IS THE LONDON STOCK EXCHANGE WEAK-FORM EFFICIENT?

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ABSTRACT

Whilst the Efficient Market Hypothesis (EHM) is widely considered as robust, its position as one of the most widely accepted Economic theories is becoming subject to increased scrutiny from researchers in the fields of capital markets and behavioural finance. In light of the increased scepticism regarding the EMH, this project tests the weak-form efficiency of the London Stock Exchange. Stocks used in this analysis were carefully controlled to avoid a thin-trading bias. It was found that on the whole, period to period price changes of stocks listed on the LSE were independent. This was in keeping with the majority of work already conducted in this field. No evidence was found that stocks representing companies in the same industry displayed significant similarities nor was it noted that different sectors produced noticeably different results when correlation tests were conducted. It was suggested that the advancements in real-time information services played a pivotal role in maintaining the efficiency of the stock market.

This research project is laid out in the following way: Chapter two gives a brief introduction on the LSE including the history of the exchange as well as a summary of market regulation. The theoretical models that are imperative to understanding the efficient market hypothesis specifically in the weak sense are outlined in Chapter three, particular attention is paid to the martingale hypothesis and the random walk model of weak-form efficiency. Chapter four presents a review of previous studies on market efficiency. The review is by no means
exhaustive but it covers a wide spectrum of literature from complete support of the EMH to complete rejection. The main focus of the review is literature based on developed markets as the LSE fall into that category, however there is also a section analysing work on developing markets to assess if any notable differences can be observed. The main emphasis of the review is weak-form efficiency because this is what this project is specifically analysing, though papers are included that look at both semi-strong and strong-form efficiency for completeness. Effort was made to arrange the literature into work that was similar in nature and results. The Methodology section comprises Chapter five. This includes the measurement of the variables as well as the derivation of the models used to measure the variables. The findings are reported in Chapter six followed with the interpretation of those findings. Chapter seven concludes the project outlining possible areas for further research.
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Bibliography
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CHAPTER ONE

INTRODUCTION

The efficient market hypothesis (EMH) has been a central theory of financial markets for over 30 years. Fama (1970) outlined an efficient market as one where all security prices fully reflect any available information including associated risk premiums. Therefore, any information regarding future cash flows gained from holding a particular security will be reflected in its trading price, meaning abnormal profits cannot be achieved in the long term because prices will quickly adjust accordingly. In an efficient market, price changes only result from the availability of new information and seen as there is no reason to expect this information to occur non-randomly ie information will not be pre-empted by the market before its official release, price changes will therefore also exhibit randomness and be independent of past changes.

Fama distinguished between 3 types of market efficiency: weak-form, semi-strong and strong-form. Weak form market efficiency is the idea that it is impossible to achieve superior risk-adjusted returns based on the knowledge and analysis of previous prices as price and volume changes follow a random walk whereby future price changes are independent of previous movements. Semi strong form efficient markets occur when investors cannot earn superior risk adjusted profits by taking advantage of any publically available information. That is, as soon
as information is released into the public domain, prices immediately reflect it meaning no advantage can be obtained from being ‘better informed’. When decisions regarding a company’s future are made, there is a time period between the decision and the announcement of that decision to the public. Strong Form Efficiency states that making excessive returns on non-public knowledge (insider trading) is impossible because the information will quickly leak out and be incorporated into prices.

The aim of this research is to test the weak form efficiency of the London Stock Exchange (LSE). The LSE was founded in 1801 conducting its business from the coffee houses of that time and has become one of the largest stock exchanges in the world with an average daily trading value of over £12 billion (although this has subsequently decreased in light of the current financial crisis), making it an integral part of the world financial system. It is also recognised as being the most ‘international’ of the world’s stock exchanges with more than 3000 companies from 70 nations admitted to trade on its markets. The LSE has four core areas of trading:

i) Equity/capital markets – where shares are issued and traded

ii) Trading services – trading in securities

iii) Information services – provision of real time prices, news etc

iv) Derivatives – Assets derived from other financial instruments design to manage risk traded though EDX London
Existing studies on the London Stock Exchange are somewhat divided in their findings. On the whole the literature concludes that the LSE is efficient, at least in the weak sense (Kendall, 1953; Brealey, 1970 among others). There is however evidence which contradicts these findings, highlighting the presence of autocorrelation in stock market returns (Schwartz and Whitcomb, 1977; Opong et al, 1999).

1.1 Why the stock market is likely to be efficient.

Securities and stock markets possess unique characteristics that could result in them being more efficient than other ‘goods’ markets. Although these characteristics on their own do not ensure efficiency, they provide the platform for a perfectly competitive market to flourish, and in economic terms, a perfectly competitive market is an efficient one.

1.1.1 Availability of information

Due to the vast amount of money invested on the various stock exchanges it is of the upmost importance that traders have access to the most up-to-date information that is available as early as possible. All of the exchanges invest large sums of money in developing real-time information services which allows market participants to base investment decisions on all available information.

1.1.2 Homogeneity of Product

Unlike most other markets, the securities markets comprises of mainly one product. That is, a claim or entitlement to future returns while been subjected to a degree of risk. Although there
are vast differences between the companies the securities represent and the types of business these companies conduct, the share prices reflect the expected future claim subject to the appropriate risk premium. Therefore, despite the different industries and nature of business represented on the various world exchanges, the securities are essentially the same product and are almost perfect substitutes. This means that if a security is deemed to be over-valued, traders can sell it and purchase another one that is more efficiently priced resulting in a price decrease of the over-valued security.

1.13 Taste independence

Securities markets, unlike many others, are not subjected to the same taste-bias. For example, an ‘in-fashion’ designer can demand a high premium for their work for sometimes no more justified reason than it has their name on it. With securities, it is pricing, not taste models that determines value. Although it true that individual investors may have different preferences or ‘tastes’ concerning risk, this only influences the type of portfolio they would hold, ie the combination of risky and riskless securities, and not the preference between individual securities with the same associated risk.

1.14 Location independence

While the value of many goods is influenced by location, particularly those that have high transport costs or are tied to a specific location, security markets are not subject to these factors. With the increase in Dual-listed companies combined with a reduction in foreign exchange
costs, there is increasing accessibility to the entire world exchanges irrespective of one’s normal place of business (Keane, 1983).

1.2 Possible causes of inefficiency

Despite the famously assertion by Michael Jensen that ‘there is no other proposition in Economics which has more solid empirical evidence supporting it’ (1978 pg. 95), there still exists some opposition to the theory. The main source of this opposition comes from the relatively new area of Economics, **behavioural finance**. Behavioural Finance draws on many disciplines such as Psychology to explain how some of the fundamental characteristics of human nature can be responsible for creating market inefficiencies. After all, even though the market is complex mechanism of complicated securities and derivatives, the decisions and trades are made by human beings. If agents behaved in accordance with economic principle they are said to be frame independent. However, frame independence stems from agents being influenced by the manner in which a particular problem is presented to them. Frame dependence is considered by many to be the most prominent cause of investor error and inefficiencies. Some examples of characteristics that can be attributed to frame dependence are as follows:-

1.2.1 Representativeness

Representativeness refers to judgements based not on new information but on stereotypes and prejudices (Kahneman and Tversky, 1979). This can occur when people miss-apply the theory
of large numbers (or law of averages) to smaller sample sizes and therefore expect individual stocks to behave in the same manner as the ‘representative group’.

