GEOMETRIC BROWNIAN MOTION BASED NEW HYBRID STATISTICAL APPROACH FOR STOCK MARKET FORECASTING

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Abstract

Capital Investments in the stock market is the easiest and fastest way of building the healthy financial foundation for future life. In the past few decades, stock markets around the world have become more institutionalized and advanced as the main forms of investments for making profit investments in numerous organizations as well as individuals to arrange their large investment funds to the general public. As a result, the stock market prediction has become one of the great challenges caused by its complexity and eruptive nature. Generally, stock prices are chaotic and show both linear and nonlinear behaviors. Therefore, the accuracy of the forecast might be enhanced by modeling the non-linear behaviors of the series as well. The main purpose of this study is to take an attempt to understand the behavioral patterns as well as seek to develop a new hybrid forecasting approach based on Geometric Brownian Motion (GBM) for estimating price indices in Colombo Stock Exchange (CSE), Sri Lanka. Indeed, the Autoregressive integrated moving average (ARIMA) approach is used as a comparison mode. The current study was carried out on the basis of CSE daily trading data from January 2010 to May 2018 were extracted and tabulated for calculations. Because of the nonlinear behavioral patterns in the CSE, the mean absolute percentage error analysis results suggested that new proposed hybrid model (HGBM) is highly accurate than traditional ARIMA (HGBM (0.521%) < ARIMA (7.18%)) for forecasting one day ahead predictions. Furthermore, the results reveal that, the new proposed model is more significant for investors to make their investment decisions precisely.

Keywords: Geometric Brownian Motion, ARIMA, Hybrid model and Colombo Stock Exchange

Introduction

Capital Investments in stock market is the easiest and fastest way for building healthy financial foundation for future life. In the past few decades, stock markets around the world have been becoming more institutionalized for making profit investments (Abraham, 1986). Currently, the numerous organizations as well as individuals have been arranging large investment funds to make profit in the general public (Asteriou, 2011). As a result, the stock market prediction has become one of the great challenges caused by its complexity and eruptive nature.

In the modern world, the global growth of market prices has been changing in a highly volatile fluctuations under the irregular manner (Sayanthan, 2005); especially, it is common phenomenon that, when the company has obtained their capital needed, the shareholders will benefit through dividends paid by companies (Rathnayaka, 2014).

Numerous types of methodologies have been available in the literature to estimate the market predictions under the high volatility such as high order fuzzy algorithms, Markov- Fourier Grey Models, Auto regressive moving average methods (ARMA) and clustering, Genetic Fuzzy systems etc (Tilakaratne, 2010)(Dutta, 2007). The ARMA is a basic model that can be applied only for forecasting data under the stationary conditions. Because of the poor forecasting ability with non-stationary behavioral, miscellaneous types of new methodologies have been generalized from ARMA model under the different conditions (Cortez, 2004). Among them, autoregressive integrated moving average (ARIMA) and their extensions are significant.

Because of the complications regards to the traditional time series approaches, the main purpose of this study is to take an attempt to develop new hybrid forecasting approach to handle incomplete, noise and uncertain data estimating in the multidisciplinary systems. In this purpose, Artificial Neural Network (ANN) and Geometric Brownian Motion (GBM) are mainly used. Indeed, the ARIMA model is used as a comparison mode. The proposed methodology is successfully implemented for forecasting price indices in the Colombo Stock Exchange (CSE), Sri Lanka.

Problem Definition

The study was carried out on the basis of secondary data, which were obtained from Colombo Stock Exchange official database, Annual statistical reports from Central Bank of Sri Lanka, different types of background readings, other relevant sources and etc. Colombo Stock Exchange (CSE) is one of the modernized stock exchange in the South Asian region with a fully automated trading platform. It maintains market capitalization over US$23 billion with average daily turnover rising to over US$18 billion.

