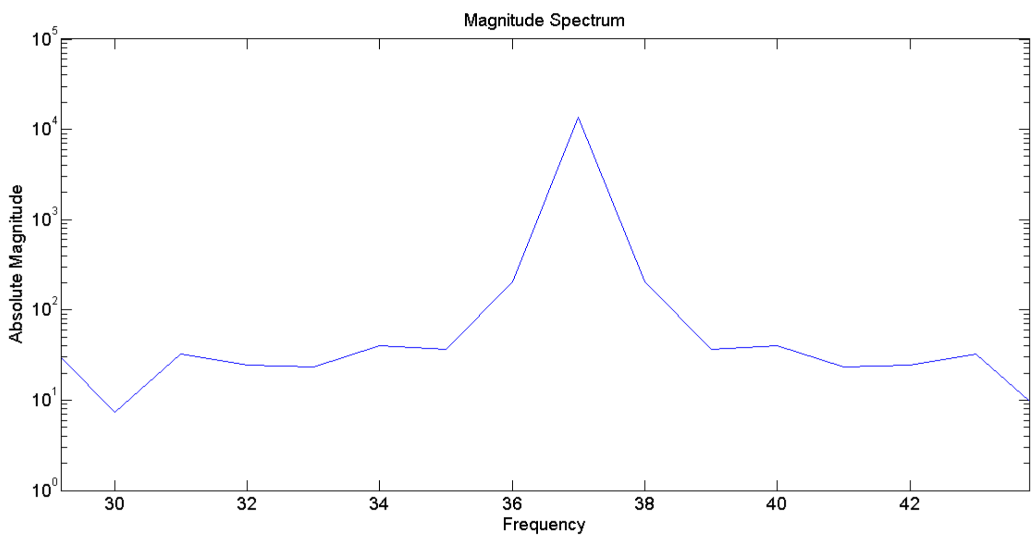


Figure 129 Price spectrum after

No significant changes in the spectra of both price and revenue are noted.

Polar plot

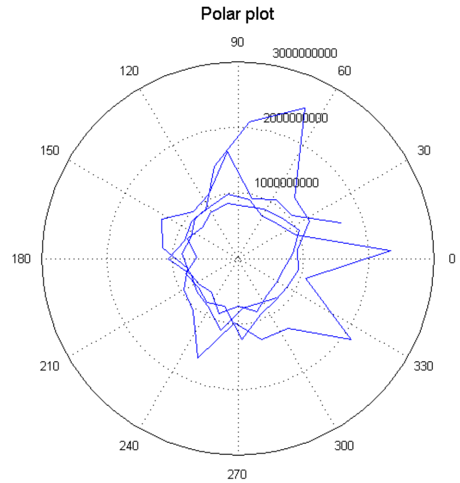


Figure 130 Revenue polar plot before

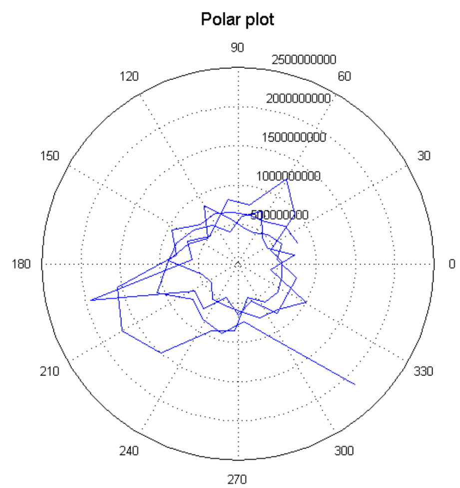


Figure 131 Revenue polar plot after

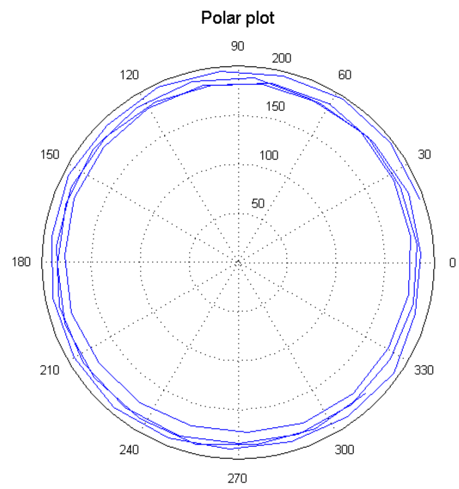


Figure 132 Price polar plot before

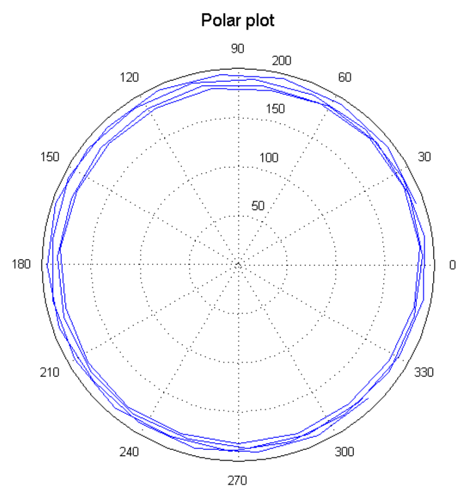


Figure 133 Price polar plot after

The revenue polar plot indicates a major shift in the share purchasing trend over a month. The focus shifted towards 'mid-month purchase' from 'month-end' purchases. This implies that the announcement of layoffs and Q1 results made the share purchasers a little more wary and cautious regarding the purchase of shares.

