



Chaotic Test and Non-Linearity of Abnormal Stock Returns: Selecting an Optimal Chaos Model in Explaining Abnormal Stock Returns around the Release Date of Annual Financial Statements

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ABSTRACT

For many investors, it is important to predict the future trend of abnormal stock returns. Thus, in this research, the abnormal stock returns of the listed companies in Tehran Stock Exchange were tested since 2008- 2017 using three hypotheses. The first and second hypotheses examined the non-linearity and non-randomness of the abnormal stock returns ' trend around the release date of annual financial statements, respectively. While, the third hypothesis tested the potential of the chaos model in explaining future abnormal returns based on the past abnormal returns around the release date of the annual financial statements. For this purpose, BDS, Terasvirta Neural Network, and White Neural Network tests were used to investigate its non-linearity. In addition, Lyapunov exponent, correlation dimension, Dickey-Fuller, and Hurst exponent tests were used for testing non-randomness and the fitness of AR, SETAR, and LSTAR models to determine the optimal model in explaining the abnormal returns utilizing R software. Results of these tests represented a non-linear and non-random process and chaos in the abnormal stock returns, implying the predictability of abnormal stock returns. Also, among three used chaos models, the LSTAR model had lower error and more predictability than the other two models.

1 Introduction

The main factor that each investor considers in his decisions is return. Investors are looking for the most productive opportunities to invest their surplus resources on capital markets. Therefore, extracting a process or framework that can show the behaviour of the prices and stock returns has attracted the attention of the researchers. In economics, monetary and financial markets are the most suitable cases for using chaos theory; because, if the process of determining monetary variables follows a certain nonlinear process, one can predict their changes. Also, in the event of detecting a final order in the trend of monetary variables, the possibility of gaining great benefits is provided [11]. Unless there is clear

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and correct information about the performance of the companies, abnormal returns can be gained. Therefore, accounting information and its transparency are effective in generating and predicting abnormal returns. One of the main goals of accounting is to provide the information that can predict future business events [22]. Therefore, investors and market participants have sought to use techniques derived from the theoretical and empirical fields for estimating and explaining the market future. By considering the importance of predicting stock returns and analysing its future behaviour in order to decide on buying and selling and developing optimal stock portfolios, the focus of this research is on the predictability of stock returns. Using technical analyses after reviewing past performance, the current data related to the abnormal stock return around the release date of the financial statements were gathered to determine whether a pattern existed and in case of its confirmation and with the help of discovering the behavioural patterns of abnormal stock returns and using chaotic nonlinear models, abnormal stock returns were determined and anticipated. For this purpose, the nonlinearity and non-randomness of the trend of abnormal stock returns around the release date of financial statements were examined to detect the chaos of this return.

2 Literature Review and Hypothesis Development

Analysts use a variety of methods to analyse and evaluate securities and predict the price trend and returns or supply and demand of securities. These can be categorized into two general groups of conventional methods and new methods of price analysis. Common methods of price analysis include technical, fundamental and random analyses (effective market theory). New methods of price analysis include chaos theory and artificial neural networks.

2.1 Technical Analysis

Technical analysis involves prediction techniques based on measuring the historical patterns of stock price behaviour and the historical features of other financial information. After reviewing the past behaviour, the analyst examines the current stock price information to determine if the established pattern is applicable and if so, predictions can be made [16]. Brooke et al. were the first who used common and accepted laws such as moving average, and protector and resistant limits, showing that these laws could lead to the profitability more than purchase and maintenance strategies. Following the publication of the study of Brooke et al., Many studies showed the usefulness of the rules of technical analysis. For the first time, some authors examined and compared the utility of technical analysis methods in 10 developing countries and emerging stock markets. They showed that even with the inclusion of transaction costs, technical analysis methods in 82 of 100 tests (ten tests in ten countries) continued to be effective. Following that, Chang et al. conducted similar research in Asian financial markets, reporting similar results.

