Testing the S&P/TSX Composite Index for Weak Form Market Efficiency

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ABSTRACT

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In an efficient market, stock prices are accurately priced and the opportunity of making abnormal returns through predicting prices, is impossible. This research, tested the daily closing price of the S&P/TSX Composite Index for weak form market efficiency, from the period of 11th of December 1996 to 11th of December 2019. This was carried out by using tests like Autocorrelation, Ljung box (Q) statistics, runs test, Augmented Dickey Fuller test, Variance ratio test and One-sample Kolmogorov Smirnov test. The Autocorrelation and Ljung box (Q) statistics results revealed that, the stock price movement are not independent. The runs test showed that, there is presence of serial independence, which implies that the stock prices are random. The ADF test is in line with the autocorrelation test and showed that there is no presence of unit root in the S&P/TSX Composite Index (1996-2019), which implies that, there is a trend in the series. The variance ratio test is in line the runs test, as it failed to reject the random walk for all periods observed. We observed that the K-S test, kurtosis and skewness all showed non-normality for the S&P/TSX Composite Index and is also in line with the ADF test. The robust variance ratio test and runs test, are better deterministic factors for the state of efficiency of a stock market. As it test for the presence of random walk. Therefore, the S&P/TSX Composite Index is weak form efficient through time. Hence, investors cannot make abnormal profits by using past data. The study serves as an updated information for investment banks, fund managers and most importantly investors, who are looking to expand their investments.

Key words: Weak Form Market Efficiency, Random walk, Variance ratio, Runs Test

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LIST OF ABBREVIATIONS

EMH: Efficient Market Hypothesis

JB: Jerque Bera

K-S: Kolmogorov Smirnov

ADF: Augmented Dickey Fuller

TSX: Toronto Stock Exchange

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The EMH has been a major issue since the 1960's in the finance literature and the concept of EMH is sound even till today. The logic of RWH is associated with the ideology of the EMH. Equity prices, which are created from public information and the purchase and sale transaction, all serves as a guide for investors in makings decisions on their investment, which are accurate. It also aids in better allocation of funds between companies and helps in providing a stronger economic growth rate (Yartey and Adjasi, 2007). The concept of efficient market and RWH are two vital subjects in terms of explaining the movement of security prices and the behavior of investors within the economy and finance literature (Atakan, 2008).

The idea that the movement of prices are formed randomly in the stock market, and the distribution of the prices are incidental, and hence, cannot be predicted was first suggested by Paul Samuelson (1965) and Fama (1965) which is termed "efficient market hypothesis" and is based on the idea that financial asset prices fully reflect all available information. Both of them stated that, the EMH presumes that stock return arranges for any new information immediately (Kofarbai and Zubairu, 2016). Fama (1970), who pioneered the idea of an efficient market hypothesis, described it as a market in which various rational benefit maximization actively compete, the potential market value of each equity is attempted to be predicted and all the essential current information can be accessed almost cost-free by all market participants (Chuvakhin, 2001). The EMH is finding answers to the issue of how the forms of information such as historical prices, internal information and other data and information will be used to generate above average returns. Fama (1970) categorized market efficiency into three types, based on the levels of data and information availability: weak-form, semi-strong, and strong-form. The weak-form of the EMH assumes that, all historical data should be entirely reflected on the current stock prices such as (historical prices and volumes of trading). Semi-strong form of the EMH, suggests that not only historical information should be fully reflected on recent stock prices, but also newly publicly available information such as: (accounting practices, dividend announcements, and all news whether political or economic) should be fully reflected on recent stock prices. Finally, the strong-form of the EMH suggests that, besides the previous criteria listed in the previous version of the EMH, all information's from both sources whether private or public, should be entirely reflected on the recent stock prices.

The EMH relates to the direction and speed of new information in the market. within an efficient market, if the new information on equity values emerges as a result of investor's contest, the full effect of this information would automatically be reflected on the market prices (Fama, 1970). This research is based on "weak form efficiency" and due to recent information, it is impossible for investors to gain abnormal returns when security prices are applied to the recent information expeditiously and accurately (Nisar and Hanif, 2012).

1.2 THE SIGNIFICANCE/RELEVANCE OF THE STUDY

The stock market performance is seen as a very critical measure for evaluating the economy's performance. Accordingly, stock or equity markets play a significant role in every economy. For an efficient market, stock prices completely contain all important information and therefore, stock returns will demonstrate an unpredictable behaviour. Prices of stocks that are not defined by a random walk, a transient portion dominates the return generation cycle and hence, future returns can be estimated by the historical return sequence. Finally, the potential of stock markets to fulfill the position ascribed to them, which draws international investment, stimulates domestic savings, and enhance the availability and pricing of capital, all depends on the existence of a random walk. A market attributed with a random walk is consistent with equity being properly priced at a level of equilibrium, whereas the absence of a random walk indicates distortion in capital and risk pricing. This has important consequences (implications) for resource (capital) distribution within an economy, and thus, the overall economic growth (Worthington and Higgs, 2006). This implication illustrates what is known as an inefficient market. An inefficient market cannot exhibit the accurate allocation of resources, as this depends on an efficient market. The main purpose to an inefficient market is its incapability to accurately and adequately process and interpret information, and this reallocation of resources is essential for information processing. This gives relevance to this study as the researcher aims at testing the S&P/TSX Composite Index for weak form market efficiency. Understanding the efficiency of a market is of great importance to portfolio investors, policy makers, a country's government and also firms or organizations.

For investors, the idea of market efficiency is very important because it aids them in making more rational choices. The only possible way they can make abnormal gains from investing in various markets is by taking advantage of any anomalies as they arise. Investors may not be able to make above-average gains while the market is running efficiently, but any anomalies should be exploited (Carter, 2011). The efficiency of capital markets acts as a powerful tool in attracting investors, in terms of providing them with a sense of protection, to boost investment and have a positive effect on economic growth and development. On the other hand, inefficient markets may struggle to distribute resources (capital) efficiently and regulatory authorities may call for necessary reforms. Consequently, information about market efficiency has significant implications for an investor's portfolio decisions and investment strategies (Shamshir, Baig and Mustafa, 2018).

Numerous studies have been carried out since Fama's (1965) seminal work, in analyzing the levels of efficiency in developing and developed markets of the world, while using various techniques. (Lo and MacKinlay, 1988; Fama and French, 1988; Poterba and Summers, 1986; 1988) looked at the US market. Working (1934), Kendall and Hill (1953), Cootner (1962), Lee (1992), Lee *et al.*, (2000), Poon (1996) on United States and European developed stock markets. Similarly, Choudhry (1994) examined stock indices of Canada, United States, United Kingdom, Germany, Japan, France and Italy. Alexeev and Tapon (2011), Freund and Pagano (2000) and Shiller and Radikoko (2014) all examined the Toronto stock exchange for weak for market efficiency. Li and Liu (2012) look at group of international markets for weak form market efficiency which also included the Canadian market. Falaye, Frank and Oluwasegun (2018) and Afego (2012) on the Nigerian stock market. On the other hand, Worthington and Higgs (2004) and Borges (2010) studied the developed and emerging European equity markets for the presence of random walk.

This research will contributes to the existing literature in the following ways, Firstly, Some research has been done on the Toronto stock exchange, such as the works of Alexeev and Tapon (2011), Freund and Pagano (2000), Shiller and Radikoko (2014) and Li and Liu (2012), But not a lot of research has been done on the S&P/TSX composite index, which is the benchmark index of the Toronto Stock Exchange. This gives value to this research, as the study will give insight into the S&P/TSX Composite Index and its recent performance and investigate if it is weak form efficient under the period studied. Also, a more robust statistical test such as the variance ratio test which were not implemented in Alexeev and Tapon (2011), Freund and Pagano (2000) and Shiller and Radikoko (2014) works will be employed to validate if the S&P/TSX Composite Index is actually weak form efficient or not. Finally, this research will also be useful to investors who are planning on investing in the Toronto Stock Exchange, as this study will serve as a guide in making proper decision on their investments for the long-term.

From the above understanding, this research aims to test the S&P/TSX Composite Index for weak form market efficiency. It will examine if S&P/TSX Composite Index is attributed with an efficiency in the weak form or not for the period of 1996-2019. The closing daily price of the S&P/TSX Composite Index will be sourced from yahoo finance and the period used for the study is from 11th of December 1996 to 11th of December 2019.

1.3 OBJECTIVE OF THE STUDY

The main objective of this research is to test the S&P/TSX Composite Index for weak form market efficiency. While the researcher's precise objectives are;

- To investigate if the S&P/TSX Composite Index is associated with a random walk movement or not.
- To test if the S&P/TSX Composite Index price movement are independent or not.

1.4 RESEARCH QUESTIONS

From the specified objectives above, the researcher's research questions can be deduced as follows;

- Does the S&P/TSX Composite Index follow a random walk model and could it be efficient in the weak-form?
- Are the price movement of S&P/TSX Composite Index independent or not?

The researcher's hypothesis are as follows;

H_0: The S&P/TSX Composite Index follows a random walk model.

H_1: The S&P/TSX Composite Index does not follows a random walk model.

1.5 ORGANIZATION OF THE STUDY

This research is outlined into five chapters and it is structured as follows:

Chapter one is centered on the introduction, which specifies the background of the study, relevance of the study, objectives of the study and finally the research questions.

Chapter two gives some introductory insight into the literature review. After that, the conceptual framework on market efficiency, random walk hypothesis and the different forms of efficient market hypothesis such as weak form, semi-strong form and strong form will be discussed alongside the S&P/TSX Composite Index. Also, the empirical framework will be discussed and will end with a conclusion to the literature review.

Chapter three will specify the methodology and also the data used. Thereafter, the chapter will explicitly discuss the forms of methodologies that will be utilized and will end with the research design, philosophy, approach and also methods.

Chapter four will illustrate the data analysis of the study. In this chapter, several tests will be implemented such as Descriptive statistics (Jarque-Bera), which will be used to examine the normality of the data series. Autocorrelation test (it entails assessing the correlation coefficient between the S&P/TSX Composite Index stock prices and also the lagged number of the periods of the stock price). The Runs test will also be employed, to examine the serial independence of the stock prices. Variance ratio test (this involves examining the statistical significance of the Z-statistic of the variance ratio for some number of *q*-periods). Also, Augmented Dickey Fuller test will be used to evaluate if the stock prices exhibit any unit root for the period of observation. So, if the data series exhibit a unit root then it is considers non-stationary and as such follows a random walk or otherwise, its stationary and hence, does not portray a random behavior. Lastly, One-Sample Kolmogorov Smirnov test will be introduced to examined the normality of the data series. Thereafter, the results will be interpreted, explained and also conclusion to the study will be drawn.