C. Nonlinear Analysis

Lyapunov Exponent

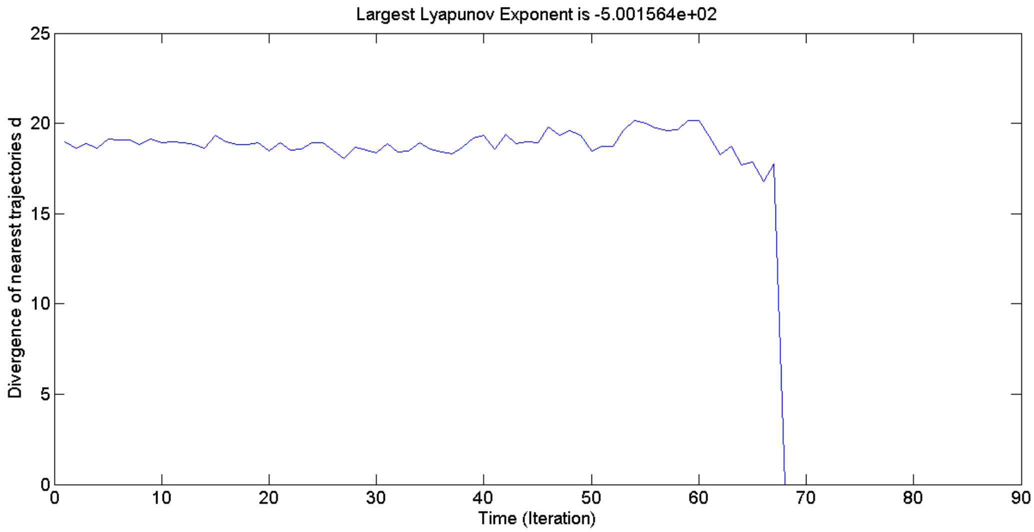


Figure 134 Revenue LLE before

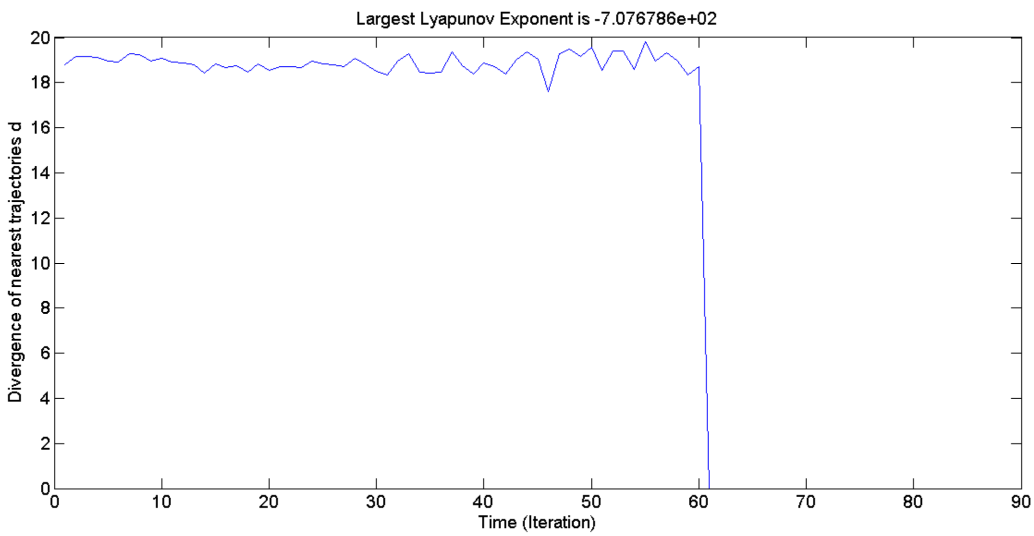


Figure 135 Revenue LLE after

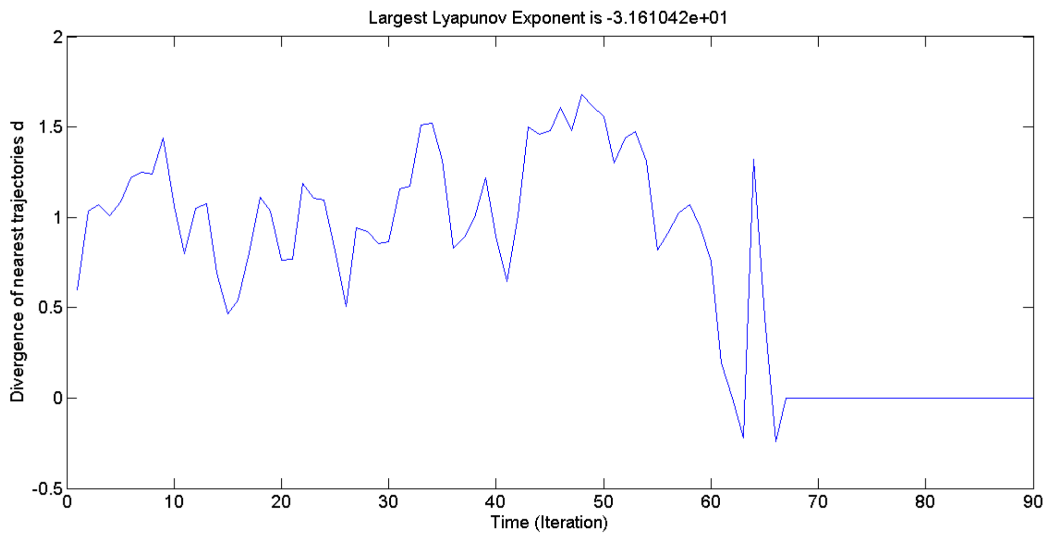


Figure 136 Price LLE before

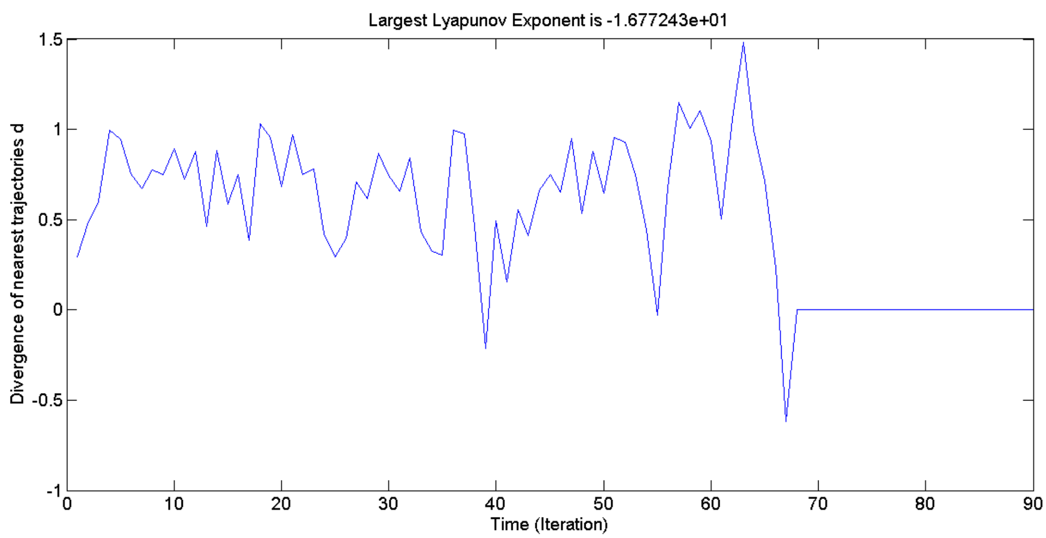


Figure 137 Price LLE after

Lyapunov exponents of the Q1 revenue data are extremely high at -500. This indicates a very sensitive phase in the share market. The LLE further rose to -707 in Q2 further increasing the sensitivity.

The high value of sensitivity clearly highlights the mixed perceptions of the layoffs in Q1. O the other hand price LLE dropped from -31.61 to -16.77. This indicates the decrease in sensitivity and hence the price range variability in the share price.

Fractal Dimension and Kolmogorov Entropy

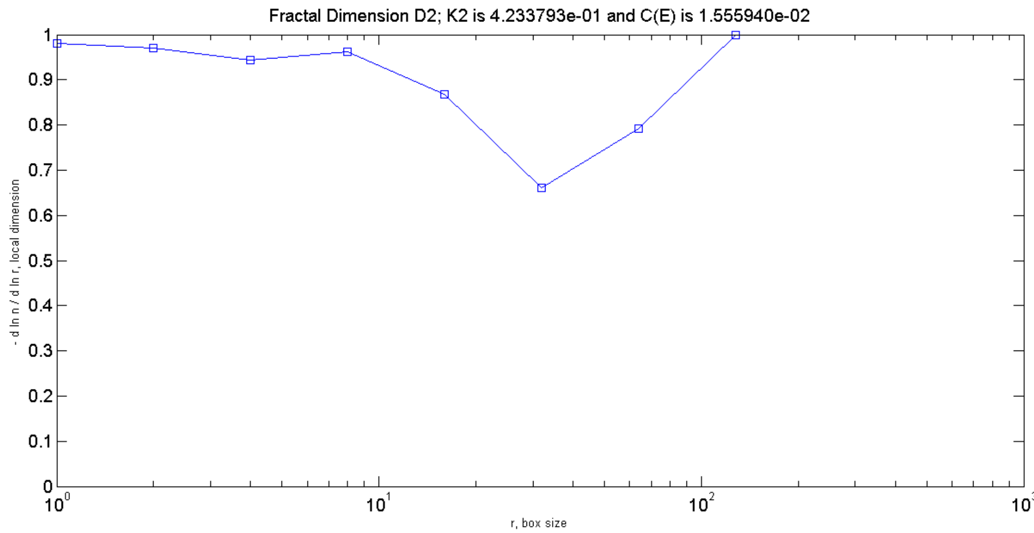


Figure 138 Revenue K2D2 before

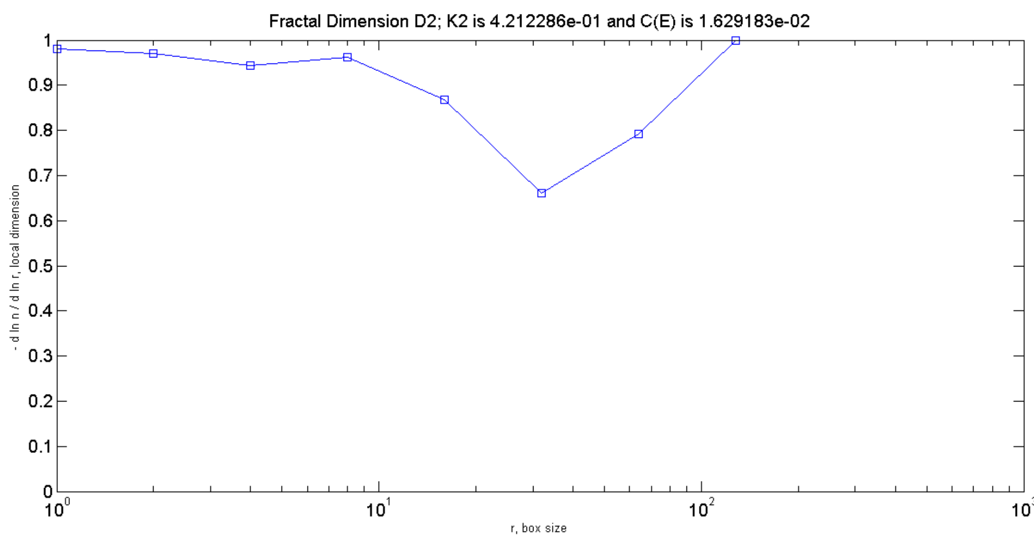


Figure 139 Revenue K2D2 after

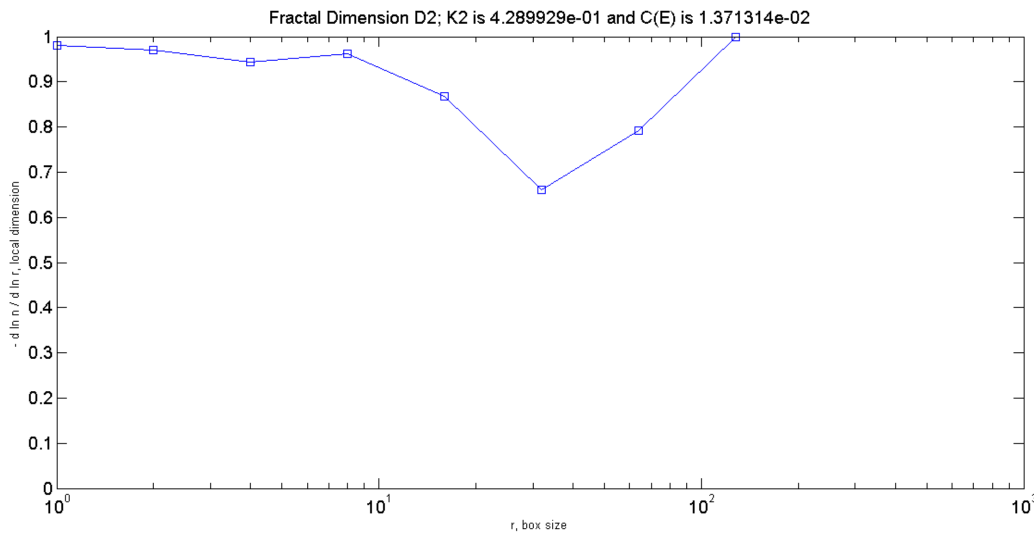


Figure 140 Price K2D2 before

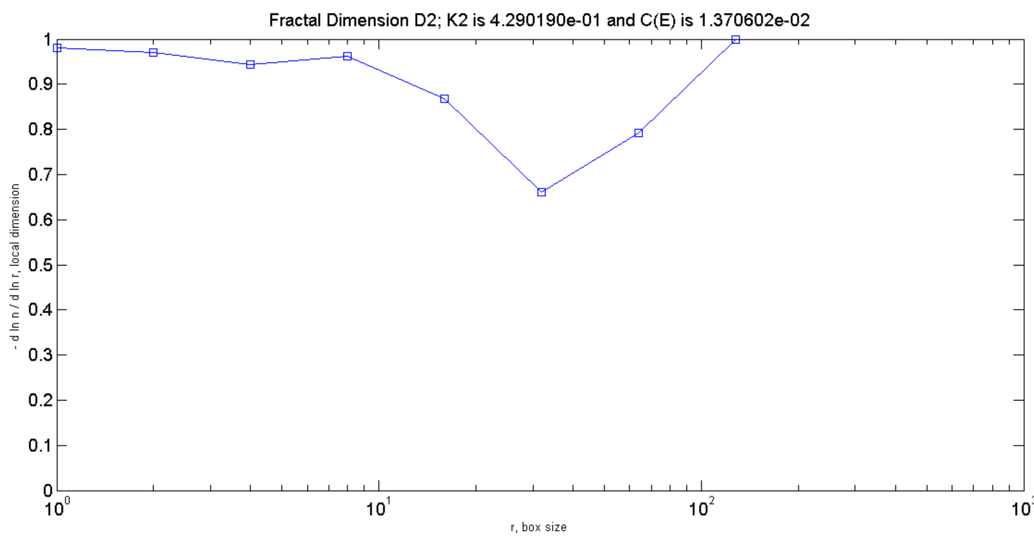


Figure 141 Price K2D2 after

A constant D2 value of 0.68 for both Q1 and Q2 indicates moderate instability prevailing throughout. Revenue K2 decreased from 4.23 in Q1 to 4.21 in Q2. Price K2 increased from 4.28 to 4.29.

