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Correlation structures in short-term variabilities of stock indices and exchange rates

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Abstract

Financial data usually show irregular fluctuations and some trends. We investigate whether there are correlation structures in short-term variabilities (irregular fluctuations) among financial data from the viewpoint of deterministic dynamical systems. Our method is based on the small-shuffle surrogate method. The data we use are daily closing price of Standard & Poor's 500 and the volume, and daily foreign exchange rates, Euro/US Dollar (USD), British Pound/USD and Japanese Yen/USD. We found that these data are not independent.
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1. Introduction

It is usually considered that market prices are interconnected or interrelated in some way or another to varying degrees. That is (for example), change of Euro/US Dollar (USD) exchange rate may influence Japanese Yen/USD exchange rate. The aim of this paper is to examine whether there are correlation structures in short-term variabilities (irregular fluctuations) of stock indices and foreign exchange rates, where all of these data show irregular fluctuations and some trends (See Figs. 1 and 2 in Section 4).

Recently to investigate correlations of price changes, random matrix theory (RMT) is often applied [1–3]. RMT predictions represent an average over all possible interactions [1]. In the approach of RMT the distribution of the eigenvalues of a cross correlation matrix is compared with that of relevant ensemble of the random matrix. Broadly speaking, when there are eigenvalues that are outside the RMT predictions, it is considered that the deviations might suggest the presence of information of the marketwise effects [1]. This result shows that there are correlations among data used in the matrix. This information is useful, but also rather limited, because it does not specifically indicate which data exhibits the correlation. That is, we still do not know which data are related to one another. Moreover, to apply RMT we need to use very large matrices [3].

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One of the useful statistics that can directly investigate some kind of relations among data and do not need very large matrices is the cross-correlation function (CC). This statistic can investigate correlations in short-term variabilities of two signals. However, the statistic is also restrictive because correlation is only a useful measure of linear similarity [4]. That is to say, even when two signals are not similar, there are still possibilities that these systems have some kind of correlation structures (that is, the systems are interconnected or interrelated). This means that it is not enough to use only statistics such as CC in all cases. To investigate correlation structures more reliably, an approach from the viewpoint of a deterministic dynamical system is useful and necessary. However, such an approach is not easy because it is difficult to treat data which exhibit short-term variabilities and some trends. Financial data usually have such features.

To accomplish this, we apply a method based on the small-shuffle surrogate (SSS) method [4]. We apply our method to daily closing price of Standard & Poor's 500 (S&P500) and the volume, and to daily exchange rates, Euro (EUR)/US dollar (USD), British Pound (GBP)/USD and Japanese Yen (JPY)/USD. The analysis of these data is the major novel contribution of this paper.

In Section 2 the SSS algorithm and the hypothesis will be discussed. Our method is based on this algorithm. In Section 3 we present our choice of discriminating statistics and describe how to test our null hypothesis. In Section 4 we apply the method to financial data.

2. The small-shuffle surrogate method

To investigate whether temporal correlations in data are absent or data are independently distributed (ID) random variables even if it exhibits trends, the SSS method is useful [5]. Moreover, the SSS method does not depend on the specific data distribution. The SSS method has proven to be effective for tackling data exhibiting short-term variabilities and long-term trends [5–8].

SSS data are generated as follows; Let the original data be $x(t)$, let $i(t)$ be the index of $x(t)$ (that is, $i(t) = t$, and so $x(i(t)) = x(t)$), let $g(t)$ be Gaussian random numbers and $s(t)$ will be the surrogate data.

(i) Obtain $i'(t) = i(t) + Ag(t)$, where A is an amplitude.
(ii) Sort $i'(t)$ by the rank-order and let the index of $i'(t)$ be $\hat{i}(t)$.
(iii) Obtain the surrogate data $s(t) = x(\hat{i}(t))$.

We have found that choosing $A = 1.0$ is adequate for nearly all purposes. In the SSS data, local structures or correlations in irregular fluctuations (short-term variabilities) are destroyed and the global behaviors (trends) are preserved. Further details of the method and the mechanism are provided in Refs. [4–7]. The null hypothesis (NH) addressed by this algorithm is that irregular fluctuations (short-term variabilities) are ID random variables or time-varying random variables (in other words, there is no short-term dynamics or determinism) [4–7]. The SSS method also can be applied to multivariate data, irrespective of whether the data have similar or different long-term trends. The NH is that there is no short-term correlation structure among data or that the irregular fluctuations are independent [4].

3. When to reject a null hypothesis

Discriminating statistics are necessary for surrogate data hypothesis testing. The SSS method changes the flow of information in the data. Hence, we choose to use the cross-correlation function (CC) and the average mutual information (AMI) as discriminating statistics. These statistics can determine, on average, how much one learns about one signal by observing the other [9].

After the calculation of these statistics, we need to inspect whether a NH shall be rejected. We employ Monte Carlo hypothesis testing and inspect whether the estimated statistics of the original data fall within or outside the statistical distribution of the surrogate data [10]. When the statistics fall within the distributions of the surrogate data, we conclude that the hypothesis may not be rejected. In this paper, we generate 99 SSS data and hence the significance level is between 0.01 and 0.02 for a one-sided test with two non-independent statistics [4].

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