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Application of Chaos Theory in Incomplete Randomized Financial Analysis

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Abstract: In the new economy, some tech companies have rapidly built market power and modernization led to the unpredictable bank-to-client relationship. Moreover, financial markets are confronted with big data and as a result, digitization and further introduction of mathematical techniques and new models were brought into the financial industry. Uncertainty has increased markedly in the macroeconomic risk, payment systems, capital accumulation and investment. But so far, timid attempts are made to elucidate the possibilities of the chaos theory application in finance. To verify a theoretical model whether or not is an accurate representation of an empirically observed phenomenon is one of the most challenging investigations in the scientific field. The following study explores the problem related to incomplete randomized financial analysis. The behavior of financial market relates to the circumstances that are both internal and external. Chaos mathematics is an acute methodology to be applied in the analysis of the randomness in financial markets instead of completely randomized design. The completely randomized design places the emphasis on which the factor effects are constant and assumes the observation from experiments to be statistically independent. However, this hypothesis is often not realistic and practical. The correlated impact should not be ignored. This article attempts to clarify some points related to the possibility of using chaos theory in finance.

Keywords: Incompletely Random, Chaos Theory, Human Social Activities, Modeling of Random Variables

1. Introduction

Unprecedented global trends have been observable in the financial systems since the financial crash of 2008-2009. The symptoms are lower economic growth and greater inequality.

Table 1. *Economic Data in 2018.*

Country	GDP%[1]	Consumer Price%[2]	Unemployment Rate%	Interest Rates%[3]
US	2.9	2.5	3.7	3.16
China	6.6	2.1	3.8	3.24
Japan	1.1	0.9	2.3	0.14
Britain	1.3	2.4	4.1	1.44
Canada	2.3	2.3	5.8	2.44
Europe	2.1	1.7	8.1	0.39
France	1.7	2.1	9.3	0.77
Russia	1.6	2.9	4.5	8.81
Australia	3.2	2.1	5.0	2.70

1 GDP% change on year ago
2 Consumer Price% change on year ago
3 Interest Rate 10-yr government bonds

Country	GDP%[1]	Consumer Price%[2]	Unemployment Rate%	Interest Rates%[3]
HK	3.4	2.2	2.8	2.37
India	7.4	4.6	6.9	7.73
Malaysia	5.0	0.9	3.3	4.16
Korea	2.8	1.6	3.5	2.19
Taiwan	2.6	1.7	3.7	0.92

Source: Data arranged from The Economist

In the new economy, some tech companies have rapidly built market power and modernization led to the unpredictable bank-to-client relationship. Moreover, financial markets are confronted with big data and as a result, digitization and further introduction of mathematical techniques and new models were brought into the financial industry. Uncertainty has increased markedly in the macroeconomic risk, payment systems, capital accumulation and investment.

For successful modeling of the quantitative finance, mathematical finance and statistical finance, it is important to understand the character of the stochastic process that underlies the dynamics of financial variables. The microstructure of a marketplace and the continuous sequence of events bring about conditions with specific and distinct characteristics. The concepts of chaos theory have gained considerable attention in various scientific fields. But so far, timid attempts are made to elucidate the possibilities of its application in finance. Initially, Peters, E. E. (1996) suggested the chaos theory be used to develop tools for trading stocks. And Dieboltt, C., Kyrtsou, C. Springer (2005) expanded the scope of its application in financial markets in their publication "New Trends in macroeconomics".

Today is the ear of information technology. In this article, attempts are made to clarify that the chaos theory allows approximating the complex behavior of financial markets by a more appropriate model which takes account of variable factors of uncertainties and thus it is an acute methodology to be applied in the analysis of randomness in financial markets.

2. Completely Randomized Designs

2.1. Requirement of Factors

Statistics is concerned with learning that results from the collection and interpretation of information. Analysis of variance procedures are very much introduced as a methodology for the simultaneous assessment of factor effects. The completely randomized design is a method to perform a comparative research. It is a study where subjects are assigned to treatments by randomization. Generally the completely randomized design can be used to compare any number of treatments if the experimental factors are homogeneous or uniform. The common collection of statistical principles and methods can be applied. In the analysis of complete randomized experiments, the factor effects are fixed. The completely randomized design is popularly used in the areas where factors under investigation hardly change. Having a properly randomized study is a critical component of the analysis of a comparative study.

2.2. Limitations

In the completely randomized design, the experimental units are only regarded as containments with no assignable variation. The resulting compound symmetric error structure will not only affects estimation and inference procedures but also the efficiency. The completely randomized method has been originally designed for detection of change-points in regression relationship and is especially efficient in some samples of data. The randomized analysis of a completely randomized growth curve model is derived from the basic assumptions of the design. Best linear unbiased estimators for contrast curves and mean growth can be obtained. But its testing for treatment effects is only at a point in time. This analysis assumes experimental factors are homogeneous or uniform. However, this hypothesis is often not realistic and the correlated impact should not be ignored. In the real world, almost all natural, socio-economic systems are inherently nonlinear. They have a very broad range of characteristics, which can be the combined existence of nonlinear interdependence, or sensitive dependence in systems. Therefore, the completely randomized design should only be used when extraneous factors can easily be controlled and applied in studies where conditions and experimental factors are homogeneous.