2.2 Chaos Theory

According to this theory, although the affairs of the universe are disordered, accidental and therefore unpredictable, they are, at the same time, of an order and certainty [18]. Chaos theory 's advocates believe that there is some sort of order in the seemingly random patterns of different phenomena (from meteorological systems to organizations and stock markets). A challenging effort by the researchers in this area is the discovery of some rules for predicting the behaviour of "seemingly unpredictable complex systems." According to the chaos theory, if we consider such a system by examining its states at different moments of time, we will see that the system is always showing its own inherent order. Even the most unpredictable (chaotic) systems always travel within certain boundaries and never get out of

it. Usually, within a state of chaos and instability, there is a pattern of order that is amazingly beautiful. The chaos theory predicts the future direction of their movement due to the identification of ways to detect hidden order in the complex systems.

2.3 Literature Review

Using Brock, Dechert and *Scheinkman* (*BDS*) test, *Lyapunov exponent*, correlation dimension, and artificial neural network, some previous research has shown that the distribution and fluctuations of stock returns follow a chaotic process, having a predictable trend [12,23,20,31]. Prior research also showed that the price index and cash returns in Tehran Stock Exchange follow a chaotic system [8,21]. Other research indicated that there is chaos in the time series of macro variables such as oil and gold coin prices [2,19,25]. In a research aimed at predicting daily market of Tehran Stock Exchange through the evaluation and comparison of linear and nonlinear methods using *BDS* test, Zeranezhad and Raufi [32] examined the linearity or non-linearity, and then chaotic performance of the total index return of Tehran Stock Exchange. Results showed that this variable follows a nonlinear behaviour and nonlinear models have better performance than the mixed autoregressive and moving average. Some studies have been conducted on the process of price, returns and stock indices of USA. The results of Scheinkman and Lebaron [24] showed that the stock price had a nonlinear process but they failed to show chaos in it. But, Hsieh [9] showed that the US Weekly Returns Index did not follow the random step process. Other studies examined the existence of nonlinear affiliations and chaos in the UK index, and four major stock returns' indices including the UK stock index, the US stock index, the German stock index, and the Japanese stock index, using binary tests, *BDS* and *Lyapunov exponent*. They were able to demonstrate the existence of a nonlinear process in these series but the existence of a chaotic process was not proved [1].

Prior research was carried out using correlation dimension, *Lyapunov exponent*, Hurst exponent index, and *BDS* tests. Results indicated that there is chaos in the time series of exchange rate, return on exchange rate, as well as stock returns [4,29,14,7,15]; but the results of another research denied the chaos likelihood of the dollar and euro [6]. Yousefpour et al [30] examined the existence of chaos in some stocks of Tehran Stock Exchange using *BDS* test, *Lyapunov exponent*, and rapid returns. Their results indicated that none of the investigated stocks was chaotic, but evidence of non-linearity was observed in them. Chevallier [3] concluded that nonlinear models have less predictive error than linear models. In a research on the chaos in technological changes, Hung and Tu [16] reviewed the degree of chaos in the technological changes using correlation dimension and *Lyapunov exponent*. Results indicated the development of a chaotic model due to the technological changes. Tong [27] was the first to use the nonlinear model of *TAR* in the scientific research. Then, Tong and Lim [26] studied the model at the same time. Tang and Yeung [29] used the *SETAR* model to test the market value of the assets. Emrah Hanifi [5] concluded in his research that the *SETAR* model, which is a nonlinear time series of *TAR*, has a better performance than linear and nonlinear models. According to the above-mentioned points and literature review, the following hypotheses were stated as follows:

- 1-The trend of abnormal stock returns around the release date of annual financial statements is non-linear.
- 2- The trend of abnormal stock returns around the release date of annual financial statements is non-random.
3. Non-linear *LSTAR* model has better performance than *AR* and *SETAR* models for explaining abnormal stock returns around the release date of annual financial statements.

3 Methodology

This study was correlation using descriptive methods. The population of the study consisted of listed companies in Tehran Stock Exchange since 2008- 2017 from which the companies with the following conditions were selected as the sample:

1. Selected samples were a member among the listed companies of Tehran Stock Exchange during the whole study period.
2. The fiscal year of all study companies was unchanged during the study.
3. Financial information (quarterly financial statements) of the selected companies was available during the study.
4. The selected companies were not in the list of banks or investment, insurance, and financial mediator companies.