1.22 Over Confidence

Evidence shows that more than half of people think they are above average drivers. This is, of course impossibility. The same mind set can be applied to traders. For every trade that occurs, there must be a winner and a looser, if the price increases, the buyer of the share wins and vice versa. However, again more than half of traders believe they are better than average which could result in them not trading with the required level of caution because they over estimate their chances of ‘beating the market’. There are two main implications arising from investor over confidence. (i) Firstly, that investors engage in ‘bad bets’ because they fail to realise that due to the problem associated with asymmetric information they are at an information disadvantage. (ii) The second is that they tend to trade more frequently than is deemed prudent resulting in excessive trading volumes.

1.23 Anchoring and Adjustment

Anchoring and adjustment (Edwards, 1982) is a problem associated with the task of financial analysis. Analysts form their initial beliefs based on a given information set, say, regarding expected profit. A problem can arise if the company then release figures which either under or outperforms the previous level. For example, if a company that has previously been performing poorly announces positive earnings. Evidence shows that there is a tendency for analysts not
to adjust their expectations sufficiently in accordance to the new information as the previous data still dominates the decision process.

1.24 Aversion to Ambiguity

Aversion to ambiguity or risk aversion is the idea that human beings do not like experiencing uncertainty as it poses a risk and makes decision making difficult. A risk adverse investor will refrain from including ‘risky’ assets in their portfolio even though they have the potential to generate larger profits than a relatively riskless asset.

1.25 Loss aversion

Loss aversion can be described as the reluctance to accept a loss. This can result in investors holding on to stocks that are losing value even if there is only a low probability of the value eventually increasing, therefore incurring further losses, rather than selling the stock and accepting a guaranteed loss.

1.26 Regret

Regret results from feeling responsible for a mistake or loss and can occur for a number of different reasons. One of the most common causes of regret stems from losses occurring simultaneously with a change in routine or investment strategy even if the risk associated with either strategy was the same. Regret can result in investors having a low preference for variety and encouraged them to follow the same routine and ultimately miss out on viable investment opportunities.
1.27 Money Illusion

Money illusion refers to the tendency for agents to think of currency in nominal not real terms and therefore creating a risk that investment decisions will be made using nominal values instead of accounting for inflation.

1.3 Discussion of other terms and Principle

1.31 Intrinsic Worth

If the market is efficient then the price of a stock should be equal to its intrinsic worth. That is, its fundamental value adjusted using an appropriate risk premium. It should be noted here the calculated ‘worth’ or the ‘best value’ of the stock is only what is expected given the element of risk involved and by no means guarantees the investor the calculated returns. The actual present value of a given stock is not known.

1.32 Random Walk

‘Random’ in this case should be interpreted as though share prices move in a chaotic manner without any justification. What the Random Walk hypothesis does highlight is that if share prices are efficient and therefore reflect any existing information, then any price changes must be caused by the availability of new information, and as new information cannot be predicted or follow an observable trend, the resulting price changes are considered random (Fama, 1970).
1.33 Arbitrage

Arbitrage occurs when agents are able to take advantage of price differentials of either the same stock in different markets or closely substitutable stocks in the same market therefore capitalising on this imbalance. Arbitrage is often described as risk-free profits but this is not strictly true. It relies on the markets beliefs of a price imbalance to be in line with the arbitrager or the price discrepancy could continue to grow rather than decrease subjecting them to potentially huge losses (Campbell and Kyle, 1993).

1.34 Noise

In finance, noise refers to random price fluctuations or disturbances that can distort the market, reducing the clarity of the information ‘signal’ resulting in market observation being imperfect and the decision making process clouded.

1.4 The Research Problem

The fundamental implication of the EMH is that investors cannot expect to consistently find overvalued or undervalued securities using a pre-determined strategy. That is to say it is not possible, just that it should not be expected. The presence of arbitrage will ensure that if a security is overvalued, investors will ‘short’ it, until the price converges with its fundamental value. Likewise, if a security is undervalues, investors will buy it, therefore increasing the price. Failing that, it is expected that information regarding the value of the security is available to all investors meaning that if one investor wants to sell an overvalued security, so does everyone
else. If a superior trading strategy is devised which generated substantial profits, an increasing number of investors will adopt it until the advantages gained from using it no longer persist. Under these conditions, that is, everyone has access to the same information, *Rational Expectation theory* would suggest there should be little or no trading taking place (Lo, 1997). The very existence of stock exchanges like the LSE and NYSE mean it is somewhat unconvincing to assert that information trading has no place in an efficient market.

The EMH has been widely accepted as valid with Michael Jensen stating that ‘there is no other proposition in Economics which has more solid empirical evidence supporting it’ (1978 pg. 95). However, the evidence rebuking the EMH is mounting. Some fail to accept the validity of the evidence against the EMH claiming sampling errors or incorrectly specified models as possible reasons for the contradictory results (Kothari, 2001). Many on the other hand believe the EMH leaves too many phenomenons unexplained to be completely robust, turning to behavioural theories for alternative explanations (Lee, 2001).

In light of the increased scrutiny being directed at the robustness of the EMH it is important to test the efficiency of the London Stock Exchange as many investment decisions, regulatory standards etc are to some extent dependent on the market being efficient.

Previous studies on the efficiency of the LSE are far from conclusive. Most of the original studies of the behaviour of the LSE appear to accept the Efficient Market Hypothesis, at least in a weak sense (see Kendall, 1953; Brealey, 1970; Dryden, 1970; Cunningham; 1973 among
others). However, increasingly more literature is questioning these initial findings, Schwartz and Whitcomb (1977) found evidence that returns were auto-correlated, a claim supported by Opong, Mulholland, Fox and Farahmand (1999) who highlighted the presence of patterns and cycles that occurred too often to be dismissed as random.

This research measures the absolute efficiency of the LSE as a whole, along with the efficiency of the largest 20 companies listed by trading volume.

1.5 Research Objectives

The primary objective of this research project is to test the weak-form efficiency London Stock Exchange (LSE).

The Objectives can be summarised as follows:-

- Test for week form efficiency of the LSE
- Test for weak form efficiency and compare results of 20 largest companies on LSE by trading volume.

1.6 Organisation of work

This research project is laid out in the following way: Chapter two gives a brief introduction on the LSE. The theoretical models that are imperative to understanding the efficient market hypothesis specifically in the weak sense and are fundamental to this study are outlined in Chapter three. Chapter four presents a review of previous studies on market efficiency. The review is by no means exhaustive but it covers a wide spectrum of literature from complete
support of the EMH to complete rejection. The main focus of the review is literature based on
developed markets as the LSE fall into that category, however there is also a section analysing
work on developing markets to assess if any notable differences can be observed. The main
emphasis of the review is weak-form efficiency because this is what this project is specifically
analysing, though papers are included that look at both semi-strong and strong-form efficiency
for completeness. Effort was made to arrange the literature into work that was similar in nature
and results. The Methodology section comprises Chapter five. This includes the measurement
of the variables as well as the derivation of the models used to measure the variables. The
findings are reported in Chapter six followed with the interpretation of those findings. Chapter
seven concludes the project outlining possible areas for further research in the area.
CHAPTER TWO

THE LONDON STOCK EXCHANGE

2.1 A Brief History of the LSE

The London Stock Exchange (LSE) is the world’s oldest stock exchange and remains one of the three largest today along with the exchanges in New York and Tokyo. Although officially founded in 1773, the LSE has been in operation on the streets of London since the mid 16th Century. Traditionally, the exchange was used to fund exploration ventures such as the search for the northern sea route as well as a means to trade goods from different countries such as Russia. As the exchange grew in size and became a commercial success, investors were able to sell their holdings, or purchase more shares as well as being paid dividends depending on the company’s profits. The model that is in existence today began to take shape.

