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FRACTAL ANALYSIS OF FINANCIAL MARKETS USING MACHINE LEARNING

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ABSTRACT

Financial investment theory requires a thorough understanding of financial market behaviour. The approaches for researching financial markets established in the 1960s and 1970s are only useful when market conditions are steady. They are based on the assumption that financial markets behave according to the normal distribution law. In the 1990s, they began looking at this topic through the lens of fractal analysis. The property of self-similarity has been discovered in financial time series. Mandelbrot (1983, 2006), the pioneer of fractal geometry, considered the behaviour of financial indicators in the market to be fractals.. E. Peters' books "Fractal study of financial markets" and "Chaos and order in the capital markets" describe this topic's research. The current situation of financial time series in the stock market is the subject of the research given here. Financial time series are examined as fractals in this study. The volatility and persistence of series are explored. By mixing the series, the persistence hypothesis was tested once again for the persistent series. The average lengths of non-periodic cycles in these series were also discovered.

Keywords: Fractal Analysis; Fractal Time Series; Financial Market; Volatility Of Financial Series.

I. INTRODUCTION

Stock markets are attracting an increasing number of participants, ranging from financial experts to regular traders to analysts for global corporations and government agencies. Analyzing stock market events may be done in a variety of ways. One of the methods for studying financial time series is fractal analysis. Since the turn of the century, fractal analysis has been utilised to examine financial markets. Financial time series with the property of self-similarity were the first to be identified as fractals. Long-term financial time series, also known as persistent financial time series, are the subject of this research. From a financial sense, such series are very intriguing. They are more predictable since they recall previous data in order to evaluate the signs that follow them. Two of the authors' financial series were shown to be persistent [1]. They identified the average durations of non-periodic cycles, which are important elements in financial series analysis and investing. Fractal geometry was coined by Benoit Mandelbrot, who was the first to use the term. Fractus, which meaning "broken" in Latin, is the root of the word fractal. Frangere is a Latin verb that means 'to shatter,' as in 'to form irregular fragments.'

In addition to 'fragmented,' fractus can also mean 'irregular.' Both meanings are encompassed by the term fragment. As a result, the term "fractal" is ideally suited to representing the study of scale invariant or self-similar geometric objects. Self-similar objects are an essential feature of the geometry of natural things, which is fundamental and universal. This is known as'self-similarity,' which indicates that they appear to be the same at various scales. They are self-affine, or have an affinity at various scales, otherwise[2]. Natural things' self-affinity is proved not just by their shape or geometry, but also by their temporal history. The latter situation includes financial time series and the time evolution of a self-affine stochastic field.

The Fractal Market Hypothesis is based on the fact that, statistically, a financial time series looks the same across multiple time scales. The distribution of price values over a day, for example, is similar to that over a month, which is similar to that over a year, and so on (provided there is enough data over each time scale to make the distribution—the generated histogram—statistically significant). The mathematical foundations of fractal geometry may be traced back to texts on recursion—the process of repeating things in a self-similar

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manner—published in the 17th century. This discovery was helped by nineteenth-century research on classes of continuous functions that were not differentiable in the traditional sense. In his paper 'Self-Similarity and Fractional Dimension in Statistics,' Benoit Mandelbrot looked into the origins of self-similar geometry[3]. He invented the word "fractal" in 1975, which included the ideas and results of hundreds of years of mathematical inquiry. He expanded on these concepts in his 1982 book, 'The Fractal Geometry of Nature,' which brought fractal geometry into the mainstream of professional and popular mathematics.