Table 1: Estimating the variables

Estimation method	Variable
$ar_{it} = r_{it} - r_{mt}$ <p>Abnormal stock return= Real return rate– market return rate</p>	Abnormal stock return (modified market model of Lonkani and Firth)
$r_{it} = \frac{P_{it} - P_{io} + DPS - CS}{P_{io} + CS}$ <p>r_{it} :Real return rate P_{it} : stock price at the end of the day P_{io} : stock price at the begining of the day DPS : cash earnings CS : cash reciepts of shareholders</p>	Real return rate(Bodie, Kane, & Marcus)
$r_{mt} = \frac{I_{mt} - I_{m0}}{I_{m0}}$ <p>r_{mt} : Market return rate I_{mt} : TEDPIX at the end of the day I_{m0} : TEDPIX at the begining of the day</p>	Marker return rate
Index (TEDPIX)	Market index

Regarding above-mentioned conditions, 177 companies were selected as the sample. Since the only variable of the chaos model was daily abnormal return, this model included 293304 data. To gather data in the theoretical field, library method was used. Data for the hypotheses' test was gathered, studying financial statements of listed companies in Tehran Stock Exchange and declarations and summaries of meetings of the companies by Rahavard novin Software and Codal database. The methods of estimating the variables are reflected in Table 1. In this study, abnormal stock returns of listed companies in Tehran Stock Exchange in future were considered as the independent variable and the same variable in the past was considered as the dependent variable. Thus, the only study variable was abnormal return rate for which the data of the following variables were required:

Market index: To calculate market return rate (expected return rate), market index at the beginning and end of the day is required. Used index in this study was cash return index and price. This index was extracted from Rahavard novin Software. Since the daily market return rate was required, market index for the whole study period was extracted.

Market price: In order to calculate real return rate, market price at the beginning and end of each day was needed. So, the market price for each share was obtained for all companies during the study period from Rahavard novin Software. The market value of each share was derived from dividing the total market value of the stocks by the total number of shares of the company. Given that the market value was not available for all days, for the required days, the last market value in the previous dates was used.

Cash profit: Using Rahavard novin Software, the data of the amount and date of cash profit announcement for each company was extracted during the research. The amount of cash profit on the first day after the ordinary general meeting was concerned in the calculation of the real return rate.

Cash receipt of shareholders: Using meetings' announcements gathered from Codal database and Rahavard novin Software, the amount and date of cash receipts of shareholders for all companies during the study time were gathered. That amount was used on the first day after the extraordinary meeting in calculating real return rate. After collecting the required data for the chaos model, the data were divided into two categories based on the approval date of annual financial statements of the companies (the date of the General Assembly). Thus, for each company, the approval date of the annual financial statements is considered as zero and accordingly, the data before the approval date of the financial statements was categorized in one file and the data after the approval date of the financial statements was classified in a separate file. According to this classification, tests were performed and chaotic models were fitted.

3.1 Non-Linearity Tests

BDS test: The BDS test was developed by Brock, Dechert, and Shinkman in 1987 to test the randomness of a time series. It can be used as a test of the hypothesis that the process of generating a time series is independent and similar in contrast to the linear or nonlinear dependency hypothesis of the process [20]. The correlation integral, which evaluates the randomness of the generation process of a time series versus the existence of a general correlation, is used as the test statistic. In this test, the existence of a nonlinear structure in the data is proved once the null hypothesis of the test implying the independence and co-distribution of the residues of the estimated time series model is rejected. In this way, the main and null hypothesis of this test were defined as follows:

H_0 : The data resulted from a co-distributed and independent process.

H_1 : The data didn't result from a co-distributed and independent process.

White and Teraesvirta Neural Networks' tests: Neural networks have been used as powerful rivals for nonlinear models to predict time series' trends. These tests are used to find a nonlinear process. The main and null hypothesis of this test were defined as follows:

H_0 : Linear models are suitable for data fitting.

H_1 : Nonlinear models are suitable for data fitting.

In other words, in these two tests, if the null hypothesis is confirmed, it means that the linear model is acceptable.

3.2 Randomness Tests

Lyapunov exponent test: One of the main characteristics of chaotic processes is their high sensitivity to the initial conditions, which is called the butterfly effect. The best tool for detecting the sensitivity to the initial conditions in a dynamic system is the use of Lyapunov exponent which is one of the most useful tools for detecting chaotic dynamic processes [17].

Correlation dimension test: The correlation dimension analysis is a criterion for testing chaos theory in a time series process; it is also a standard to determine the complexity level of a process.

