JASSA

Journal of Applied Science in Southern Africa
The Journal of the University of Zimbabwe

Volume 6 • Number 2 • 2000 **ISSN 1019–7788**

CONTENTS

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Vol. 6 No. 2 • 2000
ISSN 1019–7788

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Published by University of Zimbabwe Publications
P.O. Box MP203, Mount Pleasant, Harare, Zimbabwe

Typeset by University of Zimbabwe Publications
Printed by Mazongororo Paper Converters

Random walk and the Zimbabwe capital markets

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The normal distribution is by far the most important distribution in applied statistics. This paper is concerned with the validity of its use in studying and analyzing the financial markets data within the Zimbabwean context. It will be shown that the use of the normal distribution for Zimbabwean data is dubious and conclusions drawn from such analysis can be misleading.

Keywords: returns, random walk, efficient market, chaos theory.

Introduction

Some points should be made clear at the onset. Firstly, it is important to understand that in the analysis that follow, we shall not be using data from the indices, but rather the data on returns generated by these indices. The second point pertains to the importance of this study. The assumption of returns following a normal distribution has been accepted and used for the past three decades or so, but only a few years ago did this assumption come under very close scrutiny. This is true whether we are dealing with portfolio analysis (Single Index theory, Multi Index theory — which are forms of regression analysis) or Brownian Motion (Black-Scholes model and derivative). In this paper we shall not concern ourselves with the economic situations prevailing during the period the data was recorded. Lastly, time series analysis or plots for this data will not be relevant to the arguments which we wish to advance concerning the Zimbabwean markets. Recent trends internationally have prompted the study of the Zimbabwean markets.

The 'efficient markets' theory has been the pillar and justification, in investment finance, for using probability theory to analyze capital markets. This is true for the developed countries and the USA. The efficient market hypothesis simply says that the markets are priced so that all public information, both fundamental and price history, is already discounted for. This means that prices move only because of new information, and so today's change in prices is only because of today's unexpected news. The news from the previous day is no longer important, and so today's returns are unrelated to yesterday's returns. That is, the returns are independent. Now, if returns are independent they are random variables and hence follow a random walk (and so we have a Markov process). If large enough data on returns is collected, in the limit the probability distribution becomes the normal distribution (this can be understood by applying the Central Limit Theorem). One is thus justified in using the normal distribution in studying stock returns.

This the random walk version of the EMH (Efficient Market Hypothesis); in many ways, it is the most restrictive version. Market efficiency does not necessarily imply a random walk, but a random walk does imply market efficiency. Therefore, the assumption that returns are normally distributed is not necessarily implied by the efficient market. (Peters, 1996) We shall look at the data from the Zimbabwe Industrial Index and briefly at the Mining Index, which shall represent our markets, and see if the assumption of normality for the data can be justified. If the market returns turn out to be normally distributed then we may apply the statistical methods for normally distributed random variables. On the other hand, if these returns are not normally distributed, we then have a problem in correctly interpreting the results in any study that assumes normality for Zimbabwean data.

A brief history of the Zimbabwe stock exchange.

The first Stock Exchange in Zimbabwe was opened in Bulawayo by the so-called pioneer column in 1896.This Exchange lasted for only six years, that is up to 1902, at the end of the South African war. In the same year, 1896, another Exchange was established in Mutare. The Mutare Exchange lasted a little longer than that in Bulawayo, but just like the Bulawayo one, it was forced to close down in 1924. In January 1946 a new Exchange was founded in Bulawayo. A second trading floor was opened in Harare in 1951. The period between 1972 and 1973 saw the preparation of new rules and regulations which were to govern the Exchange. The Zimbabwe Stock Exchange Act reached the statute book in January 1974. The present Exchange, therefore, dates from the passing of that act in January 1974. The present day Exchange consists of 74 registered companies, 8 of which form the Mining Index while the remaining 66 constitute the Industrial Index.

Materials and Methods

Daily data for the Zimbabwe Industrial Index was obtained from the Zimbabwe Stock Exchange. This data is from 1990 up to 2000, which is a total of 2 015 data points. The method used to come up with this index is just adding up the shares of the 66 companies and the weight assigned to each company (in the summation) is found by dividing the grand total of the 66 companies by the company's number of shares. A similar method is used to calculate the Mining Index. The methods used in the analysis of data are quite simple. We first convert index data to data on returns. The data on returns is the one we shall work with. If we let R_m stand for the returns on the index, where *m* stands for the market, then

$$R_m = ln\left(\frac{S_i}{S_{i-1}}\right)$$

where S_i stands for the market level on day *i* and *ln* is the natural logarithm. Observe that one point in our data set is lost when using this formula to calculate R_m. A **histogram** of the data is constructed as a first check for the correctness of the normal distribution for our data. A normal probability curve is superimposed on this histogram as a visual aid in comparing the two graphs. Since a reasonable good fit using a histogram can be subjective, it is not a good method of determining the distribution of our data. A much more powerful visual display is to plot the values of the returns against the corresponding percentage points of a normal distribution. Such plots are called **probability plots** or **P-plots**. In our case it is called a normal probability plot. The method is as follows: let **r** be the rank order of an observation (some return in our case) in a batch of **n** observations sorted from smallest to largest. We estimate an expected normal value corresponding to that observation (return) as the standard normal value corresponding to the probability (r-0.5)/n. We plot this value on the vertical axis against the value of the observation on the horizontal line. Graphical visualization is always the first step in data analysis. The next step is to employ some well established statistical methods to check our results. We will check for normality using Lilliefors Test. This is a modified Kolmogorov-Smirnov procedure.

