ANALYSIS OF FRACTAL PATTERNS IN THE PRICES OF AGRO–BASED COMMODITIES

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Abstract

This paper aims to investigate whether commodity markets follow a pattern with respect to prices and if they do, then whether this could be determined by using basic fractal theory and determination of Hurst exponent. The determination of Hurst exponent will help us to classify the time series as persistent or anti persistent i.e. how strongly does the time series tend to revert to its long term mean value. This result would thus lead us to understand if prices in the commodity market could be remotely predicted. Hence this fractal analysis can be used to determine the characteristics of the prices in an agro-based economy.

Keywords: Prices; Pattern; Fractal Theory

1. INTRODUCTION

When we talk of patterns with respect to economic variables, the concept of memory comes to play instinctively. As per the Concept of Dynamic Memory in Economics by Valentina V. Tarasova and Vasily E. Tarasov, "the concept of memory is considered from the standpoint of economic models in the framework of continuous-time approach". With this approach in mind, we have attempted to investigate if prices in the Indian Agro-Based commodity market tend to show this behavior of possessing a long term memory. The investigation in this paper is streamlined towards the market for onions in the National Capital Delhi region. (Tarasova and Tarasov, 2017)

On an average, the last few years have seen fluctuations and volatilities in all sectors of the Indian Economy. This includes some notable price variations in the commodity market. For an agro-based economy like India, even the slightest changes in the agro-based commodity market can prove to be detrimental to the country's growth. Amongst all the agro-based products, onions nevertheless, have shown a high degree of instability in prices. Hence a study on onion prices in the Indian Economy might lead to a good insight into whether the market, in general, can be remotely predicted.

The paper is inspired by the Fractal Market Hypothesis (FMH) which analyses the daily randomness of the market and focuses on the price movements of assets and to understand the same, the Hurst Exponent approach has been used which is explained in detail in the methodology of the paper.

This paper would unfold a suitable algorithm to find the Hurst exponent using statistical methods, specifically linear regression and time series analysis, wherein time is the independent variable and price of the commodity considered is dependent. The reason why time series analysis is chosen is because of the tendency of a time series to regress strongly to its mean. The statistical measure chosen to classify time series is the Hurst exponent. (Subir Mansukhani, 2012)

2. LITERATURE REVIEW

It is quite evident that India has always been an agriculturally driven economy with an enormous section of its GDP being derived from agriculture and allied activities. Politically speaking, a lot of emphasis is laid upon policies that are directly targeted towards the welfare of the agriculture sector. Agricultural price policies in India are aimed at poverty alleviation and food security and hence have played a pivotal role in the country's development ever since Independence. With this aspect in mind if a pattern is found to exist in the prices of agro-based commodities, then this could lead to path-breaking developments in the formulation of new policies for the sector.

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In pursuit of finding such a pattern, the mathematical concept of fractals seemed not just the most intriguing but also the most suitable concept. A fractal is a never-ending pattern that is self-similar. Fractal patterns were first used in investment wherein research proved that stock markets follow a repeatable, cyclical fractal-like pattern.

This motivated us to extend this approach to agro-based commodities as the results could be quite fruitful to the economy. Based on the belief that history repeats itself, the Fractal Market Hypothesis focuses on the price movements of assets. Through the course of this research, if a similar fractal-like pattern is found to persist in the specified commodity market, then the hypothesis which previously was known to be applicable only for financial markets, will find a new domain of existence. (Kristoufek, 2012)

The research is streamlined towards the market for onions, taking onion as a representative of the agro-based commodities. Onion was chosen as the prime commodity since India is the second-largest producer of onions after China and in India, onion is more than just a vegetable. Apart from being a diet staple and hoarder's favourite, onion prices are often used as an indicator of inflation – and the attendant anger aimed at the government in charge. Moreover, onion prices have always been a mystery, as recent reports have suggested that onion prices have risen despite increased production which makes it relevant for research as it can be studied (to some extent) independent of external factors. (Ahluwalia, 2015).

It has to be noted that a similar research was done in the Chinese economy by eminent mathematicians Yi Wang, Xin Su and Xueli Zhan in 2015 taking celery as a prime product which concluded that the price series of the same was multifractal and that this result could be safely used to deal with price prediction and risk assessment in future.