Chapter five will entail discussing the implications observed from the chapter four results. Thereafter, the chapter will end with discussing the conclusion, recommendations, further research areas of the study and also, the contribution of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The formal description of "market efficiency" was given by Fama (1970 and 1991). He categorized market efficiency into 3 types: weak-form, semi-strong form and strong form. The weak-form EMH states that, stock returns are serially uncorrelated and have a constant mean. In other words, a market is assumed to be weak form efficient if recent prices completely represent all the information contained in historical prices, which means that no investor can create a trading rule focused solely on past price history to gain above average returns. A market is semi-strong efficient if stock prices instantly reflect all recent information available to the public, and Strong form efficient if stock prices reflect all forms of information available to the public or private. This statement is in agreement with Haroon (2012), as he said that, market efficiency analysis is essentially testing how the three general forms of information (past prices, other public information and inside information) can be used to achieve abnormal returns on investments. Hence, irrespective of the forms of efficiency, information is key in determining stock prices. This is relevant because, investors buy stocks solely on information which is available to them and as such, in an inefficient market, investors are able to earn abnormal returns based on the available information, thereby beating the market.

This research will focus critically on the literature review in relation to existing study on this topic. Afterwards, we will discuss the conceptual framework which inculcates market efficiency, efficient market hypothesis, random walk hypothesis and the S&P/TSX Composite Index. Lastly, the chapter will critically discuss existing literatures pertaining to the topic, this will form the empirical framework. In relation to the literature review, hypothesis for the study will be specified.

2.2 CONCEPTUAL FRAME WORK

2.2.1 Market Efficiency

An important feature of capital market is that, it is assumed to be 'Efficient'. A market is said to be efficient if prices in the market reflect all private or publicly available or historical information of the concerned security in the market. This implies that security prices are worth their intrinsic value, which means that, at any given point of time the market price of security exactly equals to the intrinsic value of the security. So, according to the Efficient Market Hypothesis (EMH), security prices reflect all available information and there is no scope for any abnormal gain or abnormal loss on the part of market participants (Sarkar, 2019).

Market efficiency has an effect on investor's investment strategy, since attempting to find winners would be a waste of time because stock markets are efficient. Also, in an efficient market, the best estimate of stock price expected returns and risk by the market will be reflected. Therefore, despite their risk, there will be no undervalued securities producing greater than expected returns. Hence, an investment approach based solely on the portfolio's total risk and return characteristics would be more sensible in an efficient market. Nonetheless, if markets are not efficient, and surplus gains will be made by picking winners correctly, then it would be best for investors to spend time identifying such undervalued securities (Rutterford, 1983, p.282).

When a market is efficient, the market responds rapidly and efficiently (Jones, 2007). In other words, security market prices are accurate security prices that are exchanged in every market and includes all the required information for transaction, and is also impartial to the latest information that comes in. On the other hand, there is a chance that the stock or security may not provide an accurate information, so the investor will not be able to properly interpret the information. This can lead to market inefficiency and the EMH's rejection (Aumeboonsuke and Dryver, 2014).

2.2.2 Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) proposed by Fama (1970), has been one of the most important theories in the field of finance for the last 50 years. According to this hypothesis, in order for the market to be efficient, all information about the stock must be reflected in the prices instantly. In efficient market hypothesis, it is assumed that, the prices of securities are the result of the new information available and that all investors react to the new information coming to the market. For this reason, it is not possible for investors to obtain a continuous return on the market. Thus, it becomes impossible to utilize any set of information in estimating future prices of stocks. Levy (1967) first segregated the market efficiency into two forms – weak and strong, later, further analysis was made by Fama (1970) and divided the efficient market hypothesis into three sub hypotheses – weak, semi-strong and strong depending on the types of information reflected in the stock prices. In order to test the market efficiency, the understanding of the three form of efficiency is important.

Fama (1970) put forward three forms of efficiency which started the discussion on efficient markets and they include:

Weak-Form of EMH:

The Weak form efficiency suggests that, all historical information such as past prices and trade volumes are already incorporated in the current stock prices (Bodie *et al.*, 2007). The weak form efficiency assertion, is very much in line with empirical results on the random walk hypothesis (i.e. changes in prices are distinct from one moment to another) (Dixon and Holmes, 1992). In other words, one cannot obtain a superior profit by analyzing only the information regarding historical prices. Hence, the technical (trend) analysis that is a method used in the derivation of historical price changes, in order to identify a relevant indication to forecast the possible path of a particular stock or stock market that is useless in itself (Jones, 1993). However, by using the fundamental analysis or through insider trading, one can beat the market and earn superior gains in the weak form efficient market.

Semi Strong Form of EMH:

Efficiency in the Semi-strong form claims that, all publicly available information including fundamental data on the company's product range, revenue estimates, dividends, stock split reports, management quality, balance sheet structure, patents retained and accounting practices will be entirely reflected in security prices, in addition to historical prices.

Therefore, using the fundamental analysis on markets which is efficient in the semi-strong form, one will not gain a superior profit. It is clear that technical analysis will not be effective in the semi-strong form efficient market, because if the semi-strong form markets are efficient, it will also be efficient in the weak form, this is due to the fact that historical prices are also regarded as publicly available information (Dixon and Holmes, 1992; Bodie *et al.*, 2007). However, in the semi-strong form of efficiency, insider traders can gain superior profits.

Strong-Form of EMH:

Efficiency in the Strong form claims that, market prices represent all information such as past (historical) prices, information available to the public, as well as all private information (Awan and Subayyal, 2016). In such a market, prices are unbiased and the market cannot be beaten by investors or insider traders (Brealey *et al.*, 1999). Hence, a market that is efficient in the strong form, will be efficient in both the weak form and the semi-strong form. So, technical or fundamental analysts cannot beat the market to yield an abnormal return in the strong form. Therefore, obviously, the strategies that do not work in the weak form and the semi-strong form of efficient markets cannot operate in the strong form.

2.2.3 Random Walk Hypothesis

The Random Walk Hypothesis (RWH) states that, the path of returns on stock prices is random and does not follow any known course or trends, they are likely to rise as they are likely to come down, irrespective of previous performance (Kendall, 1953; Fama, 1965; Samuelson, 1973).
Securities prices are dependent, according to Bodie *et al.*, (2009) and Olweny (2011), on factors that influences expected returns and risk. Information on these factors is published in the market at various intervals, and investors respond to the information differently. Therefore, security prices follow a random walk and thus, no one can correctly forecast (predict) the path and extent of their movement from past price sequences. The key goal of empirical work into the random walk theory, according to Seelenfreund (1968) and Dickinson and Muragu (1994), is to investigate if successive price changes are independently distributed random variables. Therefore, the random walk hypothesis is inextricably connected with EMH (Sunil, 1996). Within an efficient market, all recent information about a company is quickly and rationally integrated into the share prices, in respect to the direction and extent of the movement of the share prices. Security prices have the tendency of fluctuating randomly around their intrinsic values, which completely reflects the new information available in the market. No investor has an edge in forecasting returns on stock prices, because no one has access to information that is not currently available to everyone else and thus, persistent abnormal returns cannot be obtained (Fama, 1976). Accordingly, the concept of weak form efficiency is consistent with RWH, i.e. stock prices moves in a random manner, and price changes are independent. Therefore, if the weak form holds, no one will forecast future prices by earning abnormal returns based on past information, or beat the market. On the other hand, if

the market becomes inefficient in the weak form, then investors will forecast future prices using historical data and gain abnormal returns.

2.2.4 S&P/TSX Composite Index

S&P/TSX Composite Index is the benchmark Canadian index, which represents around 70% of the total market capitalization on the Toronto Stock Exchange (TSX). It has about 250 companies associated with the index. It replaced the earlier TSE 300 index. As of September 2019, one third of the members of the index were involved in the natural resource sector which inculcates forestry, mining, natural gas and oil. Other relevant members include real estate, financial services, and industrial businesses (Fernando, 2019). All together, these firms make up the 70% market capitalization of the TSX. The S&P/TSX Composite Index will be used in executing the analysis of this study. S&P/TSX Composite Index is made up of only 250 listed companies compared to the total 1,500 companies listed on the Toronto Stock Exchange and so, Canadian investors monitored this index closely, since it comprises of Canada's largest and most prominent companies, hence, it is used as a determinant for the health of the economy of Canada.

2.3 EMPIRICAL FRAMEWORK

Diverse research has been done on the weak form efficiency, in different stock exchanges around the world.

Freund, Larrain, Pagano (1997) while examining the efficiency of Toronto Stock Exchange, before and after electronic trading was introduced. They made use of rescaled range analysis for their study. The study made use of (daily and monthly) index stock data for the individual selected stocks and their results failed to reject the random walk movement. Therefore, aggregation and indexation of TSX return data was based on the difference in the daily and monthly outcomes. Also, daily 25 stock data were used to know the performance of various technical trading strategies in comparison to the strategy of buy and hold. Irrespective of a 'non-random' pattern in the return of the data, technical trading strategy was not able to gain profitable or beneficial information to beat the strategy of buy and hold. This signifies that rejecting the random walk movement does not imply abnormal performance. These findings support the findings of Freund and Pagano (2000), while using non-parametric test in measuring TSX and NYSE market efficiency before and after electronic trading was introduced. Their study revealed that, the introduction of electronic trading had no relative impact on the efficiency of TSX and NYSE. In the case of TSX, it tends to push towards the basis of an improved efficiency.

However, Shiller and Radikoko (2014) had contradictory results, while examining the index returns of the Canadian TSX equity market for randomness of return series using (autocorrelation, BG, ADF, PP, KPSS, runs) test from 1980-2008, and their results showed that all TSX returns have long-memory features with a behavior attributed with anti-persistent trend-reversing, with two indices displaying a stronger level of anti-correlation, and five indices displaying a weaker level of anti-correlation. Overall, their findings collectively rejected the RWH governing the returns on the TSX stock exchange, suggesting that Canada's stock market is inefficient in the weak form. This is in line with Li and Liu (2012) work, as they also rejected the random walk hypothesis on several international market including the Canadian market from 1988-2010. They employed the Variance ratio test and their findings revealed that, the rising variance ratios suggest a positive serial correlation in multi-period returns for the international market, However, Canadas' variance ratios declined with q and had a negative autocorrelation, which led to the random walk being rejected for Canada, which means, the Canadian market is inefficient in the weak form. The mixed results from Canada could mean that, the type of dataset and methodology used, outrightly affected the results of the above studies, as Freund, *et al.*, (1997) made used of selected individual stocks of TSX, while, (Freund and Pagano, 2000 and Li and Liu, 2012) used Index returns of TSX, while Shiller and Radikoko (2014) used all index returns of the Canadian TSX equity markets.

In the UK, Cunningham (1973), who only used serial correlation tests, found that there was no proof of substantial price change dependency, hence, providing evidence that the British Stock market was weak-form efficient. In contrast, however, Grimes and Benjamin (1975) found evidence of significant non-randomness in price movements of small, lightly traded stocks. Rosenberg and Rudd (1982) on the other hand, noted that the overall returns of the securities were lacking serial correlation, they tested for serial correlation in regards to each of the main components of a security return. A security's total return comprises of two components, the return which is common to the overall securities and the return that is specific to the individual securities. Rosenberg and Rudd (1982) observed a positive serial correlation for the specific component and negative correlation for the individual component, resulting in an improved predictability of the overall returns. There findings show that, more than one statistical test is needed in order to avoid bias results and ensure accuracy.