3. Methods of Chaos Theory

3.1. Linkage

Chaos theory means unpredictability. It is widely known as complexity theory, the theory of complex systems, quantum non-linear dynamical theory, non-linear dynamical systems theory, uncertainty theory. It established a new way of understanding. The chaos theory describes and categorizes the unified structure of systems which might seem to behave haphazardly. Unlike the traditional way of analysis of course and effect, it reveals the structure of the whole through the analysis of discrete parts. Von Bertalanffy stated that since there is interconnectedness between the parts and the whole, to analyze one part is to analyze the whole. But it is necessary to examine how the linkages or the process worked. Therefore, one aspect of chaos theory is the premise that it is crucial to understand the interconnectedness of the parts even though this understanding of the relationship between different parts might not be sufficient to understand the whole.

3.2. Sensitivity to Initial Conditions

The "Butterfly Effect" which was coined by Meteorologist

Edward Lorenz refers to the huge influence brought by a very slightly change of the initial condition governing the pattern. He discovered that the flap of a butterfly's wings in the Amazon could influence a tornado far away. This metaphor visually described the sensitivity to initial conditions. Though the axiom of chaos theory seems to make cause and effect prediction impossible, it could use similar patterns or processes within the whole in qualitative research to stimulate analysis. The characteristics of chaos theory which embeds randomness and dynamical features could easily accelerate the algorithm convergence and enhance the capability of diversity.

3.3. Principle

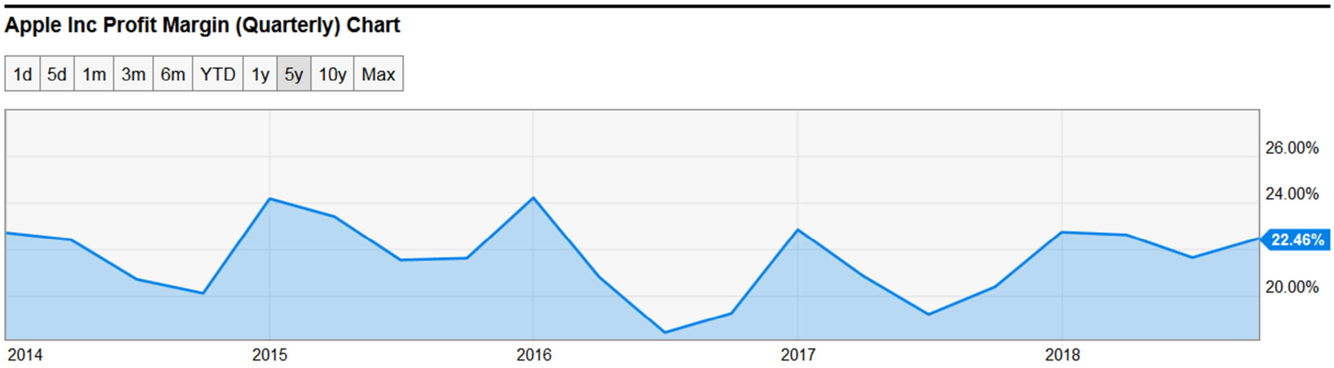
In linear methods, the relationship between factors or systems is predictable and could be easily measured. When the presence of the target factor increases, the system would just change linearly accordingly. On the contrary, elements in the chaotic systems may be considered as unpredictable. Because of sudden change, patterns of factors may disappear and new elements or patterns might unexpectedly emerge. This chaotic behavior does not mean totally disorder. Rather, the order is just difficult to describe in simple terms and requires a complex method to measure. Therefore, the chaos theory is a qualitative study which does not imply complete predictability.

3.4. Discussion

3.4.1. Time Series

The time series is a representation to describe how the variables change with respect to time. The graph itself shows the trend in "ups and down". For example, the time series of Apple Inc (AAPL) Profit Margin (quarterly) for a period of 5 years from December 2014 to September 2018 is plotted as follows.

The horizontal (x) axis indicates the time going backwards from December 2014 to September 2018. The vertical axis (y) indicates the Profit Margin (quarterly) in percentage.



Source: Ychart

Figure 1 *Apple Inc Profit margin (Quarterly) Chart.*

Some inferences can be drawn from the data:

1. The profit margin is sporadic. On most occasions the profit margin remains in the vicinity of 20%, sometimes it shoots up to as much as 24.20%.
2. A certain minimum level is maintained. Very rarely has the profit margin fallen below 18.41%.

