National College of Ireland

Testing the degree of efficiency of Ireland Capital market with Efficient Market Hypothesis (EMH):

A comparative analysis of Ireland Capital market efficiency with its neighbouring capital markets of the UK, Belgium and the Netherlands

MSc Research Project
MSC FINTECH

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MSc Project Submission Sheet

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Testing the degree of efficiency of Ireland Capital market with Efficient Market Hypothesis (EMH)

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Abstract

This paper analyses Ireland's capital market efficiency and performs a comparative analysis with its neighbouring countries of the United Kingdom, Belgium and the Netherlands using daily returns from their respective stock market indices from 1 January 2014 to 31 December 2019, a period rarely studied. The techniques used to conduct the analysis are random walk tests, namely unit root test, serial correlation test, runs test and Shannon Entropy Test. The four developed European markets were tested for their weak form of efficient market hypothesis and the information Efficiency (Shannon Entropy) was employed to ascertain the degree of information efficiency in the markets.

The empirical evidence indicates that the Ireland Stock market and its Neighboring countries (UK, Belgium, and Netherland) confirm Weak form of Efficient market hypothesis. The results from Shannon Entropy – informational efficiency point out Belgium and Netherlands to be higher in information efficiency than Ireland with UK scoring the least on the information efficiency of all the tested markets. The results concluded that in these markets a passive approach to portfolio management is a better investment strategy than an active portfolio management strategy. Furthermore, it is suggested to test the individual stocks in the index for efficiency and more complex models and test be used to ascertain efficiency in these indexes with a higher degree of certainty.

1 Introduction

A sophisticated financial sector is the backbone of a modern economy as it is needed to pool resources and domestic savings and generate capital for productive projects. Mature capital markets are needed to effectively execute productive projects to further the development agenda. They are also required to improve financial intermediation in such projects. They help in mobilising savings and thereby improve efficiency and volume of investments and are therefore indispensable for development and economic growth. Regulatory bodies are meant to step in to remove any inefficiencies if in the stock markets. "*Efficient capital markets are commonly thought of as markets in which security prices fully reflect all relevant information that is available about the fundamental value of the securities*". (NASDAQ, 2000) Three type of market efficiencies are: allocational efficiency –optimal distribution of resources among market participants; operation efficiency – capital can be allocated at least of friction at fair competitive price; and informational efficiency –when all information about a security is factored in its price (Săvoiu & Andronache, 2013). Notably, the degree of allocational efficiency depends both on operational and informational efficiency. Partly due to the practical aspects of trading and investing, most empirical studies on market efficiency are limited to informational efficiency for the need to develop a baseline price model.

Random Walk hypothesis states that subsequent stock price changes are sovereign and homogenously distributed random variables independent of historical price movements. Therefore, the Random Walk Hypothesis emerged as a model to testify the Efficient Market Hypothesis (Malkiel, 1973). EMH states that the price of an asset reflects all available & relevant information about the intrinsic value- present value of the expected future cash flows from the security. (Fama, 1991) Thus, rendering the investment analysts search for mispriced-overvalued or undervalued stocks futile in the long run as the market is expected to converge to its efficient form causing security prices to reflect its intrinsic values.

This research aims to explore the the existence of the random walk model by testing the weak form of efficiency of the EMH in Irish stock exchange and compare its efficiency with that of its neighbouring countries namely the UK, Belgium and the Netherlands.

There is considerable evidence to make a strong case that EMH can be used to discern the direction of prices of securities over short durations such as days, weeks or even months. That is, complete impact of the new information is quickly realised in the intrinsic value of the security. EMH forms the prototype of market behaviour when investors allocate capital efficiently amid other adequate factors. For practical purposes, the degree to which this shall be realised will be determined by variables such as transparency and dissemination of information, robust and effective regulatory framework, and likelihood of arbitrage driving out anomalies. Informational efficiency in prices of securities also varies from across markets and geographies.

1.2 Motivation

Analysing the Irish stock market could yield some interesting results, as it is a small market that has undergone some major changes over the last 25 years. Certain investors believe that small markets are less efficient than larger markets; if this is the case some trading strategies should be able to exploit these inefficiencies and generate excess returns. This paper investigates the profitability of momentum trading strategies in the Irish market thus determining whether the Irish market is efficient.

1.1 Research Question

In alignment with the motivation for the analysis the research question could be framed as following-

“What is the degree of market efficiency of the Irish stock market in relation to neighboring countries as measured by the efficient market hypothesis (EMH)?”

1.2 Objectives

Categorization of tests into weak, semi strong and strong allows to evaluate the level of information efficiency in the market which is imperative because certain investors can produce abnormal profits in an inefficient market, but on the other hand such investors cause abnormal losses to the majority of market participants. As business performance is an investors' fundamental right, thus in this research the main objectives are as follows-

- Review the related work in the emerging, developed and developing economies.
- Evaluate the average monthly share price performance and test it for efficient market weak form in the Irish Stock Market.
- Comparative analysis of the degree of Irish capital market efficiency with its neighboring countries UK, Belgium and Netherlands

2 Related Work

The concept of market efficiency is based on the arguments put forward by Paul A. Samuelson (Samuelson, 1965) that suggests price of an asset fluctuate randomly. Random Walk theory first proposed by Bachelier (Bachelier, 1900) and later refined by Osborne (Osborne, 1977) conceptualized Radom Walk model based on assumptions that the occurrence and evaluation of the information used by analysts to estimate intrinsic value of securities is independent.
In order to test the random walk model, Robert Levy (Levy, 1967) suggested statistical tests namely serial correlation for determining the co relation between variables at different lags of the time series data, the runs test for ascertaining the sequence of change in the variables and third approach for testing the independence of successive price changes is the simulation model.
Market efficiency is the form of market where large number of profit seeking investors actively forecast the future market values of stocks and the current information is available to all market participants at no transactional costs or fees. (Fama, 1970) In such market the benefits on acting on this information don't exceed the marginal costs of achieving this information.
Fama presented a formal review of theory and evidence of market efficiency, highlighted that in reality efficient market model is not entirely achievable however, could be served as a benchmark against which performance of market efficiency can be judged. (Fama, 1988).