Moreover, the research is inspired by V. Tarasova and Tarasov, 2015 paper on the concept of dynamic memory in economics and it seemed quite innovative to apply such a concept using mathematical methods to solve an economic problem. Lastly, the paper by L. Kristoufek, 2012 gave a detailed analysis of the Fractal Market Hypothesis being used to give reasonable predictions about the dynamics of financial markets, which served as a driving force for this research.

3. METHODOLOGY

3.1. Hurst Exponent

In order to investigate the existence of any such patterns in the agro-based commodity market, we have used the Hurst Exponent approach. The Hurst Exponent (H) can be used to quantify the character of randomness exhibited in a time series via an autocorrelation measurement.

$0 < H < 0.5$ represents anti-correlated behavior between variables
$H = 0.5$ represents a process that is purely random
$0.5 < H < 1$ represents positively correlated behavior and the persistence of definite patterns.

Autocorrelation function can be obtained by $C=2^{2H-1} - 1$, which is used to describe the influence of the present on the future. The Fractal Dimension can also be calculated from Hurst exponent by using the simple relation $D=2-H$, which is a statistical quantity that gives an indication of how completely a fractal appears to fill space, as one zooms down to finer and finer scales. (Wang, Su and Zhan, 2015 and Mansukhani, 2012)

3.2. Data Collection

Onion prices for the years 2013-2017 are considered. This data set has been derived from the official website of the Consumer Affairs Department of the Government of India. The daily retail prices for Delhi for the month of July, August and September were observed and analysed. Onion is grown as an annual crop in India. Therefore it was suitable to take these three months such that the external factors do not differ month-wise.

3.3. Method: Determination Of Hurst Exponent By Monofractal Analysis

(R/S) Analysis has been used to apply monofractal analysis which basically consists of finding the Hurst exponent.

The algorithm of finding Hurst exponent using R/S analysis is the following :

1. Split the time series of size N into disjoint subsets of time intervals T_a(a=1,..., A), each of size n. Calculate the mean of values of the commodity in each of these subsets denoted by $\overline{x_a}$. Also, each value to the corresponding time value is represented by $x_{i,a}$, i=1,...,n.

2. The cumulative deviation $\widehat{x_{k,a}}$ (k=1,...,n) is calculated for each T_a.

3. Range $R_a = \max(\widehat{x_{k,a}}$, k=1,...,n) - $\min(\widehat{x_{k,a}}$, k=1,...,n)

4. S_a= Standard Deviation for each T_a

5. $(R/S)_n$= average of R_a/S_a for a=1,..., A.
Then on applying linear regression to the equation
$$log(R/S)_n = log\ c + H\ log\ n, (c = constant) \quad (1)$$
the value of H, Hurst exponent is estimated. (Wang, Su and Zhan, 2015)

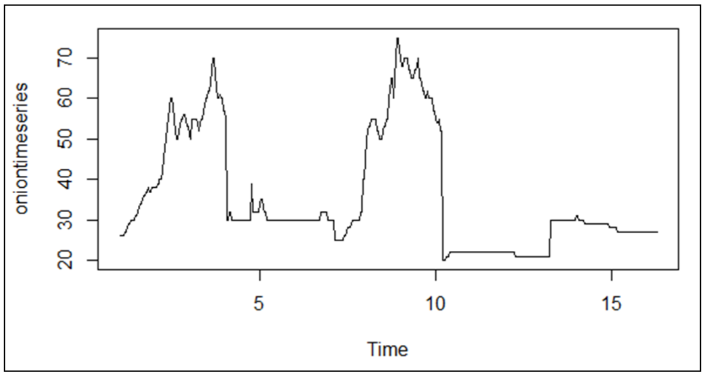
4. RESULTS AND ANALYSIS

4.1. Data

Figure 1 is the price graph of daily retail prices (in Rs. per kg) of onions in Delhi from the year 2013-2017 for the months of July, August and September.

Here, the x-axis represents the time period and the y-axis represents the price per kg in INR. The graph has been plotted using R software.

***Figure 1**: Daily retail prices (in Rs. per kg) of onions in Delhi from the year 2013-2017 for the months of July, August and September*



Source: Plotted by authors in R software using data from the official website of the Consumer Affairs Department of the Government of India.

