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Original Research Article

Circular Methods on Forecasting Risk & Return of Share Market Investments

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ABSTRACT

Statistical measurements developed on covariance of two or more random variables or autocorrelation of a random variable were used in forecasting stock returns. Capital Asset Pricing Model (CAPM) is a model based on covariance analysis. Vector Auto Regression Model and Auto Regressive Integrated Moving Average Models are models based on auto correlation. Risk of returns was measured by standard deviation or beta factor of CAPM. Literature reveals the incapability of CAPM in measuring risk and return. Time series data are generally auto correlated; as such standard deviation is not a suitable measurement for risk of returns. This study was focused to develop suitable models for forecasting risk and returns of share market investments. Two new forecasting techniques; Circular Model and Circular Indicator were developed. Circular Model was based on Fourier transformation, Circular Indicator was based on Newton's law of uniform circular motion. Suggested methods were tested by using Sri Lankan share market returns. Results revealed the success of both methods in Sri Lankan context. It is recommended to test the suggested methods on more share markets. Also the methods can be tested on wave like patterns find in fields of medicine, agriculture, meteorology etc.

Key Words: Circular Model, Circular Indicator, Fourier Transformation.

INTRODUCTION

Scientific forecasting in share market returns has a long history going back to 1950's. With the increasing importance in forecasting share returns and risk, a large number of studies focused on it from all over the world. Those studies can be broadly categorized into two parts: as studies based on statistical techniques and soft computing techniques (Ayodele, Aderemi & Charles, 2014). Statistical techniques are again subdivided into fundamental analysis based studies and technical analysis based studies (Konarasinghe & Pathirawasam, 2013). Fundamental analysis involves analyzing the economic factors or characteristics of a company; namely, company value, company earnings, book-to-market equity etc. in order to forecast the share returns. Technical analysis is interested in the price movements and trading volume in the market to forecast share returns. Artificial neural networks (ANNs) and Neuro-fuzzy are soft computing techniques widely used in stock market forecasting.

Forecasting stock returns by technical analysis goes back to findings of Osborne (1959). Osborne's study was based on Brownian motion which is also known as particle theory. Osborne (1959) applied the Brownian motion in stock market and laid the first mile stone to Technical analysis. Osborne (1959) showed that logarithms of common stock price changes also have a probability distribution similar to a particle in Brownian motion. Followed by Osborne (1959), a large number of studies were focused on modeling stock prices or returns based on Vector Auto Regression (VAR) models, Auto Regressive Integrated Moving Average (ARIMA) models, Generalized Auto Regressive Conditional Heteroscedasticity (GARCH) and Artificial Neural Network (ANN). A limited number of studies were based on Spectral analysis.

Covariance plays a key role in financial economics. Covariance is the measure of the degree to which returns on two or more risky assets move in tandem. A positive covariance means that the asset returns move together. A negative covariance means returns move inversely. Study of Markovitz (1952) was the first study based on covariance analysis in forecasting returns and risk of assets. According to the author, expected value is the measurement of return, variance is the measurement of risk. For example, the expected value and variance of returns of a single asset is;

$$E(R_i) = \sum_{i=1}^{n} r_i P(r_i)$$

$$Var(R_i) = E(R_i^2) - [E(R_i)]^2 \quad (1)$$

Markowitz (1952) was the base of the development of CAPM, given by the formula;

$$E(R_i) = R_f + \beta(R_{m,} - R_f) \quad (2)$$

Where R_i is the return of ith company assets, R_m is the return of total market, R_f is the risk free rate of return and $\beta = \frac{Cov(R_{i,} R_m)}{\sigma_m^2}$. The β coefficient is the risk factor introduced in CAPM. It is considered that, if β = 0, share price is not at all correlated with the market, therefore no risk. If β = +1, an average level of risk. If β >1, security returns fluctuates more than the market returns, therefore high risk. If β<1, asset inversely follows the market.

According to the literature, CAPM and VAR models were successfully applied in forecasting stock returns in a large number of stock markets. But most of them were developed markets and few were emerging markets. ARIMA also gained importance in forecasting share prices or returns in the recent past. Notably fewer applications were in Spectral analysis.

