UK MARKET EFFICIENCY AND THE MYNERS REVIEW: A UNIVARIATE ANALYSIS OF STRATEGIC ASSET ALLOCATION BY INDUSTRIAL SECTORS

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ABSTRACT

The Treasury's report "Institutional Investment in the United Kingdom: A Review" (the Myners Review) suggested in 2001 that various sectors of the UK equity market may be suitable for active investment management, tacitly assuming that some sectors are efficient whilst others are not. The validity of this assumption is tested against 29 industrial sector indices within the FTSE All Share index. Sector efficiency is taken to be that index values reflect information correctly (strong efficient) or to the point where benefits do not exceed costs (weakly efficient). Existence of a sector index following a random walk is used to identify strong efficiency with the subsequent conclusion that passive management would be appropriate. Where the time series is not random, forecasting gains less than the management costs of active trading indicate weak efficiency with the corollary that passive management is still applicable. Industrial sectors where the index can be forecast with gains in excess of costs are not efficient and are appropriate for active management.

The indices are tested for stationarity: none are stationary in levels but all reject the Dickey Fuller null hypothesis of a unit root in their first difference, the logarithmic return. Tests for randomness are based on pure random walks and random walks with drift and/or trend. Non-random time series are examined for maintained regressions based on AR, MA and ARMA. Where appropriate, ARCH is applied to the variance, utilising GARCH, Threshold GARCH, GARCH-in mean, Exponential GARCH and Component GARCH. Additionally there is a test for cointegration. All potential data generating processes' residuals are tested for independent identical distributions using the BDS test. If the maintained regression produces residuals that are IID then that series is assumed to be explained.

The results show that four indices are strong efficient and five are weak; giving nine sectors that should be managed passively. Only one sector is found where there is scope for active management to make an abnormal gain in excess of costs. Nineteen of the indices had GARCH, which indicated a possible lack of efficiency but no decision on management style. One index was unexplained. Thus the Myners review's suggestion of active management where appropriate was valid, but limited solely to the Personal Care & Household Products sector.

ACKNOWLEDGEMENTS

Teaching investment at Bournemouth University whilst acting as Chief Examiner in Institutional Investment and Fund Management for the Securities and Investment Institute highlighted the lack of academic finance research at the industry sector level but its importance in the fund management industry. The motivation for the study came from the Myners Review, identifying the need to identify asset classes where active management might be appropriate.

Thanks are due to my two supervisors, Professor Phil Hardwick and Doctor Ann Robinson. Phil particularly for his calm and helpful comments on econometrics and Ann for her insights to the writing of the Myners Review. In addition I should recognise the Institute of Business and Law (and the School of Finance and Law as was) for their support and colleagues at work for their help and comment. Most importantly is the recognition of Fiona's tolerance whilst I was in the Washhouse.

AUTHOR'S DECLARATION

Extracts of this thesis have been presented to the British Accounting Association's Doctoral Colloquium (April 2004) at the University of York and to various research seminars and workshops at Bournemouth University's Graduate School.

The thesis has 74,508 words, in line with the University recommended maximum of 80,000 words.

This thesis is entirely my own work.

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ABBREVIATIONS USED IN THE TEXT

ADF	Augmented Dickey Fuller
AR	AutoRegressive
ARCH	AutoRegressive Conditional Heteroskedasticity
ARIMA	AutoRegressive Integrated Moving Average
ARMA	AutoRegressive Moving Average
BDS	Brock, W. A., Dechert, W. D., Scheinkman, J. A.
CAPM	Capital Asset Pricing Model
EG	Engle Granger test
EGARCH	Exponential Generalised AutoRegressive Conditional Heteroskedasticity
EMH	Efficient Market Hypothesis
FTSE100	Financial Times Stock Exchange 100 share index
FTSE A/S	Financial Times Stock Exchange All Share index
GARCH	Generalised AutoRegressive Conditional Heteroskedasticity
GARCH-M	GARCH-in mean
IID	Independent and identically distributed
JB	Jarque-Berra test
LB	Ljung-Box test
LM	Lagrange-Multiplier test
MA	Moving Average
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
Myners Review	Institutional Investment in the United Kingdom: A Review
NAPF	National Association of Pension Funds
SAA	Strategic Asset Allocation
TGARCH	Threshold Generalised AutoRegressive Conditional Heteroskedasticity
TIC	Thiel's Inequality Coefficient
UIH	Uncertain Information Hypothesis
VAR	Vector AutoRegressive

CHAPTER ONE INTRODUCTION

1.1 The Myners Review

1.1.1 Context

In March 2001 the Treasury published "Institutional Investment in the United Kingdom: A Review" (subsequently referred to as the Myners Review). Instigated by the Rt Hon Gordon Brown MP and submitted by Paul Myners, the Review set out a blueprint for change in the UK savings and investment industry. Its main analysis was based upon studies of:

- pension fund trustees;
- investment consultants;
- asset allocation;
- herds and peer group benchmarks;
- performance measurement timescales;
- broking commission.

It is the third of this list, namely asset allocation, that is central to this doctoral study, exemplified by Myners' letter submitting the Review where he suggested that "asset allocation- the selection of which markets, as opposed to which stocks, to invest in- is an under-resourced activity" (p. 1). The importance of this is reflected in its inclusion in the proposed Principles, which refer to "the attention devoted to asset allocation decisions (which) should fully reflect the contribution they can make to achieving the fund's investment objectives" (p. 15). The main research hypothesis of this thesis is set out in a later chapter but this Introduction will pre-judge that discussion by giving greater focus to asset allocation and market efficiency and less emphasis to trustees, commission and the like. Unless otherwise specified, all quotations or paraphrasing set out in the Introduction are from the Myners Review of Institutional Investment, 6th March 2001.

The Myners Review defines fund managers' core service as one of "...investing client assets in order to generate superior returns for a given level of risk or the lowest level of risk to achieve a targeted return" (p. 73); in effect, to move within the feasible set towards the efficient frontier or on to the appropriate position of the Capital Market Line in the mean-variance space, as posited by Markovitz (1952). Much of the Review locates this core service within the strategic asset allocation decision, as exemplified by the following examples.

Firstly, peer group benchmarking (where the trustees delegate the strategic asset allocation decision) was recognised as being in decline, (but still encompassing a significant proportion of funds under management) and was regarded as a matter of concern with the Review believing "...that this way of managing pension funds has no satisfactory justification" (p. 56). Peer group total fund benchmarks have asset allocation "...driven by historic consensus..." (p. 55) resulting in slow changes in asset allocation, high uniformity across funds and convergence of strategic asset allocations over time. Secondly, customised total fund benchmarking, a process with asset allocation decisions made by the trustees, results in extensive reliance on their advisers (often investment consultants or consulting actuaries). The Review argues that these consultants are in turn both small in number and use similar asset-liability modelling techniques, hence causing funds to reject certain asset classes (for example private equity) and to conform to the fairly generic advice of the advisors. Thus the outcome for customisation is similar to that of the peer group method, with high concentration, low switching between advisors and similar models all conspiring to "a commonality of investment policy among pension funds" (p. 70). This is contextualised by two statistics set out separately and not conflated within the report, namely that only 1.5 basis points out of a total of 47 in the annual costs of the value added chain go to the consultant for asset allocation, but that "...investment policy dominates investment strategy.....explaining on average 93.6% of the variation in total (pension) plan return". (Brinson et al, 1986, cited in the Review, p. 60.) To offset this commonality of strategic asset allocations, or rather the need to encourage "greater diversity of asset allocation policies" (p. 5) the recommendations urge more open competition by providers, formal assessment of their performance and allocation of fees to reflect contribution to performance.

Trends identified by the Review throughout the nineteen eighties and nineties show a gradual decline in the use of in-house management. In addition there is a switch from a balanced basis (one manager responsible for all asset classes) to much greater use of specialist mandates (separate managers responsible for different asset classes), combined with the growth of foreign firms in the UK fund management market and the continued growth in funds under management. This same period also saw growth in passive investing, with the report (disparagingly) alluding to "...passive investing seek(ing) to free-ride off the more or less efficient capital allocation of active fund managers"(p. 81). Additionally, in a brief history of the fund management industry, reference is made to "...the ability of managers to 'beat the market'" (p. 81). The Myners Review would seem to view the UK equity market as inefficient in its pricing in relation to information available! This conclusion is then rejected or down played, in that when supporting or encouraging investment in venture capital, the recommendation is justified on the basis that "it is precisely among poorly researched asset classes that greater opportunities for enhanced return are likely to exist" (p. 59).

Market efficiency is similarly covered in some of the recommendations related to fund managers. They centre around capital market efficiency at the asset class level and address two main issues. In relation to actual indices, funds are urged to ensure that their selected index benchmarks are appropriate and that they have set divergence limits that are appropriate. This in contrast to the Review's later opinion that "pension funds are paying fees for active management when its true style is becoming increasingly passive: adding less and less value, and offering less and less stock-selection strategies" (p. 10). Additionally, that for each asset class, it is necessary to consider "...whether active or passive management would be more appropriate..." (p. 22) and to allow those deemed to be appropriate for active management to have "...sufficient freedom for genuinely active management to occur" (p. 22). These recommendations are supported by emphasis on the need for clarity over the performance measurement period. It is this view about the potential additional or abnormal gain to be achieved from active management that forms the basis for the thesis. There has long been a tension or debate between theory and practice, or academics and fund managers, as to whether the UK equity marketis efficient (or not) and hence whether it should be managed passively (or has scope for abnormal gain from active management). This thesis continues and contributes to that debate.

