

# REVIEW OF STATISTICAL MODELING IN TECHNICAL ANALYSIS OF FINANCIAL MARKETS

**WGS. Konarasinghe**

*Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka.  
sinasisi@gmail.com*

## ABSTRACT

*Predictability of asset returns in share market has been an immense interest over the past decades and Statistical Modeling has been playing a vital role in it. This paper reviews statistical modeling in Technical Analysis of financial markets. Linear and non linear regression models, Vector Auto Regression (VAR) Models and Spectral analysis found tested on share return and trading volume. Some common weaknesses were identified in reviewed articles. Authors have not reported the results of modeling assumptions; independence, normality and homoscedasticity of errors. Model verification criteria and results also not reported. Hence findings of their studies were not reliable. Majority of studies were focused on developed markets and very few attempts on emerging markets. Only two studies were found in Sri Lankan context and their results were contradictory. It is recommended to test GARCH /ARCH models and Spectral Analysis in Sri Lankan context.*

**Key Words:** *Statistical Modeling, Technical Analysis,*

## Introduction

Predictability of asset returns in share market has been an immense interest over the past decades; as such Statistical Modeling has been playing a vital role in financial markets. The methods used to analyze securities and make investment decisions fall into two broad categories. They were Fundamental analysis and Technical analysis. Fundamental analysis involves

analyzing the economic factors of a company while Technical analysis interested in the price movements and trading volume in the market.

Fundamental Analysis based model of asset pricing; which is known as Capital Asset Pricing Model (CAPM) has been subjected to extensive empirical testing in past few decades and showed considerable evidence that not all the markets take the behavior of CAPM. Nimal (1997), Samarakoon (1997) and Konarasinghe & Abeynayake (2014) showed that CAPM does not valid for Sri Lankan share market. But Sri Lankan stock market still depends on CAPM for forecasting returns of listed companies of Colombo Stock Exchange (CSE).

Technical analysis based studies were also very popular all over the world and has been tested on large number of stock markets. But most of the studies were applied researches. It means most of the researchers have attempted to apply existing mathematical / statistical techniques in forecasting returns. They have not tried to improve the existing models or find new knowledge in forecasting. Also technical analysis based studies were very limited in Sri Lankan context.

In order to improve existing methods or find new methods for forecasting returns, it is essential to understand the existing methods and models. As such current study was focused on mathematical perspective of previous research in technical analysis in financial markets. Objectives of the study were; understanding the various mathematical / statistical models used in technical analysis of financial markets and critiques some of the previous studies from the mathematical point of view.

## **Significance of the study**

Share trading is an important part of the economy of a country. Whenever a company wants to raise funds for further expansion or settling up a new business venture, instead of taking loans it can issue shares of the company. On the other hand an investor can get the part ownership of the company through buying shares. This gives him/ her vote at annual shareholder meetings, and a right to a share of future profits. Investors have the ability to quickly and easily sell securities. This is an attractive feature of investing in stocks, compared to other less liquid investments such as real estate. In a stock trading system, forecasting is the most important activity that helps to judge the market risk and grab scarce opportunities. As such predictability of asset returns in share market has given an immense interest over the past decades.

Literature shows considerable evidence that CAPM is unable to explain market returns of many share markets of the world, including Sri Lankan share market. Technical analysis approach also has been widely used and was successful in many developed markets, but the same was not true for emerging markets. Technical analysis based studies were very limited in Sri Lankan context. Konarasinghe & Pathirawasam (2013) and Konarasinghe & Abeynayake (2014) have done technical analysis based studies for Sri Lankan share market, but were unable to find suitable technique for forecasting. As such there exists a knowledge gap in forecasting share returns in Sri Lankan share market as well as some other markets. This study will pave the path for finding new knowledge in forecasting returns and help to fill the knowledge gap.

## **Methodology**

Scientific forecasting in any field of study is based on mathematical modeling. A mathematical model is a simplification of a real world situation into an equation or a set of

equations. Process of designing a mathematical model is split into several stages. They are; a real world problem is observed, a mathematical model is devised, real world experimental data is collected, real world expected behavior is predicted by mathematical model, predicted and observed outcomes are compared and the mathematical model is refined (if necessary).