Spectral analysis was initially established in natural sciences such as physics, engineering, geophysics, oceanography, atmospheric science, astronomy etc. and was not much used in the field of economics. Granger & Morgenstern (1963) was the first recorded application of spectral analysis in financial markets. Authors have tested the periodic function;

$$R_t = V_t + a\cos\omega t \quad (3)$$

Where R_t is the return on period t and V_t is the trading volume on period t. But the results of the study were not successful as expected. It was difficult to find the studies applying spectral analysis on forecasting stock returns. As Granger & Hatanaka (1964) emphasized, it may be due to the lack of understanding in advanced mathematical techniques: trigonometry, calculus and complex numbers. However, Konarasinghe & Abeynayake (2015), Konarasinghe Abeynayake & Gunaratne (2016-a) and Konarasinghe Abeynayake & Gunaratne (2016-b) have shown the success of Spectral analysis in forecasting stock returns. But they have recommended extending their method for further clarification.

Research Problem

If the observations of a data series are independent, then the variance or standard deviation is a suitable measure of dispersion. But time series data are generally auto correlated, as such, variance may not be appropriate in measuring the risk of returns. On the other hand, the existence of covariance between individual company returns (R_i) and total market returns (R_m) were debated by large number of scholars. Konarasinghe, Abeynayake & Gunaratne, (2015) have shown that the above relationship does not exist for many share markets, including Sri Lankan. Therefore ability of β coefficient as a risk measurement is doubtful. Hence the study was focused to extend the method of Konarasinghe, Abeynayake & Gunaratne, (2016-b) for forecasting returns and developing a method for measuring the risk of returns.

MATERIALS AND METHODS

Sri Lankan share market, Colombo Stock Exchange (CSE) is taken as the population of the study. The population consists 20 business sectors : Plantation (PLT), Oil palms (OIL), Land & Property (L&P), Motors (MTR), Manufacturing (MFG), Telecommunication (TLE), Stores supplies (S&S), Trading (TRD), Services (SRV), Power & energy (P&E), Investment trust (INV), Hotels & Travels (H&T), Heath care (HLT), Footwear & Textile (F&T), Information Technology (IT), Diversified Holdings (DIV), Construction engineering (C&E), Chemicals and Pharmaceuticals (C&P), Beverage Food and Tobacco (BFT) and finally Bank, Finance and Insurance (BFI). A random sample of five business sectors was selected and a random sample of sixteen companies was selected, representing them. Daily closing share prices of companies from year 1991 to year 2014 were obtained from CSE and monthly average returns were calculated.

Outliers are the extremely large or small values outside the overall pattern of a data set. Outlier detection and adjustment are essential in data analysis. Boundaries of outliers are defined in many ways. Following rule is often used in outlier detection (Attwood, Clegg, Dyer & Dyer, 2008).

$$L = Q_1 - 1.5 * IQR$$
$$U = Q_3 + 1.5 * IQR \qquad (4)$$

Where Q_1, Q_3 are the lower quartile and upper quartile respectively, IQR is the inter quartile range, L is the lower boundary and U is the upper boundary. Any data value above U or below L was considered as outliers. Such data points were adjusted by taking moving average of order three, using a computer program written in MATLAB.

Accuracy of this program is based on two assumptions;

i. First three values of the array are not being outliers.
ii. Three consecutive outliers not being occurred.

Outliers were manually adjusted, when one or two of the assumptions were violated.

Statistical Methods and Terminology Used in the Study

This study is based on the motion of a particle in a horizontal circle and the Fourier transformation. A particle P, moving in a horizontal circle of centre O and radius a is given in Figure 1. ω is the angular speed of the particle at time t.

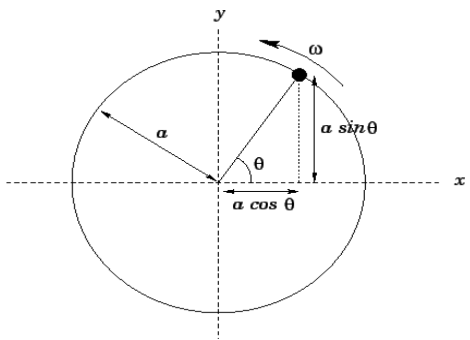

Figure 1: Motion of a Particle in a Horizontal Circle

Fourier transformation is in-cooperated to a uniform circular motion of a particle in a horizontal circle and basic trigonometric ratios. Konarasinghe & Abeynayake (2015) has shown that the individual company returns of Sri Lankan stock market follow wave like patterns. They have used Fourier transformation along with the multiple regression analysis to forecast returns.

This study used the forecasting technique of Konarasinghe & Abeynayake (2015) for modeling individual company returns. The tested model is named as "Circular Model" which is given by the formulae;

$$R_t = \sum_{k=1}^{n} (a_k \sin k\omega t + b_k \cos k\omega t) + \varepsilon_t \qquad (5)$$

$$\omega = \frac{2\pi f}{N} \qquad (6)$$

Where a_k and b_k are amplitudes, f = number of peaks / troughs of series, N= number of observations in the series.