As more companies joined the LSE, the broker profession came into being. The broker acted as an intermediary in share trading increasing the efficiency of the market and intern increasing the number of trades that occurred. By the 18th Century the market was an integral part of the economy and this period marked a number of key events in the development of the exchange including the first stock market crash in 1720. This period also saw the expulsion of many brokers for ‘rowdy’ trading practises such as shouting, arm waving etc, which would later become somewhat of a tradition on the trading floors. Many of these brokers, instead of leaving
the business, began to meet in the coffee houses of London such as ‘Jonathan’s Coffee House’ in Threadneedle Street. By 1760, around 150 brokers were trading in this manner and a decade later changed their name to ‘the Stock Exchange’.

By 1801, as individual brokers began to establish brokerage firms, the Exchange sought new premises which would become its permanent location. A year later, the Deed of Settlement was published, formally outlining the operating rules and procedure of the London Stock Exchange.

At the end of the 19th century, the London Stock Exchange amended the Deed of Settlements to create a more corporate-based exchange, which now operated on behalf of its owner as oppose to being run by its members. A further significant development occurred when the countries numerous exchanges were linked together for the first time under an Association of Stock Exchanges. The LSE briefly suspended trading during World War I, to aid the war effort, but when it was realised the war would be a prolonged one, the trading floors reopened.

The 20th Century saw the emergence of the US as the global financial leader, with the New York Stock exchange eventually replacing the LSE as the world’s richest and busiest exchange. Tokyo soon followed in the 1970’s. London remained the centre of Europe’s financial community gaining and increasingly pivotal role in the market for international stocks.

1986 marked a new era for the LSE as the Companies Act of 1985 enabled it to restructure its operations as a private limited company (plc) with the member brokerage firms becoming
shareholders although were not entitled to dividend payments as all profit was returned to the LSE and used to improve infrastructure etc.

The 1990’s saw further pressure being put on the LSE to adapt its operations as the nature of the stock market continued to change. New technologies such as electronic trading systems began to render telephone communication and face-to-face trading obsolete. The creation of the Alternative Investment Market (AIM) was deemed a necessary response to accommodate the increasing number of start-up companies, often high-technology that grew rapidly from zero to enormous market capitalisation in a short period. By the end of the decade, AIM had nearly 400 companies listed.

Now in its 4th century of trading, the LSE continues to evolve, embracing the new technologies that have seen it remain one of the most important financial centres of in the world.

2.2 Regulation of the LSE

The London Stock Exchange is regulated by the Financial Services Authority (FSA). The FSA is an independent body that regulates all financial activity in the UK. The FSA has a role in the regulation all aspects of trading in securities, from oversight of trading firms of investment companies to the trading venues themselves, mainly the LSE, as well as being responsible for the clearing and settlement infrastructure. The FSA have been granted a high level of freedom in terms of regulatory tools at their disposal, including the power to make and enforce laws.
The regulatory framework is governed by the Financial Services and Market Act 2000 (FSMA).

In the UK, there exist three primary methods in which trades can be executed. These are either (i) an Exchange, such as the LSE, (ii) an Alternative Trading System (ATS) or (iii) over the counter trading (OTC) conducted by registered firms. Each is subject to regulation by the FSA.

In the UK, exchanges, such as the LSE, seek recognition as Recognised Investment Exchanges (RIE) in order to trade, by satisfying criteria outlined by HM Treasury. The LSE currently pays £745,000 annually to maintain RIE status.

2.3 Size of the LSE

The LSE is the world’s most international market for the listing and trading of public equity and debt. Its location in London’s financial centre means that is ideally place to attract over 1600 companies from 60 different countries. The LSE comprises of some of the largest companies in the world from more than 40 sectors. The market now has a combined capitalisation of over £4.3 trillion.
CHAPTER THREE

THE THEORY OF MARKET EFFICENCY

3.1 Introduction

This chapter presents a brief overview of some of the theoretical foundations of the Efficient Market Hypothesis focusing specifically at weak-form efficiency models.

3.2 The Efficient Market Hypothesis

The main principle of the EMH is that the price of a stock fully reflects all the information that is available to the market regarding the associated risk and the expected future returns to be gained from holding the stock. In other words, the current price represents the present value of all future dividend payments which should equal the shares worth if all available information is correctly absorbed by the market, meaning:

\[ P_t \equiv V_t \equiv \sum_{i=1}^{\infty} \frac{Et(D_{t+i})}{(1+r)^i} \tag{3.1} \]

Where \( V_t \) represents the fundamental value of the share at time \( t \). \( Et(D_{t+i}) \) represents the expected future dividends given all the information that is available at time \( t \), \( r \) refers to the risk adjusted discount rate for the expected dividends and \( i \) reflects the holding period of the share.
The EMH states that the nature of stock trading ensures that all available information is reflected in the share price. The market brings together individuals with different information regarding a particular security. As it is assumed that all investors wish to maximise profit, if a stock has a lower price than is believed to be correct based on the information at their disposal they will buy, the reverse is true for overvalued stocks. Eventually, it should transpire that the market share price represents an amalgamation of all market participants information regarding that particular stock making the price mechanism the aggregator of all available information (Grossman, 1976).

### 3.3 Weak-form market efficiency models

To verify the very basis of the EMH, that all available information is fully reflected in market prices, it is important that this claim is specified in a model that can be used to obtain empirical results that can be tested rather than relying on theoretical definitions. One such model is the Martingale hypothesis.

### 3.4 Martingale Hypothesis

The martingale hypothesis is a game theoretic model designed as a tool for analysing game of chance and probability theory. The essence of this hypothesis is that the stochastic process of \( \{P_t\} \), satisfies the following condition:

\[
E(P_{t+1}|P_t, P_{t-1}, P_{t-2}...) = P_t
\]  

That is
\[ E(P_{t+1} - P_t | P_t, P_{t-1}, P_{t-2}, ...) = 0 \]  

(3.3)

The martingale model states that \( P_{t+1} \) is expected to be equal to \( P_t \), or, more accurately, the price change of an asset is expected to be zero when conditional to historic price changes, resulting in an equal probability of a price rise or a price fall. The assumption that information in past prices is fully reflected in current prices is known as the martingale condition. Acceptance of the martingale condition carries with it some major implications for the field of technical analysis. If the martingale condition is true, investors cannot expect to earn profits by analysing trends and extrapolating them into the future since it will reveal no additional information, ultimately rendering the role of financial analyst a waste of valuable time and resources.

### 3.5 The random walk model

The random walk model or hypothesis states that successive price changes are random and therefore independent of previous price changes. Take the equation:

\[ \text{Cov}[f(r_t), g(r_{t+k})] = 0 \]  

(3.4)

If (3.4) holds for all functions, ie \( f(.) \) and \( g(.) \) are unrestricted and can therefore take any form, then returns are independent of one another. The random walk model also implies that the magnitude, as well as the direction of the price change is independent and identically distributed (IDD), where \( P_t \) would be given as follows:

\[ P_t = \mu + P_{t-1} + e_t, \quad e_t \sim \text{IID}(0, \sigma^2) \]  

(3.5)
where $\mu$ is the anticipated price change.

