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Multifractal Properties of Interest Rates in Bond Market

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Abstract

In the article, we investigated the multifractal properties of interest rates, which are the core variables in bond market. In a large sample including nearly all the interest rates in China bond market, we found a clear empirical evidence of long-range correlations and multifractality. Furthermore, by tracking the shape of multifractal spectra, we found the dynamics of large price fluctuation is significantly different from that of the small ones, and the spectrum widths of interest rates are related the maturity terms and market development stage. Finally, we destroyed the long-range memories by shuffle the data to detect the underlying mechanisms of multifractality and identified the non-linear temporal correlation to be the major cause.

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Keywords: Fractal; Multifractality; Bond Market;

1. Introduction

As the measure of cost of money in modern financial market, interest rates are crucially important to nearly all countries in the world. Interest rates have become a hot research issue not only for its nature of value-measurement in bond market, but for its importance in monetary policy conduction. The change of interest rates is often cited as the signal of monetary policies tightening or easing. In this way, interest rates significantly influence money supply, lending, stock market, and real economy in the end [1].

In early, interest rates (prices of bonds) and prices of other financial properties are believed to follow random walk, thus price changes are assumed to obey Gaussian distributions. However, recent researches prove that price changes follow a complex distribution with a more obvious peak and fatter tails than Gaussian's. These properties cannot be described by normal economic methods, and recent literature focus on some mathematical or physics methods [2-3]. Some economists and physicists found that interest rates reveal some complex properties, such as long range correlation or memory [4], [6-7], fractals/multifractals [4-5], chaos [8], and so on. Thereby, the interest rates dynamics may be better described by fractals first proposed by Mandelbrot who applied it to agricultural

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commodity spot prices [9]. And fractal analysis has been widely used ever since. Literature proved returns of stock markets have monofractal properties or multifractal properties [10]. He and Chen [11] found that crude oil price also exhibit multifractal properties.

As monofractals cannot describe the multi-scale and subtle substructures of fractals in complex systems, many measures are applied to investigate the multifractality, such as height-height correlation function [12], partition function [13], multifractal detrended fluctuation analysis (MF-DMA, [14]), etc. What's more, many empirical and theoretical researches seek to find out the cause of market multifractality. Usually, there are two major sources of multifractality which can be found in various time series: one is nonlinear temporal correlation for small and large fluctuations; the other is fat-tailed probability distribution of increments.

Although some pieces of empirical literature proved the existence of long-range correlation or monofractal properties in bond market, few results reveal interest rates may embody multifractal properties, not to mention the underlying mechanisms of multifractality or offer plausible explanation to this styled fact in bond market.

In our work, multifractal properties of interest rates are analyzed in a relatively large sample, which includes nearly all the important rates in China bond market. Instead of simply providing empirical evidence, we will investigate the underlying mechanisms of multifractality formation by group the interest rates, and we also proved plausible explanation of multifractality by shuffling procedule (the underlying long-range correlation is destroyed in this way). Our contribution to current literature can be summarized as follows: firstly, we provided a clear evidence of the existence of long-range correlation and multifractality in interest rates; secondly, we reveal the underlying information in multifractal properties by means of statistic; thirdly, we proposed a plausible explanation of multifractality by shuffling the data.

Our paper is organized as follows: the first part is an introduction of background of our research. The MF-DMA method we use is briefly introduced in part two. The monofractal and multifractal analysis are present in part three, and followed part is to study the underlying mechanisms of multifractal. The paper end with a conclusion in section 5.

2. Data and Methodology

Our sample is composed of more than 500 interest rates published by China Central Depository and Clearing company (CCDC) everyday, which includes nearly all the kinds of bonds traded in the interbank market, including not only short-term monetary rates, but also long-term rates, like corporate bonds rates and policy financial bonds rates, and so on. Since we study the fractal property in time scale, the timeline is as long as possible. The study period is from January 1, 2002 to January 11, 2016. The basic data is from Wind Co..
Let us suppose R(i) (i=1,2,…,T) to be the time series of interest rates, where T is the length of the series. The fluctuation is defined as

$$\mathrm{X(t)} = |\mathrm{R(t)} - \mathrm{R(t-1)}|$$

The “profile” is given by

$$\mathrm{Y(t)} = \sum_{i=1}^{t} (X(i) - \bar{X})$$

Divide the profile (length of series is N) Y(t) into $N_s = [N/s]$ non-overlapping segments of equal length s. Since the series length N may not be a multiple of the time scale s, a proper way is to repeat the method from the opposite end. Thereby, $2N_s$ segments are obtained altogether. And then the local trends $p_v(i)$ are calculated by polynomial fit or moving average method. Some literature claimed that the moving average method is better than polynomial fit (), so the moving average method is applied in this paper. In every segment v, we use the original data minus the local trend and get the detrended time series.

$$Y_s(i) = Y(i) - p_v(i)$$