1.1.2 Focus of Thesis

The intended aim of this research is to examine or test certain aspects of the Myners Review's underlying precepts and recommendations in relation to the Efficient Market Hypothesis. This will not be a broad-brush approach as it will ignore issues such as broking commission, trustees and consultants. The main focus will instead be on asset allocation, herds or peer group benchmarks and performance measurement. In particular, this thesis will consider if UK asset classes as defined by FTSE All Share industrial sector indices are efficient. This is central to the Review, which assumes lack of efficiency in its vision of "a better-functioning system" with:

> a greater richness and diversity of benchmarks (so that) active mandates would be given where there was good reason to believe that active management could deliver outperformance...(allowing) successful active managers (to) manage with greater conviction (p. 17).

The framework for the research will therefore be the Efficient Market Hypothesis (defined later, but basically the assumption that share prices reflect information to the point where the benefits do not exceed the costs) as it could be argued that the growth of tracker funds and peer group benchmarking is tacit acceptance of market efficiency by the fund management community. Thus it is telling that the Myners Review is applying pressure to move the industry towards more active fund management, in effect rejecting the concept of efficiency, stating specifically that funds should "consider explicitly for each asset class invested whether active or passive management would be more appropriate" (p. 87). In recent years much has been published on stock selection. This has been based on stock picking techniques, fundamental analysis, technical analysis, Economic Value Added or more theoretical Portfolio Theory models. Over the same period, very little has been published in finance on asset allocation, i.e. decisions of percentage allocation of a fund to domestic versus international investment, or equity versus fixed interest stock, property, cash and all other asset classes. Thus the research area is relatively unexplored, surprising in that some research indicates that asset allocation has a significantly greater impact on performance variance than the individual stock selection process.

Fund managers involved in active management warranted further consideration by the report in relation to commission to the sell-side. Fees paid by the pension funds to the fund managers were viewed as transparent but dealing and research is more opaque. The soft commission could be responsible for the actual or perceived "inefficiencies and complexities" (p. 96) which would be removed by greater transparency. Thus it was recommended that costs of external research, information and trading costs be incorporated in the fee paid to the fund manager. This view has strong resonances with current definitions of efficiency, in relation to weak efficiency rejecting active fund management on the grounds of cost.

Table 1 Percentage ownership of UK equities

	1963	1969	1975	1981	1989	1994	1999	2004
Overseas	7.0	6.6	5.6	3.6	12.8	16.3	29.3	32.6
Insurance companies	10.0	12.2	15.9	20.5	18.6	21.9	21.6	17.2
Pension funds	6.4	9.0	16.8	26.7	30.6	27.8	19.6	15.7
Individuals	54.0	47.4	37.5	28.2	20.6	20.3	15.3	14.1
Unit trusts	1.3	2.9	4.1	3.6	5.9	6.8	2.7	1.9
ITCs*	11.3	10.1	10.5	6.8	1.6	2.0	1.9	3.3
Other financial*					1.1	1.3	5.1	10.7
Charities	2.1	2.1	2.3	2.2	2.3	1.3	1.3	1.1
Industrial/commercial	5.1	5.4	3.0	5.1	3.8	1.1	2.2	0.6
Public sector	1.5	2.6	3.6	3.0	2.0	0.8	0.1	0.1
Banks	1.3	1.7	0.7	0.3	0.7	0.4	1.0	2.7
Total	100	100	100	100	100	100	100	100

*Shown as one value to 1981.
Source: ONS, "Share Ownership: a report on the ownership of shares at 31st December 2004.

The report's contextual background to institutional investment is introduced by outlining the main types of institution and their proportionate holdings in UK equity. An expanded version of the Review's statistics is set out in Table 1 above. (The expansion is both in terms of time and type, relative to that given in the Review.) Although the Review's title infers that the original intent was to cover all institutions shown in the table, it should be noted that the main focus is on pension funds, given that with regard to life funds "...the review finds that investment performance is far from the main focus of competition....which fall beyond the remit of this review, and which I propose the Government should investigate separately" (letter, p. 2).

Other pooled institutional investment is covered briefly in the review, but only to the extent that it applies to the same recommendations as that of pensions. The main recommendation relating to pooled investments being that it should be included in a proposed review of personal investment products. Thus the primary category of institutional investor considered by the review is the occupational pension fund generally, although this is split into defined benefit and defined contribution schemes, with the chief category being UK company pension schemes. Consideration is also given to local authority pension funds, although this is very much a sub-set of the main company approach. The concentration on pension funds, when allied to the concern to increase active management and give greater attention to the strategic asset allocation processis paradoxical, in that one of the main drivers in pension fund investment is asset liability matching. A process that could be seen as dominating the investment policy of the pension fund to a greater extent than any other type of investment fund.

For the purpose of this research, the salient points within "Institutional Investment in the United Kingdom: A Review" are that funds should move away from benchmarking and be more dynamic in terms of changing asset allocations. Passive management isseen somewhat negatively as a free-ride whereas active management is more aspirational, resting on the ability of managers to achieve abnormal returns or to beat the market The focus of this being not with timing or stock picking, but in the under-utilised area of strategic asset allocation with the key assumption being that active management should be used for those asset classes where there is scope for abnormal gain. The asset classes or rather the strategic asset allocation choices are viewed as "the overall spIt between real and monetary assets" or "domestic and overseas fixed income and equities" or "specific segments, defined either by geography, sector, size or style"(p. 51).

This flies in the face of the concept of market efficiency. Definitions of efficiency or the Efficient Market Hypothesis are considered in considerable detail in the literature review, but the analysis will be based upon an asset class being strong efficient, weakly efficient or not efficient. Strong efficiency being viewed as when the asset class is always the correct level; returns are not forecastable as they are white noise. Weakly efficient asset classes will have some forecastable ability, but the cost of obtaining that benefit will exceed the benefit: returns are coloured noise. Non-efficient asset classes will be forecastable and capable of generating abnormal returns.

Given that the majority of UK investors invest within the UK (see the Literature Review for discussion of home country bias) and that the Myners Review has an institutional focus in particular in relation to equities, then this thesis will seek to test the assumption of the Review; namely to establish if the various UK equity industrial sectors are strong efficient, weakly efficient or not efficient. In effect, are individual sectors / asset classes candidates respectively for passive management, or marginal passive/active or active management?

1.1.3 Other aspects of the Myners Review

The following is a brief summary of the other Myners Review recommendations. It should be noted that they do not relate to this research study's core area of strategic asset allocation and so their inclusion is for background interest only.

Given the trust structure of most UK pension funds, the performance of the trustees was a natural starting point and the discussion was informed by a survey of many trustees. Lack of training and knowledge, lack of time and lack of support were issues identified as major detractors to the achievement of their responsibilities. Hence the report's recommendations were for trustees to consider their own effectiveness, to seek training or delegation so as to make decisions "...with the skill and care of someone familiar with the issues concerned" (p. 14). To support this, the sponsor company should provide sufficient in-house staff and should increase trustees' training. Good practice was set out to include the use of investment sub-committees and (where appropriate) to pay trustees.

Decision-making by the pension fund trustees was viewed as three-fold: asset allocation; security selection; and choice of (followed by review of) advisers/consultants and fund managers. Asset allocation was further split between insured and self-administered schemes. Other than recognising this split, the insured scheme (i.e. scheme obligations and management being passed to an insurance company) was ignored for the rest of the review. Within the sphere of self-administered schemes, considerable emphasis was placed on the choice between peer group benchmarking, where the trustees delegate both asset allocation and security selection to the fund manager, and customised total fund benchmarks, where the trustees retain the asset allocation decision but delegate security selection. Recommendations in relation to decision-making were fairly limited, encompassing the need for explicit fund objectives linked to coherent fund managers' objectives, allied to clarity in who takes what decisions.

As a separate area of debate, shareholder activism was considered. Pension fund trustees were recommended to "...incorporate the principle of the US Department of Labor Interpretative Bulletin into fund managers' mandates" (p. 93). In effect, to participate more in voting and other shareholder activities that could be seen as having an impact on the share's value.

The following additional issues within the Review are included for comprehensiveness but do not have any direct bearing on the main thrust of this review.

Defined contribution schemes came under scrutiny, resulting in recommendations such as:

- Collection by the National Association of Pension Funds of more comprehensive data

- Default options should have objectives and expected risks/returns
- Investment options should offer a range reasonable for most scheme members
- The full range of investment opportunities should be considered
- Government should keep under close review the contributions and implications for retirement incomes.

Within defined benefit schemes, the report was concerned over disputes relating to the ownership of surpluses, seeking clarity via requesting a review by the Law Commission. Additionally there was a recommendation for the tax rate on withdrawal of surplus to match the rate of corporation tax.

The Minimum Funding Requirement was an important part of the Myners review and much of the issues were set out in an open letter in November 2000. The key recommendation that the MFR should be replaced has already been acted upon by the UK government and thus is of no direct relevance to this discussion.

Private equity was a specific part of the Review's brief and the report naturally identified a variety of recommendations. These are not considered here as they relate to just that one asset class.

