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Timing matters in foreign exchange markets

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ABSTRACT

We show using nonlinear time series analysis that the timing of trades in foreign exchange markets has significant information. We apply a set of methods for analyzing point process data developed in neuroscience and nonlinear science. Our results imply that foreign exchange markets might be chaotic and have short-term predictability.

1. Introduction

For the last fifteen years, high-resolution foreign exchange data have been successfully characterized using techniques developed in econophysics [1–12]. Although price changes, the distribution of inter-trade intervals, and numbers of trades per unit time were intensively studied, the timing of trades is often assumed to be stochastic and has not been thoroughly investigated from a viewpoint of nonlinear dynamics. Here we report that trade times also provide fundamental information about foreign exchange markets. By applying techniques developed in neuroscience [13,14], we show that trade times do not follow the Poisson process and that they provide some information which cannot be obtained from short-term counts of trade times. Applications of the recently developed distance [15] for marked point processes with methods [16–18] in nonlinear science suggest that trades have serial dependence and that their generating process can be deterministically chaotic. Actually series of trades can be predicted for a short term. The results imply that by taking into account the timing of trades, the dynamics of foreign exchange markets may be controlled by chaos control [19].

2. Used datasets

Foreign exchange markets provide ideal data from a scientific viewpoint because their traded volumes are huge. Most trades in foreign exchange markets are now conducted electronically. The datasets used in our studies were taken from the foreign exchange market EBS of ICAP, which is the largest foreign exchange electronic interbank broker in the world. The datasets contain typical marked point processes, as each trade happens irregularly with a price and a volume. The time resolution of the datasets we used is 1 s. Many researchers in econophysics have studied these high-resolution datasets [1–12]; for example, they found that trend-following movements exist on the time scale of 1 min [10]. Although inter-trade intervals [6] and the number of trades per unit time [11] were studied previously, trade timing has not been studied in detail yet, possibly because timing is hard to take into account mathematically. In this paper, we analyze the trade times of the exchange rate between the US dollar and the Japanese yen for mainly the week starting on 4 June 2007 if not mentioned. In this week, there were 55361 trades. The mean inter-trade interval and the standard deviation were 7.9

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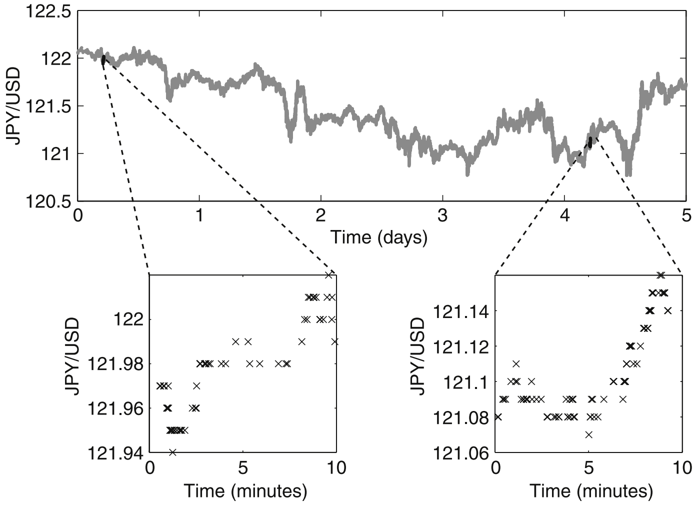

Fig. 1. Typical trade patterns for the US dollars/Japanese Yen market. The movement of the traded prices is shown by dots at the top panel. At the bottom panels, we show examples of high-resolution data at two different times which are for the same time of day but different by 4 days, where crosses showed traded times and prices.

and 18.2 s, respectively. The minimum and maximum inter-trade intervals were 1 and 1029 s, respectively. Typical trade patterns are shown in Fig. 1. We only consider transactions within which trades were actually made. Our analysis uses techniques developed in neuroscience and nonlinear science [13–18].

3. Results

Neuroscience has been leading the analysis of point processes, since the activity of neurons is usually recorded by times of action potentials, or spike trains. Recently, many new methods have been proposed [13,14,20,21] (see [22] for the overview). Distances [20,21] defined for spike trains are especially promising because they can be used to estimate the maximal Lyapunov exponent [17,18], an index for deterministic chaos, and obtain recurrence plots [16], which have been intensively studied for the last two decades. Therefore, by using and/or modifying these methods, one may characterize foreign exchange markets from the viewpoint of trade timing.

The first question that we posed was whether trade timing follows the Poisson process. The Poisson process is a standard point process in which the number of events within a certain time window has a fixed mean and is independent of the number of events for the preceding times. In neuroscience, two indices, Cv and Lv [13], are widely used to show that a spike train does not follow the Poisson process. Cv and Lv are defined as follows:

$$Cv = \frac{1}{\bar{x}}\sqrt{\frac{1}{d-1}\sum_{i=1}^{d}(x_i-\bar{x})^2},$$

$$Lv = \frac{3}{d-1}\sum_{i=1}^{d-1}\frac{(x_i-x_{i+1})^2}{(x_i+x_{i+1})^2},$$

where $x_i (i = 1, 2, \ldots, d)$ show the ith inter-trade intervals and $\bar{x}$ shows the mean of inter-trade intervals. Both Cv and Lv take the value of 1 when a point process is Poisson and close to 0 when it is very regular. We calculated these values for non-overlapping 1-hour periods within the week. Both indices presented in Fig. 2 show that trade timing does not follow the Poisson process. The index Cv is larger than 1 (two-tailed t-test: p-value <0.001), meaning that the distribution of inter-trade intervals is broad, while Lv is mostly smaller than 1 (two tailed t-test: p-value <0.001), indicating that consecutive inter-trade intervals are similar. This means that there are two phases in foreign exchange: one that contains many trades and another in which trades are rather sparse. This view is consistent with previous work [1,3,4,8]. The times where trades are dense tend to be in the afternoon in the United States and in the morning in Japan.

The next natural question that we asked was whether trade times can be characterized only by the short-term counts of trade times. To check this issue, we used rate coding surrogates [14], which were originally proposed for determining if spikes of neurons can be characterized only by short-term average firing rates. In rate coding surrogates, we randomize the times of events by exchanging inter-trade intervals so that short-term counts of trades are almost preserved. For the part of the dataset with the length of 10 000 s, we generated 210 rate coding surrogates [14] using the bin size of 100 s. We compared the original data with the surrogates by using the compression ratio as a test statistic. The result, presented