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Time-series analysis of multiple foreign exchange rates using  
time-dependent pattern entropy

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In this study, we used time-dependent pattern entropy (T-DPE) to analyze the instability of daily variations in multiple foreign exchange rates.

The value of T-DPE remaining high in some period indicates confusion in the market from some special event.

In the present paper, we propose a new method to automatically quantify the instability in high-dimensional time series of foreign exchange rates and analyze the correlation between the foreign exchange rates.

The T-DPE of seven foreign exchange rates was found to be high for a long period following the Lehman shock.

We have analyzed data about correlation patterns of the foreign exchange rates when the T-DPE takes values significantly smaller or larger than those of the corresponding random data.

The value of T-DPE remains high for the periods 19 Sep 2008 of the Lehman shock to 18 Sep 2009.

The simultaneous correlation between two  $\{|r_m(t_i)|\}$  becomes larger in the periods.

The increase in the frequency at which  $u_m(t_i)$  takes 1 (upper 4.55% of the cumulative distribution function) is considered to be due to the synchronization of volatility clustering for  $r_m(t_i)$  in the periods. A period in which the value of T-DPE remains high indicates that multiple foreign exchange rates are in an unstable state.

The value of T-DPE remains low for the periods 14 Mar 2012 to 28 Jan 2015.

The simultaneous correlation between two  $\{|r_m(t_i)|\}$  becomes smaller in the periods.

A period in which the value of time-dependent pattern entropy remains low indicates that multiple foreign exchange rates are in a stable state.

T-DPE is obtained from the map patterns  $M(t_i)$  of seven binary symbols  $u_m(t_i)$  that take 1 when  $|r_m(t_i)|$  is an extreme large log-returns (upper 4.55% of the cumulative distribution function) and 0 when  $|r_m(t_i)|$  is normal log-returns (95.45% of the cumulative distribution function).

While the correlation coefficients is obtained from simultaneous correlation between two  $\{|r_m(t_i)|\}$ .

Our T-DPE method was found to be an effective new method, in that it was able to automatically extract periods that were unstable in the past time-series variations of multiple foreign exchange rates.

This method is an especially effective analytical method for time series that are non-stationary and have leptokurtic distributions.

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