Dickey Fuller test: Before modeling a time series, it should be assured that it is stationary. One of the most useful tests on being stationary and a widely used test for root presence is Dickey Fuller test.

In this test, the null hypothesis is the existence of a unit root and the main hypothesis is the absence of a unit root in the time series:

H_0 : The time series is non-stationary (i.e. it has a unit root).

H_1 : The time series is stationary (i.e. it doesn't have a unit root).

Hurst exponent test: Hurst test is a suitable tool for detecting a non-random time series from a random one, regardless of its distribution type. This test is applicable to the phenomena that appear to be random, but they may have a regular pattern. With the aid of the Hurst test (H), the memory effect is determined in the time series. If the value of the Hurst exponent is 0.5, it implies that a time series process is independent.

Fitted Models: The group of TAR models, which are nonlinear time series models, are popular in the scientific research for being more practical than other models. The fundamental principle of the TAR model is that it allows different organizations to provide autoregressive analysis at various levels. The SETAR model, which is a group of TAR models, has played an important role in many nonlinear analyses as a common model [5]. Before using nonlinear models, the nonlinearity of the pattern should be tested using nonlinear tests. In case of rejecting the null hypothesis implying that the pattern is linear, a nonlinear model should be selected among the potential nonlinear models. In STR models, there is no clear economic theory in choosing the type of model. Thus, choosing a model type should be based on the statistical data and tests. The STR model is a regression model of nonlinear time series that can be considered as an extended form of the regression model of situation variation introduced by Bakun and Watts [13].

4 Results

The BDS statistics was tested at an error level of 5% ($5\% = \alpha$). According to the results of Table 2 and the values obtained for various dimensions of m , it can be seen that the null hypothesis cannot be verified even at 0.001 level (p value is less than the error level of the test). In other words, this test represents a nonlinear time series. Two neural network tests were tested at the error level of 5% ($\alpha = 5\%$). Results showed that P is less than α level. Thus, H_0 is rejected. Results also indicated that nonlinear models are suitable for data fitting, and the neural network model is capable of expressing time series' changes. Obtained results show that for all dimensions, the value of the Lyapunov exponent is positive, indicating the chaos in the related time series. Therefore, the time series of abnormal return is not random.

Table 2: Results of BDS test

M=5	M=4	M=3	M=2	m
-982.88	-563.61	-364.83	-329.63	BDS statistics
<0.001	<0.001	<0.001	<0.001	P value

Table 3: Results of White Neural Network test

P value	Fisher Statistics	P value	Chi square statistics
<0.001	3236.67	<0.001	6224.59

Table 4: Results of Teraesvirta Neural Network test

P value	Fisher Statistics	P value	Chi square statistics
<0.001	4821.64	<0.001	9104.4

Table 5: Results of the Lyapunov exponent

Max Lyapunov exponent	m
4.47	1
2.99	2
1.93	3
1.33	4
0.40	5

Table 6: Results of correlation dimension test

Correlation dimension	m
0.994	1
1.894	2
2.848	3
3.744	4
4.667	5

The positive value of the correlation dimension for different values of the dimension implies the existence of a chaotic process; therefore, it follows a certain process and is not random. Also, due to the large number of calculated correlation dimension, the time series is more complicated and its prediction will be more difficult. As shown in Figure 1, with the increase in the dimension, the slope of the correlation dimension curve reaches zero saturation level and the correlation dimension values converge with the increase of the lateral dimension to a constant value and this is the evidence of chaotic behavior in the data.

