A characteristic time scale of tick quotes on foreign currency markets

Aki-Hiro Sato
Department of Applied Mathematics and Physics,
Graduate School of Informatics,
Kyoto University, Kyoto 606-8501, Japan

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Abstract

This study investigates that a characteristic time scale on an exchange rate market (USD/JPY) is examined for the period of 1998 to 2000. Calculating power spectrum densities for the number of tick quotes per minute and averaging them over the year yield that the mean power spectrum density has a peak at high frequencies. Consequently it means that there exist the characteristic scales which dealers act in the market. A simple agent model to explain this phenomenon is proposed. This phenomena may be a result of stochastic resonance with exogenous periodic information and physiological fluctuations of the agents. This may be attributed to the traders’ behavior on the market. The potential application is both quantitative characterization and classification of foreign currency markets.

Key words. power spectrum density, agent-based model, stochastic resonance

1 Introduction

Empirical analysis of high-frequency financial data have been attracting significant interest among physicists as well as economists during a decade
Many features of financial markets have been clarified by many successive studies. Actually it is well-known that the markets have a characteristic time scale in long period (daily, weekly, and monthly). However recent studies (Takayasu 2003, Ohnishi 2004 and Mizuno 2004) on time-series analyses in financial markets show that the market has a characteristic time scale in short period and propose the reason why traders are mainly using strategies with weighted feedbacks of past prices. Furthermore using the self-modulation process Takayasu et al. have found that the characteristic time scale is about 2 minutes in the JPY/USD market (Takayasu 2003) (abbreviated as MT).

On the other hand Baninec and Krawiec and Holst proposed a possibility that stochastic resonance occurs in markets (Babinec 2002 and Krawiec 2003) through an Ising-like agent model. They suggest that a periodicity in the market results from exogenous periodical information (abbreviated as BKH).

In order to clarify the mechanism of this characteristic time I think that we should examine it on a different standpoint from MT and BKH. Both studies focus on prices or price returns. However, in this article, we focus on the number of tick quotes in foreign currency rates (USD/JPY) and investigate the statistical properties of them by utilizing the power spectrum technique. As the results of examining the number of tick quotes in USD/JPY market it is found that the power spectrum density (PSD) has some peaks at about 2 minutes (the peak frequency depends on the currency markets).

In order to explain this phenomena a simple agent model based on double-threshold noisy device (Sato 2004) is proposed. From a result of numerical simulations of the model it is found that the high periodicity of the number of tick quotes may happen. This result leads to a hypothesis that this periodicity is caused by common exogenous periodical information.

The purposes of this study are as follows: (1) to examine the number of high-frequency quotes lead us to deeply understand microscopic market activities. (2) this may provide useful information for market players to consider their trading strategy.

2 Data Analysis

The number of ask quotes per minute in USD/JPY is counted for a period of 1998 to 2000. Utilizing the data we calculated three PSDs for 2,048 points in
weekday and average them over the year. The averaged power spectrums on
the semi-log scale are shown in Fig. 1. They all have a peak at 0.4 (1/min),
namely 2.5 minutes. We consider that these peaks exhibit characteristic time
scales of dealers’ activities, i.e., the dealers act having the periodicity of 2.5
minutes.

3 Dealer model

We introduce a simple agent model based on double-threshold noisy devices
in order to understand the characteristic time scales found in the averaged
power spectrum density. This model contains \( N \) dealers and the \( i \)th dealer
has double-threshold \((\theta_i^{(1)} > \theta_i^{(2)})\) to decide buy(1), sell(-1) and wait(0), and
noise source \( \xi_i(t) \) to model an uncertainty in their mind. We assume that
the \( i \)th dealer must choose a decision (output) into the three ones
\( y_i(t) = \{1, 0, -1\} \) based on information (input) \( x_i(t) \) with an uncertainty \( \xi(t) \) in
his/her mind:

\[
y_i(t) = \begin{cases} 
1 & (x_i(t) + \xi_i(t) > \theta_i^{(1)}) \\
0 & (\theta_i^{(2)} \leq x_i(t) + \xi_i(t) \leq \theta_i^{(1)}) \\
-1 & (x_i(t) + \xi_i(t) < \theta_i^{(2)}) 
\end{cases}
\]  

(1)

Here we assume that \( \xi_i(t) \) is identically independent Gaussian distribution,

\[
G(\xi) = \frac{1}{\sqrt{2\pi}\sigma_i} \exp\left(-\frac{\xi^2}{2\sigma_i^2}\right),
\]

(2)

where \( \sigma_i \) are standard deviations of the \( i \)th dealer.

It is assumed that the input of each dealer is exogenous periodic information
\( s(t) = A\sin(2\pi ft) \), where \( A \) represents an amplitude, and \( f \) a frequency.
For \( s(t) > 0 \) the dealers feel it good news and tend to decide a buy, while for
\( s(t) < 0 \) they do it bad news and to decide a sell.

Furthermore the number of tick quotes per unit time \( X(t) \) is defined as

\[
X(t) = \frac{1}{N} \sum_{i=1}^{N} |y_i(t)|.
\]

(3)

For simplicity assume \( \theta_i^{(1)} = \theta \) and \( \theta_i^{(2)} = -\theta \). Obviously the activity
\( X(t) \) is always zero if \( \sigma = 0 \) and \( A < \theta \), so that, there is no uncertainty
of the dealers in their mind and the exogenous information is weaker than
the threshold for the dealers to decide their action. However if there is uncertainty $\sigma > 0$ then the activity $X(t)$ can exhibit periodicity despite of $A < \theta$ due to stochastic resonance (see Gammaitoni Hänggi Jung and Marchesoni (1998)).

As shown in Fig. 2 it is found that the PSD has some peaks from numerical simulations of the dealer model for $\sigma > 0$ and $A < \theta$. This peak is caused by stochastic resonance.

4 Discussion and Conclusion

We empirically investigate the number of the tick quotes per unit time in foreign currency market (USD/JPY). It is found that the power spectrum densities of them for a period 1998 to 2000 all have a peak at 0.4 [1/min]. From the results it is conclude that a periodical action of dealers exists.

In order to explain this phenomena a simple dealer model based on the double-threshold noisy devices is proposed. Under a hypothesis that the mechanism of this periodicity is stochastic resonance the market activity in the model shows periodicity due to uncertainty of dealers’ decision even though the exogenous periodical information is weaker than the threshold for dealers to decide their action. In fact this model is a feedforward one, however, real markets contains complicated (positive and negative) feedbacks. The future work is to consider the feedbacks to improve the dealer model.

Moreover the source of this periodicity is open problem. One possibility is an endogenous feedback mechanism of dealers as shown in MT. The other is an exogenous periodical information as shown in this paper. More detailed data analyses let us clarify the mechanism of this phenomena. To consider this problem is expected to contribute to a deep understanding of fluctuations and structure in the market.

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Figure 1: Semi-log plots of the averaged power spectrum density of the number of tick quotes (USD/JPY) over the year for a period of 1998 (top), 1999 (middle), and 2000 (bottom). They all have a peak at 0.4 (1/min), i.e., 2.5 minutes.
Figure 2: Semi-log plots of the averaged power spectrum of $X(t)$ at $\sigma = 0.3$, $\theta = 1.0$, $A = 0.4$, and $f = 0.2$. It has a peak at 0.4.