Lilliefors test for normality

Let $X_1, X_2, \ldots, X_n$ be a random sample of size n from a population with a unknown distribution function $F(x)$. We need to test whether $F(.)$ is $N(\mu, \sigma^2)$ for any μ and any σ^2. We can state this as a hypothesis test, with the null hypothesis H_0 and the alternative hypothesis H_1 given by

$$H_0 : F(x) = \Phi\left(\frac{x-\mu}{\sigma}\right) \textit{ versus } H_1 : F(x) \neq \Phi\left(\frac{x-\mu}{\sigma}\right)$$

where Φ (.) is the standard normal distribution function. The Liliefors test standardizes the data set using estimates of μ and σ, forming $Z_1, Z_2, \ldots, Z_n$ with

$Z_i = \dfrac{x_i - \bar{x}}{s}$ where

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \text{ and } s^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2$$

Let F_n (z) be the empiric distribution of the $Z_1, Z_2 \ldots, Z_n$. Lilliefors **test statistic** is

$$D_n = \sup_z \left|F_n(z) - \Phi(z)\right|$$

To test H_0 versus H_1 at level α, reject H_0 if $D_n > d_{n,\alpha}$, where $d_{n,\alpha}$ is such that

$$P_{H_0}\left(D_n > d_{n,\alpha}\right) = \alpha$$

The asymptotic critical points are:

α	$d_{n,\alpha}$
0.01	$\frac{1.031}{\sqrt{n}}$
0.05	$\frac{0.886}{\sqrt{n}}$
0.10	$\frac{0.805}{\sqrt{n}}$

Consult Dudewicz and Mishra for more details. Since *skewness* measures the asymetry of a distribution and *kurtosis* measures the degree of peakedness, we shall include these measures for comparison with the standard normal distribution. Since the normal distribution is symmetric about the mean, its skewness is 0, while the kurtosis is 3.

Results

The graphs below were produced using statistical package Systat on a Macintosh and the analysis was done in Minitab for windows version 13. Figure 1 shows the histogram of the daily returns of the Industrial Index. Superimposed on this histogram is the graph of the normal density function.