II. LITERATURE SURVEY

There are several approaches to predicting and managing market risk. Fundamental analysis is the oldest and possibly the most basic technique in financial markets. This entails doing an investigation of a business, industry, or market, as well as the economy, in the context of a prospective investment or transaction, in order to determine the cause of stock price movements. The results are then utilised to try to anticipate the future move of a stock. A underlying reason is assumed in this form of basic examination. The price, bond, derivative, or commodity is assumed to fluctuate as a result of some event or fact, which is almost always caused by another external event [4]. The implicit premise in this technique is that if the underlying cause can be identified early enough, the event can be predicted and appropriate action taken to control the risk or investment may be taken. Causes, on the other hand, are frequently opaque or unnoticeable in the actual world. Critical information is frequently unknown, indeterminable, hidden, or even distorted (for example, in the Enron or Parmalat business scandals)[25]. Furthermore, information might simply be misinterpreted by some or even all market players.

Major brokerage firms continue to hire a huge number of fundamental analysts to identify obvious trends that are often fairly correct. Certain currency rates, for example, may approach a level specified by a fundamental perspective before reversing or heading upwards. On an open market, however, this form of analysis is severely limited. The specific mood, or process, that relates news to pricing is sometimes inconclusive and subject to personal interpretation. Fundamental analysis may frequently be reconstructed in hindsight to provide exact event forecasts. However, two diametrically opposite outcomes may have been equally plausible before the fact[5]. As a result, while validity may be seen at times, it is not always the greatest basis on which to develop a risk management system. As a result, the financial sector has developed and continues to create new types of data analysis that employ more quantitative methods. Technical analysis is the second oldest type of analysis. This refers to the detection of patterns (actual or imagined) as well as the analysis of price, volume, and indicator charts in order to determine whether to buy or sell[24]. After losing popularity in the 1980s, the field re-emerged in the 1990s when the general public began to trade stocks and stocks online via the Internet.

The "modern financial theory," which comprises analytical approaches established from accidental mathematics, probability theory, statistical analysis, and probabilistic field modelling, arose from the development of this communication technology. The core premise is that we cannot anticipate the precise value of a future price, but we may estimate the (short-term) fluctuation of such a future price unless the statistical properties of the fluctuation change with time[6]. It implies that you are capable of completing the task. Risk should be viewed as a measurable quantity that may be controlled in this context. This premise underpins modern market analysis. FMH is unavoidably caused by the fact that financial time series are not ergodic. H. They're random fields that are statistically unreliable.

III. METHODOLOGY

A financial time series is essentially a digital signal, consisting of a collection of discrete values sampled uniformly with regard to a commodity's price. The time gap between successive price values might range from seconds to minutes to days and months. As a result, several frequently established signal processing programmes may be used. When data is sent to a trading centre, the analysis of financial signals relies on the use of several algorithms that generate many statistical metrics, such as attempting to quantify various elements of price changes. increase. The findings of such signal processing algorithms are focused on economics and market analysis concerns. The primary purpose of such an algorithm is to produce a quantitative analysis capable of predicting the best probable financial market moves, such as: Stock prices, option prices, and other sorts of derivatives are examples of B. To produce a "metric signal," they are usually applied on a moving

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window basis. signal, H. From a sample of the original data, a continuous time series of particular metrics is produced. Volatility and the Lyapunov exponent are two examples of such indicators. This is something that will be examined more in this white paper. n = 1, 2,..., N for a collection of N (only positive values) price values. The fractal market hypothesis, for example, was first proposed in the 1990s by Edgar Peters (Wells Manager) and Benoit Mandelbrot (mathematician)[8]. This is a natural conclusion of mathematicians and others working on the subject of fractal geometry, which was initially published in 1982 by Mandelbrot's famous book, Fractal Geometry.