This study mainly takes an attempt to predict future patterns in the CSE under the new proposed Geometric Brownian Motion (GBM) frame work. The rest of the paper is set out as follows. The estimated methodology is described in section II. The Section III presents the experimental findings and ends up with concluding remarks with Section IV.

Methodology

The Highly volatility with instability patterns are common phenomenon in the finance today; especially developing stock market in the south Asian region. As a practice, the innumerable micro and macro-economic conditions with market conditions directly affected on high volatility. The proposed methodology is consists of two major parts as artificial neural network and GBM based new hybrid approach and model comparison study based on traditional time series methods.

Geometric Brownian motion with Ito's Lemma Approach

The Geometric Brownian motion approach is one of the popular data mining task which can be used for making the proper decisions in finance today; especially financial data under the high volatility (Ali, 2011).

As a result of high volatility and unstable patterns, the traditional time series forecasting approaches can't achieve successes in both linear and non-linear domains. So, the proposed new hybrid methodology composed with two main phases based on their linear and non-linear domains as follows [1] (Wang, 2002).

$$Y_t = L_t + N_t \tag{1}$$

Where; L_t and N_t denote the linear autocorrelation and non-linear component of the time series pattern Y_t respectively (Rathnayaka, 2014). In the initial step, the GBM with Ito' lemma approach approaches is used to forecast the stock market indices under the stationary and non-stationary conditions (Ho, 1998).

As a next step, the residual of the linear component is evaluate using the equation (2) (Zhang, 1998).

$$e_t = Y_t - \widehat{L_t} \quad (2)$$

Where e_t denotes the residual of the GBM and $\widehat{L_t}$ presents the forecasted value of the estimated time series at time t. However, if we can see any non-linear behavioral patterns in residuals, as a next step, the ANN modeling approach is used to discover the non-linear behavioural patterns (Rathnayaka, 2014).

$$e_t = f(e_{t-1}, e_{t-2}, e_{t-3} \ldots, e_{t-n}) + \varepsilon_t \quad (3)$$

$$\widehat{y_t} = \widehat{L_t} + \widehat{N_t} \quad (4)$$

Where n represents the input nodes and f is the non-linear function which determined based on ANN approach.

The proposed hybrid model exploits the unique feature of ARIMA, GBM and ANN in determining different patterns. Tues, it creates an additional advantage to model linear and nonlinear patterns separately by using by separate models and then combine the forecasts to improve the overall modelling performances.

Error Implementation

The current study, MAE and MAPE are utilized to evaluate the accuracy one-step ahead forecast. The error measures are as follows (Rathnayaka, 2014).

$$\text{MAE} = \left| P_i - \widehat{P}_i \right| \quad (5)$$

$$\text{MAE} = \left| \frac{P_i - \widehat{P}_i}{P_i} \right| \quad (6)$$

Where P_i and $\widehat{P}_i$ are the actual value of the original series and predicted value from the proposed hybrid model respectively. The smaller values of these error measures are considered to find the more accurate forecast result among the focused models.

Results and Discussion

Data Preprocessing

The study was carried out on the basis of secondary data, which were obtained from Colombo Stock Exchange official database, different types of background readings, other relevant sources and etc. Two principal price indices namely ASPI and SL 20 daily trading data from September 2010 to November 2014 were extracted and tabulated for calculations. The data sample of this section is partitioned into two stagers. In the ASPI estimation stage, first 85% of 1453 daily observations were used during the training and the remaining 257 (about 15% of the sample) were considered as the out of sample. As same as in SL 20 scenario, out of 802 observations the first 682 observations (about the 85% of the sample) were allocated as training sample and the rest has been used for testing the validity of model. The visual inspection of the daily ASPI pattern in Figure 2 indicates that the data observations contain considerable noise with significant non-linear trend with considerable volatility during the sample period of time.