When the particle moves in a circle, it is constantly changing its direction. Even though the particle is moving under the acceleration with a changing direction, it does not leave the circular path. Therefore, there should be force acting towards the centre of the circle which prevents particle leaving its locus. This force is named as the centripetal force (Hooker, Jennings, Littlewood, Moran & Pateman, 2009). If the centripetal force is high, particle is more stable in its motion.

When Newton's second law of motion, $F=ma$ is applied towards the centre;

$$F = ma\omega^2 \qquad (7)$$

Hence, centripetal force (F) is directly proportional to the mass and square of the velocity, but inversely proportional to the radius of the circle. In other words the stability of a motion of a particle depends on mass of the particle, its velocity and radius of the circular motion. This law is widely applied in explaining; satellites orbiting the Earth, planets orbiting the Sun, motion of a vehicle in a circular path, motion in a banked track, Playground Merry-go-Rounds etc.

Assuming mass of the particle (per share return) as 1 unit, equation (7) is modified as;

$$F_{i,t} = r_{i,t} \,.\omega_{i,t}^2 \qquad (8)$$

Where $F_{i,\,t}$ is the force on returns of i^{th} company at time t, $r_{i,t}$ is the radius of the circular motion of i^{th} particle at time t and $\omega_{i,\,t}$ is the angular speed of the circular motion. By Newton's second law; larger the $F_{i,,t}$ higher the relative stability of a company in market performances. As such $F_{i,,t}$ can be taken as the risk measurement of the market performances. This $F_{i,,t}$, is named as the "Circular Indicator" of the motion.

It can be shown that the radius of the reference circle is equals to the amplitude or height of the wave. Hence $r_{i,t}$ was taken as the average of the radii;

$$r_i = (\sum_{k=1}^{n} | a_k | + | b_k |) / n \qquad (9)$$

Peak detection of waves of returns and model fitting were done by software MATLAB.

Goodness of fit tests and measurements of errors were used in model validation of the study. The goodness of fit of a statistical model describes how well it fits a set of observations. Plots of residuals versus fits, Auto Correlation Functions (ACF) and Partial Autocorrelation Functions (PACF) of residuals and Ljung-Box Q statistics (LBQ) were used to test the independence of residuals. Histogram of residuals, Normal probability plot of residuals and Anderson Darling test were used to test the normality of residuals.

Measurements of Forecasting Errors

Forecasting is a part of a larger process of planning, controlling and/ or optimization. Forecast is a point estimate, interval estimate or a probability estimate. One of the fundamental assumptions of statistical forecasting methods is that an actual value consists of forecast plus error; In other words, "Error = Actual value - Forecast". This error component is known as the residual. A good forecasting model should have a minimum average of absolute error and zero average of error mean because it should over forecast and under forecast approximately the same (*Stephen, 1998)*.

Measuring errors is vital in forecasting process. Measurements of errors are divided into two parts; Absolute measures of errors and Relative measures of errors. Some absolute measures of errors namely are Mean Error (ME), Mean Absolute Deviation (MAD), Sum of Squared Errors (SSE), Root Mean Squared Error (RMSE) and Residual Standard Error (RSE). Some relative measures of errors are: Percentage Error (PE), Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MAPE).

R*elative measures become undefined when data set contains value* zero. In this study, stock returns (R_t) were calculated by formula;

$$R_t = \left(\frac{P_t - P_{t-1}}{P_{t-1}} \right) 100 \qquad (10)$$

Where; P_t is the share price at time t. If share prices of two consecutive periods are equal, then the return becomes zero. As such, relative measurements of errors were not used in the study.

RESULTS AND FINDINGS

Fourier transformation is a linear transformation. A transformation moves all the points in (x, y) plane according to some rule. A special property of linear transformation is that, it involves only linear expressions of x and y (Attwood, Cope, Moran, Pateman, Pledger, Staley & Wilkins, 2008). Rotations, reflections and enlargements are examples for linear transformation. Fourier transformation employs rotation. Discrete version of the Fourier transformation is a static model. It has been applied to explain the regular waves in Physics. It is modified to describe the wave patterns associated with randomness as shown in formula (5);

$$R_t = \sum_{k=1}^{n} (a_k \sin k\omega t + b_k \cos k\omega t) + \varepsilon_t$$

Amplitudes of the series, a_k and b_k are experimentally calculated in Physics. As it is not possible in applications, this study employs multiple regression technique for the purpose; regressing R_t on $sink\omega t$ and $cosk\omega t$ for k is from 1 to 6.