Worthington and Higgs (2004) tested 20 European equity markets for random walk and weak-form market efficiency. They used the daily returns of 16 developed markets (Belgium, the United Kingdom, Austria, Denmark, France, Finland, Greece, Germany, Italy, Ireland, Norway, Netherlands, Spain, Portugal, Sweden and Switzerland) and 4 emerging markets i.e. Poland, Russia, Czech Republic and Hungary are analyzed for random walk using test like the multiple variance ratio, runs tests, Augmented Dickey-Fuller and serial correlation coefficient. Their findings, which were widely in agreement across the methods used, suggest that only Hungary is attributed with a random walk for the emerging markets and is thus, weak form efficient, whereas only the United Kingdom, Ireland, Germany, Sweden and Portugal are weak form efficient in the developed markets. The work of Maria (2007) is consistent with Worthington and Higgs (2004) as she analysed from 1993-2006, the Weak form Efficiency of the Portuguese Stock index prices of the (Lisbon Stock Exchange). For the hypothesis that stock indices follow a Random walk, runs test and serial correlation test were employed. These tests were carried out for the entire period using daily, weekly and monthly returns. Overall, the results showed that the Lisbon Stock market had shifted towards the Random Walk behavior since 2000, with the decline in serial return dependency. While, Birau (2015) had contradictory results compared to Worthington and Higgs (2004), while analyzing the Hungarian and Romanian markets in respect to the financial crisis during the period of 2007 to 2011 based on the daily price indices. His findings rejected the Weak form efficiency and concluded that both markets are inefficient. However, this inconsistency could be attributed to the aftermath of the global financial crisis because, Camelia, Cristina and Amelia (2017) also, examined both the EU and BRIC markets over a 16year period i.e.(before and after the crisis), while using Hurst exponent for (GARCH (1,1) and one-sample Kolmogorov–Smirnov test), which revealed that Hungary had the most efficient market. To this regard, it appears to be true.

Gilmore and McManus (2003) from 1995 to 2000, also examined Hungary, Czech Republic and Poland for weak-form efficiency based on the weekly comprehensive indices. They employed autocorrelation, variance ratio, unit root, Johansen and Granger causality, ARIMA, Naïve and

GARCH. Their findings were mixed: All the tests except the Granger-causality, had evidence against the weak-form efficiency in Hungary, Czech Republic and Poland. Their findings are consistent with the work of (Worthington and Higgs, 2004 and Camelia, *et al.*, 2017).

Similarly, to Birau (2015) and Camelia, *et al.*, (2017), Jethwani and Achuthan (2013), tested the weak form efficiency during, before and after the Financial Crisis which took place in the year 2002 (Dot Com Bubble) and 2007 (Sub Prime Crisis). They used the daily return of the S&P CNX Nifty from 1st January 1996 to 31st December 2012. They employed Autocorrelation, Variance Ratio test, Kolmogorov Smirnov test and Runs test. Their findings, revealed that the Indian stock market is weak form inefficient in all periods. however, after 2002, the Indian stock market behaves in a more efficient manner. So, the conclusion of Camelia, *et al.*, (2017), that the evidence of inefficiency in the Romanian and Hungarian markets of Birau (2015) during 2007-2011 is attributed to the aftermath of the financial crisis, holds. Also, the inefficiency of the S&P CNX Nifty of the Indian stock market, could be attributed to the fact that it's an emerging market, as emerging markets are perceived as being inefficient. The study of efficiency through time as implemented by Birau (2015), Camelia, *et al.*, (2017) and Jethwani and Achuthan (2013), gives an insight to this study, as it will look at the weak form efficiency of the S&P/TSX Composite index stock price through time.

Dasgupta and Glen (1995), observed significant serial correlation in the equity returns of 19 emerging markets, which suggest that the stock prices in emerging markets are against the EMH in the weak form. In regards to Dasgupta and Glen (1995) findings, Bose, Uddin and Islam (2014) measured the level of efficiency of the Chittagong Stock Exchange and Dhaka Stock Exchange. They employed ARIMA test. Their findings proved that Dhaka Stock Exchange and Chittagong Stock Exchange, do not exhibit efficiency in the weak-form and strong-form. They concluded that both stock markets are associated with efficiency in the semi-strong form and also, Chittagong Stock Exchange is more efficient than the Dhaka Stock Exchange. Likewise, Rahman, Simon and Hossain (2016) from 2006 to 2015, tested the three indices daily returns of the Chittagong Stock Exchange for weak form market efficiency. They employed the Augmented Dickey-Fuller Test, Variance Ratio Test, Runs Test, One-sample Kolmogorov-Smirnov Test and Autocorrelation Function Test. According to their findings, they concluded that the Chittagong Stock Exchange is not weak form efficient. Hence, superior profits can be gained. Similarly to Bose, *et al.,* (2014), Rehman and Hossain (2006) analyzed Bangladesh 's stock market to see whether or not the Dhaka stock exchange were efficient in the weak form. They employed the daily stock prices of 33 companies. The period covered was from 1994 to 2005. They employed the runs test, One-sample Kolmogorov-Smirnov test, parametric-tests and Lilliefors test, which revealed that the Dhaka stock markets do not exhibit efficiency in the weak form. Hence, the idea that emerging markets are inefficient holds.

On another study, Suleman *et al.,* (2010) researched several big Asian countries' stock markets and Australia i.e. India, Pakistan, China, Hong Kong, Thailand, Malaysia, Singapore, Sri Lanka, Indonesia, Korea, Philippine, Taiwan. They used the monthly stock prices and covered the period of 2004 to 2009. They employed Q Statistics test, runs test, Autocorrelation, unit root analysis and variance ratio test. Their findings revealed that, the monthly returns of these stock markets were not normally distributed and hence, traders could get an opportunity (advantage) through arbitrage technique. Similarly, Worthington and Higgs (2006) investigated the Asian stock markets for weak-form efficiency. They used the daily stock returns of emerging Asian markets and the developed markets (i.e. New Zealand, Japan, Hong Kong and Australia). In order to test if the data were normally distributed, test like unit root, serial correlation coefficient, shin unit root, runs test, multiple variance ratio and Kwiatkowski were employed. Their findings revealed that, the mentioned markets were not efficient in the weak-form. The findings for the markets used in Suleman *et al.,* (2010) and Worthington and Higgs (2006) are consistent. However, different methodologies were used.

2.4 CONCLUSION

The literature review inculcated both conceptual and empirical frameworks. The conceptual framework introduced the fundamental concepts of the research, and gave the background to the empirical framework in terms of previous studies. The empirical framework entailed the Canadian market and also the emerging and developed markets.

Some research has been done on the Toronto stock exchange, such as the works of Freund, *et al.,* (1997), Freund and Pagano (2000), Shiller and Radikoko (2014) and Li and Liu (2012), But not a lot of research has been done on the S&P/TSX Composite Index, which is the benchmark index of the Toronto Stock Exchange. This gives value to this research. as the study will investigate the S&P/TSX Composite Index for the presence of weak form efficiency from 1996-2019. Also, these studies used different datasets, which gave both rejection and support for weak form efficiency of the different Canadian index. On this note, this research is focusing on just the S&P/TSX Composite Index, in order to ensure a more reliable result. Also, these studies look at different time period of the Canadian market, which might had led to the mixed results. This observation gives insight and relevance to this study, as it we look at the efficiency of the S&P/TSX Composite Index stock price through time. This was suggested by Birau (2015), Camelia, *et al.*, (2017) and Jethwani and Achuthan (2013) in the above literature.

From the review of the literature, it was observed that, more than one statistical test is needed, in order to ensure accuracy of results for weak form efficiency. This is in line with the suggestion of Cunningham (1973), Grimes and Benjamin (1975) and Rosenberg and Rudd (1982). They argued that in order for the efficiency in the weak form to be tested in any market, it is much better to employ, more than one statistical test to ensure a stronger reliability of results. Hence, this research will implement more than one statistical test for the weak form efficiency in the S&P/TSX Composite Index, which are, Autocorrelation test, Runs test, Variance ratio test, One-Sample Kolmogorov Smirnov test and Augmented Dickey Fuller test.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

It was observed in the previous chapter by Cunningham (1973), Grimes and Benjamin (1975) and Rosenberg and Rudd (1982), that in order for the efficiency in the weak form to be tested in any market, it is much better to employ, more than one statistical test, to ensure a stronger reliability of results. To this regard, this chapter will describe the different methodologies to be used, which includes, the Autocorrelation test, Runs test, Variance ratio test, Augmented Dickey Fuller test and One-Sample Kolmogorov Smirnov test. Also, the studies done on the Canadian market used different datasets, which gave both rejection and support for weak form efficiency, which led to the mixed results. Therefore, this chapter will test the S&P/TSX Composite Index stock price through time, to ensure robustness of result, as suggested by Birau (2015), Camelia, *et al.*, (2017) and Jethwani and Achuthan (2013) in the previous chapter. Furthermore, the chapter will elucidate the research approach, philosophy, design, strategy, the data type, the sample of the research, the source of data and population of the research. Lastly, limitations and conclusion to the research will be identified.

3.2 DESCRIPTION OF THE DATA

The daily closing price of the S&P/TSX Composite Index are utilized for this study. The S&P/TSX Composite Index is the benchmark Canadian index, which represents around 70% of the total market capitalization on the Toronto Stock Exchange (TSX). It has about 250 companies and so, Canadian investors monitored this index closely, since it comprises of Canada's largest and most prominent companies. It is therefore, an essential measure in assessing the direction of the market and its movements. The data source is from Yahoo Finance. The sample will be analyzed from different periods to incorporate the dotcom bubble, financial crisis and post-financial crisis, in order to analyzing the weak form efficiency of the S&P/TSX Composite Index through time. This is constructed, based on the conflicted results in the Canadian stock markets in the literature review. As different data set and time period was an issue, in determining the state of efficiency of the S&P/TSX Composite Index, and hence, the researcher had to choose a long-time horizon, in order to have a more reliable finding. Therefore, the study periods, dates and observation are as follows,

Periods	Dates	Observations
Overall Period	11/12/96 to 11/12/19	5,782
Before Dotcom bubble	11/12/96 to 11/12/00	1,009
Dotcom bubble	11/12/00 to 11/12/02	504
Before Financial Crisis	11/12/02 to 11/12/07	1,260
Financial Crisis	11/12/07 to 11/12/09	504
Post-Financial Crisis	11/12/09 to 11/12/19	2,509

Source: Authors Construction

The research analysis will be undertaken using MATLAB and EViews software. The daily returns of the S&P/TSX Composite Index as discuss above, can be computed as follows,

$$R_t = LN\left(\frac{P_t}{P_{t-1}}\right) \qquad \text{(I)}$$

Therefore, R_t = Return at time t

LN = Natural Logarithm

P_t = Current closing price

P_{t-1} = Previous closing price.

According to Worthington and Higgs (2006) and Bose, *et al.*, (2014), the log-returns has to be implemented in analyzing the statistical techniques, as logarithmic returns are stipulated as being normally distributed, which is a basis utilized for statistical tools in respect to any given data set. Hence, the plotted graph of the S&P/TSX Composite Index logarithmic returns and its raw stock data are included in the appendix.