D. Interpretation and Discussion

The layoffs in 2014 Q1 have invariably been perceived adversely by the share market. This reflects in the clear drop in the share revenue during mid-February as witnessed by the multiscale analysis. While people followed the general trend of month end purchase of shares, the announcement of Q1 results changed the mindset. The average market value of the share went down in Q2, since people were not ready to take extravagant risks by quoting out of the money (OTM) prices. This is reflected by the decrease in LLE and increase in K2 for the price data. On the contrary, mixed opinions prevailed in the volume of shares purchased. This showed as significant rise in LLE and a drop in K2. In other words, lesser information about the revenue was available, and people were in a slightly confused state. Overall, the moderate value of D2 and the extremely high values of LLE clearly indicated periods of extreme sensitivity.

4. Dividend declaration in Q1, 2013

In contrast with the earlier case studies, this one is of relatively lesser importance, but significant nevertheless. Near the close of each fiscal year, IBM declares the dividends and earnings per share. This has a significant influence on the share market performance. On April 30th 2013, IBM declared a 2013 Q1 dividend of $0.91 per share. To analyse the effects, two time durations are considered:

1. Before the declaration: January 2nd 2013 to April 30th 2013.
2. After the declaration: May 1st 2013 to August 26th 2013.

A. Temporal Analysis

Time Series

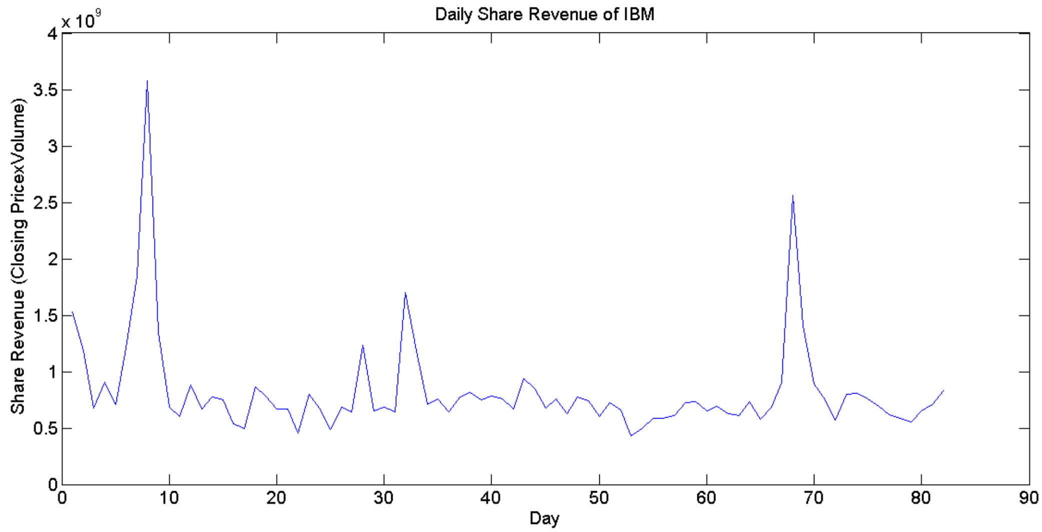


Figure 142 Revenue time series before

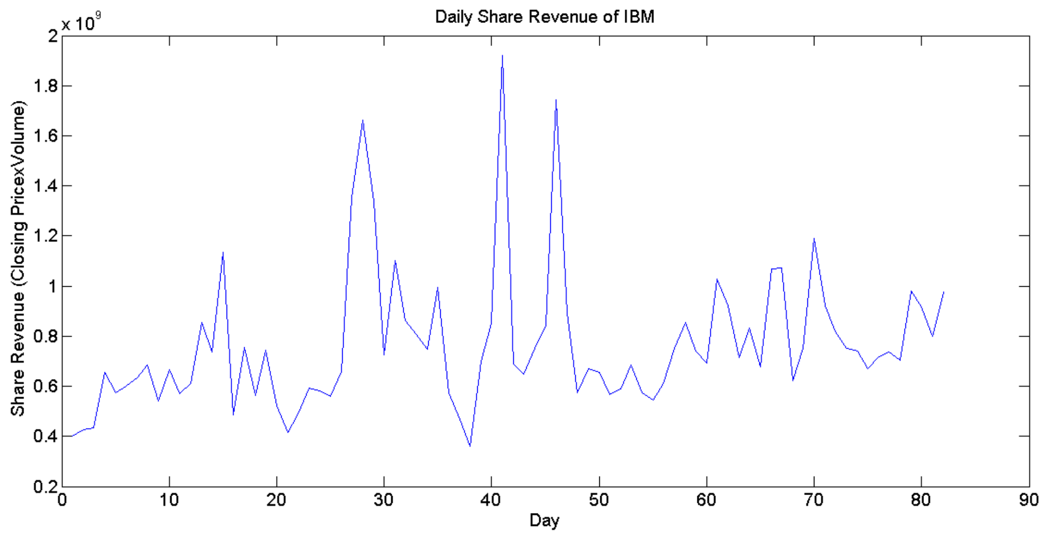


Figure 143 Revenue time series after

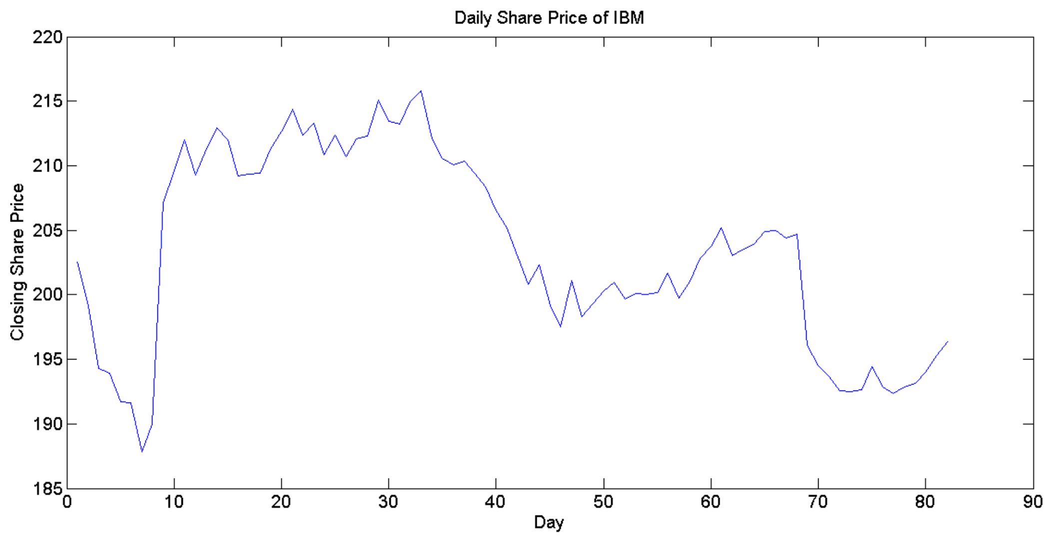


Figure 144 Price time series before

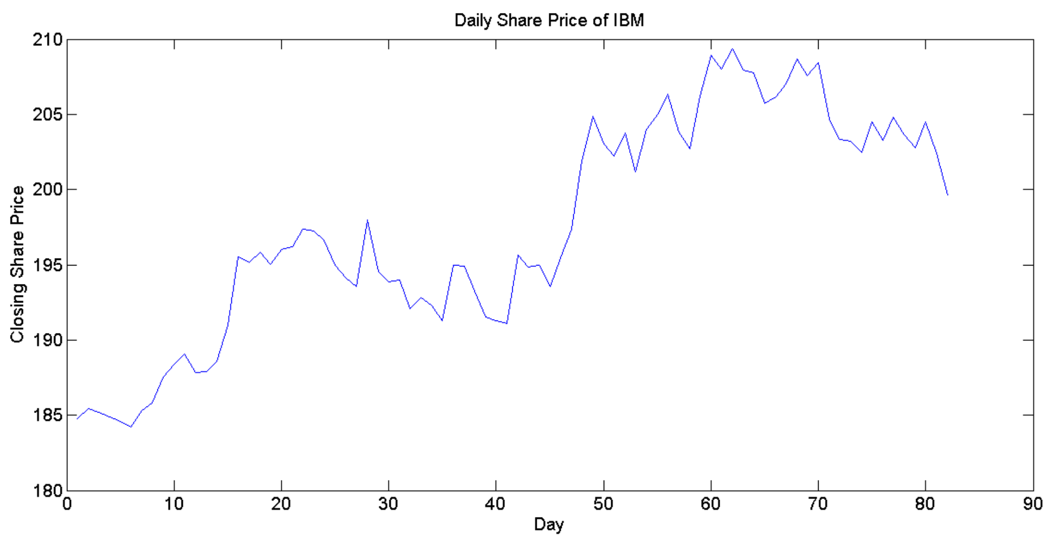


Figure 145 Price time series after

The time series data indicate a marginal decrease in both the price and revenue of shares after the dividend declaration. The baseline however seems to be unaffected.