The recent studies conducted to show the efficiency of the financial market and the use of various types of econometric techniques and data frequencies are presented to explain this theory.

Gu (A.Y, 2004) tested NASDAQ composite index over the period spanning from 1971 to 2001 using the daily returns. The results determined that daily returns of the NASDAQ index are not weak form of efficient implying that the returns movements could be forecasted using technical or fundamental analysis. Weak form of market efficiency on 20 European markets by Worthington and Higgs (Worthington, 2004) for the period August 1995 to May 2003 by

implementing various random walk tests namely variance ratio test and Augmented Dickey Fuller Test to ascertain the stationarity and the correlation in the markets over the holding period. The results indicated that the distributions of the market returns are asymmetrical and only five countries are observed to be following random walk hypothesis sternly namely UK, Germany, Spain and Ireland.

Borges (Borges, 2008) tests the existence of the random walk and EMH for European stock markets, namely UK, France, Spain, Germany, etc. by using ADF tests, variance ratio and correlation tests for monthly stock prices. The mean reversion observed in the weekly returns of the UK and France results in rejecting the EFH however, the Germany and Spain do not reject EFH. Results from the variance ratio tests determine that the markets which showed serial correlation in their daily returns rejected random walk hypothesis, while all the emerging markets observed to reject the random walk process with the exception of Hungary market, implying that the emerging markets are inefficient as compared to developed markets.

Tests conducted east Asian countries namely Bangladesh, Pakistan, India and Sri Lanka examining the weak form of efficient market hypothesis through various statistical tests of random walk hypothesis concluded that the markets do not follow a random walk hence rejected the weak form of efficiency (Hanif, 2014).

Individual stocks listed on Bahrain Bourse for the period 2011- 2015 were tested for weak for of efficiency using the run test, auto correlation test, and Kolmogorov- Smirnov goodness of fit test. The results from the K-S test and run test conclude the stock prices listen on the exchange do not follow a random walk however, the autocorrelation test reveal that the share price exhibit low to moderate level correlation. The mixed results could not draw a conclusive determination about the weak for of efficient of Bahrain Bourse. (Hawaldar & Pinto, 2016)

The semi- strong form of EMH was conducted on the Mauritius forex market using the nominal spot rate daily data namely EUR/MUR, USD/ MUR, GBP/ MUR and JPY/ MUR data. The Granger Casualty and Variance Decomposition indicated correlation in the movements of the exchange rates in the long run, implying that a movement in one exchange rate could predict the movement on one of more exchange rates, therefore rejecting the semi strong form of efficiency in the market. (Lydie Myriam Marcelle Amelot, 2017).

Stock market returns of Asia- Pacific markets namely India, Sri Lanka, Pakistan, Indonesia, Malaysia, Philippine, Thailand, Singapore were tested for weak for market efficiency. Autocorrelation, Ljung-Box Q statistic test, Runs Test, Unit Root test and Variance ration test were used to test that the stock markets follows a random walk. The results from the test concluded that the stock markets do not follow a random walk and hence the investors could benefit from arbitrage process in these markets. (Hamid, et al., 2017)

Efficient market hypothesis test conducted on developed eastern European countries namely Croatia, Serbia, Slovenia, Slovakia using Augmented Dickey Fuller test, serial correlation tests,

run tests and variance tests using the historical index daily, weekly and monthly values for analysis indicated that all the market index are weak form of efficient with an exception of Serbia. (Saša Tokić (Croatia), 2018)

Past empirical studies on developed markets bear testament to no significant gains from referring to past price series which supports the weak-form efficiency of the EHM in general. But there are two contradictory schools of thoughts on market efficiency. The earlier empirical work hypothesizes that markets are efficient, and returns are uncertain concluding that the stock market is efficient owing to various factors. While on the other hand record empirical studies of 'anomalies' which contrast the theory of efficient markets. (Ritter, 2014)
Other interesting findings say stock yields tend to be particularly high in the first few days of January (January effect) and negative from the end of Friday to the close of trades on ensuing Monday (Monday effect) (Abba, 2015). However, the more recent study on the stock markets of Asia Pacific, Latin America and Europe indicated no presence of the January effect. (Jayen B. Patel, 2016)
Furthermore, stocks which have low price to earnings ratios have better risk-adjusted returns on an average than others and smaller firms generate higher risk-adjusted profits than larger companies (Size effect) (Novickytė, 2014). The counterfeiting research (Gunardi, 2018) conducted on the Calendar Anomalies on the stock exchanges of Italy, France, Spain and Germany stock. The results from the statistical tests of GARCH and OLS regression were used in order to verify the auto correlation and distribution of the returns. The results do not indicate no strong evidence of a comprehensive calendar effect in these markets.

Efficient Market Hypothesis has been researched extensively in the last couple of years however there are enough gaps in the study conducted on equity market indices around the world in the present era with little or no research on Ireland Capital Market.
The aim of this research is to analyze the degree of efficiency in Irish Capital Markets in relation to it neighboring countries as measured by EMH. Furthermore, in consensus with the "size effect" (Stéphanie & Pascal, 2016). It is believed that investors in small markets are less efficient and hence could be exploited with some trading strategies to earn excess returns, this paper investigates the size effect contributing to opportunities of earning abnormal profits thus determining if Irish stock markets are efficient.

3 Research Methodology

The knowledge discovery of database (KDD) methodology is adopted for the research thesis. KDD is a methodological approach which aims to extract meaningful insights or knowledge from large data sets datasets using a step by step process of the data selection, data preprocessing, data transformation, data mining and Evaluation or Interpretation of result, the following figure presents the aforementioned steps in the KDD method (Shafique & Qaiser, 2014) as presented in Figure 1.