3.3 METHODOLOGIES FOR TESTING THE WEAK FORM MARKET EFFICIENCY

As noted previously, weak form market efficiency is based on the fact that past stock prices cannot predict recent stock returns (random walk). Hence, testing the weak form efficiency entails analyzing the interrelationship between recent stock returns and historical stock returns (Bodie *et al.*, 2007). The idea to use different statistical test to examine the weak form efficiency of the S&P/TSX Composite Index is attributed to the vast review of the literature. Therefore, different methodologies will be utilized for this study instead of a specific statistical tool. This includes, Autocorrelation test, Runs test, Variance ratio test, Augmented Dickey Fuller test for unit root and One-Sample Kolmogorov Smirnov test.

3.3.1 Autocorrelation Test

The consolidated use of the autocorrelation test as a measure for weak form efficiency was adopted in literature review by (Shiller and Radikoko, 2014, Gilmore and McManus, 2003, Rahman, *et al.*, 2016 and Suleman *et al.*, 2010). The first test implemented when testing the random walk of the weak form efficiency, is autocorrelation. Autocorrelation is a measure of the relationship between the recent and previous stock returns (Gimba, 2012). Its equation is given as follows:

$$\rho_{\kappa} = \frac{\sum_{t-1}^{N-K}(r_t - r)(r_{t+k} - r)}{\sum_{t=1}^{N}(r_t - r)^2} \qquad \text{(ii)}$$

Where,

ρ_{κ} = Serial correlation coefficient of stock returns of lag *k*

N = Number of observations

r_t = stock return over period *t*

r_{t+k} = stock return over period *t* + *k*

r = Sample mean of stock returns

K = the lag of the period

The test is centered on discovering if the serial correlation coefficient is different from zero. Hence, the weak form efficiency has to be rejected, if the stocks returns are serially correlated (i.e. different significantly from zero). In order to test the joint hypothesis that every autocorrelation are simultaneously equal to zero, the Ljung-Box statistic (*Q*) is employed. The equation for the Ljung-Box (*Q*) statistic is as follows:

$$\mathrm{Q}_{LB} = N(N+2)\sum_{j=1}^{k}\frac{\rho_{j^2}}{N-j} \qquad \text{(iii)}$$

Where,

ρ_j = the j^{th} autocorrelation

N = number of observations

Therefore, in the Null hypothesis of zero autocorrelation at the first *k* autocorrelation (ρ_1 = ρ_2 = ρ_3 = … = ρ_{κ} = 0), the (*Q*) statistic is now distributed as chi-square with degrees of freedom which are equal to the number of autocorrelations (k).

3.3.2 Runs Test

Most of the literature looked at (Shiller and Radikoko, 2014, Worthington and Higgs, 2004, Maria, 2007, Rahman, *et al.*, 2016, Rehman and Hossain, 2006, Suleman *et al.*, 2010 and Worthington and Higgs, 2006) utilized the runs test, to examine the presence of random walk for a time series data. The runs test is a non-parametric test, that enables one determine if the observed sequence is random or not. A run can be seen as a sequence of consecutive changes in price with the same sign. Each stock price can be identified based on its position, in terms of the mean returns for the period under observation. So, we have a positive sign (+), when the stock prices are above the mean and negative sign (-), when it's below the mean. Also, since the runs test is a non-parametric test, stock prices are not expected to be normally distributed. Therefore, the test is centered on the fact that, if the data series is random, then the number of runs observed (r) in the series should be close to the number of runs expected (μr).

- 1 is attributed to stock prices being greater than or equal to the mean value
- 0 is to the stock prices being less than the mean value.

Let,

n_1 *and* n_0 = Sample sizes of items 1 and 0

In terms of large samples, where n_1 *and* n_0 are greater than 30, which are normally distributed, the following statistical equation as given by Worthington and Higgs (2004) is as follows:

$$Z = \frac{r - \mu_r}{\sigma_r} \qquad \text{(iv)}$$

Where,

$$\mu_r = \left(\frac{2n_1\, n_0}{n_1\, n_0}\right) \qquad \text{(v)}$$

$$\sigma_r = \sqrt{\frac{2n_1 n_0(2n_1 n_0 - n_1 n_0)}{(n_1+n_0)^2((n_1+n_0-1)}} \qquad \text{(vi)}$$

μ_r = expected (mean) number of runs

σ_r = standard error

Therefore,

H0: Changes in the stock prices of the S&P/TSX Composite Index are random.

Hence, the null hypothesis has to be rejected if the Z value is greater than the critical value of +1.96 and -1.96, for a specified level of significance.

3.3.3 Augmented Dickey Fuller Test (Unit Root)

According to Campbell, Lo and MacKinlay (1997, p.65), unit root test are utilized to examine the null hypothesis that a data series are difference-stationary versus the alternative hypothesis that they are trend-stationary. Augmented Dickey Fuller test are largely employed for units root tests (Al-Jafari, 2011). The aim for testing randomness, is attributed to the fact that, successful movement in stock prices are independent of each other and as such follow a stochastic behaviour. This means that recent stock prices has to be independent of previous stock prices, thereby, a random walk series attributed with a unit root implies non-stationarity. While, time series that are stationary follows a trend which are predictable. So, in order to test for unit root, the research will apply the widely accepted Augmented Dickey Fuller tests as used in the reviewed literature (Worthington and Higgs, 2006, Suleman *et al.*, 2010, Rahman, *et al*., 2016, Gilmore and McManus, 2003, Worthington and Higgs, 2004 and Shiller and Radikoko, 2014). The test is employed for testing the time series for stationarity. Therefore, the time series is stationary if its mean, variance and autocorrelation are constant for a specified time period. Hence, this means its statistical properties can be predicted as being the same for the future as in past, which rejects the ideology of the weak form efficiency and hence, does not follow the random walk behaviour and as well has no unit root. The equation for the Augmented Dickey Fuller test is expressed as follows:

$$\Delta R_t = \mu + b_1 t + \gamma R_{t-1} + \sum_{t=1}^{q} p_i \, \Delta R_{t-1} + e_i \qquad \text{(vii)}$$

Where,

R_t = Recent values of the log returns under observation

Δ = First difference

μ = Constant

b_1= trend coefficient

R_{t-1} = lagged values of the log returns

γ *and* p_i = coefficient

q = Number of lags

t = Time trend

e_i = Error term (white noise)

3.3.4 Variance Ratio Test

The variance ratio test stipulated by Lo and MacKinlay (1988), is known as being a more robust statistical measure compared to the unit root test (Lo and MacKinlay, 1988; Liu and He, 1991). This research will use the variance ratio test as employed in the literature review by (Suleman *et al.*, 2010, Rahman, *et al.*, 2016, Gilmore and McManus, 2003 and Li and Liu, 2012). The test is centered on the idea that, the incremental variance in a random walk series are linear in the sample interval. Therefore, if a data series follows a random walk behaviour, then the variance of its q-differences is said to be q times the variance of its first differences. If the VR (q) statistic is different significantly from unity, the hypothesis will be rejected with the evidences of autocorrelations in the return of the series. If the variance ratio is (>1), it implies that the returns series has a positive serial correlation. While, if the variance ratio is (<1), it means that the returns series has a negative serial correlation (Hasan, 2015).

$$Var(p_t - p_{t-q}) = qVar(p_t - p_{t-1}) \qquad \text{(viii)}$$

Where,

q = any positive integer

While, Variance ratio $VR(q)$ is given as;

$$VR(q) = \frac{\frac{1}{q}Var(p_t - p_{t-1})}{\mathrm{Var}(\mathrm{p_t} - \mathrm{p_{t-1}})} = \frac{\sigma^2(q)}{\sigma^2(1)} \qquad \text{(ix)}$$

Where,

$\sigma^2(q) =$ 1/q the variance of the q-differences

$\sigma^2(1) =$ the variance of the first differences

Therefore, the Null and Alternative hypothesis are given as;

H_0: VR (q) = 1 means that S&P/TSX Composite Index is weak-form efficient

H_1: VR (q) $\neq$ 1 means that S&P/TSX Composite Index is not weak-form efficient.

So, for a sample size of n_{q+1} observation (p_0 , p_1, ..., p_{nq}), the equation for calculating $\sigma^2(q)$ and $\sigma^2(1)$ is given as follow:

$$\sigma^2(q) = \frac{\sum_{i=q}^{nq}(p_t - p_{t-1} - q\hat{u})^2}{h} \qquad \text{(x)}$$

Where,

$h = q(nq + 1 - q)\left(1 - \frac{q}{nq}\right)$

$\hat{u} = \frac{1}{nq}\sum_{t=1}^{nq}(p_t - p_{t-1}) = \frac{1}{nq}((p_{nq} - p_0)$

While,

$$\sigma^2(1) = \frac{\sum_{i=1}^{nq}(p_t - p_{t-1} - \hat{u})^2}{(nq - 1)} \qquad \text{(xi)}$$

According to Lo and MacKinlay (1988), the assumption of the increments of homoscedasticity and heteroscedasticity are classified into two standard normal test-statistics, which are $Z(q)$ and $Z^*(q)$ respectively. There formulas are expressed as follows:

$$Z(q) = \frac{VR(q) - 1}{[\emptyset\,(q)]^{1/2}} \sim N(0,1) \qquad \text{(xii)}$$

$$Z*(q) = \frac{VR(q) - 1}{[\emptyset*(q)]^{1/2}} \sim N(0,1) \qquad \text{(xiii)}$$

Where,

$\emptyset\,(q)$ = Asymptotic variance of the variance ratio under the homoscedasticity assumption.

$\emptyset*(q)$ = Asymptotic variance of the variance ratio under the heteroscedasticity assumption.

They can be expressed as;

$$\emptyset\,(q) = \frac{2(2q-1)(q-1)}{3q(nq)} \qquad \text{(xiv)}$$

$$\emptyset*(q) = \sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2\delta(j) \qquad \text{(xv)}$$

Where,

$\delta(j)$ = heteroscedasticity(consistent estimator)

It can be computed as;

$$\delta(j) = \frac{\sum_{j+1}^{nq}(p_t - p_{t-1} - \hat{u})^2(p_{t-1} - p_{t-j-1} - \hat{u})^2}{[\sum_{t=1}^{nq}(p_t - p_{t-1} - \hat{u})^2]^2} \qquad \text{(xvi)}$$

3.3.5 One-Sample Kolmogorov Smirnov Test

The research will implement the K-S test, to examine if the S&P/TSX Composite Index daily closing prices fits a certain distribution (uniform, normal or Poisson), as adopted in the literature review by (Rehman and Hossain, 2006, Rahman, *et al.*, 2016 and Camelia, *et al.*, 2017). The K-S test is a non-parametric test, that stands as an evidence towards the stock return being normally distributed or not. To test the homogeneity of a data, the cumulative distribution function of a variable has to compared to the normal distribution. Therefore, if the K-S test shows that the data series is not normally distributed, the null hypothesis of the series following a random walk will be rejected (Afego, 2012). The K-S test as describe by Fraz and Hassan (2016), is computed as follows:

$$F_n(x) = \frac{1}{n} \sum_{i=1}^{n} I_{xi \leq x} \qquad \text{(xvii)}$$

Where,

F_n = Distribution function

n = Identical distributed random observations which are independent of each other (i.e. stock prices)

$I_{xi \leq x}$ = Indicator function which is equal to 1 if not 0

While the cumulative distribution function is expressed as;

$$D_n = Lub_x|F_n(x) - F(x) \qquad \text{(xviii)}$$

Where,

D_n = Cumulative distribution function

Lub_x = The Least upper bound.