3.4.2. Fractal Dimension

Most chaotic signals are fractal (K. Falconer, 2013). A fractal dimension is an index for characterizing fractal pattern by quantifying its complexity. "Any part of the system resembles the whole". The fractal dimension of a space denotes the degrees of freedom of a particle to move around that space (C. Tricot, 1995), which is concerned as self-similarity. The fractal index can take non-integer values, describing how a set fills its space qualitatively and quantitatively. It shows the number of active degrees of freedom which is proportional to the system size.

3.5. Method

The chaos theory can be used to approach issues in near or distant future. The property of randomness can be obtained by using probability distribution. Future research, a tool for planning and identifying the scope of possibilities, can help to make better decisions. This randomness method in optimization field is called chaotic optimization. In order to do this, we need to use scenario analysis to connect the present settings with the future ones. These are the steps of carry out this methodology.

Table 2. *Steps of scenario analysis.*

1. Decide drivers for change
2. Put drivers together into a viable framework
3. Produce 6-9 initial mini-scenarios
4. Reduce to 2-3 scenarios
5. Draft the scenarios
6. Identify the problems arising

The use of scenarios method can give planners a proactive understanding of different situations. To adapt quickly to uncertainty, plans can be adopted according to the change of situations. Therefore, a scenario building process can change the perceptions and assessments of the decision makers, so as to influence the future.

4. Human Social Activities

4.1. Human Social Systems

Nonlinear dynamical models have been used for almost over half a century in the area of family process theory. The family is conceptualized as a system to which the principles the general systems approach would apply. The individual elements serve a self regulatory function. Each interactive behavior maintains its structural integrity so as to maintain equilibrium. The different behavioral problems of the individual are considered to be outputs from families and thus contribute into the whole of the social system. The human society might change for the worse as well as change for the better. But how self regulatory behavior can contribute to structural transformation of the human social system is hard to value. The chaos framework gives us an approach to investigate social activity interaction.

4.2. Self-Organization and Dissipative Structure

Human social activity is like a system that can organize itself and as well adapt to outside influences. Accordingly it will also transform itself systemically. These two ways of changes are intrinsically linked, they utilize the energy of the system to regulate and adapt. If this hypothesis is theoretically true, then the human society just recycles itself and adapts to new environments when the conditions change. Human social activities are not completely random from the perspective of macroscopic view. "Fork in the road", variously known as a chaotic term signifying change shows how people faces the decision of new challenges or choices will alter the society as a whole. There are typical elements in Chaos Theory in organizations which consist of attractors that are the installation of bifurcation or chaos rupture.

5. Financial Models

5.1. Modeling of Random Variables

In the financial models, the application of statistical hypothesis testing and simulation techniques will lead to the conclusion differently according to the method that is applied. A group of independent random variables will probably create a random variable with new distinct stochastic characteristics. Random variable with new stochastic characteristics can usually be applied for approximation of empirically observed phenomena. The Efficient Market Hypothesis can be used to present which requires returns to be independent and distributed normally. Andersen et al. (2000) discovered that according to the theoretical expectations, realized volatility returns are close to a normal standard. But particularly, when the modeling of financial prices is considered, the financial price time series are usually non-stationary due to the profit maximizing actions of numerous market participants.

5.2. Testing of Chaos in Finance

Sakai & Tokumaru (1980) pointed out that the random of chaos is generated by a deterministic model which cannot be outlined by standard statistical tools. Grassberger & Procassia (1983) identified chaotic behavior in time series data in a physics analysis of metric procedure. Barnett & Chen (1988), Frank & Stengos (1989) and Sayers (1987) found some evidence of chaos when testing economic and financial time series data under the correlation dimension. The limitation of this test lied in that the correlation dimension did not work well on short data sets or nonstationary series. Claire G. Gilmore (2001, 2008) explained and utilized a new method - the close returns test to analyze nonlinearity so as to detect evidence of chaotic behavior in time series data.

5.3. Solution to Problems

Many researchers proposed several of methods to deal with the problem of premature convergence using adaptive method to adjust parameters or hybrid method to enhance the search capability. Chaos method is most suitable approach to solve this problem. Simulating complex financial phenomena or numerical analysis requires a long period of generating random sequences and a good uniformity. The behavior of financial market relates to the circumstances that are both internal and external. Chaos theory, which has not been used so far in financial practice, is an acute methodology to be applied in the analysis of the randomness in financial markets instead of completely randomized design. The completely randomized design places the emphasis on which the factor effects are constant and assumes the observation from experiments to be statistically independent. However, this hypothesis is often not realistic and practical. The correlated impact should not be ignored. The theory of chaos is well suited for the understanding of the financial perspectives.

6. Conclusion

Chaos theory is a methodology that has been widely applied into various issues. One of the famous applications is the use of chaos theory in optimization. Human social activities are not completely random from the perspective of macroscopic view. And the previous methods used in quantitative finance, mathematical finance and statistical finance which are based on the assumption of completely random theory are not practical. Chaotic mathematics should be applied to model incomplete randomness in financial markets. The application of chaos theory can help financial models to achieve a desired accuracy. It enhances the variety of financial movement patterns and can help to solve real-world financial problems.

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