Mathematical models have many classifications; “Deterministic models Vs Stochastic models” is one of them. A deterministic model is one in which every set of variable states is uniquely determined by parameters in the model and by sets of previous states of these variables. Deterministic models are not associated with any randomness, therefore less realistic. A model which randomness is present and variable states are described by associated probability distributions is called stochastic model. In general stochastic models are known as statistical models.

Scientific forecasting in share markets has a history going back to 1950's. Study of Osborne (1959) was the first recorded study in technical analysis of financial markets. Followed by Osborne (1959), large number of studies was done on price / return- volume relationship using various statistical techniques. This study reviewed number of research articles published between year 1959 and 2014. From the mathematical point of view, those studies were categorized in to several parts as;

- i. Studies based on Fourier analysis.
- ii. Studies based on Regression analysis.
- iii. Studies based on Auto Regression models.

Model fitting procedure and model validation procedure of those studies were considered in critique.

## **Findings**

Forecasting stock returns by Technical analysis goes back to 1950's, findings of Osborne (1959). Osborne's study was based on Brownian motion

which is known as a particle theory too Brownian motion, found by Biologist Robert Brown in 1827 is among the simplest of the continuous-time processes, and it is a limit of both simpler and more complicated stochastic processes. Osborne (1959) showed that logarithms of common stock price changes also have a probability distribution similar to a particle in Brownian motion. According to him,  $Y = \ln[P(t + \delta t) / P_0(t)]$  if where  $P(t + \delta t)$  and  $P_0(t)$  are the price of the same random choice stock at random times  $(t + \delta t)$  and  $t$ , then the steady state distribution function of  $Y$  is,

$$\phi(Y) = \exp\left[-Y^2 / 2\sigma^2\delta t / (\sqrt{2\pi\sigma^2\delta t})\right] \quad (01)$$

He also showed that the expected value of share price of a common stock ( $P$ ) increases with increasing time interval  $\delta t$ , at a rate of 3% to 5% per year and the variance of  $P$  is increasing while depend on number of transactions. Osborne has tried to address the price- volume relationship by assuming number of transactions in a Uniform distribution, but was unable to address the issue.

Followed by Osborne (1959), large number of studies was done on price / return- volume relationship using various statistical techniques. Accordingly, this article is organized as;

- i. Review of studies based on Fourier analysis.
- ii. Review of studies based on Regression analysis.
- iii. Review of studies based on Auto Regression models.

### Review of Studies based on Fourier Analysis

Fourier analysis, also known as Spectral Analysis was originated in the field of electrical engineering. Spectral analysis is a frequency domain type analysis. Fourier transformation was the first transformation between time domain (time series) and frequency domain series.

Granger and Morgenstern (1963) was the first application of Spectral analysis for finding return-volume relationship in a share market.

Authors have used weekly data of New York stock market for the period 1939-1961. First Granger and Morgenstern (1963) have tested the periodic function;

$$R_t = V_t + a \cos \omega t \quad (02)$$

Where  $R_t$  is the return on day  $t$  and  $V_t$  is the trading volume on day  $t$ . They found that this periodic function is not suitable and then they have used the Fourier transformation on it. However they could not find any correlation between returns and trading volume.

It was difficult to find any other application of Spectral Analysis in Technical Analysis. It may be due to the complicated nature of the techniques involved. A sound knowledge in Mathematics; Trigonometry, Complex numbers, Calculus etc. are essential in understanding and application of those transformations.

### Review of Studies based on Regression Analysis

Regression analysis investigates and models the relationship between a response variable and one or more predictors. Regression models can be categorized as; simple regression models, multiple regression models and logistic regression models. These can be either linear models or non-linear models. Simple regression and multiple regression models the relationship between numerical variables while logistic regression model the relationship between categorical response variable and numerical or categorical predictors. Ordinary Least Square method is used in parameter estimation of simple/ multiple regressions and maximum likelihood procedure is used in logistic regression.