3.4 RESEARCH DESIGN, PHILOSOPHY, APPROACH AND METHODS

- **Research Design:**

longitudinal research will be employed for this study. longitudinal research is centered on change and development. longitudinal research is concerned with assessing the changes over time, that may occur in an observation of one or more statistical variables or data (Wang, *et al.*, 2017). This research seeks to assess the weak form efficiency of the S&P/TSX Composite Index, using its daily closing price observed over a period of 23 years, which will incorporate the period of the dotcom bubble, financial crisis and post-financial crisis. Hence, this makes it a longitudinal research. This is in line with Birau (2015), Camelia, *et al.*, (2017) and Jethwani and Achuthan (2013) work.

- **Research Philosophy**

The positivism philosophy, mostly involves quantitative methodology, which employs experimental methods for large sample and structured data (Taylo and Medina, 2011). The researcher, thereby, takes the form of a positivist. In assessing whether the S&P/TSX Composite Index is weak form efficient, thereby a null and alternative hypothesis has to be derived based on existing theories, in order to examine large data using several statistical methods. Other alternative philosophy aside positivism are (realism, pragmatism and interpretivism).

- **Research Approach**

When carrying out a deductive research, you have to start with a theory, and reasoning deductively, implies testing the theories (Streefkerk, 2019). So, a deductive approach, will begin by specifying the hypothesis and then attribute the hypothesis in operational terms, thirdly, you test the hypothesis which are in operational terms, fourthly, analyze the results of the test in terms of failing to reject or rejecting, and lastly, you modify the theory in respect of the results. For this research, new theories will not be derived, rather existing theories will be employed in order for our hypothesis to be tested, while using collected data for the empirical research. Furthermore, conclusion will be deduced and theories can be modify according to the outcomes. Hence, we are utilizing the deductive approach adopted by (Shiller and Radikoko, 2014, Rahman, *et al.*, 2016, Suleman *et al.*, 2010). The alternative of this approach is the inductive approach.

- **Research Methods**

Looking at the literature review in Chapter 2, almost every study employed a quantitative research method (Worthington and Higgs, 2004, 2006, Maria, 2007, Rahman, *et al.*, 2016, Rehman and Hossain, 2006, Suleman *et al.*, 2010). This research is a quantitative research, as it aims to examine if the S&P/TSX Composite Index is weak form efficient. Past prices will be used over a long period of time, which will be tested using statistical measures. Also, the study is undertaken by implementing existing theories.

3.5 LIMITATIONS

It was observed from the previous chapter that the autocorrelation test, Ljung-box test, runs test, ADF test and K-S test are traditional tests utilized in examining the weak form efficiency of different stock markets. So, a more robust test like variance ratio was adopted to test if the VR (q) statistic is different significantly from unity, and to this regard, the hypothesis will be rejected with the evidences of autocorrelations in the return of the series. The variance ratio test of Lo and MacKinlay (1988) is an individual test for the value of *k* and so, carrying out separate individual tests for the values of *k* numbers, might be misleading, which will lead to the joint test being entirely rejected for the null hypothesis. Therefore, Chow and Denning (1993) suggested on using a joint multiple variance ratio test for a specified set of different time horizon. This is due to the fact that, Lo and MacKinlay (1988) test, ignores the joint nature for examining random walk behaviour. This is line with the study of (Worthington and Higgs, 2004;2006). Other robust test suggested in the literature (Bose, *et al*., 2014, Gilmore and McManus, 2003, Camelia, *et al.*, 2017) are GARCH and ARIMA.

3.6 CONCLUSION

This Chapter explicitly discussed the methodology of the research. It began with the data description (S&P/TSX Composite Index) and identified the purpose of utilizing Logarithm returns of the stock price, before analysis of the data can be tested. It went further to discuss the methodologies to be used, according to the consensus in the literature review. The autocorrelation will be used as a measure to test the relationship between the recent and previous stock returns, Ljung-Box (Q) statistic will be used to test the joint hypothesis that every autocorrelation are simultaneously equal to zero. The runs test will be employed to test the randomness or serial independence in the time series, which was not observed in the autocorrelation. The ADF test will be employed essentially in testing for unit root in the time series. The Variance ratio test on the other hand, will be employed to examine the statistical significance of the Z-statistic of the variance ratio for some number of q-periods. Lastly, the K-S test will be used to test for the randomness of the return of the stock in respect to a normal distribution.

CHAPTER FOUR

DATA ANALYSIS AND INTERPRETATION OF RESULTS

4.1 INTRODUCTION

This chapter analyzed the daily closing price of the S&P/TSX Composite Index (data), using the methodologies described in chapter 3 above. Firstly, the descriptive statistic was carried out on the data. Then the S&P/TSX Composite Index distribution pattern was plotted to test the time series for normality. Next, autocorrelation and Ljung-Box (Q) statistic was computed on the data, followed by the runs test for randomness. Thereafter, we tested the presence of unit root in the data. Then, the K-S test was employed to test the normality of the data. Lastly, the Variance ratio test was also carried out on the data, to test for the statistical significance of the Z-statistic of the variance ratio for some number of q-periods. Furthermore, the chapter discussed the outcomes of the results implemented. The outcomes aided in deriving the state of efficiency of the S&P/TSX Composite Index. Based on the empirical evidence, the decisions made were justified.

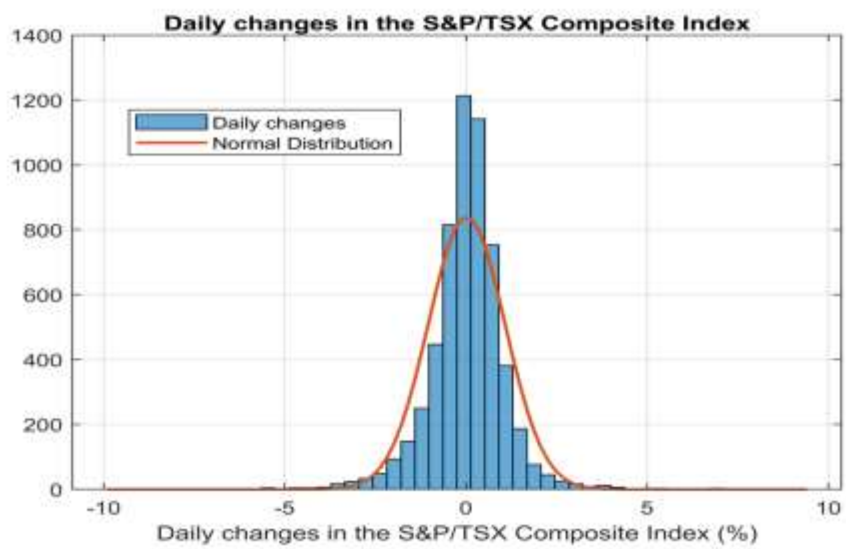
4.2 DESCRIPTIVE STATISTICS

It is vital to understand the basic features of a data set, before carrying out any analysis. Descriptive statistics are essentially used to know whether or not, the sample is normally distributed. One major insight of the random walk behaviour and the efficient market hypothesis is that, prices of stocks are seen to be normally distributed when they are random (Worthington and Higgs, 2006, Bose, *et al.*, 2014). Hence, the log-returns has to be implemented, as it gives a better representation of the returns of the stock price, than the raw data.

The histogram of the S&P/TSX Composite Index was first computed, before its descriptive statistic was carried out. The normal distribution was aligned with the histogram, to ascertain if the shape of the curve follows a normal distribution or not. If the left side of a distribution does not mirror the right side, it means it's not symmetric and therefore, skewed. If a distribution has most of its values clustered around the left tail and its right tail is longer, it's termed positively skewed. While, If a distribution has most of its values clustered around the right tail and its left tail is longer, it's termed negatively skewed. Hence, in a normal distribution skewness should be zero.

The flatness or peakedness of a distribution series are measured by Kurtosis. A normal Kurtosis has a value of 3 and its termed mesokurtic. A positive Kurtosis (peaked curve) values are higher than the sample mean and are termed leptokurtic distribution. While, a negative Kurtosis (flatted curve) values are lower than the sample mean and are termed platykurtic distribution. So, the Jarque-Bera was used as a measure of the difference between a series skewness and kurtosis with that of the normal distribution. It measures the null hypothesis for the normality of the distribution. The probability implies that, the statistic of the Jarque-Bera are greater than the observed value, in respect of the null hypothesis. Hence, the null hypothesis that the distribution are normal is rejected, if the probability is below the significance level (5%).

Figure 1: Distribution Pattern of S&P/TSX Composite Index



Looking at Figure 1, it is evident that the daily closing price of the S&P/TSX Composite Index distribution pattern, does not fit the shape of a normal distribution, for the period of (1996-2019). Therefore, it’s likely that the distribution pattern is asymmetric, as the line of symmetry on the left side of the curve, does not conform to the shape of the curve on the right side. On this note, we test the series further for normality, using kurtosis, skewness and Jarque-Bera from the descriptive statistic.

Table 1: The Descriptive Statistic Results

	S&P/TSX Composite Index
Mean	0.000186
Median	0.000712
Maximum	0.093703
Minimum	-0.097880
Standard Deviation	0.010605
Skewness	-0.694282
Kurtosis	12.68567
Jarque-Bera	23061.45
Probability	0.000000
Observations	5781

As clarified above, for a data to be normally distributed, the kurtosis and skewness should be 3 and 0 respectively or close. From table 1, we can observe that, the S&P/TSX Composite Index skewness is -0.69, which is close to zero and indicates a normal distribution. While, the kurtosis is 12.6 which is higher than 3. This means that, the distribution is not normally distributed and therefore, its leptokurtic. The null hypothesis of the JB statistic is that the distribution is normal. However, the probability of 0.00000 is statistically significant at 5% significance level. Therefore, we have to rejected the null hypothesis that the daily closing price of the S&P/TSX Composite Index are normally distributed at the 5% significance level.