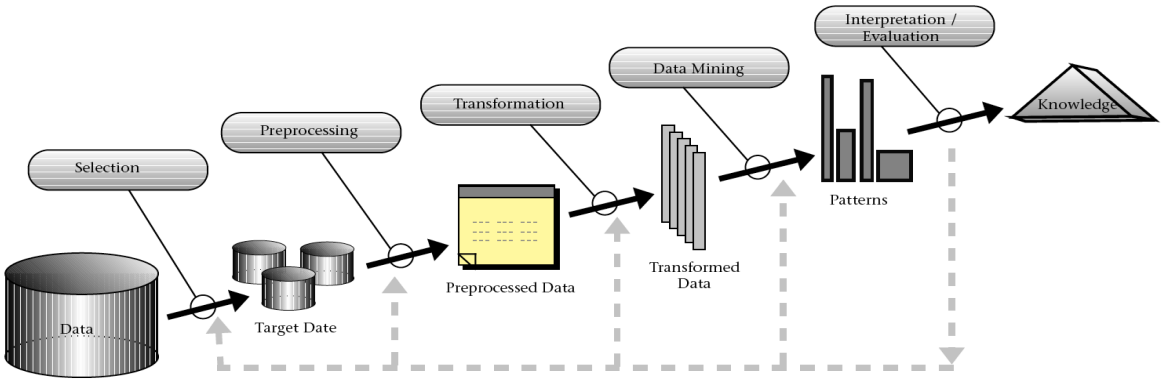

Figure 1 KDD METHODOLGY

3.1 Data

The data used for this study was sourced from the yahoo finance database, an online database that houses stocks information from the period of five years spanning from Jan 2014-Dec 2019(pre COVID-19 pandemic). The test for the weak form of efficiency for the Ireland stock market was done using the ISEQ financial time series data. It tracks the overall performance of companies listed on the Ireland stock exchange excluding the UK registered companies, it is capitalization weighted index. The Financial Times stock Exchange (FTSE) was used to test the hypothesis for weak form of EMH for the UK companies. The BEL 20(BFX) index comprises of 10 to 20 companies of the Brussels Stock Exchange Belgium was used to test the weak form of EMH for Belgium stock market and the Amsterdam Exchange index (AEX) composed of maximum of 25 Dutch companies listed on the Amsterdam stock Exchange was used to test the weak form of EMH for Netherlands stock Market.

3.2 Data preprocessing

The data is preprocessed for consistency for the R programing modelling. It involves steps for checking for missing values, interpolations, checking for noise, formatting the data, descriptive statistics, and exploratory data analysis. This section is very important for data analysis and machine learning for modelling because inconsistency in data structures will lead to errors.

3.3 Testing for the Efficient Market Hypothesis

Different statistical tests were used to test the markets for weak form of Efficient Market Hypothesis, namely-

- Unit root test
- Serial (auto) correlation test
- Runs test

3.3.1 Random Walk Theory Tests

a) The Unit Roots test

Also called the difference stationary process is used to test the stationarity in times series.

Hypothesis:

H_0: Unit root is present (Non-stationary): The stock market price follows the random walk theory

H_1: Unit root is not present (stationary): The stock market does not follow the random walk theory

- **The Augmented dickey fuller test for Unit Root**

ADF is one of the parametric tests for testing the stationarity in time series data. (Dickey & Fuller, 1979) ADF test is conducted on the prices of the financial time series data e.g. the stock prices. Mathematically, ADF involves higher order of regressive process. (Prabhakaran, 2014)

$$y_t = c + \beta t + \alpha y_{t-1} + \emptyset_1 \Delta Y_{t-1} + \emptyset_2 \Delta Y_{t-2} + \cdots + \emptyset_p \Delta Y_{t-p} + \varepsilon_t \quad (1)$$

where,

- C is constant
- β is coefficient on the time trend
- P the lag order of the autoregressive process
- y(t-1) = lag 1 of time series
- delta Y(t-1) = first difference of the series at time (t-1)

b) Serial Correlation test

A test to check the randomness in financial time series. If a variable has an association with its lagged variable, future value of the variable can be predicted using the current value of the variable, implying that the time series is not random.

Hypothesis

H0: There is no serial correlation: The stock market price follows the random walk theory

H1: There is serial correlation: The stock market does not follow the random walk theory

- **Ljung Box Test**

Ljung Box is used to test for serial correlation in time series (G. M. LJUNG, 1978), it test to determine whether a series of observations over time are random and independent. (Burns, 2002) The hypothesis of serial correlation will be accepted if the p value is less than the level of significance.

The test statistics is as follows

$$Q = n\,(n+2)\sum_{k=1}^{h} p_k\text{^}2 \;/\; (n-k) \quad (2)$$

Where,

- n is the sample size
- Pk is the sample auto regression at lag k

- H is the number of lags being tested

c) Run Test

The runs test is a non-parametric test used to determine if the sequence of data follows a random process. The run test is based on the number of runs occurring in within the sample, the runs is the sequences of change in the return of the series. (Schenkelberg, 2000)

Hypothesis

H_0: The sequence is a random sequence

H_1: The sequence is not a random sequence

The standard normal test statistics,

$$Z = \frac{(\text{obscerved} - \text{expected})}{\sqrt{Variance}} \quad (3)$$

Where Expected runs = $1 + \frac{2\ X\ R1\ x\ R2}{N}$

Variance = $\frac{2\ X\ R1\ X\ R2\ (2\ X\ R1\ XR2 - N)}{N^2(N-1)}$

R1 = the number of positive runs

R2= the number of negative runs

N = the total number of runs in the sample (positive and negative)

d) Shannon Entropy test

Shannon entropy is statistical test used to test (Shannon, 1948)for test the amount of information contained in the variables. Shannon Entropy also known as information entropy measures the information efficiency of the capital markets. It measures the uncertainty in the variance of a probability distribution, the value of a random variable. (Vajda, 2008)

Mathematically, Shannon Entropy is given as.

$$H(X) = E[\ I_b\ (x)\ ] = -\ \sum_{i=1}^{n} p(x_i) log\ _b p(x_i) \quad (4)$$

Where,

- X is the random variable, i.e the closing stock price for the stock market index
- P(X) is the probability the random variable x
- Log (P(x)) is the log of the probability of the random variables

4 Design Specification

The R studio was used for the implementation of the methodology of this research. The process can be summarized into data collection, Pre-processing and analysis. The following steps were followed-

1) Data collection

- The following library were installed and loaded into R studio for the purpose of the analysis- Quantmod, moments, performanceAnalytics, tseries, tidyverse, entropy , entropyEstimation and the randtests packages.
- The getsymbol function of the quantmod package was used to retrieve the stock market information from the yahoo finance database. The period covered was from January 01, 2015 to December 31, 2019. The ISEQ, FTSE, BFX, AEX index information was collected to proxy for the Ireland, United Kingdom (UK), Belgium and Netherlands capital markets respectively.