Financial time series have a stochastic self-affine structure, according to the hypothesis. This means that price changes are still considered random walks, but random walks with statistical distributions that are comparable across timeframes. In reality, Ralph Elliott, a professional accountant, was the first to propose this idea when he published a study in 1938 on the apparent self-affinity qualities of financial time series data. He initially realised that financial time series data windows of various widths could be scaled to be statistically equivalent, i.e., the data's histograms had (nearly) the same shape[9]. As a result of this finding, the "Elliott wave" was coined to describe financial signals. The fractal market hypothesis, created in the late 1990s, and the Elliott wave principle, introduced in the 1930s, provide a coherent financial time series model for the interpretation and analysis of financial signals and investment theory[23]. The notion is that because the fractal time series has its own memory, the price of commodities tomorrow will be influenced by previous features in some manner. The significance of this fact in financial analysis is obvious, and it has been the topic of decades of investigation. Nowadays, if the fractional derivative of a function is determined by the function's "history," this incorporates memory, self-similarity, and fractional calculus connectivity[10]. The intrinsic complexity of the global economic system is one of the reasons financial time series and other financial data exhibit self-affinity qualities. This covers the (unstable) instabilities that have lately surfaced.

Market price dynamics are the result of a huge number of interactions between agents with varying investment horizons and diverse perspectives on information interpretation, and disruption of these interactions can lead to confusion and failure. In this view, the sophistication and complexity of the global financial system, which has lately grown in the framework of a fully free global market, has led to the emergence of self-organizing systems[11]. This characteristic has prompted the development of a novel method for analysing the (unstable) stability of finance by modelling financial time series of trade and investment.

The study for the permanent series was conducted in the presence of the cycle. To accomplish so, the whole era was subdivided into sub-periods using the VStatistics financial series system. The slope of the V statistical curve was used as a separating criteria. To assess the significance of the regression equation, the Hurst index was generated for each sub-period[12]. The cycle of the perpetual financial series analysed was identified once the data were interpreted.

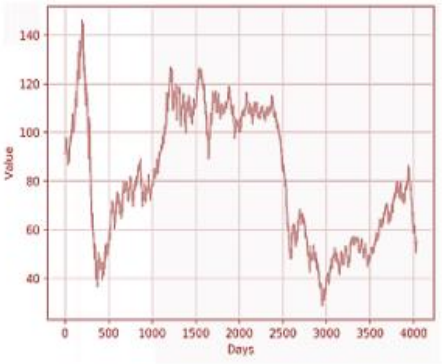

Figure 1: Quotations of Brent oil (19.12. 2007 - 01.01.2019)

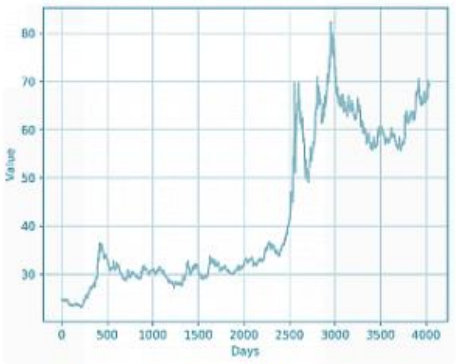

Figure 2: USD / RUB quotations (19.12. 2007 - 01.01.2019)

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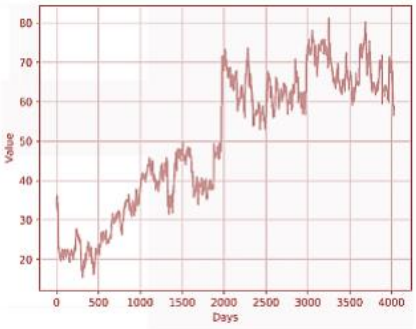

Figure 3: Quotations of ViaSat IT-company (19.12. 2007 - 01.01.2019)

IV. RESULTS

For the period December 19, 2007 to January 18, 2019, we looked at the following financial timelines: Figure 1: Brent Crude Oil Price, Figure 2: Dollar Louvre Rate, Figure 3: ViaSat's Stock Price (Fig. 3). The data came from available sources on the internet, including a stock price database. An R / S analysis was done on this data, and the Hurst index was generated. The author's Python programming language software was utilised as a study tool (the use of the language for data analysis is described in [9] and [10]). Table 1 shows the results of the regression analysis. Fisher's statistics can be utilised to establish the regression equation's significance. The proper significance level, number of variables (in this instance one), and number of items in the sample are compared to the values in the table. Student statistics should also be used to validate the significance of parameter H [13]. This is also compared to the values in the table. They turned out to be the same in our instance. F 0.05; 1; 31 = 4.17; F 0.05; 1; 31 = 4.17; F 0.05; 1; 31 As a result, the regression equation as well as its parameters are crucial. The correlation coefficient, in our situation, indicates how tight the association is. In each of these circumstances, the coefficient of determination is quite high. H. Changes in factor characteristics lead to changes in the resultant characteristics in more than 99 percent of cases.