4.2. Monofractal Analysis Results

***Table 1**: Monofractal Analysis Results*

Year	Value of Hurst exponent(H)	$C=2^{2H-1}-1$ (Autocorrelation function)	D=2-H (Dimension)
2013	0.8096	0.5360	1.1904
2014	0.5028	0.0039	1.4972
2015	0.6175	0.1769	1.3825
2016	0.5281	0.0397	1.4719
2017	0.8018	0.5195	1.1982

Source: Authors' calculation

Table 1 lists the Hurst exponent values for each year from 2013-17. It also lists the autocorrelation function value and fractal dimension for each year. Autocorrelation function value describes the influence of present on the future. Fractal dimensions indicate how completely a fractal appears to fill up space as one zooms down to finer and finer scales. Also, as it is clear from the values calculated in the table, fractal dimensions are fractional in nature unlike dimensions of shapes in classical geometry.

Hurst exponent has been calculated by running a suitable code in R software.

Since the Hurst Exponent for each year is greater than 0.5, therefore the variations are not completely random and can be predicted in short terms. The variations show fractal characteristics.

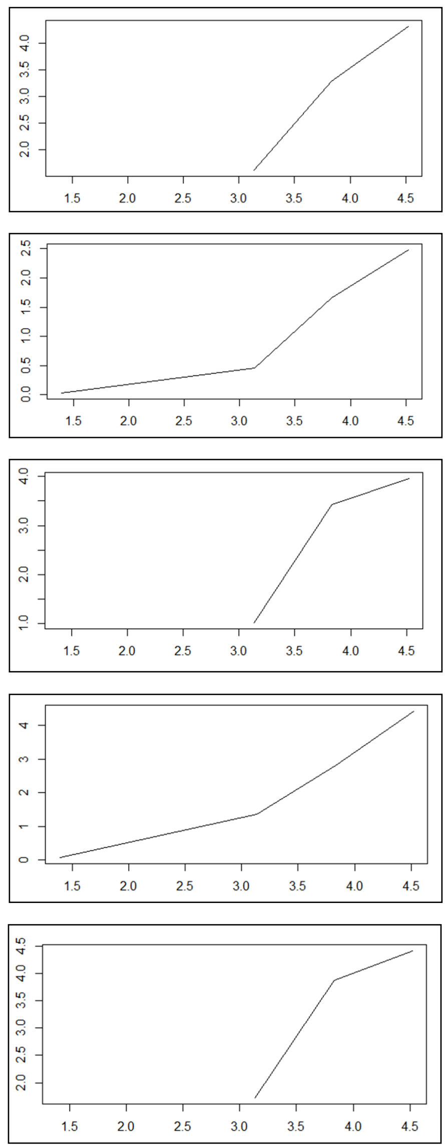
V statistic is given by:

$$V_n = \frac{(R/S)_n}{\sqrt{n}}$$

V_n vs log(n) graph is used here to test for the stability of the Hurst exponent. If the process is persistent, the graphs should be upward sloping.

The following are V_n versus log(n) graphs for each year:

***Figures 2-6:** V_n versus log(n) graphs for each year*



Source: Authors' calculation

Since the V_n versus log(n) graphs for all the years are upward sloping, and it was claimed that the process is persistent, therefore the stability of the Hurst exponent is established. (Wang, Su and Zhan, 2015)

5. CONCLUSIONS

By the values of the Hurst Exponent derived for onions for the year 2013-17 for the months of July, August and September, it is evident that the prices exhibit fractal characteristics. Therefore, the retail onion price series is Monofractal i.e. the price series is fractal in one characteristic of the fluctuation.

So, further scope of this research includes extending this analysis to Multifractal Analysis which can describe more than one characteristic of the fluctuation.

It can be observed that the fractal dimensions calculated are fractional in nature, unlike the usual dimensions which are natural numbers.

We also conclude that the time series of onion prices is persistent in nature. This may or may not be generalised to the other agro-based commodities of the Indian market but this fractal analysis can be used to determine the characteristics of the prices in an agro-based economy. Lastly, this result could be of benefit to the policymakers of India while drafting policies targeted towards the agriculture sector since this paper proves that prices can be remotely predicted and that they are not completely random. Hence agricultural price policies could be made more efficient via the scope of this research.

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