The ideal that the increments of the price change $\epsilon_t$ are independent and identically distributed with a mean of zero and variance equal to $\sigma^2$ is reflected in the term IID(0, $\sigma^2$). Providing that the volume of trades is sufficiently large then the price changes across different periods will be the sum of a large number of independent variables. Given this, the Central Limit Theorem stated that the period to period price changes will take the shape of a normal distribution. Normality of weekly price changes has been tested by Kendall (1948), who found the distributions to be primarily leptokurtic, however it was also observed that the distribution was such that there was strong enough evidence to support a distribution of near normality.

The primary outcome of the random walk model is a price change occurring in period $t$ has not been influenced by price changes in period $t-1$ etc. This again has implications for investors by effectively showing that analysing graphs of historical data is of no real value in the pursuit of profits.

It has been argued however that in reality errors or noise may be dependent. For example, a well-respected investor may influence other investors trading behaviour as they attempt to mimic their success. In this case, it may follow that there exists a dependence in the errors of investors’ estimates of intrinsic worth.
3.6 A case against market efficiency

De Bondt and Thaler (1985) published a paper on the winner-loser effect. They argued that investors can become overly pessimistic about past losers (stock that has lost value) or overly optimistic about past winners (stock that has gained in value) causing the market prices to deviate from the stocks fundamental value. It was also noted that eventually the market will correct itself with past winners losing in future periods and past losers eventually increasing in value.
CHAPTER FOUR

LITURATURE REVIEW

Since Fama (1970) there have been a large number of studies conducted in the area of market efficiency. Even though Jenson (1978) professed that there was no other proposition in economics that has more solid empirical evidence supporting it, there is still an obvious divide in the EMH literature ranging from complete acceptance to complete rejection with many inconclusive studies in between.

4.1 Theoretical Foundations of the EMH

The Efficient Market Hypothesis is based on 3 key assumptions. (i) First, investors are rational in their behaviour and therefore value securities rationally. (ii) Second, when investors’ behaviour is not rational, their irrational tendencies are random and uncorrelated so cancel each other out. (iii) Third, arbitrageurs eliminate any effect that irrational trading has on security prices. When investors are rational they value a security for its fundamental value that is, net present value of future cash flow discounted using the appropriate risk premium. Investors respond immediately to new information by increasing their value of a security if the news is
favourable or lowering their value if the information is not so favourable. Samuelson (1965) showed how, in competitive markets returns are unpredictable and security prices follow a random walk suggesting that point (i) holds and investors are indeed rational. However, as points (ii) and (iii) state, rational investors is not a fundamental foundation of the EMH without which the theory will not hold. Friedman (1953) describes how the presence of arbitrageurs effectively cancels out any non-rational trading. The way arbitrage works is as follows. Shleifer (2000) states that if there exists a security that had become over priced by the market as a result of irrational investors, this security now represents a bad buy as its fundamental value is lower than the price. Arbitrageurs can sell or even short this security and buy a similar security assuming one exists therefore hedging their risks. This has the effect of reducing the price of the overvalued security returning it to its fundamental value. If arbitrage fails to remove the influence of irrational investors then market forces will serve to remove them from the market. Investors cannot lose money indefinitely and eventually will no longer have the funds available to continue investing (Friedman, 1953).

4.2 Empirical Foundations of the EMH

There exists a great deal of fairly comprehensive empirical evidence in support of the EMH. The empirical studies on the EHM focus on two main facets of the theory. Firstly, that security prices adjust quickly to new information, that is, an investor obtaining the information late cannot use it to make a profit from buying the security. The second facet tested is that security prices adjust accurately following the release of new information meaning the new price again
reflects the true fundamental value of the security. This implies that if the EMH holds there should be no price trends or price reversals or correction caused by either information frictions (i.e. it taking some time for the new information to permeate through the market) or initial over shooting of prices.

The implication of this is that if a quick and accurate price adjustment follows the release of new information, investors cannot use existing or ‘stale’ information to their advantage, Fama (1970).

Fama’s (1965) findings supported the weak-form efficient market hypothesis that security prices follow a random walk (approximately). He explored the possibility of using trading systems based on historical security values and found that there was no systematic evidence that systems like buying stocks that had just gone up or selling stocks that had just gone down yielded any abnormal profits.

Event studies were also conducted by Fama et al (1969) analysing the markets response to new information such as profits, dividend payments etc. Their findings were that prices often rose in anticipation of a favourable announcement, then ‘jumped’ to a new price almost immediately following the announcement. This supports the EMH theory of quick and accurate price responses.
4.3 Theoretical challenge to the EMH

As research into the EMH grew, challenges began to arise on firstly empirical grounds, which were later substantiated by theoretical reasoning.

The first major theoretical challenge was aimed at the assumption that all investor behaved rationally. Fischer Black (1993) describes how investor often trade on ‘noise’, that is, they formulate demands for securities base on irrelevant information. There was also evidence to suggest that investor use strategies base on trends and past values that were not in keeping with an efficient market, (Kahneman and Riepe 1998). Firstly, most investors exhibit to a greater or lesser degree loss aversion. That is, they make decisions that will minimize potential losses not maximize gains. Odean (1998) highlighted the reluctance of investors to sell loosing stocks sometimes referred to in behavioural finance literature as ‘get-evenitis’, because investors do not want to sell at a guaranteed loss but would prefer to hold out until the price increases to at least what they paid for it, which might never happen.

One the most significant challenges to the EMH was that investors make different decision based on the same information depending on how that information is presented, or framed. This idea was discussed by Benartzi and Thaler (1995) who discovered that investors would irrationally allocate a large proportion of wealth to stocks instead of bonds if they were presented with a favourable history of long term stock return relative to those on bonds rather than if they just had access to the volatile short term stock returns information.
However, as mentioned earlier the credibility of the EMH does not solely rely on rational investors (if it did, these challenges would probably be enough for many to discard the theory).

The claims of (ii) state that individual investors irrational behaviour is random and uncorrelated, so will cancel out maintaining the correct fundamental security price. Kahneman and Tversky (1979) argue that the psychological evidence shows that people do not deviate from rational behaviour randomly, but rather most deviate in the same way. For example, investor bonuses often cause investors to buy the securities that other investors are buying because if they do not, and the investment yields a high return they may lose their job for not being as profitable as other investors. If an investment loses money, all investors are in the same position and individuals cannot be signalled out. This means securities are often bought and sold in huge volumes at roughly the same time.

The assumption of arbitrage in (iii) has also been criticised by many academics. The central argument put forward by behavioural finance is that, in the real world arbitrage is extremely risky and therefore limited, so cannot be used as an effective tool to regulate prices. The reason for this is that if a price discrepancy is identified it is not possible to tell what stage the price deviation is at. The price of the two securities could therefore diverge further before eventually converging at the fundamental value which would inflict potentially massive losses on the arbitrager. Also arbitrage relies on the existence of a close substitute in order to hedge against the price change, in reality one might not exist (Campbell and Kyle 1993).
4.4 Empirical Challenges to the EMH

Shiller’s (1993) work focusing on stock market volatility was one of the earliest empirical challenges to the EMH. He argues that stock market volatility was such that it could not be justified by a simple model where security prices are determined by the net present value of future dividends. Even though Shiller was criticised for misspecification his work provided the basis for further research.