2) Data preprocessing and exploratory data analysis

- The data is preprocessed for ensuring consistency, the summary function is used to check for missing values on the stock information collected. The observed missing values in the ISEQ, FTSE and BFX stock information are interpolated using the , na.approx function from the zoo package.
- In order to conduct exploratory data analysis the chartseries function from the quantmod package was used to give visual representation of the stock index time series closing prices. The daily return function was used to get the daily return for the four stock market index considered, the table.stats was used to obtain the descriptive summary of the return such as mean, median, maximum, kurtosis etc. The distribution of the return series for the four capital markets was assessed using the chart.Histogram function of the performanceAnalytics packages. Jarque.test function from the moments package is used to test for normality of the returns of the four capital markets. The correlation of the series was also assessed.

3) Analysis

In testing for the weak form of market efficiency hypothesis, the unit root, serial correlation and the run test were performed on the time series data. The adf.test from the tseries package which uses the Augumented dickey fuller methodology is used to test for the unit roots in the four capital markets . The Ljung box test is used to test for serial correlation, the Box.test function from the stats package was used for this. The runs.test function from the randtest package was used to test for the hypothesis of random walk process for the efficient market hypothesis. Finally, the entropy function and Entropy.z function from the entropy and Entropy Estimation packages respectively is used to calculate the Shannon entropy for informational efficiency. The entropy value was then standardized for comparative analysis across all the markets. The output of our Implementation is presented in the following section, the results are interpreted and compared.

4.1 Distribution of the returns

4.1.1 Descriptive Statistics for ISEQ, FTSE, BFX, and AEX

Statistics	ISEQ	FTSE	BFX	AEX
Minimum	-0.1041641	-0.0477976	-0.0661323	-0.0587313
Median	0.0003381	0.0004795	0.0004142	0.0007504
Arithmetic Mean	0.0002513	0.0001144	0.0001450	0.0002762
Geometric Mean	0.0001939	0.0000765	0.0001002	0.0002278
Maximum	0.0444659	0.0351542	0.0380147	0.0397081
Variance	0.0001137	0.000 0757	0.0000893	0.0000966
Stdev	0.0106639	0.0087026	0.0094504	0.0098285
Skewness	-1.2173606	-0.2156667	-0.5415110	-0.4493167
Kurtosis	10.8822484	2.4959423	3.6138493	3.2789521

4.1.2 Jarque Bera Test for Normality

Statistics	ISEQ	FTSE	BFX	AEX
JB statistics	6564.7	337.63	756.71	614.56
P value	2.2e-16	2.2e-16	2.2e-16	2.2e-16