Price- volume relationships were tested on simple regression and multiple regression models;

$$Y = \alpha + \beta_i X + \varepsilon \quad (03)$$

$$Y = \alpha + \sum \beta_i X_i + \varepsilon \quad (04)$$

Where, (3) is the simple linear regression model and (4) is the multiple regression model.  $X_i$ 's are the predictor variables and  $\varepsilon$  is the random error. In regression analysis it is mandatory to test several assumptions about errors. They are; independence of errors (errors are not serially correlated), normality of errors and homoscedasticity (constant variance) of errors. If any of these assumptions is violated then the forecasts and economic insights yielded by a regression model may be inefficient or misleading.

Study of Crouch (1970) has tested Regression models on daily share price changes and trading volume data. His study based on New York stock exchange, data collection period was seven months, from December 1966 to March 2007. Results of the Crouch (1970) have given evidence for positive linear relationship between absolute price change and trading volume. But  $R^2$  of the models were below 50% for daily data, therefore author had used hourly share price data and trading volume to improve the model. This is clearly a disadvantage of his method, because stock market forecasting is practically not useful on hourly basis. Further his data collection period, which is seven months also not sufficient. It is mandatory test model assumptions; normality of residuals, serial auto correlation of residual and homoscedasticity of residuals, but author has not reported the results of corresponding tests. Also it is essential to do model verification in model fitting procedure, but author has not done model verification too.

Clark (1973) has applied subordinate stochastic process for speculative price changes. In the study he has tested following linear and non-linear models;

$$\Delta P = \alpha_1 + \beta_1 V + \varepsilon \quad (05)$$

$$\log(\Delta P)^2 = \alpha_2 + \beta_2 V + \varepsilon \quad (06)$$

$$\log(\Delta P)^2 = \alpha_3 + \beta_3 \log V + \varepsilon \quad (07)$$

$$Var(\Delta P) = Ae^{cV} \quad (08)$$

Where share price change and  $V$  is trading volume. His study evidenced for relationship between share price change and trading volume. However Clark (1973) has not performed tests on residuals, not done model verification. As such validity of the fitted models is doubtful. At the time of Clark (1973), most of the academics and economists believed that share price changes and share returns are normally distributed. But Clark (1973) found distribution of returns and trading volumes follow Log- Normal distribution.

Study of Timothy (1994) is based on daily All Ordinaries Index (AOI) values and trading volume statistics of Australian stock market from April 1989 to December 1993. He has tested linear and non linear regression models between trading volume and magnitude of return;

$$V_t = \alpha_0 + \alpha_1 |R_t| + \alpha_2 D_t |R_t| + \varepsilon_t \quad (09)$$

$$V_t = \alpha_0 + \alpha_1 |R_t^2| + \alpha_2 D_t |R_t^2| + \varepsilon_t \quad (10)$$

Where,  $R_t$ : return on day  $t$ ,  $V_t$ : trading volume of day  $t$ ,  $D_t = 1$  if  $R_t < 0$ , and  $D_t = 0$  if  $R_t \geq 0$ . His findings support the relationship between price change and trading volume, irrespective of the direction of the price change. Also Timothy (1994) tested trading volume in the context of conditional volatility using Generalize Auto Regressive Conditional Heteroscedasticity (GARCH) framework and showed that GARCH model is suitable for volatility explanations.

GARCH model is an improvement of Auto Regressive Conditional Heteroscedasticity (ARCH) models of Engle (1982). Traditional time series models assume a constant one-period forecast variance. Engle (1982) generalize this implausible assumption, introducing a new class of stochastic processes called Auto-Regressive Conditional Heteroscedasticity (ARCH) processes. ARCH is a mean zero, serially uncorrelated processes with non constant variances conditional on the past, but constant unconditional variances. For such processes, the recent past gives information about the one-period forecast variance.

## Review of Studies Based on Vector Auto Regression (VAR) Models

Vector Auto Regression models were introduced by Sims (1980), as a technique that could be used to characterize the joint behavior of collection of variables. The structure of VAR models is that each variable is a linear function of past lags of itself and past lags of the other variables. VAR models have been used in many fields including financial management.