De bondt and Thaler (1985) focused on the idea of weak form efficient markets, that is, when excessive returns cannot be achieved by using past price information. They compared the performance of two groups of stock (winners and losers) over two time periods. They found that on average extreme winners during the first period were losers in the second and extreme losers in the first period were winners in the second period. They concluded that the stock market can over react and prices can become detached from the fundamental value, when investors realise this, they either buy more if it is too cheap or sell if the price is too high. This occurs because often investors will extrapolate past performance too far into the future and not adjust expectations sufficiently when new information is presented. Fama (1991) even conceded that many stock returns are predictable from previous values, a major departure from his 1970 paper.
4.5 Empirical studies testing weak-form market efficiency

4.51 Empirical studies testing the efficiency of The London Stock Exchange

The LSE is one of largest and most important of the worlds’ exchanges. As a result there exists a substantial body of work dedicated to the efficiency of the LSE. Friederich, Gregory, Matatko and Tonks (2002) found that by mimicking the trading patterns of company directors’ abnormal profits could be achieved, which is a violation of the strong-form market efficiency hypothesis. Empirical studies have also been conducted on the ‘random’ nature of returns on the LSE. Schwartz and Whitcomb (1977) found evidence that returns were auto-correlated, a claim supported by Opong, Mulholland, Fox and Farahmand (1999) who highlighted the presence of patterns and cycles that occurred too often to be dismissed as random. Spyrou, Kassimatis and Galariotis (2007) examines the short-term reaction of investors to extreme events affecting the LSE between 1989 and 2004 concluding that the markets reaction to shocks is consistent with efficient market hypothesis in the case of large portfolios. However, for medium and small stock portfolios there was evidence of under-reaction to new information. Cutherbertson et al (1997) analysed the efficiency of the LSE from 1918-93. They found that the market did not behave in a way predicted by the EMH in that expected returns were not constant. They found that investors give too little weight to future dividends and returns than is expected in an efficient market. However, the evidence is far from conclusive, Marsh (1979) found no evidence to suggest one could reject the hypothesis that the LSE is efficient and price changes are random. Firth (1976) analysed the price adjustment mechanisms of the LSE and concluded
that price adjustments occur ‘speedily’ and for the most part ‘correctly’ meaning that there was no room for excessive gains to be made. Cunningham (1973) was less conclusive stating that ‘stock markets are slightly predictable’. Most of the original studies of the behaviour of the LSE appear to accept the Efficient Market Hypothesis, at least in a weak sense (see Kendall, 1953; Brealey, 1970; Dryden, 1970; Cunningham; 1973 among others). However all of these studies were conducted when the EMH was in its infancy and may therefore use outdated methods to obtain the results. The few studies of nonlinear modelling conducted on the LSE include that of Poon and Taylor (1992) who found no statistically significant Generalized Autoregressive Conditional Heterskedasticity (GARCH) effects in the returns on the LSE, and Mercado-Mendez and Willey (1992) who also supported this claim.

4.52 Studies focusing on other developed markets

The majority of studies conducted on developed markets, especially the New York Stock Exchange (NYSE) and the LSE have concluded that the EMH holds in the weak sense. However Opong, Mulholland, Fox and Farahmand (1999) found that the New York Stock Exchange is not purely random as exhibits cycles that occur more often than randomness would predict. Whereas Lim, Habibullah and Hinich (2009) found that the Chinese stock market behaved efficiently for large periods, that is, followed a random walk, but occasionally found periods of strong dependence or correlation suggesting that at certain times new information takes longer to permeate the economy and prices do not fully reflect the available information.
4.53 Studies focusing on developing markets

A great deal of the focus surrounding the EMH debate is now being directed towards emerging markets. Many of the studies conducted on emerging markets such as Singapore have found them to be inefficient according to the weak-form definition. Mlambo, Biekpe and Smit (2003) analysed the random walk behaviour of securities listed on many of the African Stock exchanges. They found a large degree of positive serial correlation to be present in the data. Suggested reasons for the departure from EMH in emerging markets are market size, thinness of trading and quality/speed of information discloser. Poshakwale (1996) conducted a study on the Indian Stock Market between 1987-1994. Again, the results provided evidence of an inefficient market with a clear presence of a ‘day of the week effect’ where stock market returns are not independent of the day in which they are generated. These findings suggest that ‘efficiency’ can only be achieved if the market is large and experiences a large volume of trades every day and that market efficiency is not an absolute term but a process which can be improved with better information and experience. Worthington, Andrew and Higgs (2004) found evidence to support the EMH in the majority of developed European countries including the UK. However, in emerging markets, only Hungry exhibited characteristics of an efficient market.
CHAPTER FIVE

METHODOLOGY

Weekly closing prices of the FTSE100 Index from 1\textsuperscript{st} January 1995 to the week ending 31\textsuperscript{st} December 2007 were used to conduct the statistical tests as well as data from the same time period (were available) of the 20 largest companies listed on the LSE measured by trading volume. The data was obtained from \textit{yahoo finance}. The data available during the financial crisis has been purposefully omitted from this study (Although the results up until the end of 2009 can be found in the appendix) in an attempt to reduce any contamination of the results. This decision was made by comparing graphs of the logs of the returns from 1995-2007 and 1995-2009. It was evident that patterns were beginning to emerge from 2008 onwards that were uncharacteristic of the previous years so a decision was made not to include this data as it could cause a bias in the correlation results.

The idea of Market Efficiency has been prominent in the study of financial markets for well over 30 years. Academics have used numerous models and statistical techniques to analyse the EMH. Significant progress has been made in the field of Econometrics since the first empirical studies were carried out but still the debate is ongoing as to validity of the theory.

If the EMH holds, is has major implications for investors, whether that is an individual or a pension fund etc. The EMH means that investors cannot hope to consistently outperform the market and all of the analysis spent on choosing stocks is effectively wasted. (Shliefer 2000).
Investor may sometimes achieve excess returns but these should not achieve consistently and should not be expected. The following strategies can be used to test for weak-form efficiency, namely correlation tests, normality tests and graphical analysis.

**5.1 Correlation Tests**

To test the independence of individual price changes, serial correlation tests are often used to determine whether successive price changes follow a ‘random walk’ or are indeed influenced by previous values.

In an efficient market, there is an even probability of the share price $P_t$ will rise or fall as changes are purely random, hence the best estimator of future prices $P_{t+1}...P_{t+k}$ is $P_t$, therefore

$$P_{t+1} = P_t + \varepsilon_{t+1} \text{ where } \varepsilon_{t} \approx N(0,\sigma^2) \quad (1.0)$$

and $\varepsilon_t$ is not correlated to $\varepsilon_{t-k}$ for all $K \neq 0$

For the prices to exhibit a random walk the returns would be a white noise process in the form

$$r_t = \varepsilon_t \quad (1.1)$$

Where:

$$\text{Cov}(f(r_t),g(r_{t-k}))=0. \quad (1.2)$$

If $r_t = \alpha_t$, then

$$\text{Cov}(f(\alpha_t),g(\alpha_{t+k}))=0. \quad (1.3)$$
For the excess return \( \varepsilon \), the serial correlation coefficient for lag \( k \) is given by:

\[
\rho_k = \frac{\text{cov}(\varepsilon_t, \varepsilon_{t-k})}{\text{var}(\varepsilon_t)} = \frac{\sum_{t=1}^{n-k}(\varepsilon_t-\bar{\varepsilon})(\varepsilon_{t-k}-\bar{\varepsilon})}{\sum_{t=1}^{n-k}(\varepsilon_t-\bar{\varepsilon})^2}
\]  

(1.4)

For this analysis, \( \rho_k \) will be calculated for \( \rho_1 \) to \( \rho_{10} \).