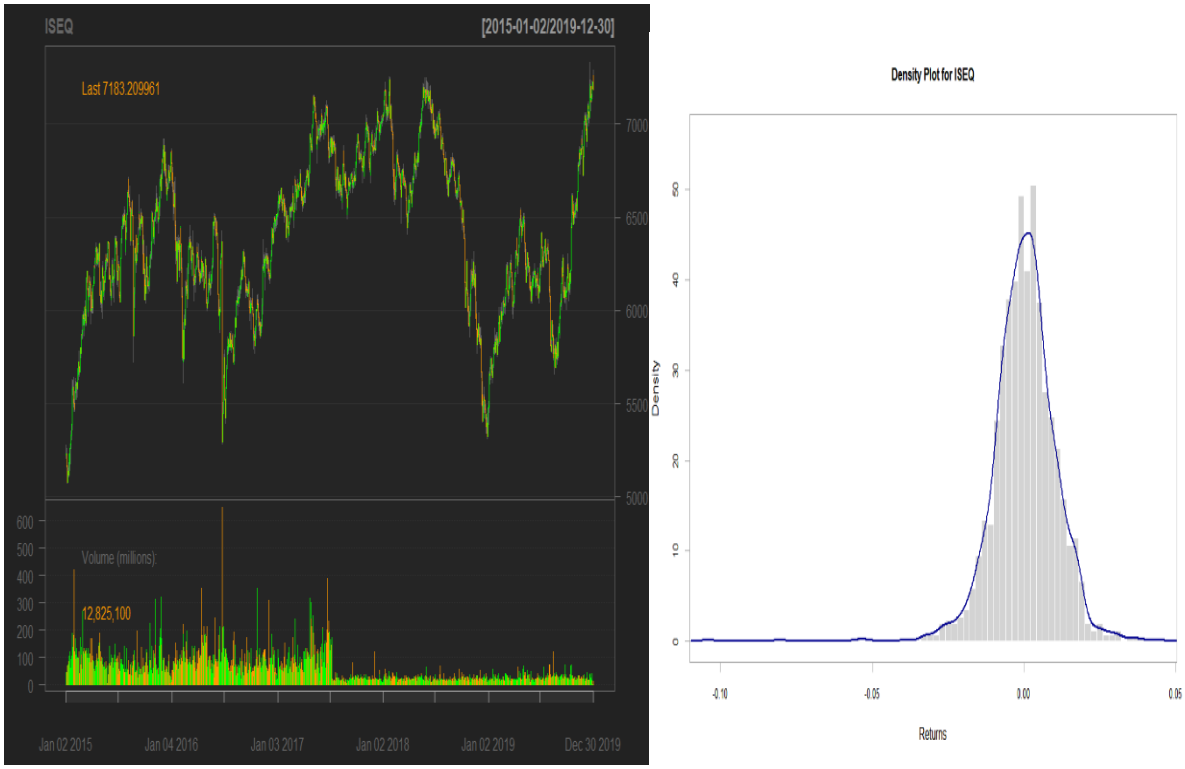

Fig 2 Time plot of ISEQ stock price and the density plot of its daily returns

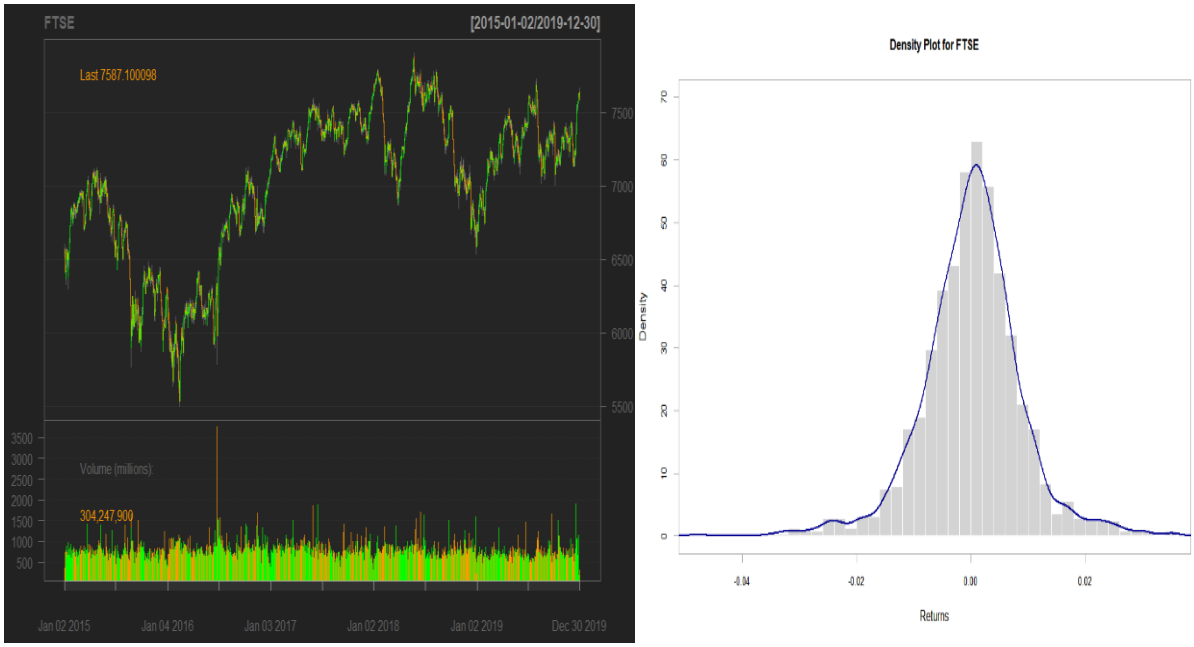

Fig 3 Time plot of FTSE stock price and the density plot of its daily return

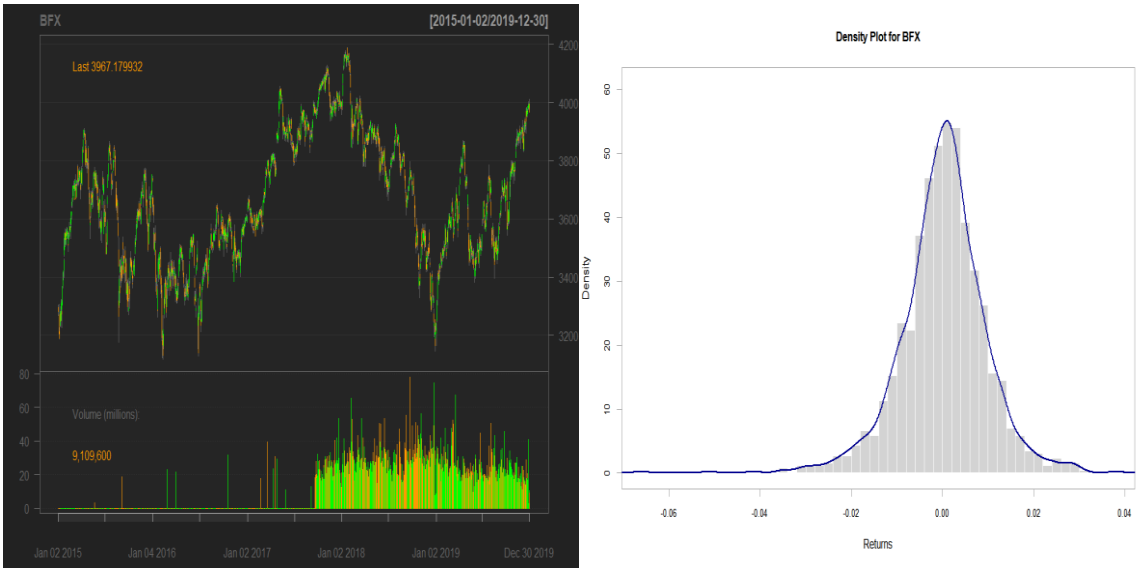

Fig 4 Time plot of BFX stock price and the density plot of its daily returns

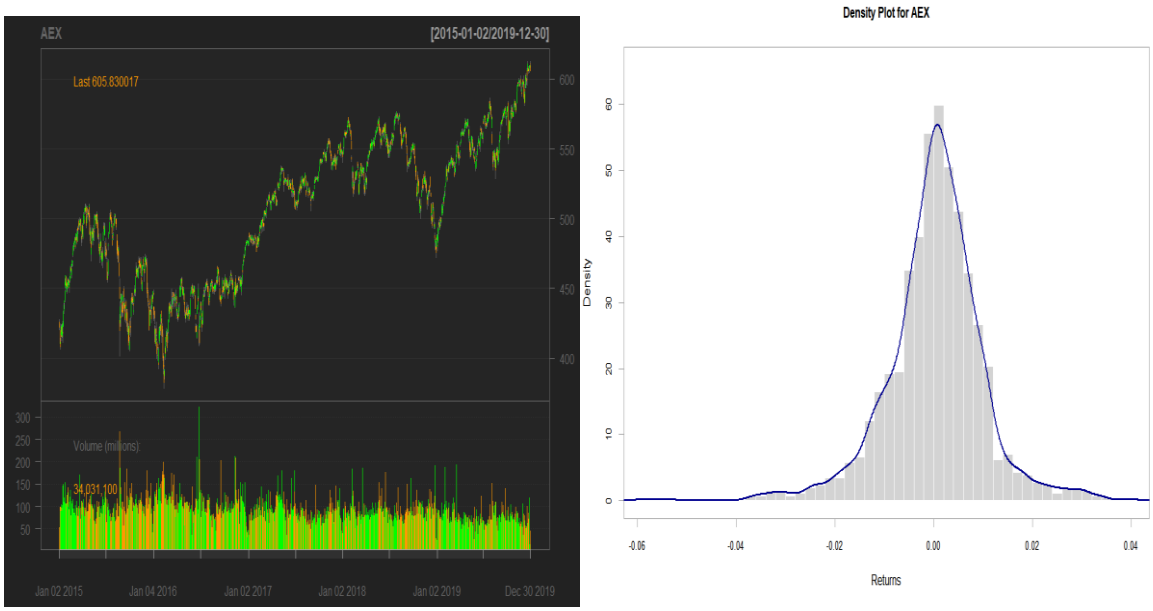

Fig 5 Time plot of AEX stock price and the density plot of its daily returns

The summary of the statistical properties of the time series distribution of all the four markets under analysis are presented in the tables 1,3,5 & 7. It is observed that all the markets have a positive return during the period considered in the study as ascertained by the values of Arithmetic mean and a compounding/Geometric mean average. The upward trend in the stock price overtime is ascertained graphically in the time series plot in Figure 2 to 5. The highest and the lowest returns recorded in the period is determined by the Maximum and the Minimum statistical values. The risk is determined by the value of standard deviation of the distribution. The negative skewness and high kurtosis value (above the normal distribution of skewness of 0 and kurtosis of 3) indicate that the distribution of the return is asymmetrical (i.e. it is tailed to the left and leptokurtic). The distribution is graphically presented in the Figure 4.1 in the density plot which visually determines that the distribution of the return is not normally distributed.

The results from Jarque Bera test for normality is presented in the Table2, 4, 6 and 8 which ascertains the asymmetry of the distribution of the returns as the p vale is significant. The P value is smaller than the level of significance ($\alpha = 0.01$), it implies that the test statistics does not fall within the acceptance region, therefore the Null hypothesis of Normality is rejected for all the four markets.

4.2 Correlation between the returns of ISEQ, FTSE, BFX, and AEX

Returns	Correlation	P value	Lower CI	Upper CI
ISEQ to FTSE	0.6629	6.1094e-160	0.6307	0.6928

ISEQ to BFX	0.7794	2.4660e-258	0.7568	0.8002
ISEQ to AEX	0.7444	2.0588e-233	0.7187	0.7680