Timothy (1992) used VAR models on share returns and trading volumes. Weekly data of NASDAQ stock market (an American stock exchange.) from 1972 to 1986 used in model testing. In the study, Timothy (1992) tested following univariate causal models;

$$R_t = \alpha_0 + \sum_{i=1}^n \beta_i R_{t-i} + e_t \quad (11)$$

$$V_t = \lambda_0 + \sum_{j=1}^n \rho_j V_{t-j} + \varepsilon_t \quad (12)$$

$$V_t = \lambda_0 + \sum_{j=1}^n \rho_j R_t^2 + \gamma_j D_t R_t^2 + \varepsilon_t \quad (13)$$

And following multivariate causal models;

$$R_t = \alpha_0 + \sum_{i=1}^n \beta_i R_{t-i} + \sum_{j=1}^n \gamma_j V_{t-j} + e_t \quad (14)$$

Where  $R_t$  is the return of week  $t$ ,  $R_{t-i}$  is the return of  $i$  lag behind,  $V_t$  is the trading volume of week  $t$ ,  $V_{t-j}$  is the trading volume of  $j$  lag behind and  $D_t$  is the dummy variable. He could find no evidence for multivariate causal relationship between returns and trading volume but found evidence for model type (11), univariate causality of returns. Author has been tested regression coefficients, but not tested modeling assumptions and not validated the selected model.

Saatcioglu and Starks (1998) have examined the stock price-volume relation in a set of Latin American emerging markets. They have collected data from six emerging Latin American

stock markets with at least \$5 billion in market capitalization; they are Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela. In their empirical tests, they have employed the monthly value-weighted total return index in both U.S. dollars and local currency for all six markets from January 1986 to April 1995. They have tested VAR models;

$$V_t = \alpha_0 + \alpha_1 \ln\left(\frac{P_t}{P_{t-1}}\right) \quad (15)$$

$$V_t = \alpha_0 + \alpha_1 \left| \ln\left(\frac{P_t}{P_{t-1}}\right) \right| \quad (16)$$

Where the dependent variable ( $V_t$ ) is volume measured by monthly turnover, the percentage of market capitalization traded in a given month, and the independent variable is the natural logarithm of the price relative (or its absolute value) for a given month. They found evidence for return- volume relationship for four of the six markets, but not for all. They also have not performed tests for residuals and not done model validation.

Chordia and Swaminathan (2000) formed set of portfolios based on USA stock databases in order to test trading volume and cross auto-correlations in stock returns. Models tested in the study were;

$$\begin{aligned} R_{A,t} &= \alpha_0 + \sum_{i=1}^k a_i R_{A,t-i} + \sum_{i=1}^k b_i R_{B,t-i} + e_t \\ R_{B,t} &= \alpha_0 + \sum_{i=1}^k c_i R_{B,t-i} + \sum_{i=1}^k d_i R_{A,t-i} + \varepsilon_t \\ R_{0,t} &= \alpha_0 + \sum_{i=-k}^k \beta_{0,i} R_{m,t-i} + v_{0,t} \end{aligned} \quad (17)$$

Where,  $R_{A,t}$ : return on the lowest trading volume portfolio of A on day  $t$ ,  $R_{B,t}$ : return on the highest trading volume portfolio B on day  $t$ ,  $R_{0,t}$ : return of zero net investment portfolio on day  $t$ . Data collection period was 1963 to 1996. Daily and weekly equally weighted portfolio returns were modeled with corresponding trade volumes. Authors have concluded that trade volume is a significant determinant of the cross- auto correlation patterns (lead –lag patterns) in stock

returns. But  $R^2$  of all the tested models were low. They also have not performed model verifications and test for errors. As such their selected models would not have been suitable for forecasting.

Study of Wen-Hsiu, Hsinan, and Chwan-Yi (2004) was similar to the study of Chordia and Swaminathan (2000). Wen-Hsiu et. al.(2004), have used data from the Taiwan stock market from January 1991 through December 2002. Results of their study were different and they did not find a causal relationship between returns and trading volume.