Phase Portrait

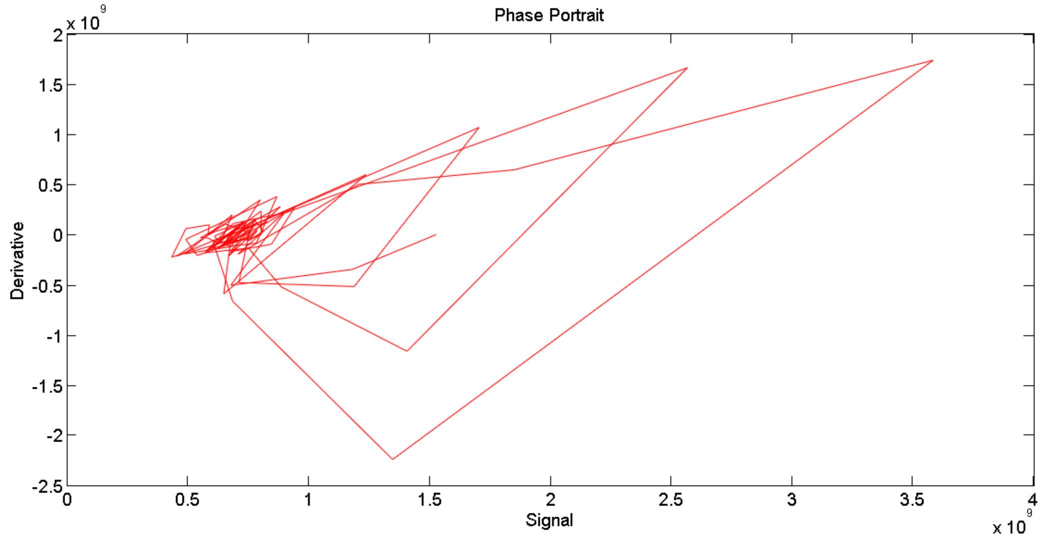


Figure 146 Revenue phase plane before

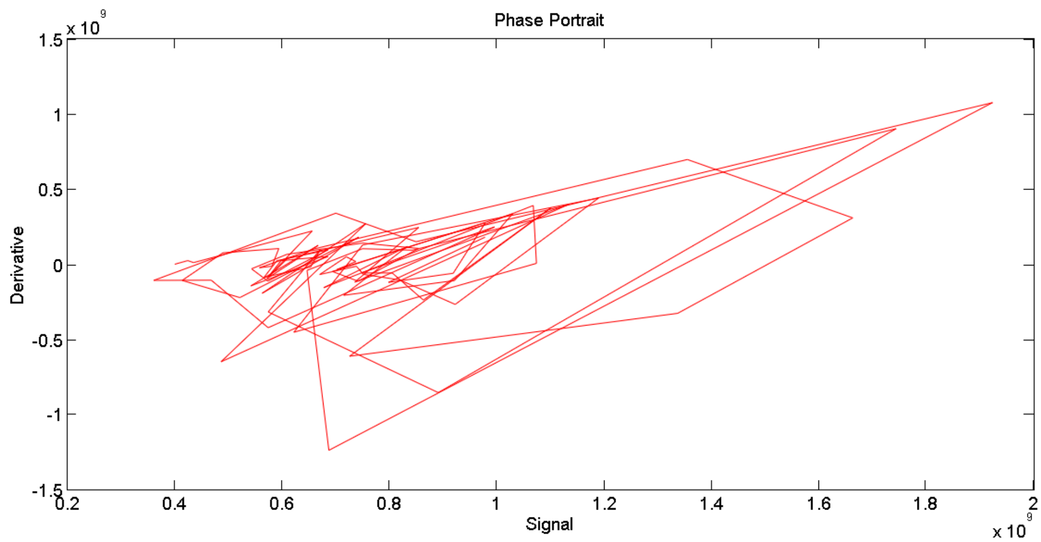


Figure 147 Revenue phase plane after

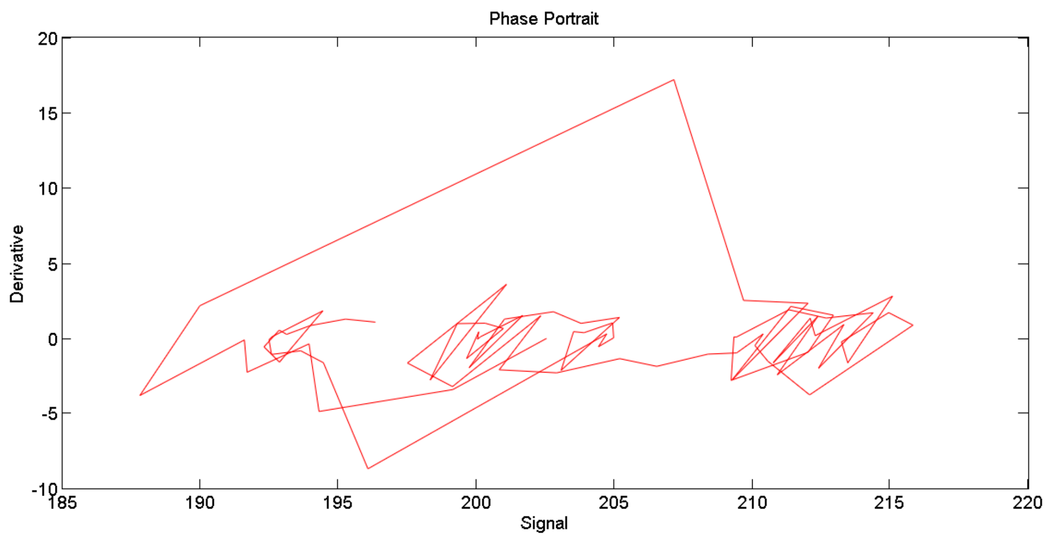


Figure 148 Price phase plane before

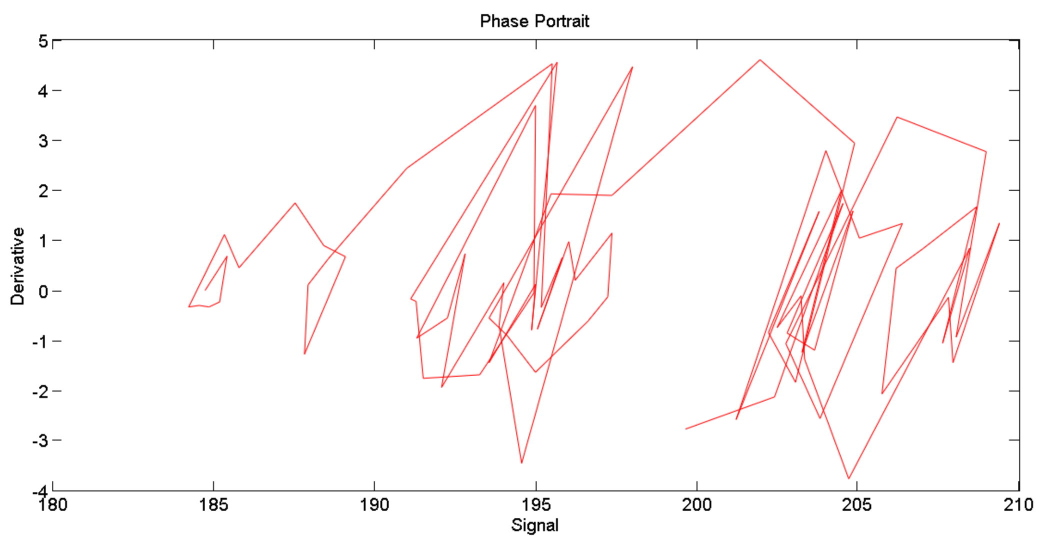


Figure 149 Price phase plane after

The phase portraits of price and revenue indicate moderate amount of complexity that has not been affected by the dividend declaration. The price data show tri stable states before and after the declaration.