FTSE to BFX	0.7930	8.9474e-273	0.7715	0.8126
FTSE to AEX	0.8538	0	0.8381	0.8681
BFX to AEX	0.9014	0	0.8906	0.9112

Table 9 the correlation of the returns of ISEQ, FTSE, BFX, and AEX

The correlation matrix as presented in Table 9/Figure 6 shows that the returns of ISEQ has a positive and strong association with the returns of FTSE, BFX and AEX. The association are also significant since the p value is less than the level of significance. The P value are all greater than the level of significance ($\alpha = 0.01$), therefore the Null hypothesis of association or correlation is not rejected.

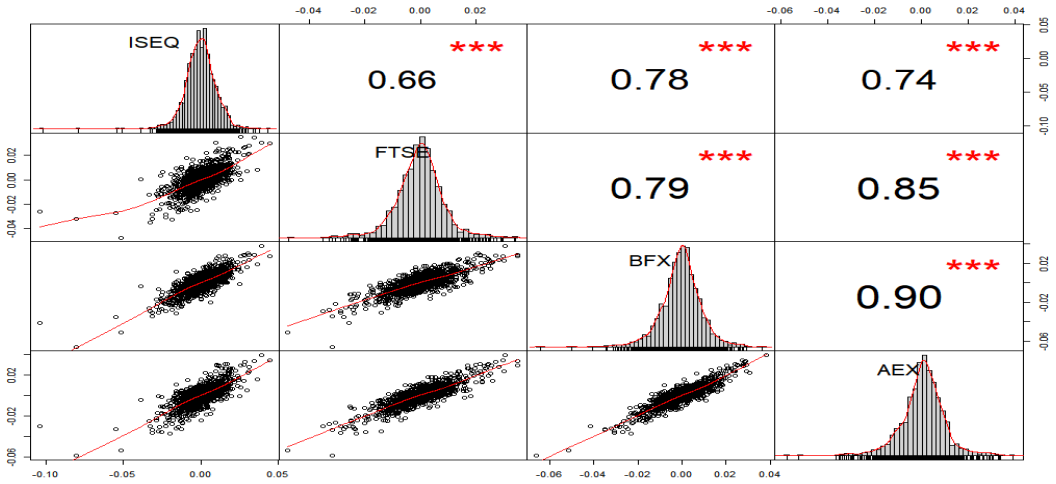

Fig 6 The correlation analysis graph

4.3 Weak Market Hypothesis

To test then weak form EMH, the random walk hypothesis is tested for ISEQ, FTSE, BFX, and AEX using the unit root, serial correlation and the run test analysis.

1) Unit Root Test

Table 10 Augmented Dickey Fuller Test statistics

Statistics	ISEQ	FTSE	BFX	AEX
Dickey-Fuller	-2.6597	-2.2501	-2.3941	-2.3537
Lag Order	15	15	15	15

P value	0.2991	0.4724	0.4115	0.4286

From the result presented, the p value are all greater than the level of significance (α=0.01) for the four stock markets index. Therefore, the null hypothesis is not rejected, there is presence of unit root in the return series as a result the series follows a random walk process.

2) Serial Correlation

Table 11 Ljung Box test statistics

Statistics	ISEQ	FTSE	BFX	AEX
X squared	51.025	26.243	35.691	28.901
Lag Order	15	15	15	15
P value	8.178e-06	0.03554	0.001958	0.01656

From the result presented, the random walk hypothesis is rejected for the ISEQ and the BFX stock index as their p value (8.178e-06 and 0.001958 for ISEQ and BFX respectively) are less than the level of significance (α=0.01). Therefore the null hypothesis of no serial correlation is rejected. This can be explained from the plot of autocorrelation as there is significance spike at lag1, lag4, lag5 for the ISEQ and BFX stock index. The hypothesis of random walk was not rejected for the FTSE and AEX stock index as their p value (0.03554 and 0.01656 respectively) are greater than the level of significance (α=0.01). Therefore, the null hypothesis of no serial correlation is not rejected.