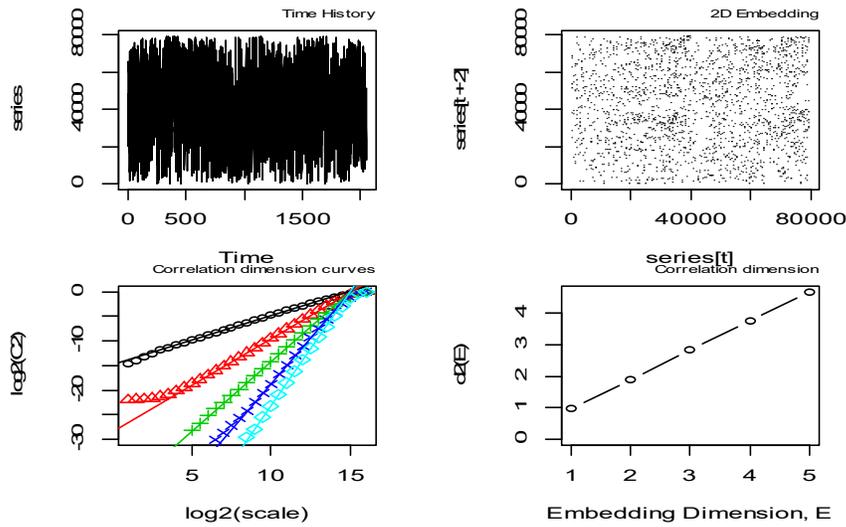


Fig. 1: Correlation dimension

Table 7: Results of Dicky Fuller Test

P value	Statistics of Dicky Fuller Test
0.01	-33.909

Given that in a stationary test, the resultant value was less than the test error level of 0.05, the null hypothesis was rejected and the time series did not have a unit root; thus, the time series was confirmed to be stationary. According to the results of the research, it was found that the process of abnormal returns for which a pattern can be prepared is not random.

Table 8: Results of Hurst test

coefficient Hurst	R/S ratio
0.52	0.56

Table 9: Results of AR model

Intercept	Phi..1	Phi..2
-0.031	-0.051	-0.068
$X_t = -0.031 - 0.051 X_{t-1} - 0.068 X_{t-2}$		

The presence of the Hurst coefficient, which is 0.52 and is between 0.5 and 1, implies a long-term time series with a long memory so this time series is not random. Considering that in this study abnormal returns data had nonlinear and non-random structure and were chaotic, two non-linear models of SETAR and LSTAR which are used more in research and AR linear model were used for fitting data to explain future abnormal returns around the release date of annual financial statements and identify model errors.

AR model: The linear AR model was defined as follows:

$$X_{t+s} = \phi + \phi_0 X_t + \phi_1 X_{t-d} + \dots + \phi_m X_{t-(m-1)d} + \varepsilon_{t+s}$$

In order to compare the linear model with other nonlinear models, this model was fitted. Subsequently, after presenting the results of nonlinear models, these models were compared with each other.

SETAR model: The non-linear SETAR model was defined as follows

$$X_{t+s} = \begin{cases} \phi_1 + \phi_{10} X_t + \phi_{11} X_{t-d} + \dots + \phi_{1l} X_{t-(l-1)d} + \varepsilon_{t+s} & Z_t \leq \text{th} \\ \phi_2 + \phi_{20} X_t + \phi_{21} X_{t-d} + \dots + \phi_{2H} X_{t-(H-1)d} + \varepsilon_{t+s} & Z_t > \text{th} \end{cases}$$

The overall results for the SETAR model (2,2,2) were as follows in Table 10.

Table 10: Results of the SETAR model

low regime	Intercept	Phi.L.1	Phi.L.2
	-0.006	-0.061	-0.009
High regime	Intercept	Phi.H.1	Phi.H.2
	-2.332	-0.206	0.009
Z=0.0202			
$X_{t+1} = \begin{cases} -0.009 - 0.061 X_t - 0.006 X_{t-1} \\ -0.009 - 0.205 X_t - 2.33 X_{t-1} \end{cases}$			

According to the definition of the non-linear SETAR model, the model is based on the data available at the end of Table 10.

Table 11: Results of the LSTAR model test

Low regime	Intercept	Phi.L.1	Phi.L.2
	-0.0094	0.062	-0.0059
High regime	Intercept	Phi.H.1	Phi.H.2
	-6.28	-0.513	1.046
Z=0.80			
$X_{t+1} = \begin{cases} -0.0094 - 0.062X_t - 0.0059X_{t-1} \\ -6.28 - 0.513X_t + 1.046X_{t-1} \end{cases}$			

LSTAR model: The LSTAR model is defined as follows:

$$X_{t+s} = (\phi_1 + \phi_{10} X_t + \phi_{11} X_{t-d} + \dots + \phi_{1l} X_{t-(l-1)d})(1 - G(Z_t, \gamma, \text{th})) + (\phi_2 + \phi_{20} X_t + \phi_{21} X_{t-d} + \dots + \phi_{2H} X_{t-(H-1)d})G(Z_t, \gamma, \text{th}) + \varepsilon_{t+s}$$

This model is referred to as the extended SETAR model. G is the logistic function and Z is also the threshold value. The overall results for the LSTAR model are reflected in Table 11. According to the definition of the non-linear LSTAR model, the model is based on the available data in the last part of the Table 11.

