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Market efficiency in foreign exchange markets

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Abstract

We investigate the relative market efficiency in financial market data, using the approximate entropy(ApEn) method for a quantification of randomness in time series. We used the global foreign exchange market indices for 17 countries during two periods from 1984 to 1998 and from 1999 to 2004 in order to study the efficiency of various foreign exchange markets around the market crisis. We found that on average, the ApEn values for European and North American foreign exchange markets are larger than those for African and Asian ones except Japan. We also found that the ApEn for Asian markets increased significantly after the Asian currency crisis. Our results suggest that the markets with a larger liquidity such as European and North American foreign exchange markets have a higher market efficiency than those with a smaller liquidity such as the African and Asian markets except Japan.

Keywords: Approximate entropy(ApEn); Market efficiency; Degree of randomness

1. Introduction

Recently, the complex features of financial time series have been studied using a variety of methods developed in econophysics [1,2]. The analysis of extensive financial data has empirically pointed to the breakdown of the efficient market hypothesis (EMH), in particular, the weak-form of EMH [3–8]. For example, the distribution function of the returns of various financial time series is found to follow a universal power law distribution with varying exponents [3–5,7]. The returns of financial time series without apparent long-term memory are found to possess the long-term memory in absolute value series, indicating a long-term memory in the volatility of financial time series [9–13].

In this paper, we use a method developed in statistical physics to test the market efficiency of the financial time series. The approximate entropy (ApEn) proposed by Pincus et al. can be used to quantify the randomness in the time series [14,15]. The ApEn can not only quantify the randomness in financial time series with a relatively small number of data but also be used as a measure for the stability of time series [16]. Previously, the Hurst exponent was used to analyze various global financial time series, which suggested that the mature markets have features different from the emerging markets. Thus, the Hurst exponents for the

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mature markets exhibit a short-term memory, while those for the emerging markets exhibit a long-term memory [6,11]. It was also shown that the liquidity and market capitalization may play an important role in understanding the market efficiency [17]. Using the ApEn, we study the market efficiency of the global foreign exchange markets. We use the daily foreign exchange rates for 17 countries from 1984 to 1998, and for 17 countries from 1999 to 2004 around the Asian currency crisis.

We found that the ApEn values for European and North American foreign exchange markets are larger than those for African and Asian markets except Japan. We also found that the market efficiency of Asian foreign exchange markets measured by ApEn increases significantly after the Asian currency crisis.

In Section 2, we describe the financial data used in this paper and introduce the ApEn method. In Section 3, we apply the ApEn method to global foreign exchange rates and investigate the relative efficiency of the diverse foreign exchange markets. Finally, we end with a summary.

2. Data and method

2.1. Data

We investigate the market efficiency of the financial time series for various foreign exchange markets. For this purpose, we use the return series of daily foreign exchange rates for 17 countries from 1984 to 1998 (Data A) and from 1999 to 2004 (Data B). The Data A and Data B are obtained before and after the Asian crisis, respectively. The data are grouped into European, North American, African, Asian and Pacific countries (from http://www.federalreserve.gov/RELEASES/). The returns of the financial time series are calculated by a log-difference and properly normalized, respectively. The normalized return R_t at a given time t is defined by

$$r_t = \ln P_t - \ln P_{t-1}, \quad R_t = \frac{\ln P_t - \ln P_{t-1}}{\sigma(r_t)}, \tag{1}$$

where P_t is the daily foreign exchange rate time series, r_t the return time series after a log-difference, and $\sigma(r_t)$ the standard deviation of the return.

2.2. Approximate Entropy(ApEn)

Pincus et al. proposed the ApEn to quantify the randomness inherent in time series data [14,15]. Recently, Pincus and Kalman applied the ApEn method to a variety of financial time series in order to investigate various features of the market, in particular, the randomness [16]. The ApEn is defined as follows:

$$\mathrm{ApEn}(m, r) = \Phi^m(r) - \Phi^{m+1}(r), \tag{2}$$

where m is the embedding dimension, r the tolerance in similarity. The function $\Phi^m(r)$ is given by

$$\Phi^m(r) = (N - m + 1)^{-1} \sum_{i=1}^{N-m+1} \ln[C_i^m(r)], \tag{3}$$

$$C_i^m(r) = \frac{B_i(r)}{(N - m + 1)}, \tag{4}$$

where $B_i(r)$ is the number of data pairs within a distance r,

$$B_i \equiv d[x(i), x(j)] \leqslant r. \tag{5}$$

The distance $d[x(i), x(j)]$ between two vectors $x(i)$ and $x(j)$ in R^m is defined by

$$d[x(i), x(j)] = \max_{k=1,2,\ldots,m} (|u(i + k - 1) - u(j + k - 1)|), \tag{6}$$

where $u(k)$ is a time series.

The ApEn value compares the relative magnitude between repeated pattern occurrences for the embedding dimensions, m and $m + 1$. When the time series data have a high degree of randomness, the ApEn is large.