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The study of RMB exchange rate complex networks based on fluctuation mode

Can-Zhong Yao *, Ji-Nan Lin, Xu-Zhou Zheng, Xiao-Feng Liu

School of Economics and Commerce, South China University of Technology, Guangzhou, 510006, China

HIGHLIGHTS

- Out degree distributions of fluctuation network follow power-law distribution.
- A frequent mode has a long-range memory characteristic.
- Clustering coefficient and out degree obey approximated negative correlation.
- The transmission route appears partially closed loop, repeat and reversibility.

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ABSTRACT

In the paper, we research on the characteristics of RMB exchange rate time series fluctuation with methods of symbolization and coarse gaining. First, based on fluctuation features of RMB exchange rate, we define the first type of fluctuation mode as one specific foreign currency against RMB in four days' fluctuating situations, and the second type as four different foreign currencies against RMB in one day's fluctuating situation. With the transforming method, we construct the unique-currency and multi-currency complex networks.

Further, through analyzing the topological features including out-degree, betweenness centrality and clustering coefficient of fluctuation-mode complex networks, we find that the out-degree distribution of both types of fluctuation mode basically follows power-law distributions with exponents between 1 and 2. The further analysis reveals that the out-degree and the clustering coefficient generally obey the approximated negative correlation. With this result, we confirm previous observations showing that the RMB exchange rate exhibits a characteristic of long-range memory.

Finally, we analyze the most probable transmission route of fluctuation modes, and provide probability prediction matrix. The transmission route for RMB exchange rate fluctuation modes exhibits the characteristics of partially closed loop, repeat and reversibility, which lays a solid foundation for predicting RMB exchange rate fluctuation patterns with large volume of data.

0. Introduction

As a key macro-variable of economy for global resources distribution, exchange rate together with interest rate, unemployment rate, price index and economic growth rate multi-dimensionally and synergistically influences variation of world economy in both volume and structure. In temporal aspect, exchange rate and other macro variables are probably in a correlative relationship of either lag or lead, and in spatial aspect, exchange rate may vary among countries in different amounts

* Corresponding author.
E-mail address: ycz20120911@gmail.com (C.-Z. Yao).

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and structures. From the perspective of global economy system, their complex, non-linear and dynamic features evolve into an open complex giant system [1]. Since Watts [2] and Barabási [3] respectively proposed works on *Nature* in 1998 and *Science* in 1999, and revealed the property of Small-world and Scale-free, the theory of complex networks has attracted worldwide attention. Additionally, complex networks theory has become an efficient method for detecting complex systems especially for emerging situation, and shed a new light on observing complex fluctuation phenomenon of variables in economic system. For logistics system, Yao et al. [4] have examined the power-law distribution of time intervals for populational warehouse-out operation behaviors, and further verified the fractal characteristics of warehouse-out quantity via visibility graph algorithm.

On topic of RMB exchange rate fluctuation complexity, the empirical research is relatively scarce. Due to managed floating exchange rate and limit available data, the research of fluctuation complexity is mainly concentrated on other financial sequences like the stock market data.

In addition, previous studies seldom characterized the complexity based on complex networks models. As the enhancement of RMB internationalization, a research focusing on complexity of RMB exchange rate fluctuation become increasingly significant. Qin et al. [5] provided an insight into RMB exchange market fluctuation by the multifractal detrended analysis method, and found the effectiveness relationship between mainland onshore market and Hong Kong offshore market. Yang et al. [6] constructed a complex network of US dollar against 6 foreign currencies, and explicitly illustrated the scale-free and hierarchy features, as well as the relationship of scale exponents, HURST exponent, and the multi-fractal feature. Their work about *EURO* against *YEN* could be used for risk estimation of exchange rate, and provided significant support for economic time series analysis based on complex networks.

For literature reviews of methodology, proposed methods for transforming time series into complex networks are sufficiently and widely applied. Zhang et al. [7] proposed a method to characterize dynamics of time series by network model. They first calculated the optimal length of cycles in sequences, and then considered cycles as nodes and relation between cycles as edges. That method could be universally and effectively applied into pseudoperiodic sequences like electrocardiogram sequence [7] and traffic flow [8].

Besides, Lacasa et al. [9,10] introduced visibility graph algorithm into the transformation of the time series and revealed the characteristics between the time series and its corresponding networks. For example, the fractal Brown motion time series correspond to scale-free networks.

The coarse graining mode and regression pattern method are proposed by Gao et al. [11,12] and An et al. [13]. They mainly concentrated on the transmission ability of time series and combined the traditional *Least Square Method* with complex networks models.

Furthermore, Xu et al. [14] focused on local property of different subgraphs within network, and introduced the phase reconstruction algorithm, including phase space reconstruction and critical threshold determination. In addition, Yang et al. have done great works in correlation networks constructed from time series [15] and complexity measures of sequences [16], which have become another effective model for complex networks modeling in transforming time series [17]. Donner et al. [18] utilized the concept of recurrences in phase space, and calculated the recurrence matrix of a time series to construct networks, revealing statistical properties in underlying dynamics.

With the emergence of a large number of high-frequency data, the simple network construction methods or regression methods are considered to be inefficient in terms of data mining and solving the noise problems. However, the coarse graining mode networks may solve the high-frequency data problems partially.

Hao [19] introduced a new method of characterizing complexity by coarse graining, and symbolic sequences. He argued that the emergence of complexity stems from three situations: first, a repeated use of simple rules may emerge into extremely complex behaviors or patterns; second, a projection of physics process from an original high-dimension space into a low-dimension one would probably strike out complexity; third, a misuse of framework of reference may lead to unnecessary complexity.

The symbolic-network model based on coarse graining and symbolization is also demonstrated to be significant for transforming time series into complex networks and it does provide an advantageous attempt for analyzing time series from network perspective. Corresponding to the research Hao stated above, the essence of this process is to transform a relatively complicated sequence in one reference-scale into a relatively simple sequence in another reference-scale, which may be summarized as the scale-transformation via symbolization.

Combining complex networks theory with coarse graining method, we undertake to further investigate the RMB exchange rate sequences.

Additionally, Brida [20] first proposed the method by using symbolic time series for calculating the distance of stock. From then on the symbolic method had been universally used for fields of time series analysis, like crude oil prices networks [21], forex burden on international oil prices [22] and, etc.

Most latest applications of symbolic mode networks just simply transformed the signal trends with equal probability, however, this constant-probability simplifications method would leave out masses of important information and roughly neglect the extent of fluctuation. Still an equal probability separation may lead to over convergence of symbols on a certain ranges. Besides, most of the research described above focused on coarse graining of unique time series, and seldom researched on coarse graining and symbolization of multi-sequences at one time.

RMB exchange rate sequences can be characterized as complexity of fluctuation, and its monetary value is influenced by inflation rate, trade account, interest rate, expectation, arbitrage, accidental events, manipulation and, etc. So far no matter