Physica A xx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Multifractal characterization of gold market: A multifractal detrended fluctuation analysis

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HIGHLIGHTS

- The fluctuating pattern of local and global gold market is studied.
- We employ the multifractal detrended fluctuation analysis for this purpose.
- Results are compared with the generalized binomial multifractal model.
- Origin of observed multifractality is investigated by shuffling and surrogating the data.

ARTICLE INFO

Article history:
Received 25 January 2014
Received in revised form 14 May 2014
Available online xxxx

Keywords:
Multifractality
Detrended fluctuation analysis
Consumer price index
Long-range time correlation
Generalized binomial multifractal model

ABSTRACT

The multifractal detrended fluctuation analysis technique is employed to analyze the time series of gold consumer price index (CPI) and the market trend of three world's highest gold consuming countries, namely China, India and Turkey for the period: 1993–July 2013. Various multifractal variables, such as the generalized Hurst exponent, the multifractal exponent and the singularity spectrum, are calculated and the results are fitted to the generalized binomial multifractal (GBM) series that consists of only two parameters. Special emphasis is given to the possible source(s) of multifractality in these series. Our analysis shows that the CPI series and all three markers series are of multifractal nature. The origin of multifractality for the CPI and Indian market series is found to be the long-range time correlation, whereas it is mostly due to the fat-tailed probability distributions of the values for the Chines and Turkeys markets. The GBM model series more or less describes the time series analyzed here.

1. Introduction

In general, a fractal is a rough or fragmented geometrical shape that can be subdivided into parts, each of which is (at least approximately) a reduced-size copy of the whole. A fractal system is usually described by a scale invariant parameter called fractal dimension [1]. Many fractals arising in nature have a far more complex scaling relation than simple fractals and require a set of parameters to specify the objects. Such objects are known as multifractals. Several approaches have so far been developed and applied to the exploration of fractal properties of nature. For instance, the rescaled adjusted range analysis introduced by Hurst [2,3] (see also [4]), and he himself applied the method to his hydrological study. Due to the difficulty of the rescaled analysis in capturing long-range correlations of nonstationary series, Peng et al. [5] proposed an alternative approach to analyze DNA sequences which is known as detrended fluctuation analysis (DFA). Although the DFA method is widely used to determine monofractal scaling properties, it cannot properly describe multi-scale and fractal

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http://dx.doi.org/10.1016/j.physa.2014.06.076
0378-4371/© 2014 Published by Elsevier B.V.

subsets of time series data. One of the simplest type of multifractal analysis has been developed based on the standard partition function multifractal formalism [4,6]. This is a highly successful method for the multifractal characterization of normalized and stationary measures, but it does not give the correct result for nonstationary time series. Based on a generalization of the DFA method, Kantelhardt et al. [7] introduced the multifractal detrended fluctuation analysis (MF-DFA) for the multifractal characterization of nonstationary time series. As a remarkable powerful technique, MF-DFA has so far been applied to various fields of stochastic analysis, for instance, in markets return analysis [8–15], in geophysics [16–20], in biophysics [21–24], and also in various branches of basics and applied physics [25–30].

The study of financial time series has been the focus of intense research by the physics community in the last years. Nowadays, there are some excellent compilations available on this subject, e.g. [31–33], just to cite some of them. The prime objective of this kind of analysis is to characterize the statistical properties of the time series with the hope that a better understanding of the underlying dynamics could provide useful information to create new models able to describe the real facts. Moreover, such knowledge might be crucial to tackle relevant problems in finance, such as risk management or the design of optimal portfolios. Henceforth our discussion will be restricted to the time series of gold market in China, Indian, Turkey and the global consumer price index (CPI).[1]

Gold being one of the most precious metals is always considered as the safest investment. Presently the fluctuations of gold market seem quite confusing even to the regular traders, and it becomes almost impossible to predict its accurate rise or fall. As we know, over the last 2/3 years gold market increases so rapidly that the gold rate nowadays is approximately double of the average rate of 2010. The market gains its highest value of about 1900 USD/ounce in the year 2011, and the recent value is about 1300 USD/ounce. Moreover, the day-to-day variation of the market is also quite remarkable during the last few years. It is now believed that gold is not a commodity anymore, rather a currency which always maintain an inverse relation with the US economy. So it is quite possible that a part of the change in gold price is really just a reflection of a change in the value of the US dollar. Sometimes such change is insignificant and often the opposite is true. Whatever may be the reason, the dynamical nature of the gold market is quite complex, and one needs to study the time series of gold price from all possible directions in order to understand the underlying mechanism.

In this article we apply the MF-DFA technique to characterize the time series of the gold CPI and the gold market in China, India and Turkey during the period 1993–July 2013. According to the World Gold Council, these three countries are the world's major gold consuming countries in the globe with a combined consumption of about 70% of the total demand. The individual consumptions of these countries are: China 33%, India 28% and Turkey 9%. Hence, it is expected that the CPI of gold is mainly governed by the markets of these three countries. In order to visualize the recent market pattern, we separately analyze the series of about the last three years period—from 2010 to June 2013. Various parameters related to multifractality of the studied time series are computed and are fitted to the two-parameter generalized binomial multifractal (GBM) model [4,16]. Special emphasis is given to the possible origin(s) of multifractality in these series. For this purpose we analyze a randomly shuffled series and a surrogate series corresponding to each of the original series. The article is organized as follows: in Section 2 the MF-DFA methodology is described along with the outlines of the GBM model. In Section 3 we describe the data and the results of our analysis, and the article is summarized in Section 4.

2. MF-DFA methodology

Though nowadays the MF-DFA technique becomes a standard tool of time series analysis, for the sake of completeness we provide in this section a brief description of the method which is followed by the outlines of the GBM model used to compare the empirical data.

Let $\{x_k : k = 1, 2, \ldots, N\}$ be a time series of length N. The MF-DFA procedure consists of the following five steps:

Step 1: determine the profile

$$Y(i) = \sum_{k=1}^{i} [x_k - \langle x \rangle], \quad i = 1, 2, \ldots, N, \tag{1}$$

where $\langle x \rangle = (1/N) \sum_{k=1}^{N} x_k$ is the mean value of the analyzed time series.

Step 2: divide the profile $Y(i)$ into $N_s = int(N/s)$ non-overlapping segments of equal length s. One has to choose the s value depending upon the series length. In the case, the length N is not a multiple of the considered time scale s, the same dividing procedure is repeated starting from the opposite end of the series. Hence, in order not to disregard any part of the series, usually altogether $2N_s$ segments of equal length are obtained.

Step 3: calculate the local trend for each of the $2N_s$ segments. This is done by a least-square fit of the segments (or subseries). Linear, quadratic, cubic or even higher order polynomial may be used to detrend the series, and accordingly the procedure

[1] A consumer price index (CPI) is an estimate as to the price level of consumer goods and services in an economy which is used as a way to estimate changes in prices and inflation. A CPI takes a certain basket of common goods and services, for instance a gallon of gasoline and diesel fuel or an ounce of gold, and tracks the changes in the prices of that basket of goods over time. The gold CPI, according to the World Gold Council [34], is composed of the 5 largest gold consuming country currencies, ranked by and weighted by 3 year average gold demand.

Please cite this article in press as: P. Mali, A. Mukhopadhyay, Multifractal characterization of gold market: A multifractal detrended fluctuation analysis, Physica A (2014), http://dx.doi.org/10.1016/j.physa.2014.06.076