Local authority pensions were examined but the Review did not identify "...any issues specific to local authority funds...., (nor) to suppose that the broader analysis in the report does not apply" (p. 199). Thus although there were local authority pension fund-specific recommendations they fall in with the generality set out above. Finally, there was a set of recommendations on Principles, namely:

- Pension funds' Statement of Principles should explain their adherence to the Review's principles
- That legislation should follow if the industry does not adopt the principles voluntarily
- The Government reviews the effectiveness of the principles in two years (i.e. 2003)
- The planned review of personal investment products develop similar principles

1.2 Outline of the Thesis

1.2.1 Format

The structure of this thesis follows the recommended model as set out by Ryan, Scapens and Theobold (2002). This suggests generic sections and approximate sizes (for research based on empiricism) of:

Introduction	5,000 words
Literature Review	25,000 words
Methodology	5,000 words
Research Problem	5,000 words
Method	5,000 words
Results	25,000 words
Conclusion	5,000 words.

The Literature Review of Chapter 2 begins with consideration of the development of the Efficient Market Hypothesis and associated tests. This initially is partly historical and as such tends to be descriptive rather than critical. The focus then shifts to a summary of forty years of testing for efficiency, including links with asset pricing models, serial correlation (as a test for weak form efficiency), event studies (the main methodology for the semi strong form), anomalies and the more recent approaches to testing. This includes consideration of the growth of behavioural finance. It is then extended to encompass efficiency type analysis that is linked to fund managers and the fund management process (for instance, active versus passive management and performance persistence) and then more specifically to strategic asset allocation, so as to give greater focus to the issues developed within the Myners Review. This is then contextualised by a brief examination of actual strategic allocations by high level asset classes. Finally the topic moves to a more sectoral view in the consideration of share indices and random walks as this forms the basis of much of the techniques used within the analysis. Little has been written on efficiency tests at the industry sector level, so this final section of the Literature Review is perforce somewhat limited.

Chapter 3 on methodology locates the research approach within various research paradigms. The main areas of discussion are particularly those that relate to the predominantly quantitative nature of this research, but this chapter also includes more detailed consideration of the views of Hayek.

His work helps to inform development of the research problem as set out in Chapter 4, (the Research Problem), the main area already having been briefly identified above. This sets out the centrality of market efficiency to this research, chiefly through the tests for randomness in indices' time series and its application to UK industrial sectors

Similarly, this is combined with the relevant parts of the Literature Review to describe in Chapter 5 the appropriate research method and its attributes and critical problems. This includes an introduction to the use of the BDS test. Many statistical or econometric tests and techniques are well known and commonly used: these are taken as givens and little time or space is devoted to their explanation. For the BDS test the opportunity is taken to give greater explanation.

The results section is in three separate parts. Chapter 6 begins the analysis by testing for stationarity and random walks. Chapter 7 seeks to estimate regression equations that describe the data generating processes for the various industrial sector share indices. Chapter 8 attempts to test the validity of these processes by means of forecasting out of sample values of the share indices' returns.

Chapter 9 concludes, with discussion of findings, impact for the fund management sector and for government policy. Finally there is the identification of further research.

1.2.2 Doctoral requirements

The Quality Assurance Agency (2001) suggests level descriptors for undergraduate, masters and doctoral qualifications. For a Doctor of Philosophy the requirements are

> the creation and interpretation of new knowledge, through original research or other advanced scholarship, of a quality to satisfy peer review, extend the forefront of the discipline, and merit publication;
>
> a systematic acquisition and understanding of a substantial body of knowledge which is at the forefront of an academic discipline or area of professional practice;

the general ability to conceptualise, design and implement a project for the generation of new knowledge, applications or understanding at the forefront of the discipline, and to adjust the project design in the light of unforeseen problems;

a detailed understanding of applicable techniques for research and advanced academic enquiry. (part 2)

These are interpreted within the Bournemouth University Research Awards Handbook (2001) as, inter alia, a critical investigation and evaluation resulting in an independent and original contribution to knowledge. This manifests itself in this thesis in three main ways. Firstly, although there has been a vast amount of research over the last thirty years into market efficiency, there has been very little activity in relation to efficiency by industrial sector share indices. Typical studies have tended to be: a) at the individual company/share level, or b) aggregated up to a total market index, or c) non-sector specific groupings by various attributes such as size or return. The examination of efficiency by sector indices thus represents a new and original extension of an already densely researched field. Secondly, many research papers on efficiency, particularly those concerned with weak form efficiency, test for randomness in the share index. The majority of these papers just concentrate on a pure random walk and so ignore random walks with drift or random walks with trend. The tests for randomness/stationarity within the analysis of this paper are applied to the full range of random walks with/without drift and/or trend. This is not new or innovative, but it is much more comprehensive than the majority of papers, even at a market level, let alone by sector. Thirdly, all possible data generating processes that are considered as being potential forecasting mechanisms for a share index are tested using the BDS test (covered in detail in later chapters). This test is relatively new and although it has been used before in efficiency testing, does provide a third strand that makes the analysis an original contribution to knowledge.

CHAPTER TWO LITERATURE REVIEW

2.1 Development of the Efficient Market Hypothesis

2.1.1 Outline

This literature review is in six main sections. The first is solely based upon the efficient market hypothesis. This uses the work of Fama as its main thread, not because he was the sole arbiter on market efficiency, but merely as a format to follow the development of the theory. Tests of market efficiency over the thirty five years of its existence are then considered, to examine its validity or (in extremis) its dogma. By necessity, this section also brings in the background to models of asset pricing. The third section looks at issues surrounding fund management in relation to market efficiency, which then logically progresses in section four to consideration of fund management's strategic asset allocation. To conceptualise this, section five gives some high level aggregations of descriptive data in relation to actual asset class allocations. Finally the sixth section looks at sector level research and tests of efficiency.

2.1.2 Theory development

It was Fama (1965) who introduced (or at least gave the name to) the concept of the efficient market hypothesis. Prior to this seminal paper, prices of investments were to a large extent seen to change as if following a random walk pattern. From the early work, such as Bachelier (1900, cited in Fama 1965) through to Samuelson (1965) the perceived wisdom developed towards the view of a random walk hypothesis. In this model, returns of assets (typically but not only equity) are assumed to be independent and to have constant distributions over time. Thus the return in any one period has no relationship with returns in prior periods. Commonly linked with this hypothesis was the use of the roulette wheel analogy, for instance Roberts (1959, cited in Fama, 1965) stated "If the stock market behaved like a mechanically imperfect roulette wheel, people would notice the imperfections and by acting on them, remove them" (p. 98). Similarly Elton and Gruber (1995) reason "Each period the wheel is spun, and the return for the next period is read from the wheel. The outcomes...are unrelated through time...". (p. 405)

Samuelson's (1965) "enigma posed" (p. 41) concerned the fair game or martingale property of an unbiased random walk. In this type of approach, X_t (a stochastic variable such as American stock prices as used in his paper) follows such a random walk if

$$X_{t+1} = \delta + X_t + \varepsilon_{t+1} \qquad (2.1)$$

where δ is a drift parameter and ε_{t+1} is an independent random error variable. If $\delta = 0$, then X_t follows a random walk without drift and $X_{t+1} - X_t$ is a fair game. This can apply to both discrete and continuous variables, such that:

	Discrete	Continuous
$P_i \geq 0$ and	$\Sigma P_i = 1$	$\int f(X)\,dx = 1$
First moment $\mu = E(X)$	$\mu = \Sigma P_i X_i$	$\mu = \int X f(X)dx$
Second moment $\sigma^2 = Var(X)$	$\sigma^2 = \Sigma P_i X_i^2 - (E(X))^2$	$\sigma^2 = \int X^2 f(X)\,dx$

Within the properties of a random walk, the higher conditional moments (e.g. Var (X)) are assumed to be statistically independent whereas with a martingale they are not so restricted. Thus

$$E_t(\varepsilon_{t+1}) = 0 \qquad (2.2)$$

and $$E_t(\varepsilon_a . \varepsilon_b \mid X_t) = \begin{cases} \sigma^2 & a = b \\ 0 & a \neq b \end{cases}$$

(see Cuthbertson 1996)

Given that the ε are independent for t, then the conditional function for $a \neq b$ applies to any linear and non-linear relation between ε_a and ε_b. Therefore in relation to Samuelson's reference, changes in stock prices are unpredictable but $E(\varepsilon_{t+1} \mid X_t)$, the conditional variance, may be a function of past prices if a martingale, but not if a random walk. In effect, in a fair game the information available at time t is of no use in achieving abnormal returns in time t+1. Unfortunately this approach was not extended to include the third version of random walks, namely a random walk with trend.

Although there are close links between a random walk model and the (weak form of the) efficient market hypothesis it was interesting that Roberts assumed stationarity in the time series of the returns (not directly necessary in Fama's work) and used the concept of arbitrage ("...people would notice.."), again a factor not applicable to efficient markets. At the same time there was little or no focus on the role of information, a central part of the efficient market hypothesis.

Informational efficiency in security prices as an economic construct thus began with Fama (1965) and is currently interpreted to mean that the price of a security reflects all information that is available. The first version of the hypothesis has however evolved through a series of expansions or more specific definitions. The original approach saw Fama (1965) define an efficient market such that:

> a situation where successive price changes are independent is consistent with the existence of an "efficient" market for securities, that is, a market where, given the available information, actual prices at every point in time represent very good estimates of intrinsic value. (p. 90)

Thus at this stage there were no links with the various later 'forms' and the main thrust was a review of the extent to which the history of prices or returns are an indicator of future returns.