4.3 AUTOCORRELATION TEST

$$\rho_{\kappa} = \frac{\sum_{t-1}^{N-K}(r_t - r)(r_{t+k} - r)}{\sum_{t=1}^{N}(r_t - r)^2}$$

The log returns of r_t and r_{t+k} for the S&P/TSX Composite Index, will be measured to see if they are independent of each, in order to compute the autocorrelation. This is done to examine the repeated patterns of the returns until a certain lag period. We used lag 20, which was chosen by the autocorrelation function. This implies that, the autocorrelation of lag 20, are the correlation between the log returns of r_t and its corresponding return of r_{t+k} which are observed 20 periods earlier. The r_{t+k} are the lagged returns and so, the Ljung-Box (Q) statistic are employed to examine the joint significance of the autocorrelation. The result of the autocorrelation function are shown below:

Figure 2: Autocorrelation of S&P/TSX Composite Index from 1996-2019

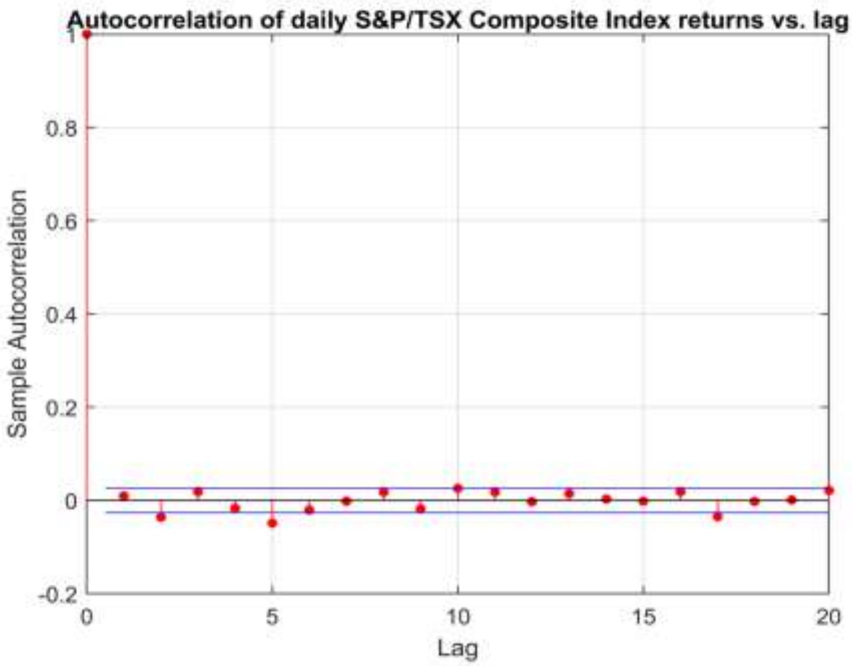


Table 2: Ljung-Box Statistics Result

	Ljung-Box Q-Test					
Periods	**P-values**	**Lags**	**DOF**	**Chi-Square Test(stats)**	**Critical Value**	**Remarks**
1996-2019	0.00019184	20	20	50.4349	31.4104	Significant
1996-2000	0.000009548	20	20	59.1751	31.4104	Significant
2000-2002	0.50212	20	20	19.3045	31.4104	Not Significant
2002-2007	0.51471	20	20	19.1096	31.4104	Not Significant
2007-2009	0.046301	20	20	31.7265	31.4104	Significant
2009-2019	0.0036928	20	20	41.0295	31.4104	Significant

Findings: figure 2 shows the autocorrelation of the S&P/TSX Composite Index log returns under the study period. The Ljung-Box (*Q*) statistic was also examined for the time series. The autocorrelation test was set to examine if the null hypothesis shows that the successive changes in the stock price of the S&P/TSX Composite Index are independent. However, the p-values of all period are significant statistically (i.e. < 0.05) except for the period of 2000-2002 and 2002-2007. This implies that, there is a high correlation in the log returns and therefore, there is a presence of autocorrelation (i.e. dependence) in the lagged values of the time series for all period except 2000-2002 and 2002-2007. The result of the Ljung-Box (*Q*) statistic shows that the Chi square statistic of (50.43, 59.17, 31.72, 41.02) are greater than the critical value of (31.41), for all periods except 2000-2002 and 2002-2007. Hence, despite the non-significance of periods 2000-2002 and 2002-2007, we are 95% confident that periods (1996-2019,1996-2000, 2007-2009, 2009-2019) log returns are autocorrelated and therefore, we reject the null hypothesis of no autocorrelation. In retrospect, we can conclude that the S&P/TSX Composite Index stock returns are not independent through time.

4.4 RUNS TEST

A run can be seen as a sequence of consecutive changes in price with the same sign. The run test was employed on the S&P/TSX Composite Index, to see if the value of one price is influenced by the price value following it. If there are no influence on the prices, it implies that, its random and independent. For a large sample as employed in this study, the runs test calculates the total runs for a Z-statistic. So, the Z-statistic shows the difference between the actual and expected number of runs. The null hypothesis, test if the changes in the stock prices of the S&P/TSX Composite Index are random. The null hypothesis has to be rejected if the Z value are greater than the critical value of +1.96 and -1.96.

The results of the runs test can be seen below:

Table 3: Runs Test results

RUNS TESTS	1996-2019	1996-2000	2000-2002	2002-2007	2007-2009	2009-2019
Cases < Test values (n0)	2,952	521	255	641	257	1277
Cases >= Test values (n1)	2828	486	247	617	245	1230
Total Cases	5,782	1,009	504	1,260	504	2,509
Number of Runs	3,774	616	337	829	339	1651
Z-stat	-2.4698	-4.1248	0.1589	-0.6355	0.3708	-0.9554
Asymp. Sig (2-tailed)	0.01351705	3.71124E-05	0.8737394	0.5251317	0.7107932	0.3393717

Findings: From table 3 above, it is evident that the Z-stat of (0.1589, -0.6355, 0.3708, -0.9554) for periods (2000-2002, 2002-2007, 2007-2009, 2009-2019) are less than the critical value of (+/-) 1.96. Also, their p-values are greater than 0.05. However, periods (1996-2019, 1996-2000) Z-stat are greater than the critical value of -1.96. Therefore, the null hypothesis that the changes in the successive prices of the S&P/TSX Composite index are random, cannot be rejected at the 5% significance level for period (2000-2002, 2002-2007, 2007-2009, 2009-2019) but is rejected for period (1996-2019, 1996-2000). In retrospect, despite the rejection of period (1996-2019, 1996-2000), we are 95% confident, that the consolidated outcomes of period (2000-2002, 2002-2007, 2007-2009, 2009-2019) for the daily closing price of the S&P/TSX Composite Index are in fact random and does exhibit weak form efficiency through time.

4.5 AUGMENTED DICKEY FULLER TEST (UNIT ROOT)

According to Campbell, Lo and MacKinlay (1997, p.65), unit root test are utilized to examine the null hypothesis that a data series are difference-stationary versus the alternative hypothesis that they are trend-stationary. The ADF test was employed for testing the time series for stationarity. A time series are stationary, if its mean, variance and autocorrelation are constant for a specified time period. This means, its statistical properties can be predicted as being the same for the future as in past, which rejects the ideology of the weak form efficiency and hence, does not follow the random walk behaviour and as well has no unit root.

Table 4: Augmented Dickey Fuller Test Results

	Augmented Dickey Fuller Test		
Periods	**Test Stats**	**Critical Value (5%)**	**P-Values**
1996-2019	-13.8701	-1.9416	0.001
1996-2000	-5.2326	-1.9416	0.001
2000-2002	-3.9263	-1.9412	0.001
2002-2007	-6.2992	-1.9416	0.001
2007-2009	-3.7853	-1.9412	0.001
2009-2019	-10.8665	-1.9416	0.001

Findings:

The null hypothesis that the log returns through time exhibit a unit root is rejected in table 4. So, the computed t-statistics of (-13.87, -5.23, -3.92 -6.29, -3.78, -10.86) are greater than the critical value of (-1.94) at the 5% significance level for all periods observed. Also, their p-values of (0.001) are less than 5%. Therefore, we reject the null hypothesis.

4.6 ONE-SAMPLE KOLMOGOROV SMIRNOV TEST

The K-S test was utilized in testing the normality of the S&P/TSX Composite Index daily closing price. It measures how best a random sample fits a certain distribution. It also serves as an evidence for the normality of a time series. Therefore, the K-S test was employed to examine if the data follows a normal distribution or not.

Table 5: K-S Test Results (for Normal Distribution)

K-S TEST	
PERIODS	**P-Values**
1996-2019	0.0000
1996-2000	0.0006
2000-2002	0.2743
2002-2007	0.0057
2007-2009	0.0004
2009-2019	0.0000

Findings: Table 5 shows that the p-values of (0.000,0.000,0.005,0.000,0.000) for all period observed are less than the 5% significance level, except for period (2000-2002), which had a p-value of (0.27). Therefore, with the exception of period (2000-2002), the consolidated outcome of all other period observed, rejects the null hypothesis that the S&P/TSX Composite Index daily closing price are normally distributed. This implies that, the S&P/TSX Composite Index are not normally distributed through time and also does not exhibit a random walk.

4.7 VARIANCE RATIO TEST

We employed the variance ratio test of Lo and MacKinlay (1988), to improve the robustness of our findings for the state of efficiency of the S&P/TSX Composite Index. the null hypothesis for a random walk, states that the variance ratio is equals to 1 and also, the test statistics are standard normally distributed asymptotically. If the VR (q) statistic is different significantly from unity, the hypothesis will be rejected with the evidences of autocorrelations in the return of the series.

Table 6: Variance Ratio Test Results

Variance Ratio Test		**Test Intervals (q)**		
S&P/TSX Composite Index	**2**	**4**	**8**	**16**
1996-2019				
VR(q)	1.0097	0.98833	0.92358	0.90657
Z*(q) 5%	0.3375	-0.22628	-0.95361	-0.77855
P-value	0.73574	0.82091	0.34028	0.43625
Critical value	1.96	1.96	1.96	1.96
1996-2000				
VR(q)	1.1259	1.136	1.021	1.0704
Z*(q) 5%	3.2571	1.8206	0.17413	0.39181
P-value	0.0011256	0.068662	0.86177	0.6952
Critical value	1.96	1.96	1.96	1.96
2000-2002				
VR(q)	0.98478	1.0214	1.0969	1.1546
Z*(q) 5%	-0.29322	0.21052	0.61109	0.68006
P-value	0.76936	0.83326	0.54114	0.49646
Critical value	1.96	1.96	1.96	1.96
2002-2007				
VR(q)	1.0149	1.0043	0.95082	0.91726
Z*(q) 5%	0.49109	0.07397	-0.53238	-0.59476
P-value	0.62336	0.94103	0.59446	0.552
Critical value	1.96	1.96	1.96	1.96
2007-2009				
VR(q)	0.90193	0.82185	0.76542	0.77046
Z*(q) 5%	-1.2919	-1.341	-1.1441	-0.74486
P-value	0.19639	0.17992	0.25256	0.45636

Critical value	1.96	1.96	1.96	1.96
2009-2019				
VR(q)	1.0713	1.0792	0.98855	0.87648
Z*(q) 5%	2.6136	1.5065	-0.13744	-1.0123
P-value	0.0089605	0.13194	0.89069	0.31141
Critical value	1.96	1.96	1.96	1.96

Findings: Table 6 shows that for all q periods (assuming heteroscedasticity consistent), the null hypothesis for random walk was not rejected for all periods observed, at the 5% significance level. With the exception of period (1996-2000, 2009-2019), which rejected the null hypothesis at the 5% significance level at period $q = 2$. The findings show that, the S&P/TSX Composite Index through time is collectively weak form efficient and statistically not significant.