Therefore, the hypothesis to be tested will be

\[ H_0 : \rho_k = 0 \] (Efficient market)

\[ H_1 : \rho_k \neq 0 \] (Inefficient market)

If the serial correlation coefficient is significantly different from 0, we can reject the null hypothesis that price changes follow a random walk. The test will be conducted at 5% levels of significance.

Note: while non-zero correlation implies dependence, zero correlation does not necessarily indicate independence but the absence or presence of serial correlation.

5.2 Normality Tests

The basic assumption of serial correlation tests is that the sample data is normally distributed.

Therefore, in order to be confident about the validity of result it is first necessary to test the extent to which the data follows a normal distribution. The normality tests to be performed will be the skewness, the kurtosis and the Jarque-Bera statistics.

Skewness is the measure of asymmetry of the probability distribution.
**Skewness**

\[ S = \frac{1}{N} \sum_{i=1}^{N} \left( \frac{r_i - \bar{r}}{\hat{\sigma}} \right)^3 \]  

(2.0)

Where \( \hat{\sigma} \) is based on the biased estimator for the variance and \( N \) is the number of observations.

The skewness of a normal distribution is zero. Positive skewness means that the distribution has a long right tail and negative skewness implies that the distribution has a long left tail.

**Kurtosis**

\[ K = \frac{1}{N} \sum_{i=1}^{N} \left( \frac{r_i - \bar{r}}{\hat{\sigma}} \right)^4 \]  

(2.1)

Where the variables are as stated above. The Kurtosis expected of a normal distribution is 3, any value exceeding 3 means the distribution is peaked relative to a normal distribution (leptokurtic). Any value less than 3 means the distribution is relatively flat (platykurtic).

The Jarque-Bera (JB) is a statistic for testing whether a series is normally distributed. The test statistic measures the difference of the skewness and kurtosis of the series with those from the normal distribution.

\[ JB = \frac{N-k}{6} \left( S^2 + \frac{1}{4} (K - 3)^2 \right) \]  

(2.2)

Where \( S \) is the skewness, \( K \) is the kurtosis, and \( k \) represents the number of estimated coefficients used to create the series (Bickel and Doksum, 1977). The observed probability is the possibility that a Jarques-Bera statistic exceeds (in absolute value) the observed value under the null hypothesis of normal distribution; a small probability value leads to the rejection of the null hypothesis of normal distribution.
5.3 Graphical Representation

An informal approach to investigate the data would be to view it graphically. A scatter diagram can be used to highlight any apparent trends or correlations in the data as successive price changes in the same direction will be easily identified. Skewness and Kurtosis can be analysed by comparing a histogram of the obtained data against the normal distribution curve, which is bell-shaped. If the data is approximately normally distributed the two curves will bare a close resemblance. By analysing the data graphically, any extreme events or ‘shocks’ that may otherwise cause biased test results will also be identifiable and appropriate measures can then be taken to avoid any influence. Graphical representation can also be used to get a better ‘feel’ of the general characteristics of the data which may not be achieved by only using test statistics which can sometimes appear quite abstract.
CHAPTER SIX

RESULTS AND ANALYSIS OF RESULTS

Firstly, we analysed the normality of the data. Then tests to detect for the presence of autocorrelation were conducted to determine whether the stock price changes on the London Stock Exchange followed a ‘random walk’. Finally, the results were displayed graphically to obtain an overall ‘feel’ of any trends that may be present or to emphasis the random nature of the price movements.

6.1 Normality Tests

The results of the normality tests are displayed in the table below.

<table>
<thead>
<tr>
<th>Company</th>
<th>Observations</th>
<th>Standard Deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Jarque-Bera</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTSE 100 Index</td>
<td>678</td>
<td>0.02104</td>
<td>-0.2374</td>
<td>4.7184</td>
<td>89.7927</td>
<td>0.00</td>
</tr>
<tr>
<td>ARM.L</td>
<td>398</td>
<td>0.09188</td>
<td>-4.7347</td>
<td>61.014</td>
<td>5730.88</td>
<td>0.00</td>
</tr>
<tr>
<td>BARC.L</td>
<td>256</td>
<td>0.03458</td>
<td>-0.1731</td>
<td>4.5859</td>
<td>28.1057</td>
<td>0.00</td>
</tr>
<tr>
<td>BAY.L</td>
<td>261</td>
<td>0.05023</td>
<td>0.11933</td>
<td>5.05799</td>
<td>46.6782</td>
<td>0.00</td>
</tr>
<tr>
<td>B.P.L</td>
<td>261</td>
<td>0.02633</td>
<td>-0.10904</td>
<td>3.3999</td>
<td>2.2567</td>
<td>0.32356</td>
</tr>
<tr>
<td>BSY.L</td>
<td>261</td>
<td>0.03001</td>
<td>-1.11729</td>
<td>10.7669</td>
<td>710.341</td>
<td>0.003</td>
</tr>
<tr>
<td>BT.A.L</td>
<td>321</td>
<td>0.03547</td>
<td>0.53932</td>
<td>7.13905</td>
<td>244.698</td>
<td>0.003</td>
</tr>
<tr>
<td>CAN.L</td>
<td>166</td>
<td>0.03027</td>
<td>-0.36424</td>
<td>4.06817</td>
<td>11.5623</td>
<td>0.003</td>
</tr>
<tr>
<td>CW.L</td>
<td>261</td>
<td>0.04742</td>
<td>0.11854</td>
<td>7.63688</td>
<td>234.431</td>
<td>0.00</td>
</tr>
<tr>
<td>HSBAL.L</td>
<td>398</td>
<td>0.02982</td>
<td>-0.40513</td>
<td>6.91973</td>
<td>265.677</td>
<td>0.00</td>
</tr>
<tr>
<td>KGF.L</td>
<td>234</td>
<td>0.03259</td>
<td>-0.32606</td>
<td>4.12849</td>
<td>16.5626</td>
<td>0.00</td>
</tr>
<tr>
<td>LGEN.L</td>
<td>261</td>
<td>0.03705</td>
<td>0.39671</td>
<td>6.84075</td>
<td>167.267</td>
<td>0.00</td>
</tr>
<tr>
<td>LLOY.L</td>
<td>398</td>
<td>0.03624</td>
<td>-0.19686</td>
<td>4.19369</td>
<td>26.2004</td>
<td>0.00</td>
</tr>
<tr>
<td>OML.L</td>
<td>261</td>
<td>0.03815</td>
<td>0.53855</td>
<td>4.52123</td>
<td>37.7826</td>
<td>0.00</td>
</tr>
<tr>
<td>PRU.L</td>
<td>261</td>
<td>0.04101</td>
<td>-0.40482</td>
<td>4.68135</td>
<td>37.8714</td>
<td>0.00</td>
</tr>
<tr>
<td>RBS.L</td>
<td>261</td>
<td>0.03015</td>
<td>0.53308</td>
<td>6.92140</td>
<td>179.591</td>
<td>0.00</td>
</tr>
<tr>
<td>RSA.L</td>
<td>261</td>
<td>0.04819</td>
<td>-0.86802</td>
<td>9.88971</td>
<td>538.891</td>
<td>0.00</td>
</tr>
<tr>
<td>RSL.L</td>
<td>66</td>
<td>0.03791</td>
<td>-0.57719</td>
<td>4.66794</td>
<td>11.3152</td>
<td>0.003</td>
</tr>
<tr>
<td>TSCO.L</td>
<td>261</td>
<td>0.02471</td>
<td>0.19810</td>
<td>3.51323</td>
<td>4.57168</td>
<td>0.10169</td>
</tr>
<tr>
<td>VOD.L</td>
<td>261</td>
<td>0.03080</td>
<td>-0.30707</td>
<td>3.78576</td>
<td>10.8164</td>
<td>0.004</td>
</tr>
<tr>
<td>XTA.L</td>
<td>302</td>
<td>0.05621</td>
<td>-1.89648</td>
<td>14.9984</td>
<td>1992.56</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Of the 21 stocks tested, 16 were calculated to be negatively skewed. While all stocks have a kurtosis value greater than 3, although the values for 3 of the stocks could be considered close enough for statistical analysis (BP.L, TSCO.L and VOD.L). This means that all the stocks were peaked relative to that of a normal distribution and leptokurtosis is present. Only 2 stocks had a probability of more than 0.05 that their Jarques-Bera statistic exceeds the observed value. While 16 stocks had a calculated probability of zero when rounded off to five decimal places.