Fama's initial paper began with a review of random walks, specifically price change independence and the allied probability distributions. Perfect independence was rejected as not being "...an accurate description of reality..." (p. 35), but possibly a forerunner of the 1991 version of strong/weak efficiency with the dependent gain lost in transaction costs (see below). The more relaxed independence was seen as consistent with shares' intrinsic value such that ε was viewed as noise. With regard to the probability distributions, this was described as the less important of the two factors (distribution and independence) with the main concerns being empirical evidence raising doubts about normality (or Gaussian) models resulting in support for Mandelbrot's (1963) hypothesis of empirical leptokurtosis.

In a paper submitted in 1966, but not published for another three years, Fama, French, Jensen and Roll (1969) (FFJR) reviewed efficiency in relation to new information. The research approach was based on event studies, specifically the returns of securities surrounding the announcement of share splits. In their conclusion FFJR stated:

> the information implications of a split are fully reflected in the price of a share at least by the end of the split month but most probably immediately after the announcement date. (p. 20)

This focus shows how the emerging hypothesis had moved from the latent weak form of historic prices towards the semi-strong form and the impact of current information. Also evident is the importance or relevance of the 'speed' with which the new information is assimilated.

The use of speed of reaction to news as a definition of market efficiency did not detract from the earlier (1965) approach of independence and was seen as giving no scope for abnormal return "…unless of course, inside information … is available" (p. 21). An allusion to the later forms of efficiency.

In 1970 Fama reviewed the body of empirical work based upon the first version of the efficient market hypothesis and gave greater focus to the role of information. In particular it was assumed that an efficient market was one where security prices always fully reflected available information, at the same time making this conditional on there being no trading costs, costless information and all participants interpreting the information in the same way so as to reach the same conclusion. It was at this stage that the hypothesis was sub-divided (as posited by Roberts) into three nested sets:

Weak form	all information contained in historic prices is fully reflected in current prices
Semi-strong form	publicly available information is fully reflected in current prices
Strong form	all information (public and private) is fully reflected in current prices.

The review referred back to the original paper by stating that "a market in which prices always 'fully reflect' available information is called 'efficient'." (p. 383). It then considered all the available evidence, collated into tests for weak, semi-strong and strong. As well as bringing the three nested forms into the hypothesis, the paper reached conclusions as to the strength of the efficiency. These were summarised by Fama as:

> weak form tests are the most voluminous, and it seems fair to say that the results are strongly in support. (p. 414)
>
> semi-strong form tests... have also supported the efficient markets hypothesis. (p. 415)
>
> for the purpose of most investors the efficient markets model [strong form] seems a good first ...approximation to reality. (p. 416)

Referring back to the earlier random walk models, expected return theories were described as

$$E(\breve{E}p_{j,t+1} \mid \Phi_t) = p_{j,t}\,(1 + E(\breve{E}r_{j,t+1} \mid \Phi_t)) \qquad (2.3)$$

where p is the security price

r is the return, based on $(p_{j,t+1} - p_{j,t}) / p_{j,t}$

Φ is the information set

Ě assumes randomness when viewed from t.

The expected return approach implied a fair game and its attendant properties and was then extended into a sub-martingale with the assumption

$$E(\breve{E}p_{j,t+1} \mid \Phi_t) \geq p_{j,t} \qquad (2.4)$$

in effect that $E(\breve{E}r_{j,t+1} \mid \Phi_t) \geq 0$. This non-negativity implies that investment decisions linked to active trading cannot have abnormal expected profits. Future return independency (the random walk model) was stated as

$$E(\check{E}r_{j,t+1} \mid \Phi) = E(\check{E}r_{j,t+1}) \quad (2.5)$$

thus distinguishing the martingale's distribution of r's independence of Φ_t from that of a random walk where all the distribution is independent of Φ_t.

Following criticism that the definition of market efficiency was tautological, Fama revised the hypothesis in 1976. The main change being that the market participants correctly use all available information. In effect the hypothesis was now in the three nested forms and assumed what is currently referred to as market rationality, i.e. that prices reflect fundamental values.

In parallel to Fama's work on market efficiency, a growing body of work developed in the sphere of information economics. In his review of the development of stock market efficiency, Ball (1992) views this information economics as being distinct from Fama's hypothesis in terms of the users of the information. He emphasises that the efficient market hypothesis of Fama assumes that it is the market that is efficient in terms of the information set. The market is an entity. This distinguishes the hypothesis from the later information economics models in that they place the interpretation of data with the individual and then aggregate up to the market.

By the mid 1970's the concept of market efficiency was well established and had a considerable body of empirical evidence supporting Fama's theory. At its core was the definition of an efficient capital market being one where security prices reflect all available information. This rather rigid definition is subdivided into the three forms of weak, semi-strong and strong, which in turn gives rise to concern over the speed at which the market assimilates new information. This definition of the theory has not changed greatly in subsequent years, although the focus has become more concerned with security returns instead of their absolute prices. Subsequent research has chiefly been concerned with testing the various forms, or seeking extensions to the concept of the original hypothesis.

By the end of the 1980's there had been a huge volume of papers on the efficient market hypothesis, the various asset pricing models and their relationship. Fama (1991) attempted to replicate his 1970 paper in terms of a review of the literature, recognising that "The literature is now so large that a full review is impossible..." (p. 1575). Market efficiency was simply taken to be that security prices fully reflect all available information, although a (different to the original) split posited two versions:

strong:	where information and trading costs are zero, and
weaker:	where prices reflect information to the point where the benefits do not exceed the costs.

The evolution of the Efficient Market Hypothesis, albeit with extensive simplification, can thus be viewed as follows.

Pre 1965	price changes viewed as	independent over time (random walk)
1965	price changes viewed as	independent over time
	and	price = value
1969	price changes viewed as	independent over time
	and	price = value
	and	rapid reaction to new information
1970	price changes viewed as	independent over time
	and	price = value
	and	rapid reaction to new information
	and	three forms in nested sets
1991	price changes viewed as	"fully reflecting all available information" (strong or weaker)

2.2 Tests of Market Efficiency

2.2.1 Efficiency and asset pricing

Tests of market efficiency have been numerous and extensive, with much ofthe earlier work being generally supportive. Examples from this vast body of work include most of the factors linked to efficiency or the model against which efficiency is tested. The following are thus not the seminal papers in this arena, but merely a sample of the approach taken and the specific results or conclusions.

If market efficiency is to be tested, then the main approach is to compare actual prices with expected prices (or actual returns with expected returns). The growth in research into market efficiency had coincided well with the development of new models for predicting expected returns. In addition to providing the base for tests of efficiency in the sense of speed of response to new information, there was also an expectation that they would provide a test of market rationality in that any successful model should set expected returns in step with economic fundamentals. The most common of the models used in tests of market efficiency is that of the Capital Asset Pricing Model (CAPM) developed independently by Sharpe (1964) and Lintner (1965).

The Sharpe-Lintner model is a form of general equilibrium relationship in the market-place and although the original version had many unrealistic assumptions it has evolved over the years to encompass a variety of non-standard forms that attempt to reduce the assumptions and make the model more realistic. Many empirical tests have taken place with the model, for instance Miller and Scholes (1972) tested bias, nonlinearity, heteroskedasticity, errors in beta measurement and skewness in return distribution. Black et al (1972) undertook time-series and cross-sectional tests. Gibbons (1985) tested for the non-linear restrictions, as did Stambaugh (1982). Some of the findings rejected aspects of the model whilst others gave varied levels of support. Against this background Roll (1977) argued that the model was not testable in that the tests are solely tests of the researcher's market proxy.

The CAPM in its basic (unconditional) form assumes that rational investors hold mean-variance efficient portfolios and that the relationship between risk and return is:

$$E(R_i) = R_F + \beta_i(E(R_M) - R_F) \qquad (2.6)$$

where $E(R_i)$ is the expected return of security/portfolio i and is a linear function of the risk free rate R_F , the security's/portfolio's beta β_i and the excess return of the market over the risk free rate $(E(R_M) - R_F)$. The beta being the slope of the linear regression line using time series data:

$$R_{it} = \alpha_0 + \beta_i R_{Mt} + \xi_{it} \qquad (2.7)$$

The model is more commonly expressed using risk premia such that:

$$E(r_i) = \beta_i E(r_M) \qquad (2.8)$$

where r are the excess returns for security/portfolio i and the market. The conditional form expresses the basic risk/return relationship using risk premiums as:

$$E(r_{it}|\Phi_{t-1}) = \beta i|\Phi_{t-1}(E(r_{Mt})\,|\Phi_{t-1}) \qquad (2.9)$$

with $E(r|\Phi_{t-1})$ the expectation (of any of the variables) conditional on data/information available at time t-1. Thus the main difference from the unconditional model being the time-varying nature of the risk premium.