4.8 DISCUSSION OF FINDINGS FOR THE S&P/TSX COMPOSITE INDEX

Key findings: The main objective of this research is to test the S&P/TSX Composite Index for weak form market efficiency. While the researcher's precise objectives are;

- To investigate if the S&P/TSX Composite Index is associated with a random walk movement or not.
- To test if the S&P/TSX Composite Index price movement are independent or not.

From the test done above, we have evidently proven that the S&P/TSX Composite Index is weak form efficient. Despite the fact that, the traditional test of the (autocorrelation, ADF and K-S test) rejected the weak form efficiency for all or most of period observed, the robust test of the variance ratio and the runs test for random walk collectively failed to reject the weak form market efficiency, which stands as our deciding factor for the state of efficiency of the S&P/TSX Composite Index.

The autocorrelation test showed that the S&P/TSX Composite Index stock returns are highly correlated with each other, and therefore not independent. The Ljung-Box (Q) statistic showed the dependence of the stock prices on one another. Weak form efficiency suggests that, recent stock prices cannot be predicted using past stock prices and also prices of stocks are independent of each other. This implies that, for the autocorrelation result, recent prices are not independent and therefore, past stocks price can be used in determining current stock prices. Hence, we can conclude that the S&P/TSX Composite Index is not weak form efficient and also significant. The autocorrelation finding is consistent with the empirical studies of (Worthington and Higgs, 2006, Suleman *et al.*, 2010, Rahman, *et al.*, 2016, Jethwani and Achuthan, 2013, Gilmore and McManus, 2003, Shiller and Radikoko, 2014).

The runs test was initiated to examine the stock prices for serial independence. The result, indicated a presence of serial independence, which implies that the stock prices are random. This means that investors cannot make abnormal profit, while using past data and therefore, cannot beat the market. Hence, the S&P/TSX Composite Index is weak form efficient. This is line, with the studies of Worthington and Higgs (2004) and Freund and Pagano (2000). The result is however, inconsistent with the studies of Worthington and Higgs (2006), Suleman *et al.* (2010), Rehman and Hossain (2006), Rahman, *et al.*, (2016), Jethwani and Achuthan (2013) and Shiller and Radikoko (2014).

The ADF test shows that, the log returns of the S&P/TSX Composite Index are stationary. It means that a trend is observed in the series. Therefore, the test of the log returns being non-stationary was rejected for the null hypothesis. This finding, suggest that the stock prices can be predicted. Our finding is consistent with Worthington and Higgs (2006), Suleman *et al.*, (2010), Rahman, *et al.*, (2016), Gilmore and McManus (2003) and Shiller and Radikoko (2014). However, inconsistent with Worthington and Higgs (2004). The findings of the ADF, is in line with the autocorrelation test.

The K-S test was utilized in testing the normality of the S&P/TSX Composite Index daily closing price. The finding was in line with the plotted distribution pattern (histogram), which indicated that stock prices are not normally distributed. The kurtosis of the normal distribution was below 3, which shows that the data series are not normally distributed. The p-value of the Ljung-Box (Q) statistic was statistically significant, which does not support a distribution being normal. Also the normal distribution curve was leptokurtic, which further reflects non-normality. The null hypothesis that the returns are normally distributed was rejected and so, the S&P/TSX Composite Index is weak form inefficient and also, does not exhibit a random behavior. This is supported by Rehman and Hossain (2006), Rahman, *et al.*, (2016) and Jethwani and Achuthan (2013) but inconsistent with Camelia, *et al.*, (2017). The findings of the K-S test, is in line with the autocorrelation and ADF test.

The variance ratio was employed to examine the statistical significance of the Z-statistic of the variance ratio for some number of *q*-periods. If the VR (q) statistic is different significantly from unity, the hypothesis will be rejected with the evidences of autocorrelations in the return of the series. The variance ratio result, revealed that all periods observed, are not statistically significant at the 5% significance level. This implies that, the random walk hypothesis cannot be rejected and so, the S&P/TSX Composite Index is weak form efficient. However, period (1996-2000, 2009-2019), saw signs of significance at the 5% significance level for period q = 2. This could be attributed to the change of mechanism, in trading and settlement (trading through the internet) between the period of 1996-2000. As, on April, 1997, the Toronto stock exchange initiate a virtual (electronic) trading system. While, for the period of 2009-2019, is due to the aftermath of the global financial crisis. The findings are not consistent with (Suleman *et al.*, 2010, Rahman, *et al.*, 2016, Jethwani and Achuthan, 2013, Gilmore and McManus, 2003). This is due to the fact that, most of the markets used in these studies are emerging markets and so, are regarded as being inefficient. The variance ratio test is in line with the runs test.

4.9 CONCLUSION

The ADF test, K-S test and autocorrelation test all rejected the weak form efficiency of the S&P/TSX Composite Index. However, it was argued by Lo and MacKinlay (1988) and Liu and He (1991), that these test are traditional test and do not always determine the true state of efficiency of any stock market. So, Lo and MacKinlay (1988), suggested that the robust variance ratio test, is a better deterministic factor for the state of efficiency of a stock market. As it test for the presence of random walk. Also, the runs test examines the presence of random walk. Therefore, the findings of both test shows that, the S&P/TSX Composite Index follows a random walk and its weak form efficient through time. Hence, we can conclude that, investors cannot make abnormal profits by using past data.

CHAPTER FIVE

IMPLICATIONS, CONCLUSION, RECOMMENDATIONS AND AREAS FOR FURTHER STUDIES

5.1 INTRODUCTION

In the previous chapter, we evidently concluded that, the daily closing price of the S&P/TSX Composite Index is weak form efficient, based on the outcomes of the Variance ratio and runs test. This chapter however, will discuss, the implication of this outcome, in the Canadian context as a country. Afterwards, the conclusion, recommendations, areas for further studies and the research contribution to knowledge will be drawn.

5.2 IMPLICATIONS OF A WEAK FORM EFFICIENT MARKET

An efficient market prevents any one from the opportunist advantage of gaining abnormal profit from their investment. As, every investment should not earn above the expected return, associated with a certain level of risk(i.e. a commensurate reward to risk). However, in an inefficient market, both private and institutional investors are able to beat the market by utilizing the historical data of the past, to determine the current returns of the future. Thereby, beating the market and earning above average returns on their investments, which means they can earn above the expected return on their investment at a lower level of risk. However, when a market is efficient, such as the S&P/TSX Composite Index, the chance of earning abnormal returns by market participants is prevented.

Corporate executives aside investors, are also interested in the efficiency of a market. As, their actions and decisions about their firm's value is attributed to the market being efficient. The firm's value is perceived to be its intrinsic value unlike in an inefficient market, which is not capable of pricing securities timely and as such, their firm's value is not its intrinsic value. When a market is efficient, it makes it difficult for supervisors and operators to carry out the functions of the stock market. The functions could include, facilitating investments and channeling the wealth of individuals to firms who need the fund for expansion. But an inefficient market, negatively affects the expected return of investors and as well harms the economy as a whole. However, an efficient market like the S&P/TSX Composite Index will rectify such inefficiency in the market and the economy at large.

Another crucial implication of an efficient market is adequate allocation of resources. It was proved by Worthington and Higgs (2006), that the allocation of resources to important sectors, is beneficial for the growth of the economy. Unlike an efficient market, an inefficient market is unable to interpret and process information in a accurate and timely manner. As information processing is relevant in the reallocation of resources, an efficient market will enhance the allocation of resources to sectors which have the possibilities of having higher returns and take from those sectors with poor prospects.

5.3 CONCLUSION

The objective of the research, was to test the S&P/TSX Composite Index for weak form efficiency for the period of 1996-2019. From the analysis undertaken, based on the variance ratio and runs test for random walk, we found that the S&P/TSX Composite Index is weak form efficient.

5.4 RECOMMENDATIONS

In view of the implication specified above, the researcher has deduced some recommendations to maintain the efficiency of the S&P/TSX Composite Index. This could take the form of the government and shareholders in the S&P/TSX Composite Index assuring potential investors of the likely opportunities in the stock index. This can be initiated by showing them the benefits of the stock market in terms of investment, without focusing on making abnormal profits. Yartey and Adjasi (2007), suggested that a way to do this is, reducing transaction cost which encourages interest in the stock market. They argued that, the market becomes informationally efficient, when there are more traders in the market. This is due to the fact that, when there are more active users such as individuals, corporations, investors and mutual funds in the market, holding information becomes difficult.

Supervisors and operators of the market, should ensure the consistency of the effectiveness of banks, insurance companies and hedge funds with the international best practices. As, investors will only engage with institutions that are transparent, efficient and strong. So, regulators should discourage market participants from making short term abnormal returns, in order to encourage long-term profitability which propagate an efficient market.

5.5 AREAS FOR FURTHER STUDIES

One important finding in terms of the literature review, is the contradictory outcomes for the weak form efficiency. As, the weak form efficiency were accepted for all markets studied in the works of Freund, *et al.*, (1997), Freund and Pagano (2000), Camelia, *et al.*, (2017), Cunningham (1973) and Maria (2007). On the other hand, there were rejections for the weak form efficiency, in the studies of Shiller and Radikoko (2014), Li and Liu (2012) Birau (2015) Gilmore and McManus (2003) Jethwani and Achuthan (2013) and Rahman, *et al.,* (2016). This is was due to the fact that, different parameters were implemented such as different methodologies, countries(developed and emerging), data sets and also time periods. Despite the valid reasons for the acceptance or rejection of the weak form efficiency across countries, the validity of the theory of efficient markets becomes questionable. As, behavioral finance brings up questions such as, can we say in an efficient market, investors cannot gain abnormal returns on their investments or that recent returns cannot be determine, using past data. According to Fama (1970), investors are consider as being rational. But, according to behavioral finance, investors are humans and are influence by different things and as such act irrational.

In regards to the lack of sufficient studies on the anomalies of stock exchange and behavioral finance in the S&P/TSX Composite Index. Hence, further studies can be carried out on the S&P/TSX Composite Index, in relation to behavioral finance. This encompasses herding mentality, beliefs and personal judgement and also overconfidence.

Another area that can be studied further, is the implementation of a much better robust statistical test such as the multiple variance ratio, GARCH and ARIMA, to testing the weak form efficiency of the S&P/TSX Composite Index. This is due to the fact that, the robust variance ratio test, ignores the joint nature for examining random walk behaviour. This was suggested by Bose, *et al.*, (2014) Gilmore and McManus (2003), Camelia, *et al.*, (2017) and Worthington and Higgs (2004) in the literature review.

Finally, in respect to testing the weak form efficiency of any stock market, it was highlighted in the literature review by (Jones, 1993), that one of the consequence of the weak form market efficiency is that technical analysis is futile. It was observed that, one cannot always make abnormal returns by testing only the historical data of the stock market. Therefore, further studies can be explored for the stock prices of the S&P/TSX Composite Index, by utilizing both technical and fundamental analysis for testing the presence of weak form market efficiency.