The normality assumption was rejected for all stock returns except two, these being BP.L and TSCO.L. Mills (1995), Fama (1965) among others, also concluded that the LSE exhibits a distribution that is both ‘skewed and extremely kurtotic’. A characteristic normally associated with developing markets (Mlambo et al, 2003).

Mlambo et al. (2003) also suggested non-parametric testing should be used in cases, such as this, where there is strong evidence to suggest a major departure from normality as the test does not assume a specific distribution, normal or otherwise. However it has been argued that, despite the rejection of normality with the presence of leptokurtosis and mainly negative skewness, near-normality can still be assumed for the sake of statistical analysis, providing the there are a large number of observations (Kendall, 1953; Moore, 1962 among others). This means that there is still some justification for performing correlation tests despite non-normality in order to test for higher order serial correlation.
6.3 Correlation Tests

The results for the correlation tests are presented in tables 5.4 and 5.5.

**Table 6.4 Autocorrelation Coefficients of the price changes**

| Company | Lags | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|---------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| FTSE 100 Index | -0.039 | 0.001 | -0.055 | -0.035 | 0.00 | 0.020 | -0.039 | 0.007 | 0.003 | 0.025 |
| ARM.L | -0.065 | -0.023 | 0.024 | -0.063 | 0.113 | -0.047 | -0.104 | -0.112 | -0.027 | 0.133 |
| BARC.L | **-0.138** | 0.017 | 0.079 | -0.00 | -0.081 | 0.036 | -0.044 | 0.121 | -0.034 | 0.042 |
| BAY.L | -0.083 | -0.027 | -0.018 | 0.055 | 0.018 | 0.097 | -0.072 | 0.079 | 0.034 | 0.001 |
| BP.L | -0.029 | -0.031 | -0.035 | -0.080 | -0.045 | -0.043 | -0.078 | -0.057 | 0.017 | -0.049 |
| BSY.L | 0.027 | -0.079 | -0.103 | 0.085 | -0.057 | 0.053 | -0.025 | -0.022 | -0.001 | 0.048 |
| BT-A.L | -0.028 | -0.046 | -0.123 | -0.026 | 0.099 | 0.002 | -0.086 | 0.020 | -0.070 | 0.081 |
| CAN.L | -0.040 | -0.085 | **-0.255** | 0.040 | **0.063** | 0.071 | **0.038** | -0.146 | **0.066** | -0.040 |
| CW.L | -0.037 | 0.110 | -0.121 | -0.004 | -0.057 | 0.068 | 0.081 | -0.043 | 0.081 | -0.015 |
| HSBA.L | -0.023 | 0.009 | -0.075 | -0.015 | -0.058 | -0.015 | 0.053 | -0.183 | **0.104** | -0.044 |
| KGF.L | -0.035 | -0.131 | 0.076 | 0.054 | 0.051 | 0.062 | -0.004 | 0.001 | 0.015 | -0.058 |
| LGEN.L | **-0.192** | 0.024 | -0.015 | 0.057 | -0.036 | 0.063 | -0.037 | 0.058 | -0.038 | -0.016 |
| LLOY.L | -0.039 | -0.070 | -0.026 | -0.024 | 0.015 | 0.119 | -0.116 | -0.034 | -0.037 | -0.036 |
| OML.L | -0.078 | -0.154 | -0.011 | 0.080 | -0.051 | 0.074 | -0.072 | 0.044 | -0.062 | -0.016 |
| PRU.L | -0.056 | -0.141 | -0.142 | 0.110 | 0.014 | 0.002 | -0.030 | 0.051 | -0.068 | -0.034 |
| RBS.L | -0.046 | -0.088 | -0.013 | -0.126 | 0.022 | 0.126 | -0.022 | 0.093 | 0.065 | -0.073 |
| RSL.L | 0.079 | 0.123 | 0.021 | **0.149** | **0.060** | -0.027 | 0.049 | 0.015 | -0.048 | -0.171 |
| TSCO.L | -0.173 | **0.000** | 0.109 | -0.002 | -0.075 | 0.078 | -0.158 | 0.111 | -0.097 | -0.038 |
| VOD.L | **-0.123** | -0.024 | -0.048 | 0.111 | **0.124** | 0.002 | -0.113 | **0.045** | -0.041 | 0.040 |
| XTAL.L | **-0.163** | 0.017 | 0.032 | -0.054 | -0.068 | 0.025 | 0.077 | -0.001 | 0.044 | -0.045 |

Bold type denotes values where the null hypothesis of no serial correlation is rejected at the 5% significance level.