Multiscale Analysis

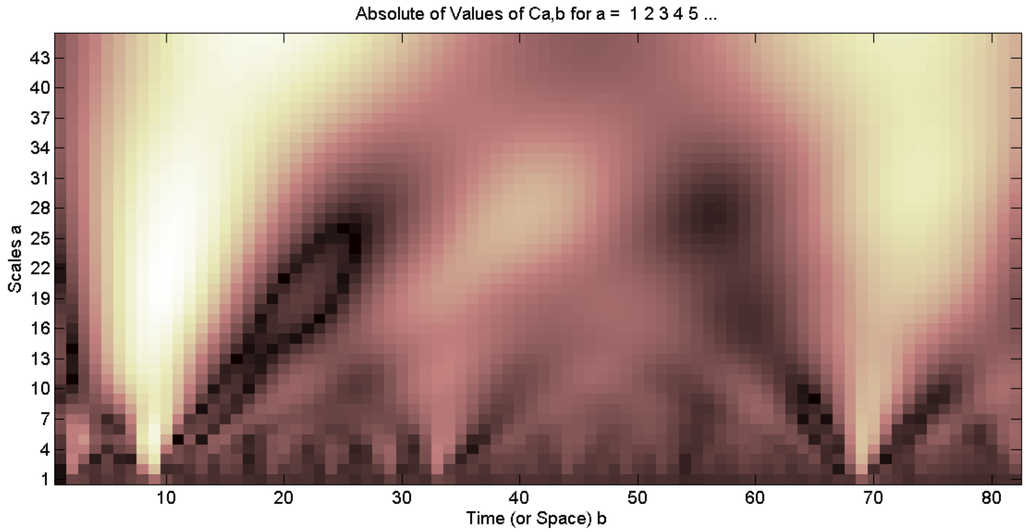


Figure 150 Revenue multiscale analysis before

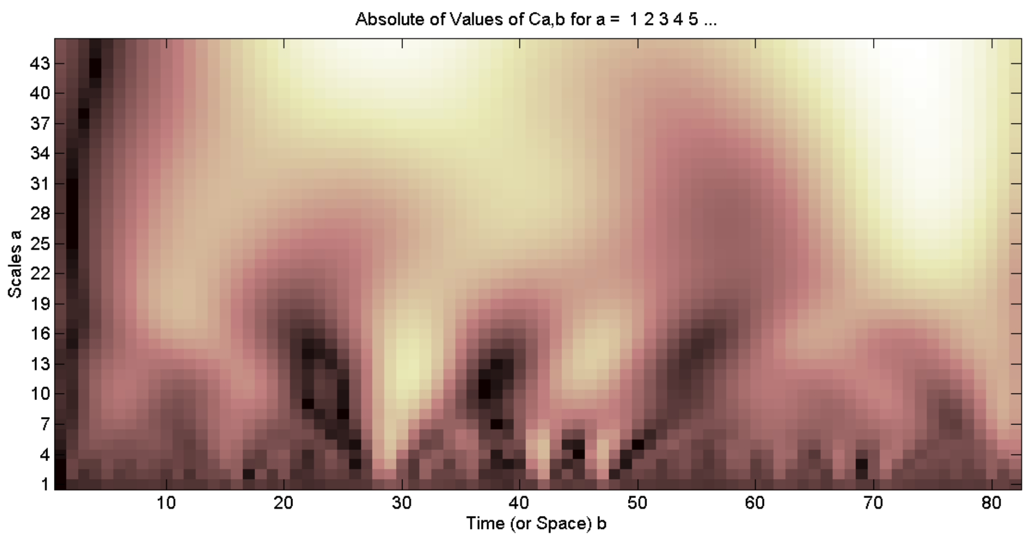


Figure 151 Revenue multiscale analysis after

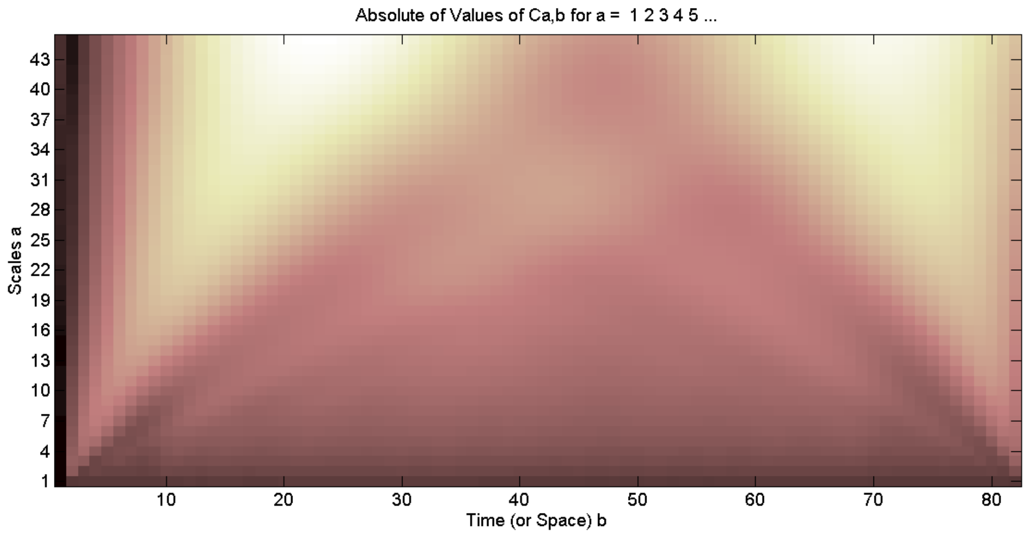


Figure 152 Price multiscale analysis before

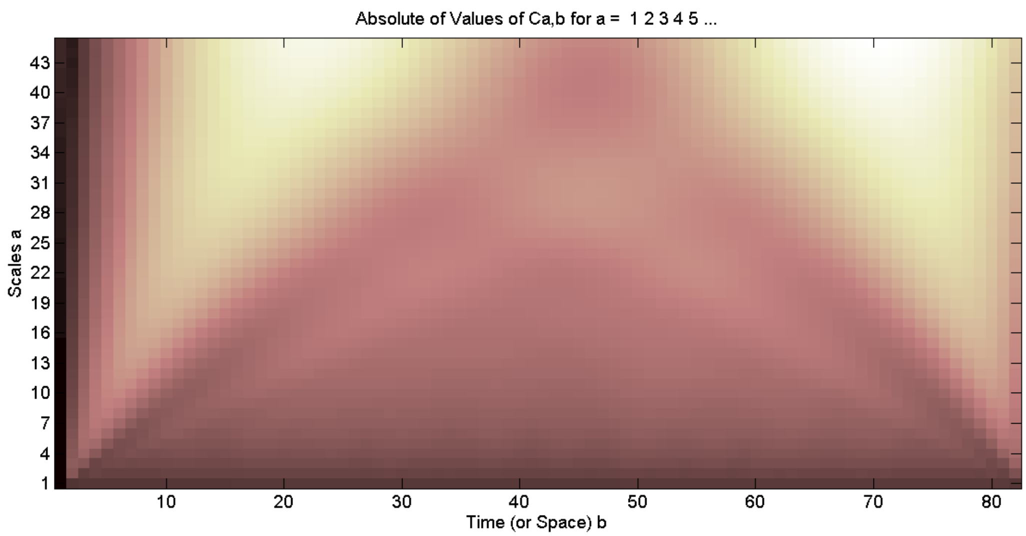


Figure 153 Price multiscale analysis after

The revenue multiscale analyses indicate a reduction in the time scales of contrasting share purchases from nearly 25 days before the dividend declaration to around 15 days after the declaration.

B. Spectral Analysis

Magnitude Spectrum

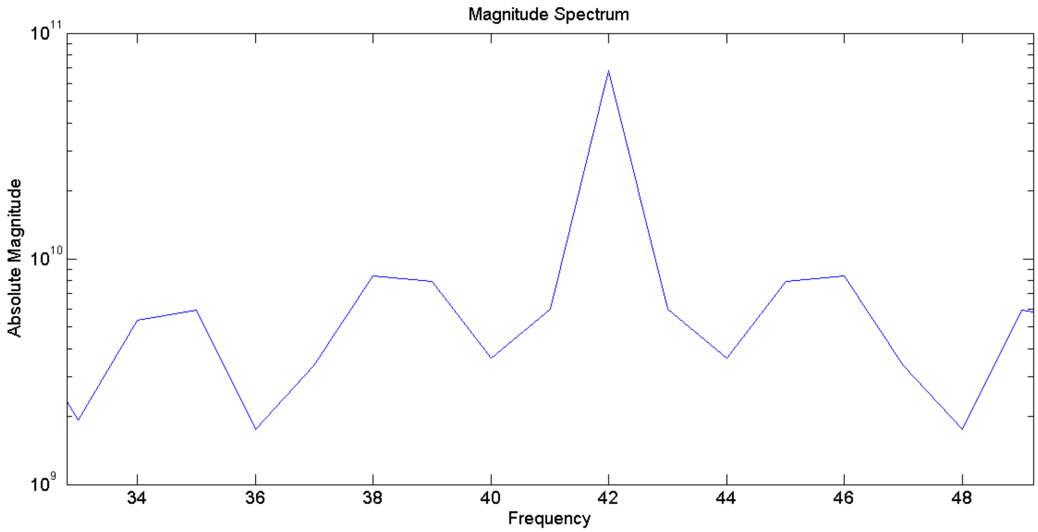


Figure 154 Revenue spectrum before

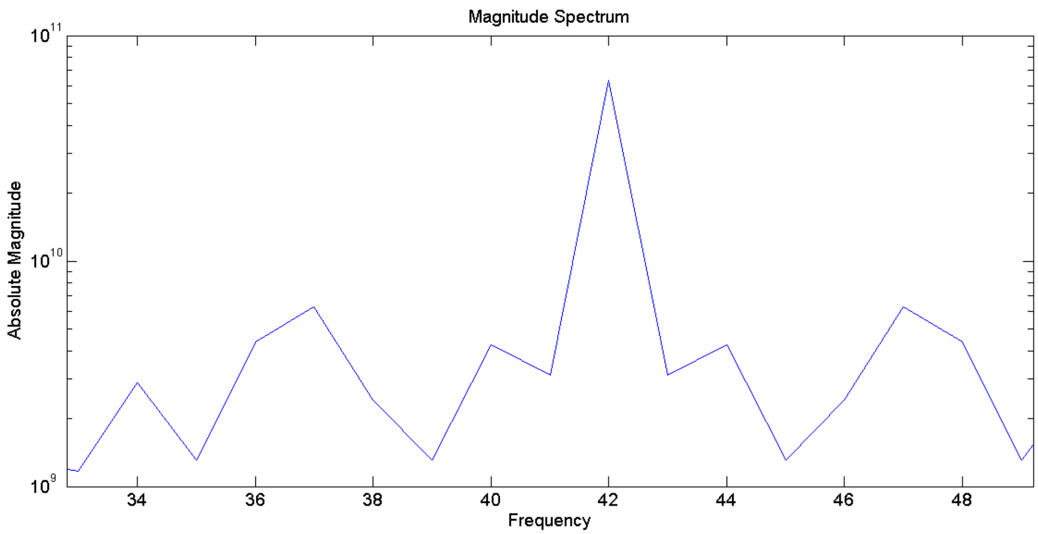


Figure 155 Revenue spectrum after

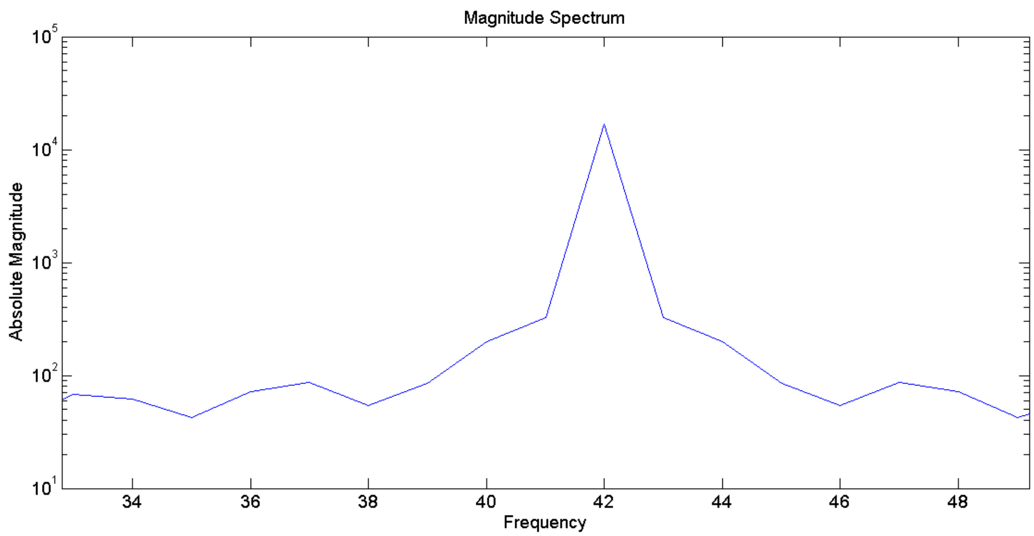


Figure 156 Price spectrum before

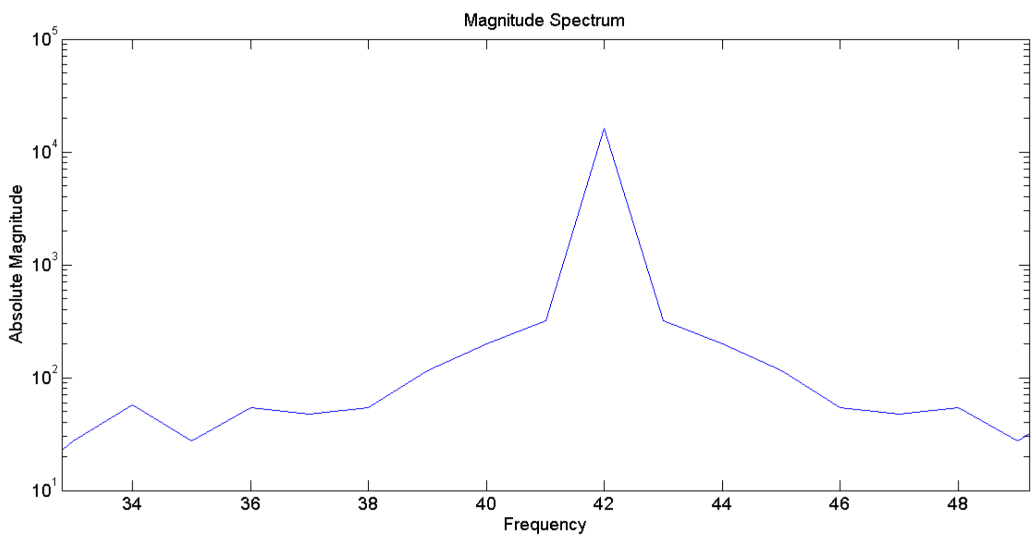


Figure 157 Price spectrum after

The spectral data of both price and revenue show negligible influence on the dividend declaration.