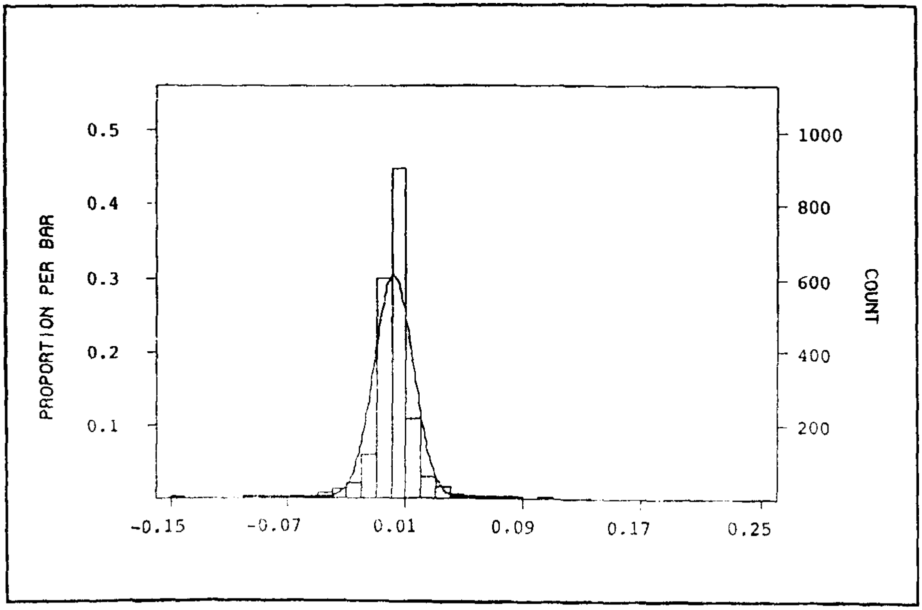

Figure 1

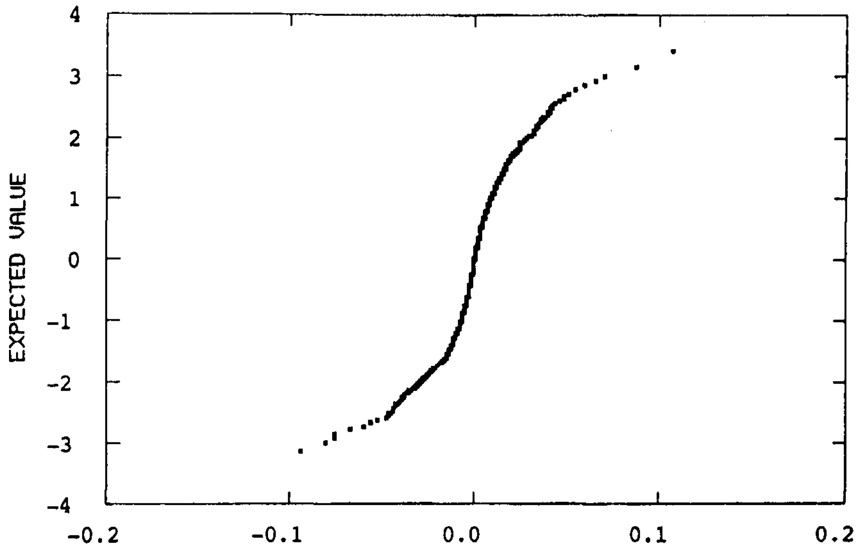

Figure 2

Figure 2 is the normal probability plot of the Industrial Index. The Lilliefors test for normality shows that for the Industrial Index.

$$D_n = \sup_z |F_n(z) - \Phi(z)| = max\ (0.129048, 0.129545) = 0.129545.$$

Discussion

The first thing to notice in Figure 1 is that the peak of the histogram is much higher than that predicted by the normal distribution. Actually, the kurtosis of the data was found to be 16.84 as compared to 3 for the normal distribution. We also observe that the normal curve drops below the points of the histogram as it touches the base line, which is a sign of fat tails for the histogram as compared to the normal curve. In fact, skewness was found to be −0.89 which means that the distribution for this data is skewed to the left and asymetric. The scale on the right (COUNT) helps in showing the number of cases in each bar. The scale on the left (PROPORTION PER BAR) is the proportion of the sample in each bar of the histogram. Figure 2 shows the normal probability plot of the returns from the index. For a normal distribution we would expect the points of the plot to lie approximately on a straight line. The points plotted in Figure 2 do not lie on a straight line. This true even if we ignore some of the tail points. Actually, the P-plot is 'S' shaped. This represents a strong violation of the normal assumptions for the returns. The Lilliefors test for normality shows that for the returns of the index

$$D_n = \sup_z |F_n(z) - \Phi(z)| = max(0.129048,\ 0.129545) = 0.129545.$$

At level $\alpha = 0.05$ and for $n = 2014$,

$$d2014{,}0.05 = \frac{0.886}{2014} = 0.01974$$

Since $D_n > d_{n,\alpha}$ we reject H_0. That is, the sample did not come from a normally distributed population. In fact, the null hypothesis is rejected at levels $\alpha = 0.01$ and $\alpha = 0.1$ as well. Since the Mining Index consists of 8 companies some of which do not trade for months, with some almost collapsing (Mhangura), data from this index is not suitable for this analysis. However, the Lilliefors test was run for the daily returns calculated from this index. The data was compiled daily from 1990 to 1997, that 1800 data points.
The results obtained for this index were:

$$D_n = \sup_z |F_n(z) - \Phi(z)| = max(0.19379{,}0.19435) = 0.19435.$$

With $n = 1799$,

$$d_{1799,0.05} = \frac{0.886}{2014} = 0.01974$$

Here too, H_0 is rejected at all the above values of α.

Conclusion

We have shown that the assumption of the normal distribution for the returns is suspect in the Zimbabwean market. These results greatly weaken the use of the normal distribution for the Zimbabwean market. Since the normal distribution has a stable and finite variance, the use of the standard deviation to define risk is acceptable when returns are normally distributed. But what happens now, given that the market returns are not normally distributed? This question and its answer has far reaching consequences since all the analysis for the past 40 years or so has been based on the normal assumption for the returns. This has been true for large economies such as that of the USA. Even in such large capital markets people have started questioning the normal assumption for returns. The notion of approximately normal is no longer acceptable. Numerous studies have been carried out in the USA using the Dow Jones and the Standard and Poor indices and results have turned out that the returns are not normally distributed (Turner and Weigel, 1990). The next logical step is to find the correct distribution for the returns.
A distribution that has been proposed is one of the Stable Pareto distributions. This was suggested by Mandelbrot in 1964. The problem with this family of distributions is that the variance may be infinite or undefined. Now, if this is the true distribution of returns, then we cannot use the standard deviation as a measure of risk. These distributions are sometimes referred to as Fractal distributions. In the economic

literature they are called Pareto or Pareto-Levy distributions. We need much research of these distributions with respect to local data. The word 'fractal' suggests that we are entering the area of Chaos Theory. Indeed, this seems to be one area which needs to be investigated in our search. There have been suggestions in this direction and Edgar Peter's book should be our starting point. Since the Zimbabwean market is relatively young and thin, we have the chance of ratifying the situation right at the onset. The other point that has been highlighted is that the methods that are proper in some given market may not be proper in other markets. That is, we must resist the temptation of using some methods, which may be very suitable in other markets, without first scrutinizing the underlying assumptions. This may be a sound warning to those involved with market analysis in Zimbabwe.

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