**Table 6.5 Partial correlation Coefficients of the price changes**

| Company | Lags | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|---------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| FTSE 100 Index | -0.039 | -0.00 | -0.055 | -0.040 | -0.003 | 0.017 | -0.042 | 0.002 | 0.005 | 0.022 |
| ARM.L | -0.065 | -0.028 | 0.020 | -0.061 | 0.107 | -0.038 | -0.102 | -0.138 | -0.035 | 0.116 |
| BARC.L | **-0.138** | -0.003 | -0.079 | -0.023 | -0.086 | 0.007 | -0.043 | 0.099 | -0.004 | 0.029 |
| BAY.L | -0.083 | -0.034 | -0.023 | 0.051 | 0.026 | 0.105 | -0.052 | 0.074 | 0.044 | -0.001 |
| BP.L | -0.029 | -0.031 | -0.037 | -0.084 | -0.053 | -0.054 | -0.093 | -0.081 | -0.010 | -0.076 |
| BSY.L | 0.027 | -0.080 | -0.099 | 0.085 | -0.079 | 0.062 | -0.023 | -0.034 | 0.022 | 0.024 |
| BT-A.L | -0.028 | -0.047 | -0.126 | -0.037 | 0.086 | -0.011 | -0.088 | 0.037 | -0.072 | 0.051 |
| CAN.L | -0.040 | -0.087 | **-0.264** | **0.004** | **0.020** | **0.015** | **0.068** | -0.120 | **0.088** | -0.037 |
| CW.L | -0.037 | 0.109 | -0.115 | -0.023 | -0.033 | 0.056 | 0.093 | -0.065 | 0.075 | 0.019 |
| HSBA.L | -0.023 | 0.008 | -0.075 | -0.018 | -0.058 | -0.023 | 0.051 | -0.192 | **0.096** | -0.040 |
| KGF.L | -0.035 | -0.132 | 0.067 | 0.043 | 0.043 | 0.074 | 0.075 | 0.011 | 0.007 | -0.001 | -0.071 |
| LGEN.L | **-0.192** | **-0.014** | **-0.014** | **0.054** | **-0.015** | 0.055 | -0.014 | 0.046 | -0.017 | -0.034 |
| LLOY.L | -0.039 | -0.072 | -0.032 | -0.002 | 0.008 | 0.116 | **-0.107** | -0.026 | -0.049 | -0.045 |
| OML.L | -0.078 | -0.161 | -0.039 | 0.053 | -0.048 | 0.088 | -0.072 | 0.053 | -0.070 | -0.028 |
| PRU.L | -0.056 | -0.145 | -0.163 | 0.070 | -0.017 | 0.006 | **-0.003** | 0.044 | **-0.067** | -0.038 |
Both the autocorrelation coefficient and the partial correlation coefficient show that, in the majority of cases, there is little dependency in stock returns at the 5% level of significance, even for the first lag. All but 2 of the correlation coefficients are negative for the first lag, the exceptions being BSY.L and RSA.L, with only 5 of the 21 stocks tested found to exhibit first order serial correlation. Only 3 of the stocks with significantly correlated returns for the first lag also have serial correlation present in the second lag. The coefficients that are significantly correlated for the higher lags do not appear to follow an observable pattern but it is more common for consecutive lags to be significantly correlated if one lag exhibits significant correlation, RSA.L being the only notable exception. 9 out of the 21 stocks tested displayed no evidence of significant serial correlation for any number of lags. TSCO.L is the only company tested that showed significant serial correlation for all ten lags. There are many potential explanations for this and it is difficult to pinpoint the exact cause. What is evident however is that over the past few years, Tesco has diversified into new areas of business, such as finance, insurance, travel as well as mobile phones, more so than any of its rival companies. The rise in Tesco Express mini stores serve as a signal to the market that Tesco is a prosperous and financially healthy firm which can help to facilitate a high level of noise trading, which can result in price changes being correlated. The FTSE 100 index did not display significant serial

<table>
<thead>
<tr>
<th></th>
<th>RBS.L</th>
<th>RSA.L</th>
<th>RSL.L</th>
<th>TSCO.L</th>
<th>VOD.L</th>
<th>XTA.L</th>
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<td>-0.008</td>
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Bold type denotes values where the null hypothesis of no serial correlation is rejected at the 5% significance level.
correlation for any of the lags, which is in keeping with the EMH that states, the greater the volume of trades made, the more efficient a market is likely to be as individual investor errors will eventually sum to zero.

The 5 stocks that displayed significant serial correlation appear to have little in common. They are from a diverse range of industries including finance, mining, telephone communication and food retailing making it difficult to determine the roots of these inefficiencies.

By analysing the 20 stocks listed on the LSE by trading volume, the problem of inefficiencies caused by thin-trading were eliminated, which is the major cause of a departure from the EMH in many smaller markets in developing countries. The famous Wall Street proverb “it takes volume to make prices move” sums up this idea quite nicely. It is basically saying that the adjustment mechanisms which are in place that increase market efficiency, such as arbitrage, are only effective in doing so if sufficient numbers of trades are placed to influence the price and revert it to its fundamental value. Without a high volume of trades, prices will not be influenced enough to maintain efficiency.

It is therefore concluded that the London Stock Exchange can be considered efficient in the weak sense of the definition.

It is interesting to note that the majority of the correlation coefficients calculated for the LSE are negative, especially for the first lag. This can be interpreted as the market over-reacting to new information and then having to undergo a self-correction process in the next period. This
does not mean that the market is inefficient in the weak sense because this corrective movement occurs rapidly. The reason why this process occurs relatively instantaneously is that the LSE has invested vast sums of money into real time information provision services, *Infolet*, which has gained awards for being the ‘data provider of the year’. *Infolet* provides a wide range of data published in real time that allows inventors to make decisions based on all available information, resulting in the market adjusting rapidly to any new information.

**6.6 Graphical Analysis**

The movements of the FTSE 100 index are presented in graph 6.61. There exist clear trends throughout the period that this analysis focuses on and two distinct peaks. From 1995 to the beginning of 2001 there is an observable upwards trend as the index increased from 3000 to nearer 7000. A substantial proportion of this gain was mitigated in the preceding years as the FTSE 100 dropped to approximately 3500 in the early months of 2003. The market then continued following an upwards trend until the end of the analysed period in 2007. The presence of two clear upward trends, in hindsight, presented investors with excellent trading opportunities, for example, a portfolio that tracked the FTSE 100 from 1995 to 2000 would have doubled in value. It is interesting to note that in the early years of the 1995-2000 upwards trend, that the volatility of closing prices remained relatively low indicating a fairly unanimous belief that the market was embarking on a healthy period of growth. By mid-1998 there is a clear increase in the price volatility, as well as a 1000 point drop in the latter part of 1998 indicating the market was beginning to anticipate the preceding decline of 2000 to 2003.
The logs of the weekly price changes are presented in Graph 6.62. These results support the EMH in the weak-sense of the definition. It is clear that no obvious trends are present in the data and the mean of the logs of the price changes converges almost on zero, 0.001 to be precise indicating that the price changes are in fact unanticipated and random.
Graph 6.62

![Graph of returns](image)
CHAPTER SEVEN

CONCLUSION AND POSSIBLE AREAS FOR FURTHER RESEARCH

The objective of this study was to test the weak-form efficiency of the London Stock Exchange. In an efficient market successive price are independent of each other and are therefore uncorrelated. The efficiency of the LSE was examined using correlation tests. The correlation tests that were conducted revealed that there was little evidence to suggest dependence in successive price changes of the shares listed on the LSE and the FTSE 100 itself. Where correlation was detected, the coefficients were only marginally lower than the values expected given no dependence. It was therefore concluded that the LSE is an efficient market.

The findings of this study are consistent with the majority of earlier work on the LSE. (See Marsh, 1979; Firth, 1976; Kendall, 1953; Brealey, 1970; Dryden, 1970; Cunningham, 1973 among others). By selecting the 20 most traded company stocks on the LSE for this study it ensured that all of the price adjustment mechanisms previously mentioned will have been captured and prices would reflect a vast array of individuals’ information and knowledge, increasing the likelihood of the market prices being efficient. For example, a stock may be considered underpriced but is infrequently traded resulting in a considerable time lag until the market price converges with the fundamental value, during this period the stock would be considered inefficiently priced. If a stock is traded more frequently, the correction process occurs more rapidly and efficiency is maintained. The real-time information services used by
the LSE ensure that trades can be placed using all available information resulting in a share price that reflects this. Any future price changes should only occur because of the availability of new information which cannot be anticipated and is therefore random.

Although the findings of the study agree with the majority of studies conducted of a similar nature, it is important to realise a few limitations of this work. Fama (1965) stated that the dependence of price changes is complex which could result in standard statistical analysis, such as correlation tests underestimating the degree of dependence. However, for measuring the direction and degree of dependence, correlation tests are one of the most powerful tools statisticians have at their disposal.

7.1 Areas of future study

As this study only focuses on the most frequently traded stocks, which, as theory would tell us, have the greatest probability of being efficiently priced, a natural progression from this would be analyse not only stocks listed on the FTSE 100 but also stocks listed on the AIM for example to see if the results differ notable for less frequently traded stocks. The problem of thin-trading has been highlighted as one main causes of inefficiencies in developing markets so it would be interesting to explore whether the superior information services of the LSE offsets this problem.
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