Model (5) was tested on monthly returns of sample of sixteen companies. Summary of best fitting models are given in Table 1;

Circular model was fitted for twelve out of sixteen companies. All four companies of sector PLT, four out of five companies of L&P, and three out of four companies of BFT were among them. RMSE and MAD of all the fitted models were small. Residuals of the models were normally distributed and uncorrelated. As such fitted models are suitable for forecasting.

Angular speed (ω) is obtained by a MATLAB program. Radius of the circle is calculated by fitted models. Circular Indicator was calculated for each company for year 2014; given in Table 2.

Largest *CI* in the table is of the company EAST and the smallest *CI* is of the company DISTIL. Accordingly the most stable company in market performance is EAST; while least stable company is DISTIL.

Table 1: Summary of Fourier Transformation in Forecasting Returns.

Sector	Company	Best Fitting Model	Model Fitting		Model Verification	
			RMSE	MAD	RMSE	MAD
PLT	AGAL	$R_t = -0.5995 + 2.1701\sin 3\omega t - 2.549.\sin 5\omega t$	8.8	7.1	7.8	5.9
	BALA	$R_t = 0.07576 - 2.5256 \sin 3\omega t$	8.54	6.7	8.26	6.04
	BOGA	$R_t = 0.2733 - 3.1889 \cos 3\omega t$	9.3	7.3	8.6	6.7
	WATA	$R_t = -1.3162 - 2.2455 \cos 6\omega t$	7.9	6.3	6.6	5.3
L&P	CLAND	$R_t = -0.930 - 1.476 \cos 6\omega t$	7.8	6.1	6.9	5.6
	EAST	$R_t = -0.34951 - 4.3751\sin 5\omega t$	10.1	7.9	9.3	7.1
	EQIT	$R_t = 0.5024 - 2.1354\sin \omega t$	7.9	6.4	9.1	7.2
	PDL	$R_t = 0.1549 - 1.4199\sin 5\omega t - 1.4872\cos 6\omega t$	5.7	4.6	5.2	4.1
	KELSEY	Model does not fit				
C&P	LANK	$R_t = 0,0525 + 2.1114\sin \omega t$	10.5	8.3	8.8	7.3
	CIC	Model does not fit				
DIV	JKH	$R_t = 0.43027 + 2.2917 \cos 3\omega t$	7.35	5.88	4.53	3,43
	RICHA	$R_t = -0.35993 + 1.5138 \cos 5\omega t$	7.35	5.93	5.43	4.53
	CARSO	Model does not fit				
BFT	BREW	$R_t = 1.665 + 2.4188 \sin 4\omega t$	8.3	6.6	6.0	4.6
	DISTIL	$R_t = 0.0179 + 1.47 \cos 6\omega t$	6.96	5.57	4.59	3.61
	NESTL	$R_t = 1.5412 - 1.4092 \cos 3\omega t$	4.44	3.51	4.11	3.21
	CCS	Model does not fit				

Table 2: Circular Indicators (*CI*) of Returns

Sector	Company	Angular Speed (ω)	Amplitude (r^*)	Circular Indicator (*CI*)
PLT	AGAL	1.217	2.359	6.777
	BALA	1.691	2.525	10.790
	BOGA	1.605	3.188	16.328
	WATA	1.267	2.245	6.392
L&P	CLAND	1.466	1.476	3.194
	EAST	1.363	4.375	26.105
	EQIT	1.112	2.135	5.068
	PDL	1.498	1.453	3.165
C&P	LANK	1.2828	2.111	5.718
DIV	JKH	1.424	2.291	7.479
	RICHA	1.472	1.513	3.373
BFT	BREW	1.5466	2.418	9.048
	DISTIL	1.193	1.479	2.612
	NESTL	1.424	1.409	2.828

CONCLUSIONS

Objectives of the study were two fold; test Circular Model of Konarasinghe & Abeynayake (2015) for forecasting returns and develop an indicator for measuring risk of returns. Sample of sixteen companies, representing five business sectors of CSE were used for the analysis. Results revealed that the Circular Model (CM) is suitable in forecasting returns of all the five sectors. It was concluded that the CM is suitable for forecasting returns of all the business sectors of CSE.

Circular Indicator is a new approach for measuring risk of returns. It was developed on the basis of Newton's law of circular motion in physics. As such Circular indicator is a suitable measurement for risk of returns.

Both Circular model and Circular indicator are applicable only if the returns follow wave like patterns, without any trend. It is recommended to extend both techniques for de-trended data, when trend appears.

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