Polar Plot

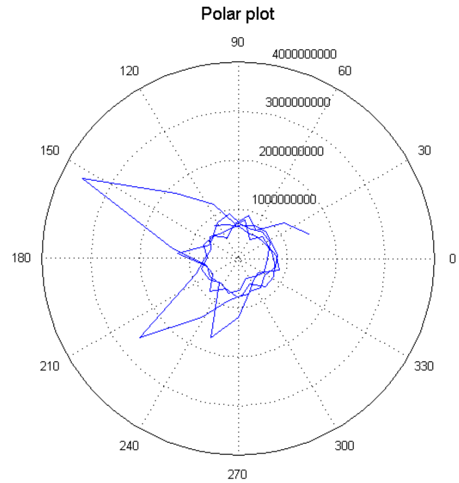


Figure 158 Revenue polar plot before

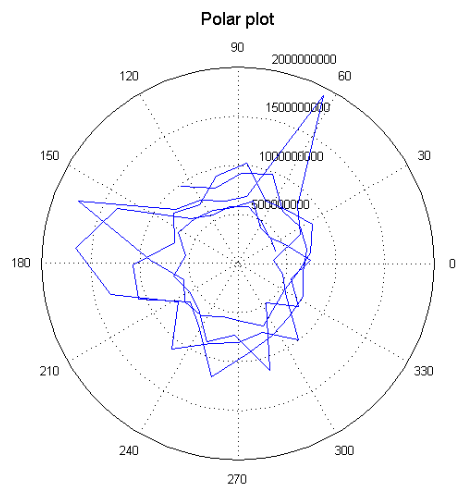


Figure 159 Revenue polar plot after

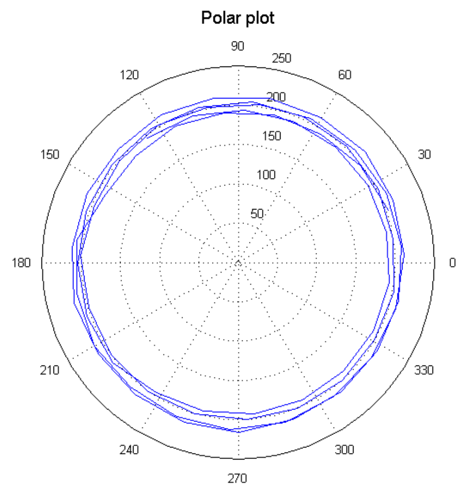


Figure 160 Price polar plot before

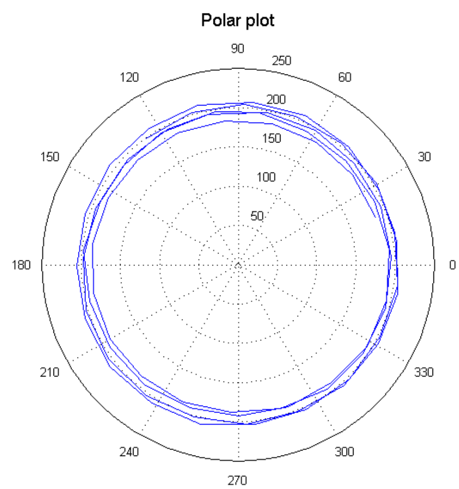


Figure 161 Price polar plot after

The polar plot of the revenue indicates the shift of one of the major peaks from the third week of the month to the first week of the month. Thus, the share purchase pattern shows a change, though the overall share revenue is not likely to get affected.

C. Nonlinear Analysis

Lyapunov Exponent

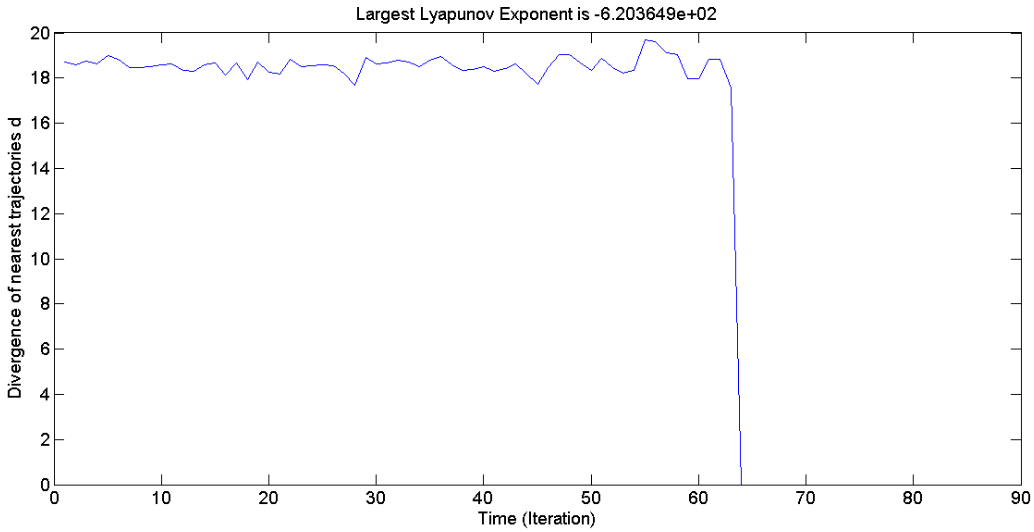


Figure 162 Revenue LLE before

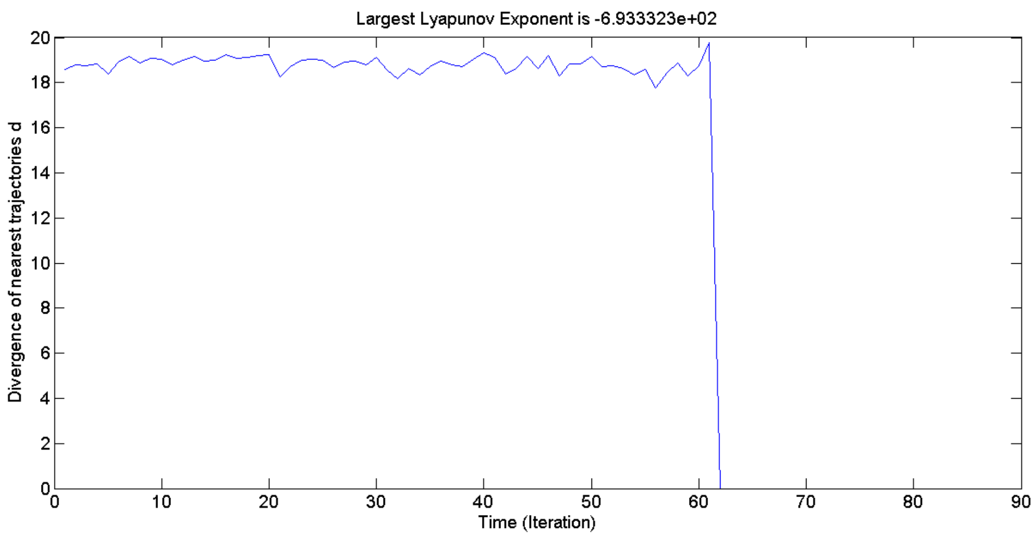


Figure 163 Revenue LLE after

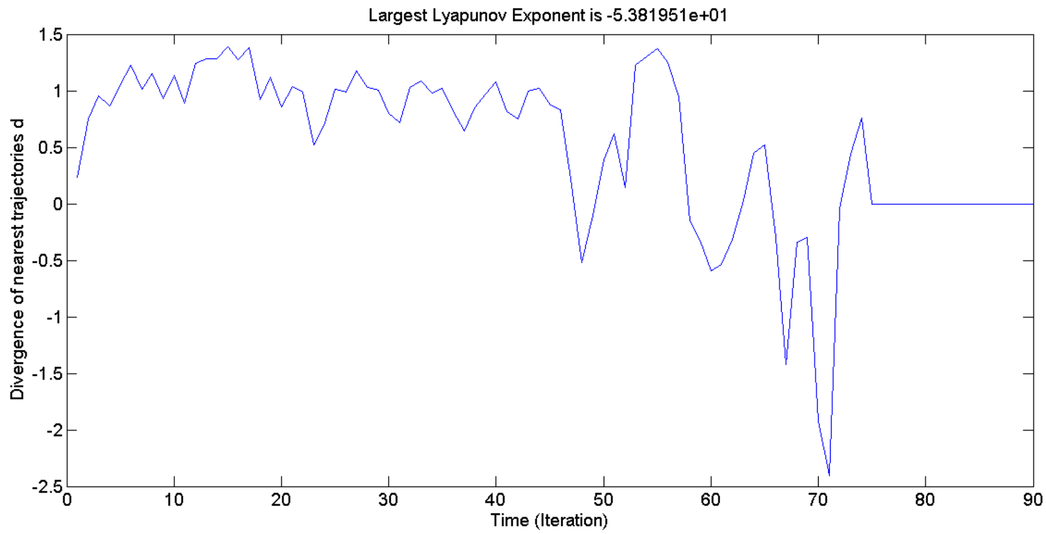


Figure 164 Price LLE before

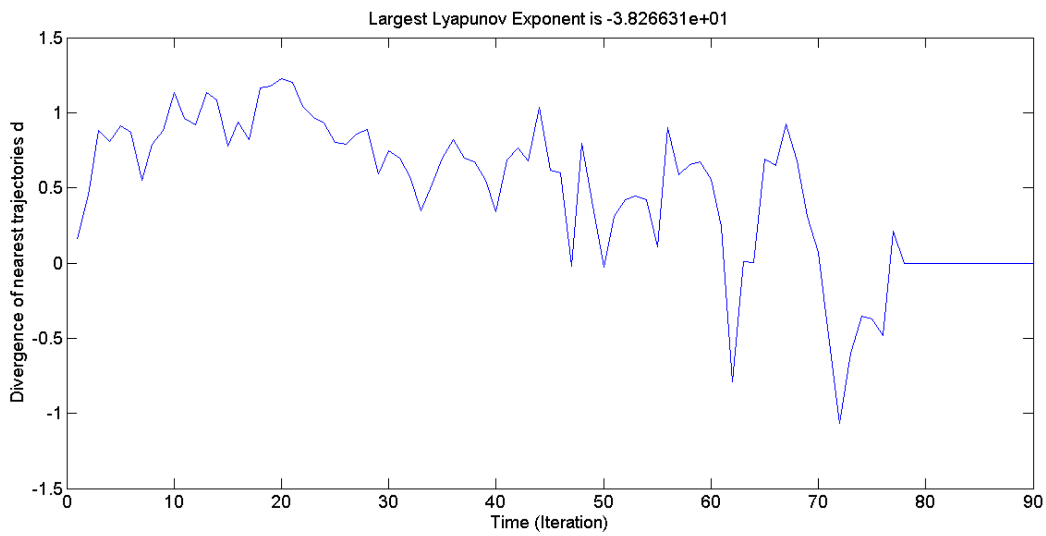


Figure 165 Price LLE after

The LLE of revenue has increased from -6.2 to -6.9 indicating increase of sensitivity. However, price LLE decreased from 5.38 to 3.82, thus signifying the decrease in price variability.

