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Phase correlation of foreign exchange time series

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Abstract

Correlation of foreign exchange rates in currency markets is investigated based on the empirical data of USD/DEM and USD/JPY exchange rates for a period from February 1 1986 to December 31 1996. The return of exchange time series is first decomposed into a number of intrinsic mode functions (IMFs) by the empirical mode decomposition method. The instantaneous phases of the resultant IMFs calculated by the Hilbert transform are then used to characterize the behaviors of pricing transmissions, and the correlation is probed by measuring the phase differences between two IMFs in the same order. From the distribution of phase differences, our results show explicitly that the correlations are stronger in daily time scale than in longer time scales. The demonstration for the correlations in periods of 1986–1989 and 1990–1993 indicates two exchange rates in the former period were more correlated than in the latter period. The result is consistent with the observations from the cross-correlation calculation.

Keywords: Foreign exchange rate; Time series; Phase correlation

1. Introduction

Financial markets are complex systems consisting of a large number of traders, institutions, and regulatory agents interact one another on the basis of market information to determine asset prices. Traditional studies of financial systems relies heavily on economic fundamentals such as dividend yield, long-short interest rate spreads, risk, book value, etc, and tend to address issues on drawing trading strategies for traders and investors. With the increase of knowledge on financial systems and developments of new algorithms for statistical analysis, some previous studies have provided rich information for such purposes [1].

However, previous studies have also suffered by a limit of scope from the statistics of return and its derivatives. As a result, cross disciplinary studies on financial systems have attracted much attention in recent decades [2–7]. With the aid of ideas and techniques from other fields, there have been significant advancements on the studies of economy science. One of great achievements has been the applications of statistical mechanics to economic systems, which has been later referred to *econophysics* [5]. Some correspondences between quantities in economic systems and physical systems were found, and knowledge in physics such as phase transitions in criticality [8], finite-size scaling theory [2,5,6], etc, were suggested to be fundamental concepts behind.

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There are also developments on the analysis of financial time series in methodology [3,4,9]. For example, the method of random matrix theory has been developed to study statistical structure of multivariate time series [3,4], and given remarkable agreement between theoretical prediction and empirical data [3,7]. Furthermore, the wavelet transform modulus maxima approach [10] has been applied to study non-stationary time series such as physiologic systems [11–14] and economic systems [9]. Quite recently, Wu et al. proposed a new approach to study stock time series [15]. The approach was based on the concept of instantaneous phase defined from the return time series can catch the characteristic structures of financial time series [15]. To implement the proposal, the Hilbert–Huang time signal analysis method [16] was used to define and evaluate instantaneous phase of return time series. Based on the investigations of phase distribution and phase correlation of the so-called intrinsic mode functions (IMFs), Wu et al. concluded that the return time series fall into a class which is different from other non-stationary time series, and the statistics of phase differences further provided useful observations on the trading activities in Dow-Jones and NASDAQ stock markets.

In this paper, we will follow the approach proposed in Ref. [15] to study correlation of foreign exchange time series. We use the empirical data of USD/DEM and USD/JPY exchange rates for the study. There are some significant differences between foreign exchange markets and stock markets. In contrast to stock markets which are highly regulated, foreign exchange markets function under a very loose, essentially self-policing environment. Furthermore, the foreign exchange market is the largest market in the world, with $1.9 trillion in all currencies changing hands each day [17]. However, due to relatively moderate price variations of foreign exchange rates in currency markets, there are fewer reports on the investigations of foreign exchange rates in comparison with rich studies on stock markets. It is heuristic to demonstrate the application of the approach to foreign exchange time series.

The main purpose of this study is to provide an alternative and promising scheme for the demonstration of correlations of exchange rates in currency markets. To have quantitative descriptions on the correlative behaviors revealing from the return of foreign exchange time series, we first employ the empirical mode decomposition (EMD) method [16] to decompose a return time series into a set of IMFs and then apply the Hilbert transform to calculate instantaneous phases of these IMFs. We measure the correlation between two exchange time series by calculating the distribution of phase differences of the IMFs in the same order. Our results show explicitly the correlations are stronger in daily time scale than in longer time scales, and two exchange time series were more correlated in the period of 1986–1989 than in the period of 1990–1993.

The rest part of this paper is organized as follows. In next section, we briefly introduce the source of the empirical data under consideration. Return time series of USD/DEM and USD/JPY are shown in Section 3 for an exploration. The analyses of phase correlation are presented in Section 4. Finally, we conclude our results in Section 5.

2. Data

The empirical data used in this paper includes the transaction prices of USD/DEM and USD/JPY exchanges over the period from February 1 1986 to December 31 1996 [18]. The ownership of the data belongs to the Olsen & Associates and the authorized use in the current work was under the agreement between the author's institution (Academia Sinica) and Olsen & Associates. The original data of the USD/DEM and USD/JPY exchange time series were separatively recorded and the data lengths were not consistent. After deleting the dates without records, and then aligning the opening and closing prices by date for each contract, we finally got a set of time series with totally 3843 sampling points for the study. In general, the number of sampling point is too few for scaling analysis, but is enough for a whole-set statistics to give reliable estimation. Therefore, we will focus on the latter in this paper.

3. Time series of intraday returns

To examine the pricing transmission of the USD/DEM and USD/JPY exchange rates, we define the intraday return $R(t)$ as

$$R(t) = \frac{Y_c(t) - Y_o(t)}{Y_o(t)}, \tag{1}$$