Extensions to the original asset pricing model are numerous. One such enhancement is the two factor model of O'Brien and Dolde (2000), where the two factors are the global market portfolio and a currency index. This is an extension of a global CAPM, a single factor model criticised for not pricing systematic exposure to exchange rates. Similarly it goes further than an international CAPM which typically prices exchange rate exposure by utilising all the varying cross rates. O'Brien and Dolde suggest a two factor international CAPM to circumvent the GCAPM and ICAPM problems. Their unconditional risk premium form is:

$$E(R_i) - r = \beta_{im}(E(R_m) - r) + \beta_{ix}(E(R_x) - r) \qquad (2.10)$$

where expected returns are nominal returns in the pricing currency, r is the nominal risk free rate, the betas are bivariate regression coefficients of R_i versus R_m (return on the unhedged global market portfolio) and R_x (return on an index of currency deposits and the change in the currency value relative to the pricing currency) and R_i is the return on asset i including currency change.

Many tests of market efficiency attempt to compare actual returns with a theoretical return as suggested by an asset pricing model. Unfortunately the joint test problem means that any results that may indicate lack ofefficiency could instead be put down to the bad model problem. This has resulted in a plethora of attempts to improve the pricing models. The Journal of Finance took advantage of the millennium to review the status of some of the central areas of finance theory and the contribution of Campbell (2000) on asset pricing is a good summary of the (then) situation. Campbell's extensive paper can be broken down into various sections, namely the stochastic discount factor, factor structure, cash flows, consumption and portfolio choice, equilibrium models and other issues. It is not the intention of this literature review to consider asset pricing in the same level of detail as market efficiency, but their inter-relationship is such that some consideration should be given. Campbell's review provides a useful vehicle for this, although not all of his above listed sections will be included.

The context of asset pricing is introduced with the emphasis on the impact of uncertainty on investors' behaviour and stock prices. Thus the link with market efficiency is immediately established. Against this, Campbell feels that "...the evidence for predictability (of aggregate stock returns) survives at reasonable if not overwhelming levels of statistical significance" (p. 1523). His view being that, at least in terms of the US market, the majority of financial economists accept a predictable element in returns.

This ties in with weak form autocorrelation tests of EMH which confusingly is not that part of efficiency tested using asset pricing models. The basic factor model is credited to Sharpe and Lintner (op cit), with investors showing rational expectations, being homogeneous mean-variance optimisers and with a linear beta relationship. As with efficient markets, the early empirical work was broadly supportive of CAPM, although it is interesting that the anomalies identified by Campbell are in effect the same as those for EMH. These include the size effect, the value effect, failure to set the correct market proxy and time effects.

Whilst some if not all of the anomalies can be laid at the door of CAPM it is argued by Campbell that they do not provide "genuine evidence against a broader rational model in which there are multiple risk factors" (p. 1528). There have been many post Sharpe/Linter models put forward to cope with the underlying assumptions (eg with tax, with friction, conditional versus unconditional, international, etc) and similarly there are many multi-factor models. Campbell focuses on Fama and French (1996) and their three-factor model (see below). An alternative view put forward is that the anomalies are not a function of a risk factor omitted from the model, but instead are mistakes that "disappear once market participants are aware of them" (p. 1528).

Three asset pricing puzzles are addressed by Campbell in relation to asset pricing models, although yet again these can also be viewed as market efficiency puzzles. The *equity premium puzzle* whereby market return is too high to be explained by an asset pricing model. To compensate for this, it has to be assumed that risk aversion at a market level must be higher than has been assumed in recent years. *The market volatility puzzle,* whereby market volatility is too high to be explained by the asset pricing model. There is no obvious solution to this, with Campbell concluding that "volatility of stock returns must be explained by changes in the equity premium itself" (p. 1545). Finally the *risk-free rate puzzle* whereby elasticity of inter-temporal substitution (EIS) is very low, resulting in a theoretical high real rate of interest. To compensate, it is argued that high risk aversion resulting from the equity premium puzzle allows the EIS to move away from an equilibrium value.

A more recent and UK-specific consideration of the Capital Asset Pricing Model using ARCH was undertaken by Morelli (2003). Both unconditional and conditional versions of the model were tested using a UK data set for the period 1980 to 1999. The main findings were a negative but not statistically significant coefficient on average market premium when using unconditional betas and a positive but not statistically significant coefficient when using conditional betas. Years of high market volatility when viewed in isolation produced statistically significant positive risk premia. The general conclusion being a "failure to accept the CAPM (although) the …model…has value in periods of relatively high volatility" (p. 222).

Pastor (2000) put asset pricing models in a Bayesian context, assuming that investors facing portfolio selection choices have "a certain belief in an asset pricing model. In the extreme cases of complete confidence and complete scepticism about the model" (p. 207). These beliefs effect the optimal allocations and, as argued by Pastor, have less extreme values. This applies particularly to home country bias (see later) but is less important in relation to the Fama and French three factor model (also see later). Prior beliefs also have a resonance with behavioural finance, so Pastor's model could be viewed as integrating many facets of asset pricing puzzles.

In parallel to Campbell's millennium review of asset pricing, an equivalent consideration of continuous time methods was undertaken by Sundaresan (2000). This wide-ranging paper chiefly addressed derivatives but did include consideration of asset pricing, including Merton's (1973) Intertemporal CAPM. The main efficiency implication being that "dynamic consumption-portfolio behaviour (indicate) empirical evidence that equity returns show long-term memory" (p. 1571).

Much of the earlier literature on efficiency and asset pricing assumes that returns are normally distributed. A current practitioner-based approach making this assumption is the use of risk-based metrics such as Value at Risk (VaR). In fact its acceptance is exemplified by the use of VaR in the Basle Accord for capital adequacy. Against this is empirical evidence of non-normality from the earliest days of modern portfolio theory such as Mandelbrot (1963) through to Harris and Kucukozmen (2001). The latter paper argues that long time horizons seem to approximate to a normal distribution but that in the short to medium term there is strong evidence of leptokurtosis and skewness. Their approach is to model returns using a wide range of probability density functions, including a review of Paretian, student-t, Box-Tiao, logistic, Poisson and chiefly exponential generalised beta and skewed generalised-t.

Recent research in this field such as Hsia et al (2000) or (say) Faff et al (2000) casts doubt on such models. For instance, Faff et al , using UK data, conclude that "...market model betas are unstable and systemically time-varying" (p. 551). If market model betas are unstable then much of the received wisdom on asset pricing is suspect.

2.2.2 Predictability and serial correlation

The original tests for weak-form efficiency were based on serial correlation. This is still utilised, either as tests of the efficiency hypothesis itself, or as applied by Laurence et al (1997) as tests of specific markets, with the underlying assumption that emerging markets are not efficient, but that with growth and greater international exposure, efficiency will increase. Laurence et al test the four stock exchanges in China from 1993 to 1996 and find evidence of significant serial correlation in all four of the markets. The conclusions are that the Chinese markets are not weak-form efficient, that opportunity for abnormal gain exists , but that over the review period efficiency was increasing, with the suggestion that "...the four Chinese markets are gradually being integrated into the global economy" (p. 306).

Likewise there have been many tests for randomness in share prices. Typical (but fairly recent) is the work of Kavussanos and Dockery (2001) who use a cross section of prices from the Athens Stock Exchange to test for predictability. If efficient there should be no pattern "and prices should follow a random walk process, or at least be a martingale" (p. 575). They establish that prices are not stationary, whereas returns are, but are unable to confirm that the market is efficient, possibly caused by low liquidity and limited transparency in the market.

Weak form efficiency is also tested by examination of trading rules. As an example, Goodacre et al (1999) examine the UK market looking at technical analysis methods such as volume, relative strength, moving averages and particularly the CRISMA trading rule (a filter system, based on **C**umulative volume **R**elatIve **S**trength **M**oving **A**verage). Using the FTSE 350 index over 1988 to 1996, extracts from their conclusions strongly support the concept of Fama's 1991 definition of weekly efficient in that:

> in general, the UK results were not impressive....Overall, the promise of the CRISMA trading rule does not seem to be fulfilled in the UK market....any conclusions reached on the efficacy of technical analysis, or on weak form market efficiency, based on US data needs careful replication using local data before such conclusions can be considered valid in the UK. (p. 466)

Thus, Goodacre et al give a moderately current and firm support of the UK market being weakly efficient.

One corollary of market efficiency is that volatility linked to news should exist but not to any overly significant extent. Existence of high levels of volatility being argued as a rejection of EMH. At one extreme can be seen consideration of the market crash of 1987. For instance Cheung (2000) argued that "...US stock volatility played a leading role in the transmission of stock volatility to other major stock markets..." (p. 771). This was an extension of numerous papers on the crash, concerned with causality tests and New York stock market share price spillover. At a more prosaic level, Hauser and Levy (1998) show that for the Tel Aviv stock exchange "...stock prices overreact to new information and noise trading..." (p. 133).

A family of tests are based on the rational valuation formula. Typical of this is Cuthbertson et al (1997) who use VAR methodology to test for return predictability. Using a variety of models applied to UK data over much of the twentieth century they reject efficiency for the period 1918 to 1993 for some models but note that "the CAPM model, (sic)... gave results that are closer to efficiency" (p. 1003). The inefficiencies, where they were identified, were attributed to short-termism.

