Non-Linear Properties of the VIX Index

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ABSTRACT

This paper applies non-linear methods to analyze and predict the daily VIX index which is one of the most important stock indexes in the world. The aim of the analysis is to quantitatively show if the corresponding time series is a deterministic chaotic one and if one or more days ahead prediction can be achieved. The research employs Grassberger and Procaccia's methodology in the time series analysis in order to estimate the correlation and minimum embedding dimensions of the corresponding strange attractor. To achieve from the sample a multistep ahead prediction, the article gives the average for overall neighbours’ projections of k-steps into the future. These results make the present work a valuable tool for traders, investors, and funds.

KEYWORDS

Chaos Theory, Prediction, Time Series, Volatility

INTRODUCTION, BRIEF LITERATURE, AND SOME EXPLANATIONS

Physical models and theories from the field of non-linear dynamics are employed to describe, analyze, explain, and solve financial problems. The use of physical laws in economics as well as the use of physical principles in human behavior provides additional tools to solve economic problems, to model economic systems, and to predict economic time series as the daily VIX index where VIX is a measure of the implied volatility of the Standard & Poors (S&P) 500 index options. Commonly used and well-documented methods include non-linear time series analysis by Kodba, Perk, and Marhl (2005), and cross correlation by Garas and Argyrakis (2007), hierarchal clustering by Coronnello, Tumminello, Micciche and Mantegna (2007) which are presented in the above papers.

Alexander and Giblin (1997) enrich the nearest neighbour method by constructing a multivariate nearest neighbour prediction method. Using high-frequency data, they empirically show that the chaos in financial markets can be detected under the multivariate model. Recent evidence on implication of chaos theory in financial time series prediction comes from works of Hanias. Hanias, Curtis, and Thallasinos (2007) presents evidence on how chaos theory can be used for prediction stock returns in the Athens Stock Exchange. Hanias, Curtis, and Ozun (2008) also employ chaos theory to show if the Istanbul Stock Exchange has chaotic dynamics. Ozun, Hanias, and Curtis (2010) uses chaos theory in Athens and Istanbul Stock Exchange and empirically shows that it has informational efficiency in semi-strong form.

When a system presents deterministic chaotic behavior, we can find the number of first order differential equations that described its evolution. The appearance of nonlinear structures is important

DOI: 10.4018/IJPMAT.2017070102

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to the question of out of sample prediction, and this is done in this paper as Hanias and Curtis (2008) have shown. For this purpose, we have applied the method proposed by Grassberger and Procaccia (1983a) to evaluate the invariant parameters of VIX index as the correlation and minimum embedding dimensions. Then we have applied the results from the non-linear analysis to predict the corresponding time series with high accuracy.

**VIX DATA**

The daily VIX index is presented as a signal $x = x(t)$ as it shown at Figure 1. It covers $N = 6045$ data from January 2, 1990 to December 24, 2013. The sampling rate was $\Delta t = 1$ day. The data corresponds to closed value every night.

**THEORETICAL FRAMEWORK**

In order to evaluate the afore mentioned time series, we have used the method proposed by Grassberger and Procaccia (1983a, 1983b) and successfully applied in similar cases by Hanias and Magafas (2012) and Hanias, Curtis, and Thallasinos (2007). According to Takens (1981), the measured time series was used to reconstruct the original phase space. For this purpose, we calculated the correlation integral, for the recorded signal, defined by the following relation as Kantz and Schreiber (1997) proposed, for $r \to 0$ and $N \to \infty$,

$$C(r) = \lim_{N \to \infty} \lim_{W \to \infty} \frac{1}{N_{pairs}} \sum_{i=1}^{N} \sum_{j=1}^{W} H \left( r - \left\| \tilde{X}_i - \tilde{X}_j \right\| \right)$$

(1)

Figure 1. Time Series of VIX closed prices index
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