Guillrmo, Roni, Gideon and Jiang (2002) have studied the dynamic relation between return and volume of individual stocks listed on New York Stock Exchange and American Stock Exchange. They have used daily data from 1993 to 1998 and tested the auto regression model with interactions;

$$R_{i,t+1} = \alpha_i + \beta_i R_{i,t} + \lambda_i V_{i,t} . R_{i,t} + \varepsilon_{i,t+1} \quad (18)$$

Where  $R_{i,t}$ : return of  $i^{\text{th}}$  company on day  $t$ ,  $V_{i,t}$ : trading volume of  $i^{\text{th}}$  company on day  $t$ . Results of the study supported the return –volume relationship with interactions.

Gong-Meng, Michael and Oliver (2001) studied the dynamic relation between stock returns, trading volume, and volatility based on daily market price index and trading volume series from 1973 to 2000 for nine largest stock exchanges New York, Tokyo, London, Paris, Toronto, Milan, Zurich, Amsterdam, and Hong Kong. They have tested following bivariate auto regressions;

$$\begin{aligned} R_t &= \alpha_0 + \sum_{i=1}^5 \beta_i R_{t-i} + \sum_{j=1}^5 \gamma_j V_{t-j} + e_t \\ V_t &= \lambda_0 + \sum_{i=1}^5 \rho_i V_{t-i} + \sum_{j=1}^5 \zeta_j R_{t-j} + \varepsilon_t \end{aligned} \quad (19)$$

Where  $R_t$ : return on day  $t$ ,  $V_t$ : trading volume of day  $t$ ,

According to their results, returns cause volume and volume causes returns for some countries,

but not for all. Their findings suggest that more can be learned about the stock market through studying the joint dynamics of stock prices and trading volume.

Jianping, Olesya and Lubomir (2002) examine the dynamic relation between return and volume of individual stocks in Russia and other emerging markets. Their study concentrates on 28 large Russian stocks, which constitute about 93% of the market capitalization of all companies traded on the Russian Trading System (RTS). Daily closing prices daily trading volume from 1995 to 2001 used to test the following auto regression models with interactions;

$$R_{i,t+1} = \alpha_i + \beta_i R_{i,t} + \lambda_i V_{i,t} . R_{i,t} + \varepsilon_{i,t+1} \quad (20)$$

$$\begin{aligned} R_{i,t+1} - R_{m,t+1} &= \alpha_i + \beta_i (R_{i,t} - R_{m,t}) + \\ &\lambda_i (V_{i,t} - V_{m,t}) . (R_{i,t} - R_{m,t}) + \varepsilon_{i,t+1} \end{aligned} \quad (21)$$

Where  $R_{i,t+1}$ : return of  $i^{\text{th}}$  company on day  $t+1$ ,  
 $R_{m,t+1}$ : total market return on day  $t+1$

$R_{i,t}$ : return of  $i^{\text{th}}$  company on day  $t$ ,  $V_{i,t}$ : trading volume of  $i^{\text{th}}$  company on day  $t$

$V_{m,t}$ : trading volume of the market on day  $t$ ,  $\varepsilon_{i,t+1}$ : error on day  $t+1$

They have found strong evidence of return continuation following high volume days, suggesting the presence of private information trading in emerging markets.

Ciner (2003) attempted to find the linkage between trading volume and price of small-capitalization firms in the US and France. The data set consists of daily closing price values and aggregate trading volume for the S&P 600 and the NM stock indices from 1995 to 2002. They have tested the Vector Auto Regressive models including a dummy variable  $D_i$  to account for the day of the week and month of the year effects in stock returns;

Ciner (2003) also confirmed the return- volume relationship for both US and France stock markets.

Xiangmei, Nicolaas and Yanrui (2003) examine the relation between trading volume and stock returns for two Chinese A-share markets and ten individual stocks in the energy sector. The data set comprises daily data on Shanghai A and Shenzhen A share price indexes and volume (turnover) as well as prices and volume data for from 1997 to 2002 and they have tested linear regression models and auto regression models between returns and trading volume. They also have found strong evidence for causal relationship between returns and trading volume.