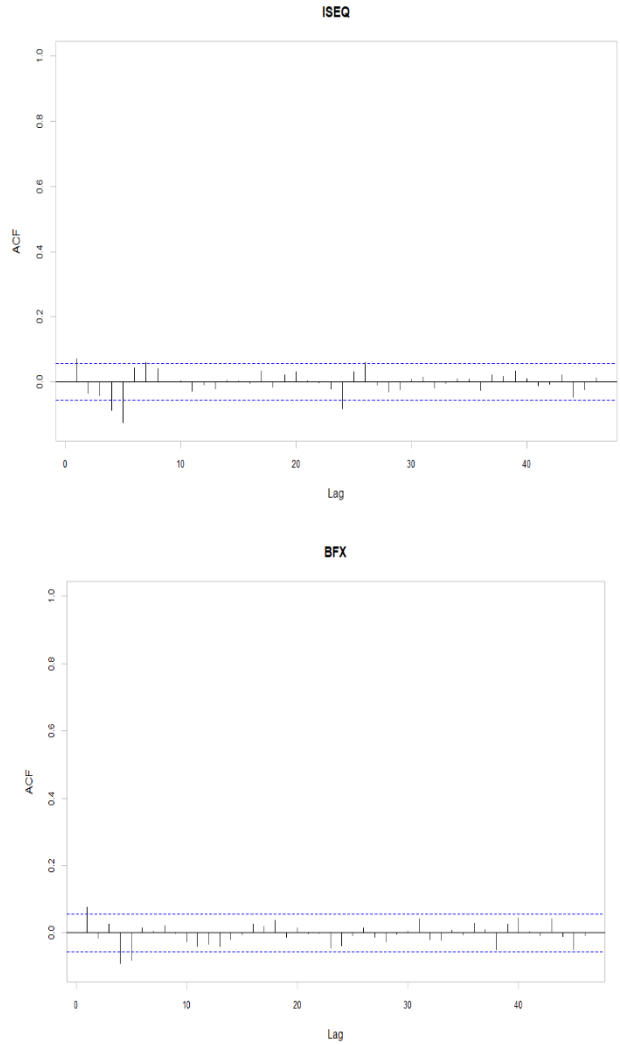

Fig 7 The graph of autocorrelation for ISEQ and BFX

3) Run Test

Table 12 Runs Test

Statistics	ISEQ	FTSE	BFX	AEX
Run statistics	-0.22493	-0.28161	0.67213	-0.22404
P value	0.822	0.7782	0.5015	0.8227

From the result presented, the p value are all greater than the level of significance (α=0.01) for the four stock markets index. It implies that the test statistics fall within ±2.33bound (acceptance region).Therefore, the null hypothesis is not rejected, it implies that the series follows a random sequences and thus follows a random walk.

4.4 Informational Efficiency

Statistics	ISEQ	FTSE	BFX	AEX
Entropy	7.721228	7.716481	7.728309	7.728309
Standardized Entropy	0.989901	0.9892925	0.9908089	0.9908089

Table 13 Shannon Entropy

The Shannon entropy measures the efficient market in term of information. Based on the result presented in the table above, FTSE is the least efficient markets in terms of information, followed ISEQ, BFX and AEX are the most efficient Markets in terms of information since their Shannon information is equal.

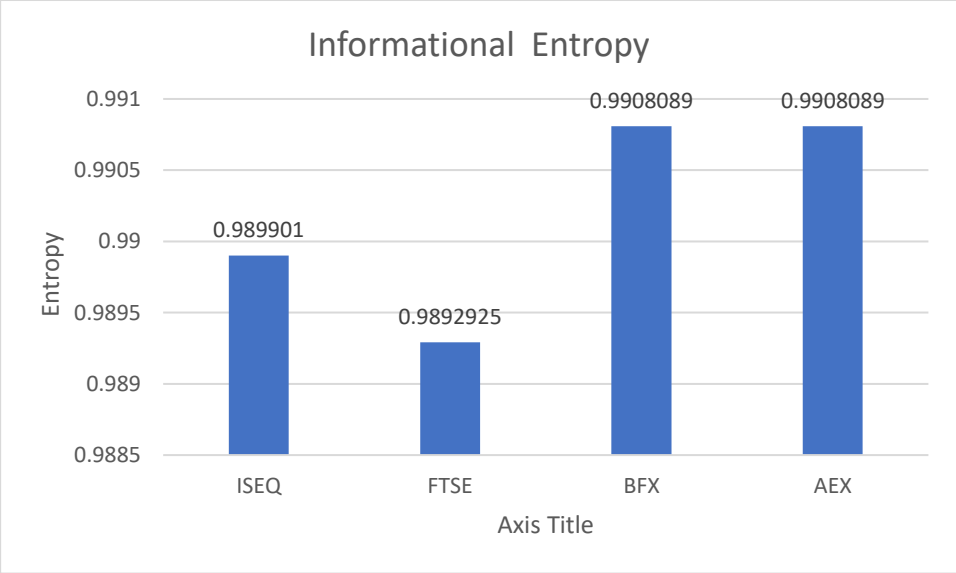

Fig 7 The standardized Shannon entropy

5 Evaluation

The aim of this study is to test the weak form of efficient market hypothesis in the Ireland stock market, and comparing it with its neighboring countries, UK, Belgium and Netherlands stock markets. The results indicate that the AEX has the highest daily return for the investor during the holding period with an arithmetic mean return of 0.02762% and a geometric mean of 0.02278%. This is followed by ISEQ, BFX and subsequently FTSE . It is to be noted that FTSE offers the lowest return to investor during the holding period.