2.2.3 Event studies

Semi-strong tests are normally concerned either with event studies or the performance of analysts. As an example, Barber et al (2001) considered analysts' recommendations over the period 1986 to 1996 for the American market and documented "...an abnormal gross return of 75 basis points per month..." (p. 533). Three possible arguments were put forward for this. Firstly, Fama's concept of data-snooping, although they felt strongly that the robustness of their results precluded this. Secondly, the bad model reason was rejected (albeit on logical rather than empirical grounds) as it would imply that recommended companies were riskier than others. Thirdly, and their most preferred reason, that the market is semi-strong inefficient. In common with many of these types of tests the abnormal returns were before trading costs, but after adjustment for this none of their strategies linked to analysts' advice generated an abnormal net return reliably greater than zero. This was reflected by Fama in his 1991 review when the nested sets of three forms were to an extent replaced by the strong version of the market efficiency hypothesis such that security prices fully reflect all available information with zero information and trading costs. This is in contrast to the weaker form whereby "...prices reflect information to the point where the marginal benefits of acting on information...do not exceed the marginal costs" (p. 1575).

Closely linked to event studies is the overreaction hypothesis whereby new information (e.g. positive) causes share prices to overshoot a new equilibrium level due to optimism by market participants. This then results in a (hypothesised) predictable price reversal. This was tested for UK data by Dissanaike (1997), on the basis that "if investors routinely overreact to news, past stock market losers should become winners, and past winners should become losers" (p. 43). The conclusion did seem to suggest an anomaly which "adds to the growing body of evidence that the EMH plus CAPM joint hypothesis is, at best, a highly simplified representation of the working of equity markets". (p. 43).

A fairly recent and comprehensive review of event studies as a test of semi strong efficiency is that of Binder (1998). This summary of event study methodology covered the period 1969 to 1998 and is more concerned with the validity of the process than the results of the research. Binder's conclusion is that:

> Regardless of which variant of the methodology is employed, it is expected that the event study, given its demonstrated statistical power and broad applicability, will continue in the future to be widely used in business and economics research... (p. 126)

2.2.4 Anomalies

Whilst much of the more recent research has had a propensity to cast doubt on market efficiency, there have been instances of taking the concept further rather than merely setting out to disprove the hypothesis. As an example, Brown et al (1988) formulated the Uncertain Information Hypothesis (UIH) in relation to the market's over-reaction to news. If markets do over-react to news then this would be an extension to the excessive volatility refutation of market efficiency. The UIH instead argues that initial response to news is based on the fact that the ultimate effect on prices of that news cannot be immediately determined. Thus for (say) bad news, prices will fall to reflect both the bad news and the increase in risk caused by extra uncertainty. As the company develops a strategy to cope with the event the uncertainty reduces and some of the price fall is recovered.

A more recent and UK based use of the Overreaction Hypothesis is that of Clare and Thomas (1995) who follow the same methods as the original US paper by DeBondt and Thaler (1985). Their results were less clear cut than the US paper, such that "the difference in performance [winners versus losers] is probably insignificant" (p. 971). Similarly, doubt has been cast on market efficiency due to the size effect (particularly when linked to the January effect). Various imperfect capital market theories have been proposed to explain asymmetries. For instance, Perez-Quiros and Timmermann (2000) suggest that "...firm size matters in determining stock returns because it acts as a proxy for some unobserved, omitted risk factor" (p. 1230). In their approach small firm risk asymmetries are generated in times of recession and expansion. The volatility of the returns are sensitive to interest rate changes to a much greater extent that that of larger firms. Whether this is evidence of failure of market efficiency is subject to debate, but Perez-Quiros and Timmermann discuss the various asymmetry models as an implication of capital market imperfections. A fairly recent review of the size effect in the UK is Dissanaike's (2002) study who noted that:

> ...in summary, although we have found a size effect within the FT500 sample and although it tended to be higher in the same periods when the winner-loser effect was higher, it was still very much smaller than the winner-loser effect. Further, the size effect is not, overall, significant at the 5% level... (p. 143)

The weekend effect mentioned above has also been subject to much research. Whilst this and other time effects have been regularly quoted as examples of non-efficiency this conclusion is not always clear cut. For instance Coutts and Hayes (1999) note that little research has been done in relation to the UK market and so test the FT30 index over the period 1987 to 1994, finding some evidence of a weekend effect, partly explained by a stock exchange settlement effect, but confirming earlier research that transaction costs as low as 0.5% would outweigh any benefits from the effect. Their conclusion is that there is no profitable strategy linked to the UK weekend effect and that "this conclusion is of course entirely consistent with the notion of market efficiency" (p. 70). Recent equivalent work on American markets has also identified a 'reverse' weekend effect, e.g. Brusa et al (2000) who dispute the stability of the anomaly.

Another common possible temporal indicator of market inefficiency is the January effect. Early research papers often attributed this to a tax selling hypothesis, but Ackert and Athanassakos (2000) who confirm existence of the January effect suggest that it is less to do with size (an earlier theory) than visibility with "highly-followed firms earn(ing) negative abnormal returns" (p. 476). Their concept of visibility is taken to be more important than the more normal suggestion of the size effect driving the January, in that small firms are less visible than large ones.

Speed of market response to news is considered by Eldridge et al (2001) with the assumption that cash and futures markets should react simultaneously to news. They refer to early work of this type indicating lags of up to forty minutes between the two markets, whereas with market efficiency there should be no lead or lag by either market. Using non-linear Granger causality tests, albeit only applied to the Australian market, they find that there is:

> no significant support for the need to account for non-linear effects (beyond the second order moment condition) in order to explain any causality. The EMH, an assumption that underlies the Cost of Carry model, seems appropriate once first and second order moment effects are accounted for. (p. 1)

2.2.5 Recent developments in testing

Typical of the many tests of weak form efficiency is Al-Loughani and Chappell (1997) who test the time series for IID (independent and identically distributed) as residuals should be random variables. Using Generalised Autoregressive Conditional Heteroscedasticity (GARCH) applied to the FTSE 30 share index over the period 1983 to 1989 they conclude that "the weak form of the efficient markets hypothesis is certainly not valid" (p. 176). Unfortunately, like many of the tests on efficiency, the apparently clear conclusions are in fact not so. In a comment on this particular approach Milionis and Moschos (2000) agree that the 1997 paper suggests that the random walk hypothesis be rejected, but argue that the weak form of market efficiency cannot be rejected.

A similar approach based on UK and US evidence was produced by Groenewold and Fraser (2001). This again tested the IID-normal assumption in relation to unconditional CAPM (the original model) and the conditional CAPM, where the market portfolio is not assumed to be observable, hence to an extent "removing the problem of joint tests of the model and the chosen proxy" (p. 776). Their conclusions were less rigid/more pragmatic than those discussed above, with the simple observations that a) the sensitivity of IID-normal tests of asset pricing models does (sometimes to a large extent) affect probability values, ie transgressing the normality assumption, and b) there was greater variation in the testing when applied to US data compared to UK data.

Yet another strand of efficiency and/or market tests is based upon return reversal or mean reversal. A much cited paper by Chelley-Steeley (2001) examined whether UK portfolio returns mirrored the US experience where up to 25% of monthly variation could be linked to the previous month's return behaviour. On a month by month basis the autocorrelations allowed up to 9% of portfolio variation to be predicted. If the months were broken down so that greater weighting could be given to the later (most recent) weeks, then the predictable component rose to 15%.

Arnold and Baker (2003) criticise the "…US-centredness …" (p. 3) of much of the mean reversion work which shows strong empirical evidence of reversal (the overreaction effect) in US exchanges. Their study of overreaction is also based upon UK shares over the period 1975 to 2001 and has numerous conclusions. Firstly they claim support to the view that "there are systematic valuation errors in the (London) stock market caused by investor overreaction" (p. 19). Secondly that there is evidence of the size effect, but that this is not the cause of the return reversal and thirdly that risk is not the cause of the overreaction. In considering possible causes, they regard the outcome as "…a serious challenge to the efficient markets advocates (and that) the phenomena … seems to lend more support to the behavioural finance school of thought" (p. 21).

The 1990's saw a parallel stream of research developing, where attention switched away from efficiency tests, with the anomalies instead being a function of the asset pricing model. Typical of this was Fama and French with a series of papers over the period 1992-1996. A fairly recent summary of this approach was Fama and French (1996) where many of the anomalies were, in their opinion, explained by a three factor asset pricing model. Specifically:

$$R_i - R_f = \alpha_i + b_i(R_M - R_f) + s_iSMB + h_iHML + \varepsilon_I \qquad (2.11)$$

where $R_i - R_f$ is the typical excess return over the risk-free rate, α_i is the intercept (in their analysis not significantly different from zero), $b_i(R_M - R_f)$ is the normal single component of CAPM and s and h are the factor sensitivities of SMB and HML. The two factors are the difference between the returns of a portfolio of small stocks and a portfolio of large stocks (i.e. Small Minus Big), to capture the size effect, and the difference between the returns of a portfolio of high book to market stocks and a portfolio of low book to market stocks (i.e. High Minus Low). Despite numerous contrary papers Fama and French conclude that the model explains returns and also copes with return reversal in the long term. They admit however that the model fails to explain short term return reversal.

A UK based application of the Fama and French three factor model by Lee, Liu and Strong (2003) produced contrary results, concluding with "…we clearly reject the hypothesis that the Fama-French model completely explains the cross-sectional return regularities examined…(such that) the factor explanation cannot fully explain the size or book-to-market premiums" (p. 28). This UK test has similarly been performed on data for a variety of other countries, many of which find equal lack of explanation. Like many of the more recent papers on asset pricing (and thus market efficiency), there is a concluding allusion to lack of investor rationality and a suggestion of behaviour induced systematic biases.