Examining the indices of the model fitness: In order to evaluate and compare the fitted models, the AIC (Akaic) and MAPE and MSE indices were calculated and represented in Table. 12. The model with the lowest AIC, MAPE, and MSE was considered as the best model.

Table 12: Results for the comparison of AR, SETAR and LSTAR models

MSE	MAPE	AIC	Model name
0.29	0.52	-96403	AR
0.26	0.19	-107858	SETAR
0.19	0.17	-129607	LSTAR

As seen in Table 12, the non-linear model of LSTAR has higher ability to fit in the related time series. The full table of the fitness for this model is as follows.

Table 13: Results of full fit of LSTAR model

	Estimation	sd	Test statistics	P value
Intercept .L	-0.009	0.002	-5.924	<0.001
phiL.1	-0.062	0.004	-15.529	<0.001
phiL.2	-0.006	0.003	-2.051	0.040
Intercept .H	-6.284	0.041	-155.152	<0.001
Phil.1	-0.513	0.006	-81.293	<0.001
phiH.2	1.046	0.030	34.705	<0.001
gamma	40.115	45.674	0.878	0.380
th	0.800	0.001	1392.360	<0.001

Table 14: Results of hypotheses test

Test result	Hypothesis
Confirmed	1-Trend of abnormal stock returns around the release date of annual financial statements is non-linear.
Confirmed	2- Trend of abnormal stock returns around the release date of annual financial statements is non-random.
Confirmed	Non-linear LSTAR model has better performance than AR and SETAR models for explaining abnormal stock returns around the release date of annual financial statements.

According to the results of Tables 2 to 4, the time series' trend of abnormal returns was non-linear and the first hypothesis were confirmed. According to the results of Tables 5 to 8, the time series' trend of abnormal returns was nonrandom and the second hypothesis was confirmed. The results of Tables 9 to 12 showed that all three used models could predict abnormal returns and nonlinear models had more ability to explain abnormal returns than linear AR models, and the LSTAR model explained future abnormal returns with lower error compared to the other two models.

5 Conclusion

Many studies have examined trend changes of many economic variables like stock price, stock return, different stock indices, exchange rate, and oil price in different countries using different tests. Results of most of these studies show non-linearity and non-randomness of the variables; but, they have not explained these variables based on their past trends. On the other hand, many studies have investigated the relationship between abnormal returns with macroeconomic variables, concerning the impact of financial information and statements 'items on the abnormal stock returns of companies using basic

models most of which suggest that financial statements have information content. Therefore, considering that in previous studies, examining abnormal return trend was not concerned and most research was focused to find the causal relationships between abnormal returns and other macro variables, and according to the research on technical analysis and the importance and the impact of technical models in predicting and explaining the future, this study used a technical analysis to study the abnormal stock returns and its ability to explain around the release date of annual financial statements in 10 years. For this means, first the non-linearity and non-randomness of abnormal return tests were examined around the release date of financial statements using the current tests. Given that the results of the research showed the nonlinear and non-random trend of abnormal returns, it was concluded that the abnormal return's trend was chaotic.

Thus, the future abnormal returns were explained based on the current nonlinear chaotic models, and using three AR, SETAR and LSTAR models, the abnormal future return around the release date of the annual financial statements could be explained. Finally, in order to determine the optimal model, we evaluated the ability of chaotic models to explain future abnormal returns. By comparing the models' errors, the LSTAR model was selected with the least error as the optimal model. It should be noted that all the research steps were performed using R software. It is suggested that in future research, after identifying the nature of the data process production, the models of random differential equations, genetic algorithm, and other dynamic and intelligent models are used to model and predict abnormal stock returns. By comparing the results of these models, we can create optimal models that can be used to predict the correct results. Economic statistics is usually impregnated with noise due to measurement errors or exogenous shocks, and if not resolved, they may influence the results of the tests. Most chaotic process detection tests in a time series require a large amount of data. Given the fact that in accounting and economics, there are statistics with seasonal frequencies, the information production with high frequency is not easily possible like other laboratory sciences.

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