Analyzing the risk associated with holding the index, it is observed that FTSE has the lowest risk with standard deviation value of 0.87026%, and the next in the line is BFX, AEX, and ISEQ with standard deviation value of 0.94504%, 0.98285%, and 1.06639% respectively. It is also observed that ISEQ offer a lower return but a higher risk when compared with AEX (highest average return). The normal distribution, skewness should be equal to 0 and kurtosis which is a degree of flatness should be equal to 3. However, the statistics results (Table1-7) indicate that all the markets show a negative skewness value meaning that the distribution is skewed to the left. The kurtosis is much above the normal distribution kurtosis of 3 meaning that the distribution is rather sharp at its average, a leptokurtic distribution with necessarily fat

tails which suggests that the distribution is not normally distributed. To confirm the conclusion, the study resorted to the JARQUE-BERA statistics which represents a test of symmetry and flatness and its associated probability. The obtained probability corresponds to the probability of being wrong in rejecting the null hypothesis (the data follows a normal distribution), here it is equal to 2.2e-16. At an α threshold of 1%, we reject the hypothesis of normality of distribution for the four capital markets under analyses. The distribution is found to be asymmetrical and tailed to the left, they have a negative skewness with value -1.2173606, -0.2156667, -0.5415110, and -0.4493167 for ISEQ, FTSE, BFX, and AEX respectively. The ISEQ has the longest tailed to the left while the FTSE has the shortest tailed to the left. A left tailed implies that the return has more and high negative return value during the holding period compared to the positive return as this can be seen in the minimum and the maximum values of the returns for instance ISEQ has a minimum return value of -0.1041641 and a maximum return value of 0.0444659.

Looking at association between ISEQ and the three stock markets, it is observed that ISEQ has a positive and significant association with FTSE, BFX, and AEX. It implies that ISEQ moves in the same direction with the other stock index, there is a form of positive relationship and the relationship is very strong. If the Stock Market for Belgium is Bullish then the stock Market for Ireland will be bullish, and vice versa. This explanation also holds true for ISEQ and FTSE and AEX. It is also observed that ISEQ has the strongest association with the BFX. In summary the return of ISEQ can be predicted using the returns for FTSE, BFX and AEX.

To test the weak form of EMH the unit root, serial correlation and the run test was conducted. From the result of the unit root test, it is observed that the four stock markets are weak form Efficient since the hypothesis of random walk for the four capital market was not rejected(P values are greater than the level of significance). It means that the statistical properties of the series such as its mean, variance are not stationary (changes) over time as a result the future mean, variance cannot be predicted as thus it is prices cannot be predicted.

From the serial correlation test, The ISEQ and the BFX are not weak form Efficient since the hypothesis of no serial correlation was rejected. From the plot of its autocorrelations, we observed serial correlation of the series with it lags at Lag1, Lag4, and Lag5. It implies that there is a serial correlation with its lag at such the stock prices can be predicted at lag1, lag4 and lag5. The FTSE and AEX are weak form efficient at since the hypothesis of no serial correlation was not rejected.

Finally, from the runs test, it is observed that the four stocks market are weak form efficient as the hypothesis of "the sequence is a random sequences" was not rejected. It implies that the runs (Positive and negative) are not symmetric nor does it follows a pattern.

Finally to rank the stock market using the information efficiency, the Shannon entropy was used. It is observed that the both BFX and AEX has the highest entropy value of 7.728309 respectively followed by ISEQ, then FTSE with value of 7.721228 and 7.716481 respectively. The FTSE is the least information efficient stock market, followed by ISEQ while BFX and AEX are the most efficient market in terms of market information.

6 Discussion

As suggested by the extensive literature on the market efficiency the capital markets in the developed countries are categorized by high liquidity, large market capitalization which makes them relatively more efficient than the developing countries. The four capital markets analyzed for efficiency namely Ireland, UK, Belgium and Netherlands are tested for their weak form of efficient market hypothesis, implying that all the past and the current information are incorporated in the prices of the securities and hence a technical/financial analysis to gain abnormal returns would be futile for these markets. Application of active or passive portfolio management depends on the degree of market efficiency if the market is inefficient an active portfolio management could be used to determine ways to exploit the market for its inefficiencies, however, if the market is efficient a passive approach is a better resort. In line with the statistical results it is concluded that all the markets are considered efficient but in the weak form. However, weak form of hypothesis should not be accepted as an absolute conclusion about the market efficiency, especially without taking into account the efficiency of the individual stocks in the index, the transactional costs of market information and conducting the semi- strong and strong tests on the market efficiency to ascertain with a greater degree of certainty about the market efficiency.

7 Conclusion and Future Work

Professional investors' goal is to leverage market inefficiencies for profit-maximization. The last few decades saw extensive research using diverse statistical analysis methods on the efficiency of the financial markets. Modern research papers indicate that while more developed markets typically have greater market capitalization and the emerging markets are more productive are characterized as inefficient with lower market cap and liquidity, partially reject efficient market hypothesis in the weak form , suggesting the possibilities to exploit these markets for inefficiencies and making above market returns taking into account the transactional costs and the slippage in such markets. Research papers often disregard the transactional costs, challenging the premise of devising market strategies to achieve returns above market rates.

This paper focuses on the weak form of the EMH using the daily index return of Ireland stock index and drawing a comparative analysis with three of its neighboring countries namely UK, Belgium and Netherlands. The hypothesis of the return distribution following a random walk is tested using various statistical tests namely serial correlation test, unit root test, runs test, and Shannon Entropy test. Shannon entropy test was used to determine the degree of information efficiency of all the markets analyzed. These tests were applied to daily index returns in the timeframe from January 1, 2015 till December 31, 2019. Considering only the results obtained in this paper, the test results indicate that all the markets studied are weak forms of efficiency; meaning the prices fully reflect all the available market information and that the past prices couldn’t not be used to devise a trading strategy predicting the future trends in the price

movement to make returns above the market benchmark in the long run, suggesting that a passive approach to portfolio management is more appropriate in these markets

Future work

In the light of the empirical research on EMH, it is suggested to analyse the efficiency of individual stocks in the index, in order to eliminate any discrepancies i.e indices could be efficient whereas the individual stocks in the index could be inefficient. Hence, to ascertain efficiency in the market with a higher degree of certainty analysis should be conducted both on the individual stocks and the indices.

Given this research is the first in the analysis of market efficiency of the Ireland stock market and also the limitation of the weak form EMH, the future work should aim at testing Ireland and neighboring countries capital market for the semi-strong and the strong Efficient market Hypothesis.

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