A fairly current history of market efficiency is provided by Dimson and Mussavian (1998) which briefly visits many of the issues discussed so far. In their conclusion they observe that:

> The efficient market hypothesis is simple in principle, but remains elusive, …it became the dominant paradigm in finance during the 1970s,….(despite) an onslaught against EMH…it is remarkably hard to profit from even the most extreme violations of market efficiency. (It) continues to provide a framework that is widely used by financial economists. (p. 100)

The question Dimson and Mussavin address is to a large extent spurious as nowhere is the suggestion made that efficiency is bi-polar. In such a world, the existence of one successful test showing inefficiency would result in the conclusion that the hypothesis does not hold. A review of finance text books shows that market efficiency as described by the EMH is still current in the academic community and regarded as an important component for the syllabus of finance courses.

It is true that many tests have identified flaws based on possible instances of excess volatility, non-normality of distributions of returns, asymmetry of return, serial correlation, speed of response, lack of conforming with fundamentals. Likewise, many alternative hypotheses have been proposed, including informational economics, behaviour theory and imperfect capital market theories. Cuthbertson (1996) concludes a review of market efficiency and its tests by stating that

> In general, failure of the EMH in empirical tests may be due either to a failure of informational efficiency (RE) or an inappropriate choice of the model for equilibrium returns or simply that the EMH does not hold in the 'real world'. (p. 114)

In effect, he come to no single conclusion. Ball (1998) is similarly ambivalent and in answering the question are stock markets efficient, concludes "yes and no" (p. 15). He argues that EMH is like all theories in that they are always in themselves imperfect and limited, but against that, it has allowed "...insights into stock price behaviour that were previously unimaginable" (p. 15). A survey of empirical evidence concentrating on stock and foreign exchange markets (Beechey et al 2000) is slightly less ambivalent, but with a similar approach to Ball. In concluding they state that "the efficient market is almost certainly the right place to start when thinking about asset price formation" (p. 23). This is then tempered in that the EMH...

> cannot explain some important and worrying features of asset market behaviour. More importantly for the wider goal of efficient resource allocation, financial market prices appear at times to be subject to substantial misalignments, which can persist for extended periods of time. (p. i)

A more extreme position is taken by Ryan et al (2002). In this text the focus is on research methodologies generally and Kuhn's relativism specifically, but they use EMH as an example. The discussion is about how replication of earlier experiments is used continuously to monitor what should be in or removed from "...the accepted canon of scientific knowledge" (p. 25). They consider that the number of papers in the late nineteen eighties which identified flaws with capital market efficiency were sufficient to throw a shadow of doubt over the efficiency hypothesis such that its rejection was "...confirmed to the satisfaction of most scholars working in the field" (p. 25).

If the definition of market efficiency is taken to be that prices fully reflect all available information, then there can be no doubt that the hypothesis has been and continues to be of great value to our understanding of finance and the capital marketplace. This despite the fact that certain tests have, and no doubt will continue to cast doubt on the total validity of EMH as set out above. Much of the inefficiency evidence is in itself suspect due to the bad model problem, flawed methodology or just our flawed understanding of asset prices. Conversely, there is much evidence that would imply similar flaws in the concept of efficiency. This does not mean that the hypothesis is no longer of use, for as Ball (1992) concludes:

> It is helpful to distinguish the statement 'for some purposes, it is useful to describe the market is efficient' from the statement 'the market is efficient', even though the latter sometimes is used as shorthand for the former. (p. 34)

2.2.6 Behavioural finance

One of the strands of tests or arguments against efficiency has been collected under the generic title of behavioural finance. It is not the intention of this literature review to consider this field in depth, but its growth and its acceptance in some areas is such that it cannot be ignored. Much of the work is based around investor rationality and one example is that of Odean (1998). In a survey of US trading records from a large brokerage house Odean uses Kahnemann and Tversky's (1979) disposition effect on investors sales of equities. The disposition effect is part of Prospect Theory and assumes an S-shaped utility function (but on gains and losses rather than absolute wealth) whereby the curve is concave for the utility of gains but convex for the utility of losses. Odean claims that based on his analysis investors do exhibit the disposition effect, in that they tend to sell winners, i.e. the shares that have achieved gains since purchase, but are reluctant to realise losses on their losers, i.e. the shares that show a loss since purchase.

This pattern exists for most of the year, but for December there is no disposition effect, suggesting that "tax-motivated selling prevails" (p. 1797). Although not included in the analysis, the disposition effect is also apparent in property (Case and Shiller, 1988).

Odean suggests that the disposition effect in equity trades can have a variety of implications (although it is recognised that the analysis was only performed on individual investors) in that:

> (disposition effects)...would appear inconsistent with mean reversion,...would stabilise falling prices below a reference point... and would slow down price rises above a reference point. (p. 1795)

At the professional investor level, De Bondt and Forbes (1999) examine UK analysts' forecasts, finding evidence mirroring US experience (Aronson, 1992, Devenow and Welch, 1996) of optimism, overreaction and herding. Their findings show that earnings are over-estimated by 17% and that this was most pronounced during 1991 to 1993 (a period of UK economic recession). In addition "...the dispersion and range of forecasted earnings is alarmingly small given the typical magnitude of the forecast errors" (p. 158). It is suggested that the conformist view is predicated on regret theory (Janis and Mann, 1977) where the need to conform increases at times of ambiguous situations.

Irrational optimism or irrational exuberance is seen by Dimson et al (2003) as having petered out. Set against the bear market of the first three years of this millennium they point out that some investors (including many institutions) are still optimistic about long-run equity returns, an optimism that is irrational. Whilst recognising that equities are an important part of any well diversified portfolio, their advice is that real returns over the last century were lower than normally considered and should not be viewed as a safe investment.

Yet another behavioural theory is suggested by Daniel et al (1998) in that attribution theory could suggest cognitive dissonance. The hypothesis being that an individual will reject information that disagrees with their own interpretations/decisions and similarly will regard supporting information as validation of their interpretations/decisions. This, referred to as biased self-attribution, is argued as being a cause "of short-run momentum and long term reversals" (p. 1842). This biased self-attribution is linked to overconfidence to produce a model that they argue "suggests a positive relationship across international markets between the strength of the momentum effect and that of post-earnings announcement drift" (p. 1865).

Wagner (2001) attempts to combine behavioural theory with portfolio selection, contrasting behavioural choices with "the concept of rational portfolio selection under uncertainty" (p. 55). Regret Theory is utilised to specify a utility function whereby actual return outcomes are compared with the alternative foregone choice; regret being experienced when the former is less than the latter. In order to try and obviate this possible distress, the portfolio selection process may become flawed, resulting in sub-optimal decisions!

Much of the work on behavioural finance is pulled together by Shleifer (2000). Although most of the text addresses issues such as those discussed above, they are grounded in his discussion of three strands of conceptual flaws in financial market efficiency, namely rationality, random irrationality and arbitrage. Investor rationality is challenged in three ways. Firstly, investors' attitude to risk is not rational as they do not "...follow the precepts of von Neumann-Morgenstern rationality" (p. 11), hence the earlier behavioural finance use of prospect theory. Secondly is the individuals' conscious or unconscious systematic rejection of the rules of probability generally and Bayes' rule particularly. Thirdly the way individuals make different decisions, depending on how a problem is presented to them. These irrational investors are thus labelled as noise traders or unsophisticated or as basing beliefs on heuristics and as such following sentiment.

The second strand of Shleifer's flaws is to dismiss the concept that although there may be irrational behaviour, this tends to be random, such that A's irrational beliefs will be compensated by B's equal and opposite irrational belief. Unsophisticated investors are viewed as not random but highly correlated in their irrationality. They behave socially (Shiller, 1984) and trade using 'common judgement errors' to such an extent that there is no scope for A's error to be offset by that of B's. The initial supposition is that it is the non-professional investor who is irrational, but the argument extends to assume that professional investors are also susceptible to human failings. Hence the existence of herding and other indications of irrationality, such that "in some situations, they [the professional investors] may be the relevant noise traders" (p 13).

Finally the third strand of serious flaws is discussed, namely that of arbitrage. It is argued that arbitrage could counteract the irrationality and the herding problems of efficiency, but against this are put a variety of factors. Not the least of these is that arbitrage opportunities do not always exist, so that "broad classes do not have substitute portfolios, and are therefore…mispriced" (p. 13). Similarly, even when there are arbitrage opportunities, there still remains fundamental risk. In addition, a high level of irrationality in the market can generate noise trader risk which cannot be arbitraged away. Shleifer's conclusion is rejected in a recent paper by Coval and Shumway (2005) who undertook a highly detailed analysis of proprietary traders at the Chicago Board of Trade. Whilst they did find evidence of irrationality they also concluded that "any price impact resulting from traders' behavioural biases dissipates extremely quickly…..(such that) limits to arbitrage do not appear to delay the elimination of behaviourally induced mispricing" (p. 33).

A superficial view of investor irrationality could be that noise traders are naïve or uninformed or uneducated. One strand of research questions this and is typified by Jenter (2005). Jenter examines the trading by top managers in their own company's shares: a group of investors who should be financially literate, rational and well informed. Interestingly he "finds little evidence that managers use valid inside information in their trades" (p. 1906) and that, after adjustment for size and book to market, the educated and informed manager achieves excess returns that "are indistinguishable from zero" (p. 1906). Whilst this could be seen as obliquely supportive of market efficiency, it does not support market rationality. Rather, the conclusion that Jenter draws is that managers have contrarian views, that their views are not randomly distributed and that they suffer from a perception of mispricing.