Table 1: Result of R/S-analysis.

No	Financial time series	Hurst's indicator	Correlation	Determination	F-statistics
	Quotations of Brent	0.61	0.998	0.996	7664
	USD / RUB quotations	0.6	0.999	0.998	14075
	Quotations of ViaSat IT-company	0.501	0.995	0.990	3170

The Hurst index was found to be above 0.6 for the financial series of Brent crude oil prices and the dollar-to-ruble ratio. As a result, we might argue that these series are eternal. H. I have a good short-term memory. The Hurst index value of the stock price of the IT business ViaSat is about 0.5, leading to the conclusion that this time-series index is essentially random.

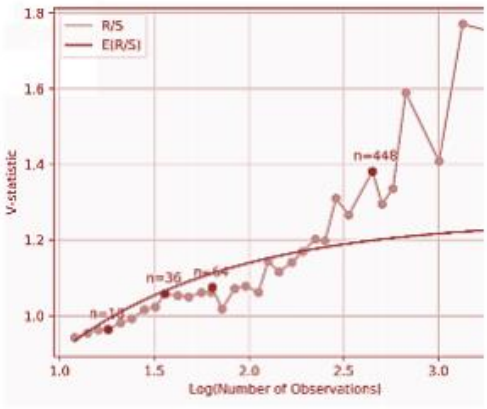

Figure 4: V-statistics of Brent oil (19.12. 2007 - 01.01.2019)

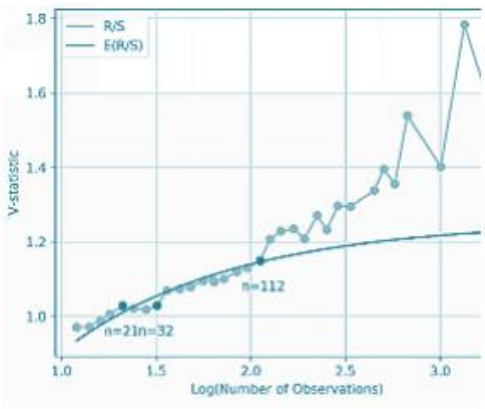

Figure 5: V-statistics of USD / RUB ratios (19.12. 2007 - 01.01.2019)

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Let's see if the above two series' persistence hypothesis is correct. Of course, if a financial series has long-term memory, the order in which the dates appear in the series is critical. It should be low when combining data and recalculating the Hirst index. The indicator's level was mixed at random, and the Hurst index of the freshly obtained series was determined. The price of Brent crude was 0.092, while the dollar ruble exchange rate was 0.078[14]. The regression equation was likewise significant, with F statistics of 163 and 295, respectively[21]. To put it another way, the theory that these series have long-term memory has been proven correct. After that, I made a Vstatistics chart as well as a chart ((R / S)). The null hypothesis is shown by the graph of the theoretically derived index ((R / S)), which depicts the behaviour of the system, which is a totally independent process. Figures 4 and 5 show the Vstatistics plots of the first two series studied for comparison. The presence of a series of financial price stability in Brent crude and dollar / ruble exchange rates is also confirmed by these charts. The volatility of each of the financial series listed above has been examined. Table 2 displays the results.