Fractal Dimension and Kolmogorov Entropy

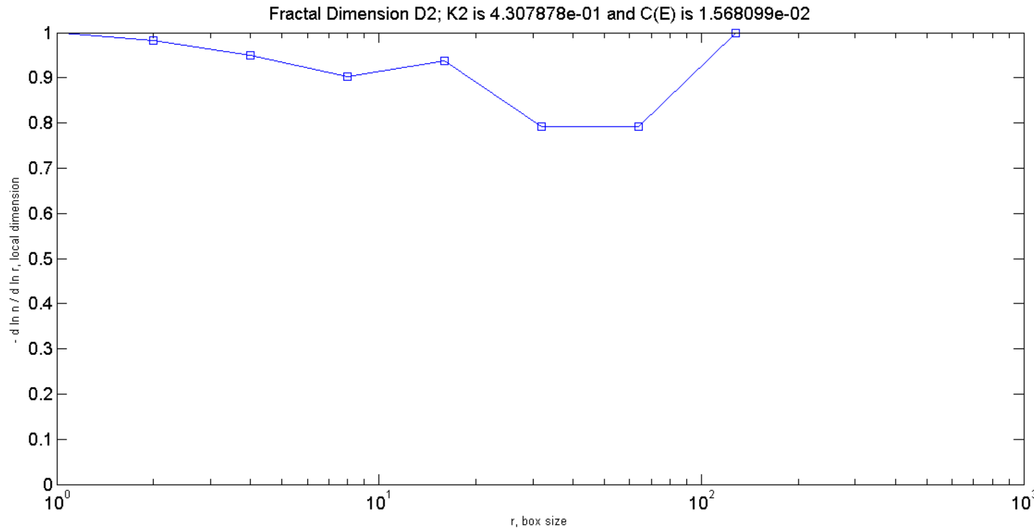


Figure 166 Revenue K2D2 before

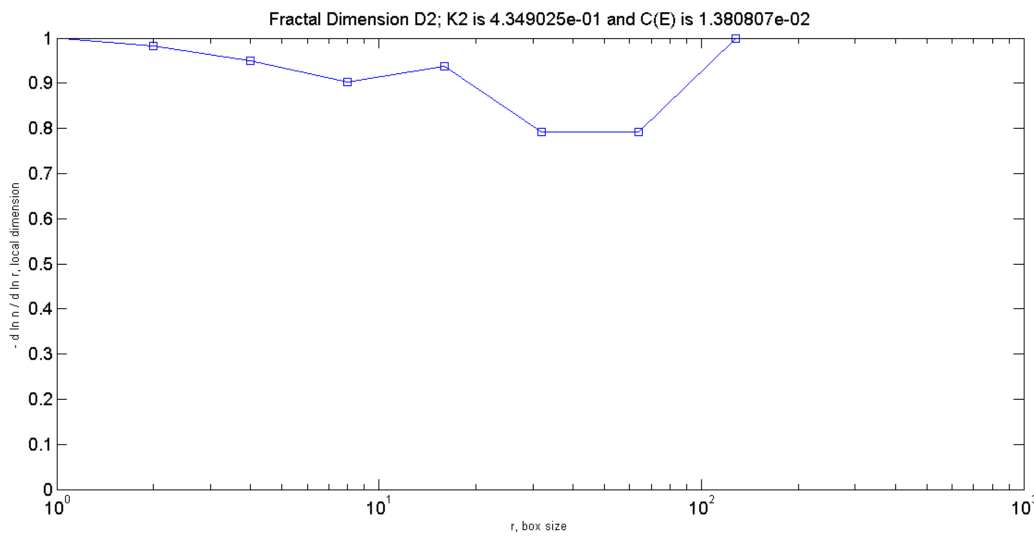


Figure 167 Revenue K2D2 after

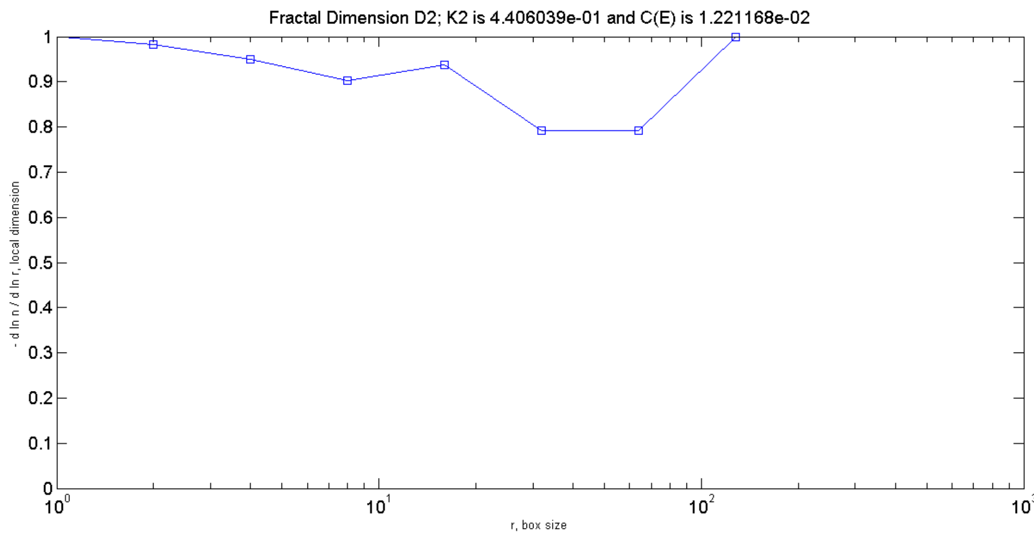


Figure 168 Price K2D2 before

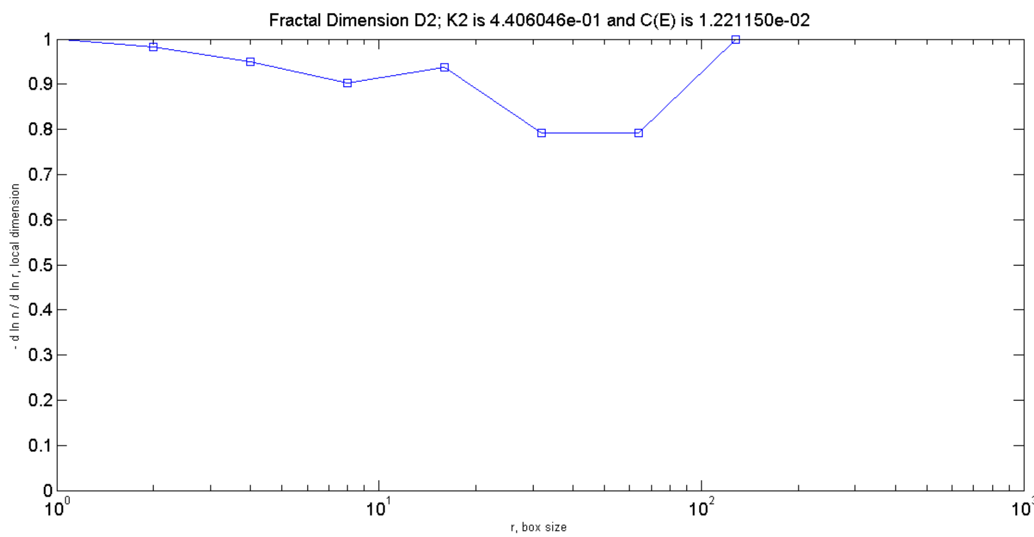


Figure 169 Price K2D2 after

A constant fractal dimension of 0.8 indicates moderate amount of instability throughout the declaration duration. Revenue K2 increased from 4.31 to 4.34, whereas price K2 remained fairly constant at 4.406. This implies that shareholders were able to get a feeler of the internal performance measures through the revenue data.

D. Interpretation and Discussion

The declaration of dividend seems to have a much lesser impact on the share market when compared to the previous case studies. In this case, the declaration of the dividend caused marginal increase on the knowledge of the revenue. This decreased the revenue contrast, and as a result the share revenue dropped marginally. Also, the buying patterns seemed to indicate a shift in focus towards the third week of the month.

5. CONCLUSION

Inferences – Summary of Contributions

While the previous chapter details the analyses and interpretations of four case studies in the recent history of IBM, this section details how the management of the business giant can benefit from such analyses.

1. System based revelations: All the four case studies and the nonlinear analyses of each clearly point towards the fact that IBM is a huge, evolving, chaotic organization. This is in accordance with the assumption made earlier. Since chaotic systems contain memory, the output signal clearly depends on the system and past values. Thus, the output signal contains a wealth of information of the system it arises from. In these case studies, the IBM management would view the share revenue data as a direct effect, a market response to their internal policies, decisions and declarations.
2. Quantification: While it may be intuitively evident that a high hike would clearly boost the company's morale and the market response would certainly be bullish, the magnitude to which such reactions occur depend heavily of what existing and potential shareholders perceive of the company. People's opinion of a company is a totally abstract quantity – a feeling. But the nonlinear analyses and parameters such as sensitivity have done an effective job quantifying them.
3. Short-term trends: Multiscale analysis such as the wavelet analysis clearly highlights the short term trends immediately before or after an event. The contrasting dark and white spots on the wavelet analysis in certain timescales clearly illustrate the magnitude of influence of such decisions on the share market. Since the equity is one of the major sources of income for IBM, proper assessment of the company decisions and policies and their influence on the share market is crucial.
4. Planning ahead: The analyses techniques proposed in the present project serve to know well in advance, how to 'award the good news' or 'break the bad news', since most declarations of dividends, hikes and layoffs affect the share market performance. For example, the 2014 Q2 results for IBM STG have been announced in July 2014 at a loss of nearly 12%. This, and given that Q1 results were also at 11% loss, prediction of the share market performance for the next three months is not so difficult. It will continue along the same trend. Also, the effect of the hike announcement in 2011, quantified in this chapter will help to assess what effect similar hike announcements will have in the forthcoming years.
5. Finer details: The polar plot reveals the share purchase pattern over the days of a month. The multiscale analysis reveals short term 'spots' and 'patches' arising due to decisions and announcements. Though the detailed analysis and interpretation of such finer details are out of scope of the present project, such analysis can be done by the company's internal management who have access to most of the employee's details about performance, customer satisfaction etc. to come up with a clearer understanding.
6. Marketing management: Once the company understands how the share market generally responds to the announcements and decisions, and is able to assess the magnitude of change to such

declarations, the company can use these to play its cards safe. It can use this as a platform to release a new product, service or technique and see how the share market responds towards promoting the long term sustenance of the same. This could be a supplement to conventional marketing management strategies like customer surveys, Delphi technique etc.