Kamath (2007)'s empirical investigation examines the causal relations between daily price changes and trading volume changes on the Nascent stock exchange of Istanbul, Turkey. The study has utilized the daily data of the Istanbul Stock Exchange from 2003 to 2006 in order to test the causality between daily index returns and daily volume. The long held view that rising markets tend to be accompanied by rising volume and declining markets tend to be accompanied by falling volume is robustly supported by the evidence uncovered for the Istanbul Stock Exchange. Findings of this study also support the notion that it takes trading volume to make the market index move.

Malabika, Srinivasan and Devanadhen (2008) have examined the empirical relationship between stock price changes and trading volume for selected Asia-Pacific Stock Market. The data set has comprised of seven national stock markets for the period 2004 to 2008. Results of the study have evidenced for significant relationship between trading volume and the absolute value of price changes for most of the selected markets, but not for all.

Sarika and Balwinder (2009), has examined the empirical relationship between return, volume and volatility dynamics of stock market by using daily data of the Sensitive Index (SENSEX) during the period from October 1996 to March 2006. The empirical analysis has provided evidence for causal relationship between volume and return.

The study of Naliniprava (2011) has investigated the dynamic relationship between stock return and trading volume of Indian stock Market and evidenced for bi-directional causality between trading volume and stock return volatility.

Habib (2011) has investigated the joint dynamics of stock returns and trading volume in a small emerging financial market, i.e., the Egyptian Securities Exchange (ESE). His analysis suggested that there is no relation between volume and stock returns.

Ong Sheue and Ho Chong (2011) have examined the short-run linear and nonlinear Granger causality between stock return and trading volume in Malaysia and Singapore cases based on the Vector Autoregression (VAR) model and Taylor expansion of the nonlinear model. They have found evidence for significant bidirectional nonlinear causality between returns and trading volume in Malaysia case while unidirectional nonlinear causality from trading volume to stock return in Singapore.

Marwan (2012) also examined the causal relationship between return and trading volume in the Palestine Exchange using weekly trading volume and returns over the period from October 2000 to August 2010. They have found that the relationship preserves after taking heteroskedasticity into account. Moreover, the results of causality tests show that there is bidirectional causality between returns and trading volume, regardless of the measures of trading volume.

Konarasinghe & Pathirawasam (2013) have tested causal relationship between returns and trading volumes in Sri Lankan share market. Their study was somewhat similar to Chordia and Swaminathan (2000). Monthly total market returns and trading volumes, monthly sector returns and trading volumes from 2005 to 2011 were used for model testing. Results of multivariate tests revealed that there is no causal relationship between market returns and trading volumes. Further they have found that stock returns are auto-correlated and stationary while trading volumes are auto-correlated but not stationary.

## Conclusions and Recommendations

Predictability of share returns in secondary markets is an immense important to the investors as well as the regulators of the market. As such Statistical Modeling has been playing a vital role in financial markets over decades. One of the main strands of forecasting returns is Technical Analysis, which has been in practice from 1950's. This paper reviewed more than twenty five articles based on return- volume relationship on view of identifying various statistical models used in them.

Regression models and Vector Auto Regression (VAR) models were the mainly tested on return/ price –volume relationship all over the world and most of the studies have given evidence for success in forecasting returns. But some common weaknesses were identified in them. Most of the authors have not reported the results of modeling assumptions and model verifications. For examples; test results of independence of errors, normality of errors, homoscedasticity of errors etc were not reported. Model verification criteria and results also not reported. Hence findings of their studies cannot be considered as reliable.

Spectral analysis has been successfully applied in fields, Engineering, Medicine, Physics and many others. But, except Granger and Morgenstem (1963), no other attempt was found in applying Spectral analysis for forecasting share returns.

According to literature, most of the studies were focused on developed markets and very few attempts were on emerging markets. Only two studies could find in Sri Lankan context and their results were contradictory.

It is recommended to test GARCH/ ARCH models and Spectral Analysis in Sri Lankan share market as well as other emerging markets.

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