5.6 CONTRIBUTION OF THE STUDY TO KNOWLEDGE

The contributions made by the study to existing knowledge includes:

- The research looked at the weak form efficiency of the S&P/TSX Composite Index through time (i.e. 1996-2019).
- It serves as an updated information for investment banks, fund managers and most importantly investors, who are looking to expand their investments (portfolios).
- As suggested by Cunningham (1973), Grimes and Benjamin (1975) and Rosenberg and Rudd (1982) in the literature review, the research employed different statistical test to avoid the findings(outcome) being bias.

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APPENDIX

Using MATLAB functionality to test the weak form of the efficient market hypothesis for the S&P/TSX Composite Index

- We plotted a history of the index and its daily returns.
- We plotted a histogram of these returns and compare the results to the normal distribution.
- We perform the Kolmogorov Smirnov test for normality and plotted a graph comparing the empirical cumulative distribution obtained from the index returns with the normal distribution.
- We checked the returns for autocorrelation, displaying the autocorrelation and using the Ljung Box statistic to test the hypothesis that the autocorrelation coefficients up to lag 20 are jointly zero.
- We use the Runs Test to test the hypothesis that the daily returns come from a random sample.
- We use the Variance Ratio test on the logarithms of the index, to test the hypothesis that the logarithm of the index constitutes a random walk with constant variance.
- We use the Augmented Dickey Fuller Test to test the hypothesis that the daily returns form a stationary series.

```
close all
%select the Close and Date from the Close
%S&P/TSXCOMPOSITEINDEX table

start_index = 1;
end_index= 5782;
Close = SPTSX{start_index:end_index,2};
Date = SPTSX{start_index:end_index,1};

my_string = "<strong> From ";
my_string =my_string + datestr(Date(1),'dd mmm yyyy');
my_string =my_string+ " to ";
my_string =my_string + datestr(Date(end),'dd mmm yyyy');
my_string=my_string +'</strong>';
fprintf('<strong> Period of Analysis </strong>')
```

```
fprintf(my_string)
```

From 11 Dec 2009 to 11 Dec 2019

```
%plot the time series history
figure
plot(Date,Close)
title('History of the S&P/TSX Composite Index')
xlabel('Date');
ylabel('S&P / TSX Composite Index');
grid on
hold on
```

```
%plot the history of the dailyReturns
figure
Returns = price2ret(SPTSX.LastPrice(start_index:end_index));
plot(Date(2:end),100*Returns);
title('DailyReturns in the S&P/TSX Composite Index')
xlabel('Date');
ylabel('S&P / TSX Composite Index Daily Returns (%)');
grid on
```

```
%plot the histogram
figure
myHist = histogram(100*Returns,50);
title('Daily changes in the S&P/TSX Composite Index')
hold on
y1=myHist.BinLimits(1);
yh=myHist.BinLimits(2);
y = linspace(y1,yh,101);
mu = mean(100*Returns);
sigma = std(100*Returns);
N = size(Returns);
scalingFactor = N(1)*myHist.BinWidth;
f = exp(-(y-mu).^2./(2*sigma^2))./(sigma*sqrt(2*pi));
plot(y,f*scalingFactor,'Linewidth',1.5)
grid on
xlabel('Daily changes in the S&P/TSX Composite Index (%)')
legend('Daily changes', 'Normal Distribution','Location','best');
```

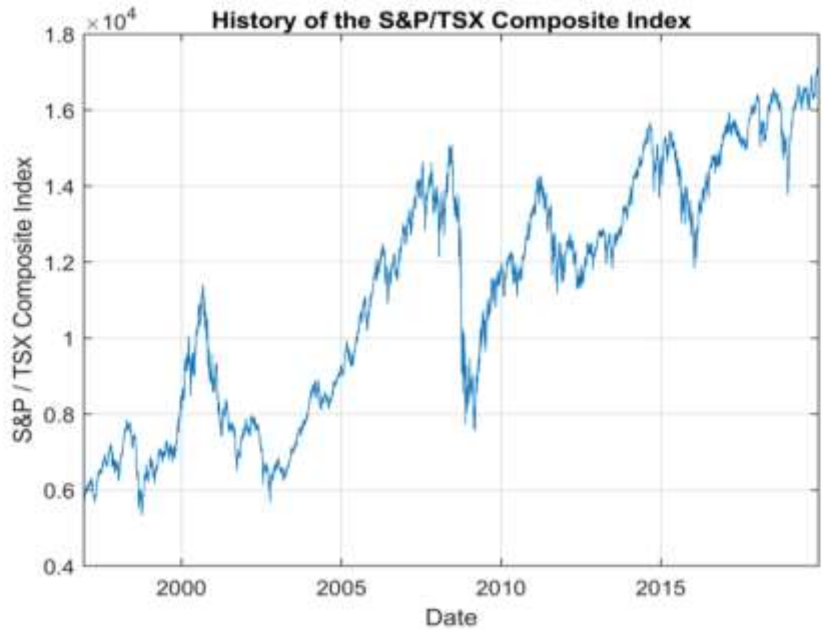
```
%Perform the Komologrov Smirnov test
%for normality
%first standardise the daily returns
x = (Returns-mean(Returns))/std(Returns);
figure
cdfplot(x)
hold on
x_values = linspace(min(x),max(x));
plot(x_values,normcdf(x_values,0,1),'r');
legend('Empirical CDF','Standard Normal CDF','Location','best');
fprintf('<strong>Komologrov Smirnov Test</strong>');
[h,p]= kstest(x,'Alpha',0.05);
if h == 1
    fprintf('Reject the null hypothesis that the returns are nornally
distributed.');
else
     fprintf('Accept the null hypothesis that the returns are nornally
distributed.');
end

fprintf('The p value = %s. \n',p);
```

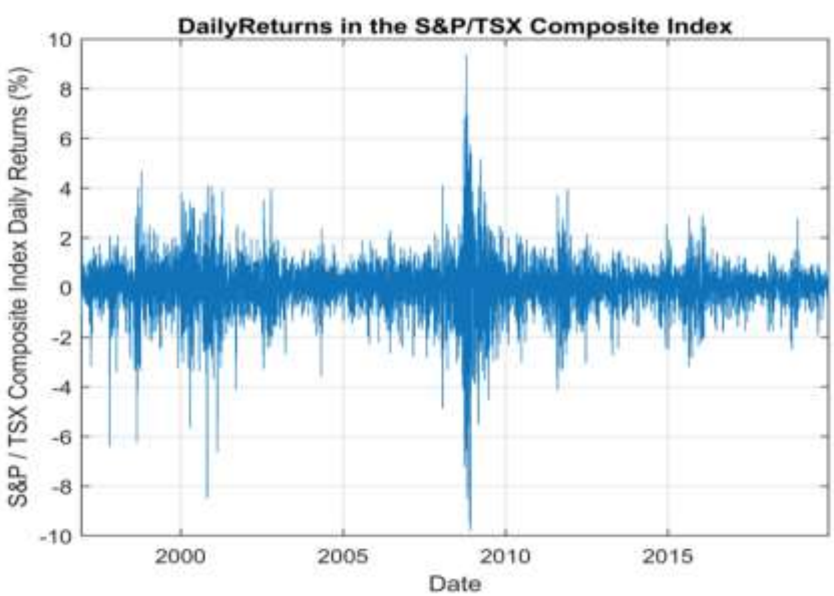
```
%check the returns for auto correlation
figure
autocorr(Returns,20)
title('Autocorrelation of daily S&P/TSX Composite Index returns vs. lag')
grid on

%Apply the Ljung BoxTest
[h,p]=lbqtest(Returns, 'alpha', 0.05);
if h==1
    fprintf('We reject the null hypothesis that the the autocorrelation
coefficients returns to lag 20 are all zero')
else
    fprintf('We cannot reject the null hypothesis that the the
autocorrelation coefficients returns to lag 20 are all zero')

end
fprintf('The p value is %s \n.',p)
```

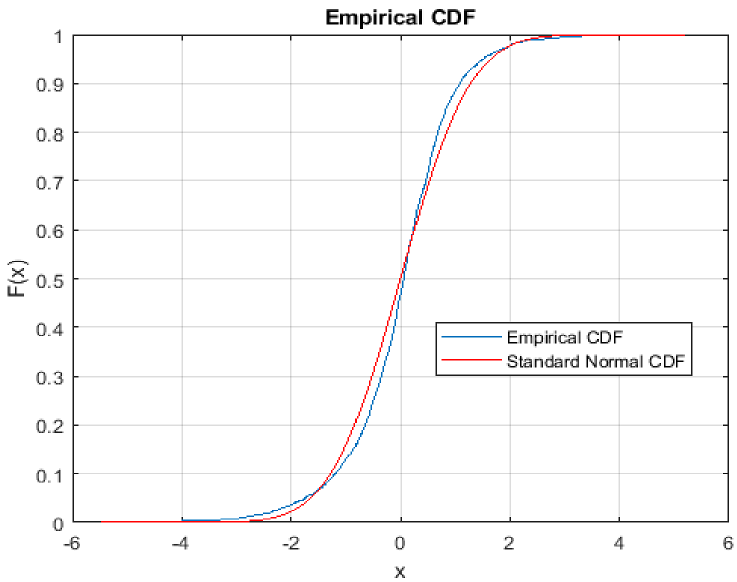
```
%Apply the Runs test
fprintf('\n')
fprintf ('<strong>Apply the Runs Test.</strong> \n')
[h,p,stats]=runstest(Returns,'ud');

if h==1
    fprintf('We reject the null hypothesis that the daily returns come in
random order, versus the alternative that they do not')
else
    fprintf('We cannot reject the null hypothesis that the daily returns come
in random order, versus the alternative that they do not')
end
fprintf('\n')
fprintf('The p value is %s \n.',p)
fprintf('The relevant statistics from the runs test are. \n')
stats
fprintf('\n')
fprintf('\n')
```

```
%Apply the Variance Ratio test')
fprintf ('<strong>Apply the Variance Ratio Test.</strong> \n')
[h,p]=vratiotest(log(Close));

if h==1
    fprintf('We reject the null hypothesis that the stock price is random
walk using the Variance Ratio Test')
else
    fprintf('We cannot reject the null hypothesis that the stock price is
random walk using the Variance Ratio Test')
end
fprintf('\n')
fprintf('The p value is %s. \n',p)
```

```
% Apply the Augmented Dickey Fuller Test for a Unit Root
fprintf('<strong> Augmened Dickey Fuller Test </strong>');
[h,p]= adftest(Returns,'Alpha',0.05);
if h == 1
    fprintf('Reject the null hypothesis that there is a unit root, i.e. that
the series is non-stationary.');
else
     fprintf('Accept the null hypothesis that there is a unit root, i.e. that
the series is non-stationary');
end

    fprintf('The p value = %s. \n',p);
    fprintf(' \n')
```


History of the S&P/TSX Composite Index
×10^4
S&P / TSX Composite Index
Date
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
2000
2005
2010
2015


DailyReturns in the S&P/TSX Composite Index
S&P / TSX Composite Index Daily Returns (%)
Date
10
8
6
4
2
0
-2
-4
-6
-8
-10
2000
2005
2010
2015


Empirical CDF
F(x)
x
Empirical CDF
Standard Normal CDF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-6
-4
-2
0
2
4
6