Table 2: The result of the analysis of the volatility of financial time series

No	Financial time series	Hurst's indicator	Correlation	Determination	F-statistics
1	Quotations of Brent oil	0.41	0.978	0.957	110
2	USD / RUB quotations	0.45	0.993	0.985	330
3	Quotations of ViaSat IT-company	0.27	0.984	0.969	154

When interpreting the findings, keep in mind that the volatility of each of the financial series outlined above is non-sustainable, with more frequent diversions than in a random sequence. Please[15]. This signifies that the process does not have a steady average, and the size of the changes is random and refundable. The relevance of the regression model created in each of the circumstances outlined above is demonstrated by comparing the F statistic values with Table 2. The series, which ended up becoming permanent, looked at if they have any cycles. Each financial series with long-term memory was separated into sub-periods for this purpose, and the Hurst index was calculated for each one. The survey findings are shown in Tables 3 and 4. We may draw inferences about the relevance of the regression equation for each portion of the partition by comparing the F statistics of Fisher's index in Tables 3 and 4 with tabular data for each subperiod.

Table 3: The regression analysis result for the subperiods on the Brent Quotations

Subperiods (days)	[12; 18]	(18; 36]	(36; 64]	(64; 448]	(448; 2016]
Hurst's indicator	0.557	0.63	0.54	0.65	0.71
Correlation	0.9996	0.9988	0.9986	0.998	0.9804
F-statistics	2690	1260	1049	2680	98.86
F table for $\alpha = 0.05$	18.51	10.13	10.13	4.84	7.71

Table 4: The regression analysis result for the subperiods on the USD/RUB quotations

Subperiods (days)	[12; 24]	(24; 36]	(36; 126]	(126; 2016]
Hurst's indicator	0.61	0.52	0.56	0.61
Correlation	0.9987	0.9985	0.9997	0.9944
F-statistics	1172	341	12333	1148
F table for $\alpha = 0.05$	10.13	161.45	5.32	4.67

As long as the Brent crude oil price and the Hurst index of the dollar ruble exchange rate both above 0.5, these financial series are steady. Furthermore, because the volatility Hurst index is less than 0.5, volatility is unsustainable. For permanent series, aperiodic cycles are defined[16]. We may deduce from the interpretation of the findings in Tables 3 and 4 that the Brent crude oil cycle price duration is 36 days, 448 days, and 2016 days for one financial series. The financial range in dollars, as well as the 24 and 2016 ruble periods. Please keep in mind that aperiodic cycles may last longer than 2016 days. However, no inferences can be taken in this area because the available time-series data spans a decade. The financial series that describes the stock price of the IT business ViaSat underwent R / S analysis, which revealed that the series under investigation were random. This series' unpredictability is likewise unsustainable[17]. Section on partitions.

V. CONCLUSION

The fractal analysis approach was used to analyse the financial time series. R / S analysis was used to identify persistent and anti-persistent series. Investors are especially concerned about the long-term memory series.

The Hurst Index score indicates how predictable the estimate is over time. When this is combined with the existence of a well-defined financial cycle, it is possible to make errors in determining when it is a good time to invest in the product under consideration and when it is required to remove those assets to optimise profits[18]. In this situation, the investment may have a long-term impact. A low value on the scale of less than 0.5 The Hurst Index suggests that prices fluctuate often. This means that such technologies can be used to carry out speculative strategies. Estimates are continuously rising and falling. This permits you to make money in short periods of time (as long as you stick to the course)[19]. Traders are interested in these series. To earn short-term profits, you can exploit the financial series' short-term memory and short-term volatility. One of the most efficient methods for studying financial data is fractal analysis. The permanent financial series, where long-term investments can be considered, is most appealing to investors. At this point in the research, multiple fractal analytic approaches were used to evaluate the series's sustainability hypothesis. The cycle can also be found there[20]. In the third example, the Hurst index was 0.501, suggesting that the process under investigation was random. To put it another way, this indication shows that upcoming values are independent of prior values. This indicates that future price behaviour will be difficult to predict for investors who elect to invest in the company's securities. As a result, dealing with such assets is very dangerous and unsuitable for both long-term investments and speculative strategies.

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