Dynamics of episodic transient correlations in currency exchange rate returns and their predictability

Milan Žukovič

1 SORS Research a.s., Moyzesova 38, 040 01 Košice, Slovakia
2 Department of Theoretical Physics and Astrophysics, Faculty of Science, P. J. Šafárik University, Park Angelinum 9, 041 54 Košice, Slovakia

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Abstract: We study the dynamics of the linear and non-linear serial dependencies in financial time series in a rolling window framework. In particular, we focus on the detection of episodes of statistically significant two- and three-point correlations in the returns of several leading currency exchange rates that could offer some potential for their predictability. We employ a rolling window approach in order to capture the correlation dynamics for different window lengths and analyze the distributions of periods with statistically significant correlations. We find that for sufficiently large window lengths these distributions fit well to power-law behavior. We also measure the predictability itself by a hit rate, i.e. the rate of consistency between the signs of the actual returns and their predictions, obtained from a simple correlation-based predictor. It is found that during these relatively brief periods the returns are predictable to a certain degree and the predictability depends on the selection of the window length.

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1. Introduction

Recent empirical studies suggested that returns of financial time series depart from the random walk hypothesis by showing a certain degree of long-term or short-term dependent relationships, thus violating the weak-form efficient market hypothesis [1–3]. The efficiency/non-efficiency can, for example, be assessed by evaluation of the Hurst exponent [4] or the approximate entropy [5], as measures of long-term memory and randomness in time series. Since the efficient market hypothesis in its weakest form implies that the returns should be serially uncorrelated, its validity can also be assessed by looking for evidence of significant linear [6, 7] and non-linear [8] serial autocorrelations (henceforth, correlations) in the returns. A systematic review of literature on the weak-form market efficiency of stock markets using a wide array of statistical tests, such as the linear serial correlations, unit root, low-dimensional chaos, nonlinear serial dependence and long memory was provided by Lim and Brooks [9]. However, the market efficiency vary with time and the character of pos-
sible serial dependencies is not known. Moreover, they are of transient nature, showing up in random intervals just for a short time, which makes it difficult to exploit them for prediction purposes [10].

In several previous studies [10–13] the non-linearities were investigated by calculation of the bicorrelation test statistic, due to Hinich [14], and performing the windowed-test procedure [15, 16]. In order to capture the time variation, the data were split into a set of non-overlapping windows, the length of which was set to some ad-hoc fixed value. However, considering the episodic and transient nature of the correlations, these may or may not be detected, depending on the window length used. Furthermore, the window length also influences the onset and offset of the significant correlations. Shorter lengths facilitate quicker response to changes in the correlation strength and can help pinpoint the arrival and disappearance of the transient dependences, but on the other hand, they may lack adequate statistical power.

In order to track the evolution of market efficiency over time, a rolling-window approach has been adopted to calculate a time-varying Hurst exponent [17–20]. Lim [21] has proposed a similar rolling window approach for computing the bicorrelation test for various stock markets [22, 23]. It was shown that the market efficiency is not a static property that remains unchanged throughout the entire estimation period. Thus, examination of the presence of significant correlations in the rolling sample framework can provide a useful tool for tracking the changing degree of weak-form market efficiency over time as well as for its ranking among different markets. In the currency exchange market, Brooks and Hinich [24] found that Sterling exchange rates are characterized by transient epochs of dependencies surrounded by long periods of white noise.

The objective of this paper is to study the dynamics of the linear and non-linear serial dependencies in financial time series, using a portmanteau test procedure in a rolling window framework. In particular, we focus on detection of episodes of statistically significant two- and three-point correlations in the returns of several leading currency exchange rates that could offer some potential for their predictability. We employ a rolling window approach in order to capture the correlation dynamics for different window lengths. In comparison with similar previous studies, our new contribution is using tools from statistical physics in order to analyze distributions of the periods with statistically significant correlations and relate them to the predictability obtained from a simple correlation-based predictor.

2. Data

We use hourly average exchange rates per Euro (EUR) on the US dollar (USD), Canadian dollar (CAD), Swiss franc (CHF), British pound (GBP) and Japanese yen (JPY). The sample period is from March 1, 2004 to December 17, 2009 (a total of 37,620 observations). In Fig. 1 we plot the nominal exchange rates of the respective currencies vs the Euro. In Figs. 2 and 3 we show first logarithmic differences of the nominal exchange rates and their frequency distributions, respectively. The histograms and the summary statistics, presented in Table 1, indicate that the data deviate from the normal distribution. This observation is also supported by the Jarque–Bera [25] normality tests, which reject the null hypothesis of normality with very low p-values.

3. Methods

3.1. Detection of significant correlations and bicorrelations in a rolling window

Let $R(t)$ represent the logarithmic returns of the length $N$, defined by $R(t) = \ln(P(t + 1)/P(t))$, where $P(t)$ are the nominal exchange rates and $t$ is a time label, $t = 1, ..., N$. Within the rolling window framework we test for both linear and non-linear correlations in a window of a specified length $n$, that is rolling one point forward eliminating the first observation and including the next one, until the last observation. The data in each window are standardized to have zero mean and unit standard deviation, as follows:

$$x(t) = \frac{R(t) - M_R}{S_R},$$

where $M_R$ and $S_R$ are the sample mean and standard deviation of the window. The window-test procedure [15, 16] uses correlation and bicorrelation portmanteau tests for the detection of linear and non-linear serial dependencies within a time window. The null hypothesis is that the standardized data $x(t)$ in each window are realizations of a stationary pure white noise process. The alternative hypothesis is that the process has some non-zero correlations $C_{xx}(r) = E[x(t)x(t + r)]$ or bicorrelations $C_{xv}(r, s) = E[x(t)x(t + r)v(t + s)]$ within $0 < r < s \leq L < n$, where $L$ is the number of lags. The sample correlations and bicorrelations in a rolling window are calculated as follows:

$$C_{xx}(r) = \frac{1}{n - r} \sum_{t=1}^{n-r} x(t)x(t + r),$$

$$C_{xv}(r, s) = \frac{1}{n - r} \sum_{t=1}^{n-r} x(t)x(t + r)v(t + s).$$