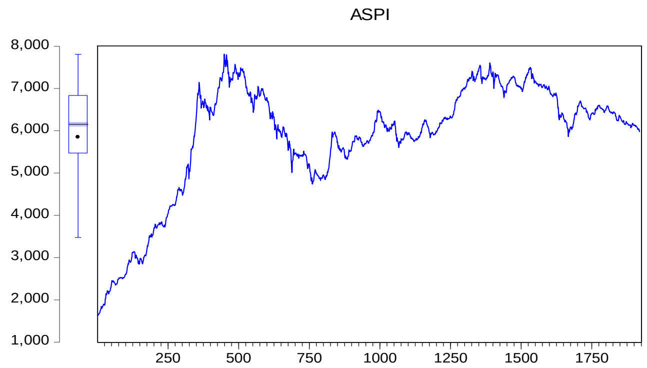

Figure 01: Time Series Plot of ASPI

To compare the unit root performances based on three different unit methods, ADF, PP and KPSS test methodologies are applied under the 0.05 level of significance.

Table 1 : Unit Root Test Result for Testing the Variable

Level Data			t-statistic	Prob*.
	Augmented Dickey-Fuller test statistic		-2.0347	0.5811
	Test critical values:	1% level	-3.9646	
		5% Level	-3.4130	
		10% Level	-3.1285	
	Phillips-Perron test statistic		-2.2123	0.4817
	Test critical values:	1% level	-3.9646	
		5% Level	-3.4130	
		10% Level	-3.1285	
	KPSS test statistic (LM Test)		0.6547	
	Asymptotic critical values*	1% level	0.2160	
		5% Level	0.1460	
		10% Level	0.1190	
1st Difference	Augmented Dickey-Fuller test statistic		-29.916	0.0000
	Test critical values:	1% level	-3.9646	
		5% Level	-3.4130	
		10% Level	-3.1285	
	Phillips-Perron test statistic		-30.2394	0.0000

	Test critical values:	1% level	-3.9646	
		5% Level	-3.4130	
		10% Level	-3.1285	
	KPSS test statistic (LM Test)		0.13079	
	Asymptotic critical values*	1% level	0.21600	
		5% Level	0.14600	
		10% Level	0.11900	

According to the Table 1, intercept (0.3335>0.05) and trend component (0.5525>0.05) of the model is not significant under the 0.05 levels. Furthermore, the result clearly indicated that, the ASPI can be categorized under the non- stationary random walk.

Data Modeling and Forecasting
To find more accurate results, best two forecast horizons of 85% training sample sizes are used and their error measures MAE and MAPE are summarized in Table 02.

Table 02: Forecasting Performances

Model	One-step-ahead Forecast	Actual Value	Error Accuracy Testing		
			MAD	MSE	MAPE(%)
ARIMA	7017.05	7020.8	3.75	14.06	0.053
GBM	7021.67		0.87	0.75	0.012
ANN-ARIMA	7018.506		2.29	5.26	0.038
ANN-GBM	7020.572		0.22*	0.05*	0.003*

*denotes the model with the minimum error values

The Table 02 results suggested that, 85% testing sample gives the best performance with minimum MAD, MSE and MAPE (%) with 0.228, 0.051984 and 0.324 respectively. Furthermore, results show that while applying neural networks alone can improve the forecasting accuracy over than single ARIMA and GBM.

Conclusions
Economical Time series models are widely used to develop the economic relationships, especially for the nonlinear models under the stationary and non-stationary frameworks. Different type of research studies have been carried out to find the best forecasting methods to predict long and short term predictions in the real-world applications; especially under the areas in finance and investments.
The current study was carried out on the basis of CSE daily trading data from January 2010 to May 2018 were extracted and tabulated for calculations. Because of the nonlinear behavioral patterns in the

CSE, the mean absolute percentage error analysis results suggested that new proposed hybrid model (HGBM) is highly accurate than traditional ARIMA (HGBM (0.521%) < ARIMA (7.18%)) for forecasting one day ahead predictions. Furthermore, the results reveal that, the new proposed model is more significant for investors to make their investment decisions precisely.

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