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Analysis of chaos and nonlinearities in a foreign exchange market

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Abstract

The benefit for analyzing financial time series such as foreign exchange rates for chaos is that it can help indicate whether random-looking fluctuations actually represent an orderly system in disguise. Furthermore, identifying chaos can lead to greater accuracy of short-term predictions by using nonlinear models since linear models cannot produce good forecasts for chaotic time series

In regard to foreign exchange market, we are interested whether exchange rate movements and trading activity is the result of new information coming to the market or a few deterministic forces interact with each other in such a way that a very complicated and volatile time path can be produced. Finally, detecting chaos can make modeling easier, since simple deterministic equations can describe chaos.

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Keywords: Chaos; nonlinearity tests; exchange market; neural network; hypthesis; Lyapunov exponent; BDS test.

1. Introduction

The concept of chaos is one of the most exciting and rapidly expanding research topics of recent years. Chaos deals mostly with how something evolves over time. It may be defined as long-term evolution occurring in deterministic non-linear system that exhibits complex behavior.

A chaotic system is evolved by a feedback mechanism in which the output of a previous time point is the input of the present. Such a feedback mechanism self-intensify interdependent events and causes irregular behavior. The main characteristic of a chaotic system is that it is very sensitive to the starting point and coefficients, an error in starting point and coefficients is accumulated exponentially and that disorders will happen when the changes are accumulated to a certain point. The benefit for analyzing financial time series such as foreign exchange rates for chaos is that it can

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help indicate whether random-looking fluctuations actually represent an orderly system in disguise. Furthermore, identifying chaos can lead to greater accuracy of short-term predictions by using nonlinear models since linear models cannot produce good forecasts for chaotic time series. Also, irregular evolution is often attributed to the effects of external factors or variables. Chaos theory shows this can be as a result of the nonlinear nature of the system rather that of the other causes. In regard to foreign exchange market, we are interested whether exchange rate movements and trading activity is the result of new information coming to the market or a few deterministic forces interact with each other in such a way that a very complicated and volatile time path can be produced. Finally, detecting chaos can make modeling easier, since simple deterministic equations can describe chaos.

Testing financial time series for presence of nonlinear dependence is also important from the point of view of market efficiency. Market efficiency implies that future returns and prices are unpredictable, rules out pure arbitrage opportunities and denies the profitability by the use of historical data. If the logarithmic price process follows a random walk then the present and past returns are not associated with future returns and hence they have no predictability for future values. Therefore, independence of return series implies the existence of an efficient market and univariate time series methods won't succeed in capturing any returns process patterns. If present, non-linear dependence would contradict the random walk model and the financial market weak form efficiency hypothesis.

There is an extensive research made on analyzing foreign exchange markets for chaos and nonlinearity. For instance, Tata and Vassilicos (1991) use tick-by-tick DM/US rates data and they find evidence for the absence of chaos in high frequency data. Kugler and Lenz (1990) analyzed exchange rates of Deutsche mark, Swiss franc, French franc, and yen against the US dollar and found significant nonlinearities for all cases. Brooks (1995) uses daily exchange rates of ten currencies against the British pound and detects the presence of nonlinear determinism in the data, but rejects deterministic chaos. However, many empirical studies on foreign exchange markets have been concentrated on US and European markets but research on emerging markets has been limited.

The aim of this study is to broaden chaos and nonlinearity analysis by using foreign exchange rates from an emerging market. More specifically we are interested in detecting existence of chaos and nonlinearities in Turkish foreign exchange market. To our knowledge, no similar study has set focus on Turkish foreign exchange market before. Popular tests have been used for our purpose including the one with neural network architecture to learn more about the time series and to enable us to closely estimate Lyapunov spectrum with fairly small amount of data. The tests we shall use are the following: neural network test by Gençay and Dechert (1992), BDS test by Brock et al (1996) and bispectrum test by Hinich (1982).

The paper is organized as follows. In the next section methodologies and tests used in this paper are discussed. The third section shows empirical results. In section four we discuss the empirical findings. The last section presents conclusions.

In this study we use daily returns of USD/TL selling rates from January 1, 1995 to December 31, 2000 with 1564 observations retrieved from statistics database of Central Bank of Turkey. Exchange rate returns are calculated as follows:

$$r=\log(P_t)-\log(P_{t-1})$$

2. Instruments.

2.1. Neural Network. Lyapunov exponent test (by Dechert and Gençay)

The Lyapunov exponent test can be used to determine whether the system under study is chaotic. It is based on the idea that the dynamics of trajectory evolution are described by the largest Lyapunov exponent. It measures the average rate of convergence of divergence of two neighboring trajectories in phase space. Its value can be negative, zero or positive. Negative values mean that the two trajectories draw closer to one another. Positive exponents, on the other hand, result from trajectory divergence and appear only within the chaotic domain. A positive Lyapunov exponent quantifies sensitive dependence on initial conditions by showing the average rate at which the distance between two close points grows exponentially. At least one exponent must be positive for an attractor (an equilibrium state or group of states to which a dynamical system converges) to be classified as chaotic. In other words the system is stochastic if $\lambda<0$, and chaos if $\lambda>0$. In n-dimensional case, where