7. Competitive advantage: By skimming through rival firms and how their decisions and announcements made an impact on the share market, IBM can have a competitive advantage in delaying/advancing these announcements if properly planned.
8. Innovation and Invention: Since IBM is one of the major players in the IP market alongside filing the largest number of patents, the company can direct its employees towards fruitful research by looking at what fields of research have been able to get the most confidence of shareholders. This is a win-win situation as it benefits the company to increase its revenue, benefits the employees to advance their career and benefits the society in general, leading to a truly "smarter planet".

Finishing Summary

In order to highlight the various steps taken and milestones achieved in the present project, this section attempts to summarize the entire work and assess what contribution each part has made to the 'big picture'.

1. The project was aimed towards proposing a 'signals and systems' based study of IBM share data and identifying patterns corresponding to remuneration changes and other policies and decisions.
2. The historical and contemporary theories of management were briefly reviewed, highlighting various approaches that were taken to management and policy framing. This literature review helped understand that two contemporary theories – systems theory and chaos theory held the key to effectively understanding and framing policies in a huge, evolving company such as IBM.
3. The essentials of 'signals and systems' were studied, as this would form the basis for the formulation of further analysis. Emphases were given to special kinds of systems such as chaotic systems.
4. A signal and system based model of organizations such as IBM was proposed. This took into account, the primary source of assets, primary source of performance assessment, and the operating focus of IBM. This model would be the platform on which analysis methods would be built.
5. An effective analysis of the signal and system model was proposed. This took into account three kinds of analyses –temporal, spectral and nonlinear. In each case, standard metrics used extensively in scientific, mathematical and economic literature were considered. The formulation of such an analysis methodology provided a general framework, not just for IBM, but for any company to assess itself and the market response its decisions evoke.
6. A sample analysis using the above mentioned formulation was carried out, and the various highlighting features were noted. This helped to understand better the analysis methodology.
7. Four case studies corresponding to major events of decisions and declarations in IBM's recent history are considered. In each case, appropriate time durations are selected and analyses carried out for 'before' and 'after' the event. The policy events were mapped to the analysis results, and the interpretations revealed how the share market perceived such decisions.
8. The inferences corresponding to the analysis and case studies are listed, and importance is given to the value that such analysis adds to the company's strategy and competitive advantage.

9. Thus the original aims of signals and systems based study, formulation of analysis methodologies and the identification of patterns corresponding to decisions and declarations were fulfilled successfully.

Future Research

The application of the basic concepts and techniques of chaos theory and systems theory to the formulation of an effective analysis methodology opens up new avenues in the field of business strategy.

The methods and techniques proposed in the present project can be adopted with slight modifications for the analysis of any company. It can also be used by Governments for effective framing of nationwide policies.

One of the advantages of the presented analysis is that it requires minimum resources. Few news releases and the historical stock quotes are the only requirements for such an analysis. Moreover the metrics proposed in this project have all been used in various departments of science and technology since a long time and have been thoroughly time tested. Also, using certain algorithms, the computations of such metrics are extremely simple and can be done with basic mathematical software.

Future steps in this direction could involve refining the analysis methodologies, inclusion of more relevant metrics, and crafting a universal analysis methodology that could lead to a whole new way of looking at management. Part of such enhancements would include proper methodologies to gather interpretations and inferences from such analyses.

Also, the analyses and interpretations could give rise to a new way of arriving at close to accurate predictions of future share prices. While this may be useful to the company, it will immensely benefit investors in the share market.

The effective harnessing of publicly available share market information and using it in a managerial capacity to understand and plan effectively for the growth of the organization, giving it a innovative and strategic competitive advantage forms the crux of the present project.

This project is thus a true testimony to “Transformation through Information”.

Long live Chaos and Evolution!

ACKNOWLEDGEMENT

First and foremost, I wish to acknowledge Assam Don Bosco University for the enlightening coursework that enhanced my outlook of the 'B-World'.

I also wish to acknowledge Semiconductor Research and Development Center, IBM India, for the employment opportunity and for giving me the first hand experience into the field.

I sincerely acknowledge Dr.R.Ganapathy, Senior Assistant Professor, SASTRA University for giving me insight into the concepts of nonlinearity and chaos theory.

I acknowledge Dr.Dattatreya Prabhu Rachakonda, my mentor at SRDC, IBM for the constant enlightenment, advice and support.

I wish to acknowledge my parents, Capt.S.Balasubramanian and B.Gomathi for their continued support and encouragement throughout the project.

Last but not the least, I thank and dedicate this work to the Divine Mother.

REFERENCES

[1] R.Kreitner and C.Cassidy, Management, Cengage Leaning, 2012.
[2] M.Lissack, The Interaction of Complexity and Management, Greenwood, 2002.
[3] A.Adekola and B.S.Sergi, Global Business Management, Ashgate, 2012.
[4] D.Targett, D.J.Grimshaw and P. Powell, IT in Business: A Manager's Casebook, Routledge, 1999.
[5] H.V.D.Heidjen, Designing Management Information Systems, Oxford, 2009.
[6] M.Wheatley, Leadership and the New Science: Discovering Order in a Chaotic World, Berret-Koehler, 2011.
[7] K.Maney, S.Hamm and J.O'Brein, Making the world work better: The Ideas that shaped a century and a company, Pearson, 2011.
[8] 20 years of IBM patents and innovation: http://www.research.ibm.com/articles/patents.shtml.
[9] 13000 IBM Layoffs expected: http://www.businessinsider.com/ibm-layoffs-expected-2014-2.
[10] F.J.Ohlhorst, Big Data Analytics: Turning Big data into Big money, Wiley, 2012.
[11] L.V.Gerstner, Who says Elephants can't dance ?: How I turned around IBM, HarperCollins, 2003.
[12] F.W.Taylor, Scientific Management, Routledge, 2004.
[13] G.Jones and J.George, Essentials of Contemporary Management, McGraw-Hill, 2012.
[14] J.Schiller, Bureaucratic Management, GRIN Verlag, 2008.
[15] K.Hegar, Modern human relations at work, Cengage, 2011.
[16] C.Bacher, Contingency theory, GRIN Verlag, 2007.
[17] R.Lussier and C.Achua, Leadership: Theory, Application and Skill Development, Cengage, 2012.
[18] A.L.Rice, The Enterprise and its Environment: A system theory of management organization, Psychology Press, 2001.
[19] R.K.Sapru, Administrative Theories and Management Thought, PHI Learning, 2013.
[20] Besterfield, Total Quality Management, Pearson, 2011.
[21] W.Curlee and R.L.Gordon, Complexity Theory and Project Management, Wiley, 2010.
[22] E.E.Peters, Fractal Market Analysis: Applying Chaos Theory to Investment and Economics, Wiley, 1994.
[23] F.Capra, The Tao of Physics, HarperCollins, 2010.
[24] Company-wide IBM Headcount drops: http://www.postbulletin.com/business/company-wide-ibm-head-count-drops/article_fb8a0760-a13e-54c7-a096-d6305e91cf21.html.
[25] M.Wheatley, Finding Our Way: Leadeership for an uncertain time, Readhowyouwant.com, 2010.
[26] M.Wheatley, Chaos and Complexity: What can Science teach?, OD Practitioner, 1993.
[27] B.Crowell, Newtonian Physics, Light and Matter, 2003.
[28] K.Jamsa, Cloud Computing, Jones and Bartlett, 2013.
[29] G.V.S.Sekhar, Business Policy and Strategic Management, I.K.International, 2009.
[30] A.V.Oppenheim and A.S.Willsky, Signals and Systems, Prentice-Hall, 1997.
[31] A.V.Oppenheim, Discrete time signal processing, Pearson, 2006.
[32] R.J.Elliot, W.C.Hunter and B.M.Jamieson, Financial Signal Processing, Federal Reserve Bank, 2000.
[33] H.K.Khalil, Nonlinear Systems, Pearson, 2013.
[34] A.C.Scott, The Nonlinear Universe: Chaos, Emergence and Life, Springer, 2007.
[35] R.Griffin, Management, Cengage, 2010.
[36] IBM Business Units: http://www-07.ibm.com/in/careers/businessunits.html.

[37] K.Furgang, How the Stock Market Works, Rosen, 2010.
[38] C.H.Skiadas and I.Dimotikalis, Chaotic Systems: Theory and Applications, World Scientific, 2010.
[39] J.Gleick, Chaos: Making a new science, Open Road Media, 2011.
[40] L.S.Packer: Graphical Phase plane methods in dynamics and vibrations, Cornell, 1956.
[41] E.Wegert, Visual Complex Functions: An Introduction with Phase Portraits, Springer, 2012.
[42] S.H.Strogatz, Nonlinear Dynamics and Chaos, Westview, 2008.
[43] F.In and S.Kim, An introduction to wavelet theory in finance, World Scientific, 2012.
[44] I.Daubechies, Ten Lectures on Wavelets, SIAM, 1992.
[45] P.Bloomfield, Fourier Analysis of Time Series, Wiley, 2004.
[46] W.S.Levine, Control System Fundamentals, CRC Press, 1999.
[47] K.Roebuck, Storing and Managing Big Data, Emereo, 2011.
[48] J.Perry, Chaos in Real Data, Springer, 2000.
[49] M.T.Rosenstein, J.J.Collins and C.J.DeLuca, A practical method for calculating largest Lyapunov exponents from small data sets, Physica D, 65, 1993.
[50] K.Falconer, Fractal Geometry, Wiley, 2013.
[51] C.Tricot, Curves and Fractal Dimension, Springer, 1995.
[52] P.Abry, P.Goncalves and L.Vehel, Scaling, Fractals and Wavelets, Wiley, 2013.
[53] C.Skiadas, Topics on Chaotic Systems, World Scientific, 2009.
[54] R.M.Gray, Entropy and Information Theory, Springer, 2011.
[55] Kolmogorov in perspective, American Mathematical Society, 2000.
[56] Rexa and M.Fazlollah, An introduction to Information Theory, Dover, 1994.
[57] Cognos Inc. Information: http://www.answers.com/topic/cognos-incorporated-usa.
[58] C.Vercellis, Business Intelligence, Wiley, 2011.
[59] S.Nunes, Smarter planet?, Island Press, 2013.
[60] IBM looking to sell chip manufacturing operations: http://online.wsj.com/news/articles/SB10001424052702303496804579367710245657016.
[61] E.Schouten, IBM SmartCloud Essentials, Packt, 2013.
[62] IBM Global Restructuring: http://www.bloomberg.com/news/2014-02-27/ibm-begins-cutting-u-s-jobs-in-1-billion-restructuring-plan.html.