Whilst Jenter (2005) felt that informed investors can suffer from irrationality, Elton et al (2004) set out to test the rationality of investors purchasing one of the most simple investments, S&P index funds; a group of products so similar that they can be viewed as a commodity. They identified various predictors for the funds that (in their assumption) would be used by rational and informed investors to select the best fund, but found that "a large amount of new cash goes to the poorest performing funds" (p. 286). Their observation was that decisions were based on the marketing activities of the funds, rather than their historic performance, tracking error or expenses. The conclusion to this was that:

> Much of the financial and economic literature assumes the law of one price holds. As we show in this paper, in markets where arbitrage is not available, the law of one price need not hold. It will only hold if all investors are rational. (p. 286).

A delightful summary of one view (or rather five views) of the (then) state of market efficiency took place at the 2001 European Financial Management Association Roundtable Discussion on "The Rationality of Capital Markets" (Doukas, 2002). The discussion started with the recognition that numerous recent papers had cast doubt on market efficiency, (termed by the panel as the rational market hypothesis) and then opened the debate to Ray Ball (RB), Kent Daniel (KD), Kenneth French (KF), Stephen Ross (SR) and Jay Shanken (JS).

RB's contribution was put in the context of Hayekian economics, in that no single person can obtain and analyse all the information relating to a company that is embedded in its share price. In effect contrasting rational liberalism, "the belief in the ability of individuals to rationally determine outcomes" (p. 230) with a more Hayekian view that "order arises from spontaneous unplanned actions of individuals" (p. 231). When applied to efficiency he returned to the issues he addressed in 1992 (op cit), claiming that in the last few years "a whole generation has come…to confuse this model of efficiency (i.e. EMH) with the concept of an efficient market" (p. 231). As such he was restating his earlier opinion that despite anomalies and despite our ignorance of how aggregation processes work, the notion of efficient markets "...has a lot going for it" (p. 232).

Using the recent internet valuations as an example KD was of the opinion that many of the identified anomalies were in fact mistakes. The difference being that anomalies persist but that mistakes either are transient or are not capable of an arbitrage opportunity so as to make abnormal return. The mistakes he alluded to were seen as being generated by 'irrational capital' or rather investors who act in an irrational manner. The lack of arbitrage and the lack of persistence, he argued, was such as to keep the market efficient as there is also sufficient 'rational capital'. This fairly extreme view was tempered by the recognition that "...there is a lot more irrational money out there than there is rational,...that there are some profit opportunities out there probably, but they are very, very hard to find" (p. 232).

KF's view of behavioural finance was that "it is more about behaviour than it is finance" (p. 235). He also introduced a light-hearted survey where observers' views of the level of efficiency can be subjectively measured on a scale of 100 (all prices are always right) to 0 (all prices are always wrong). He placed himself at 87.3 and estimated Fama at 91 or 92. Despite accepting a rather spuriously accurate 12.7% inefficiency he agreed with KD in that in trying to take advantage of this, it would still be "an incredibly hard thing to do" (p. 235). This was backed up by reference to the Japanese market, where traders knew (were of the opinion) that prices were too high, but were unable to take advantage of this.

In his opening comments SR stated "When I hear a good alternative hypothesis (to EMH), then maybe I'll start to think there's a serious contender for some throne in finance" (p. 240). In his closing comments SR stated "I think that behavioural finance will be a growing area, but that seems to me to say a lot more about the irrationality of economists than it does about the irrationality of markets" (p. 240). A passionate viewpoint, but not underpinned by any detailed analysis.

A more serious consideration came from JS (with the growth in behavioural finance causing him to drift from 87 to 83!). He argued that many of the behavioural models/theories were either a) anomalies/mistakes that should have been identified earlier (e.g. confusion between over-reaction and momentum) or b) suffered from bias-attribution, in that evidence is being ignored or dismissed. He addressed excess volatility as possibly being a function of learning. The volatility being generated not by new information, but by the market 'learning' and that in itself producing perfectly rational price changes.

Behavioural Finance has grown in recent years and could be seen as threatening the dominant hegemony of the efficient market, perhaps even replacing it. It could be tempting, when writing a finance doctoral thesis at this time in a 'paradigm shift' to go deeper into behavioural aspects, but the above concerns temper that view. It could even be argued that in fact there is no 'shift'. A good example being the work of Durham, Hertzel and Martin (2005) who "find scant evidence that investors behave in accordance with the (behavioural) model" (p. 2551) of investor sentiment. Their paper took an earlier work of Bloomfield and Hales (2002), (which was based on experiments with regime-shifting beliefs), but was more analytical, more empirical and reported "experimental results that support...the prevalence of past trend reversal as an indicator of the likelihood of future reversals" (p. 398). Bloomfield and Hales had argued that they had demonstrated that both momentum and mean reversal could be attributed to the behavioural factors of cognitive psychology, in particular that of conservatism (ignore new evidence that does not support initial beliefs) and representativeness (accept new evidence that superficially reinforces initial beliefs). Durham et al not only found conflicting evidence going against Bloomfield and Hales specifically, but also that their results did not support a behavioural model generally. One possible cause being that "the evidence we document is wholly consistent with the normal random variation in price changes that we should expect to see with efficient capital markets" (p. 2553) Perhaps the (current) last word on behavioural finance is well stated by Fama (1998, cited in Durham et al) which refers to:

> The 'daunting task' of replacing market efficiency with better, more specific models of price formation. (p. 2567)

2.3 Market Efficiency and Fund Management

2.3.1 Efficiency and passive investment

The preceding two sections give a review of market efficiency, allied asset pricing models, tests and anomalies. One factor that seems to be common among the papers is that the analysis is (almost) always based upon portfolios built up from individual company shares. Thus the analysis assumes that a portfolio is constructed on a bottom-up basis, irrespective of whether this aggregates to the whole market (or a proxy of it), or segmented portfolios using size or book-to-market as the portfolio parameter. This section of the literature review will be more focussed by examining papers that consider fund management performance in terms of market efficiency.

Passive investment has two main forms, a buy and hold strategy, which will be ignored here, and indexing. Indexation or index tracking is the production of a portfolio that in its component parts exactly or closely matches a chosen index. There are a variety of ways of achieving this and there are obviously a variety of indices that can be tracked. Irrespective of the approach there will be tracking problems caused by reinvestment of dividends, or dealing costs, or delays in rebalancing if and when the index constituents change. Despite these problems, passive investment has grown significantly over the last 20 to 30 years and is seen as a tacit acceptance, not so much of the efficient market hypothesis as the belief that the market is efficient. The logic being that an active manager engaged in stock-picking must assume that the market is not efficient, such that his/her stock selection ability allows the fund to outperform the market by generating abnormal returns. The obverse to this being that a passive (tracking) fund manager will recognise market efficiency as meaning that active management less its greater costs will fail to achieve the market return, whereas indexation will allow the fund to match the market return more closely and at a lower cost.

Gupta et al (1999) in analysing US fund managers found that it was more difficult "for domestic asset class managers...to outperform their respective benchmarks than it is for international asset class managers" (p. 33). The only exception being small-cap funds. To a large extent they felt that tracking error was the cause, rather than efficiency issues, but they did find evidence of performance persistence.

Despite the growth in attacks on market efficiency, Malkiel (2003) presents a strong defence of passive investment and states that "recent attacks on the efficient market theory do not...weaken the case for indexing" (p 1). If markets are efficient then it is argued that no trading strategy will consistently produce returns that exceed a passive strategy. If market efficiency is generally the case, but there are anomalies, then it is suggested that a) the anomalies tend to be small (less than transaction costs) and so of no use, or b) patterns identified from research tend to collapse as soon as they are identified and are thus of no use. In addition, when and if investors do not act rationally, there is no scope for arbitrage opportunities to take advantage of systematic valuation errors.

Even if the US market is not efficient, Malkiel argues that index tracking should still be the preferred strategy. This being chiefly due to his assumed 140 basis points for active management costs versus 20 basis points for passive. The difference of 120 basis points being the cause of below average performance by the stock pickers, with the implicit assumption that active management cannot generate this 120 point additional return. This is further reinforced by active management being exposed to higher taxes, brokerage costs, bid-offer spread and negative market impacts from block trades. In support of this viewpoint, fund management statistics are used to verify that passive investment outperforms active management. For instance:

> for the period 1991-2001, 71% of active funds under-performed the largest US passive fund;
>
> the median active fund had returns more than 170 basis points below the index;
>
> only five of 158 active funds had superior performance to the index fund;
>
> superior active funds could not maintain their superiority over time.

Similar results were identified for the 1980s and the 1970s, with the conclusion that "the record of professional equity investors certainly does not suggest that sufficient predictability exists in the stock market to outperform a passive portfolio with equivalent risk" (p. 10).

The above conclusions apply to US mutual funds and are replicated in many but not all US based studies. A more up-to-date survey on the European markets by Otten and Bams (2002) finds contradictory results. Otten and Bams (OB) analysed mutual fund performance in five European countries and measured outputs using Carhart's four-factor model (see below) for the expected return and the Jensen alpha for over or under performance. Differences between the European and US mutual fund characteristics were noted, although OB do not suggest that these have a direct impact on performance. Specifically, the European sector is only half the size of its US counterpart, but the number of individual funds is greater. Thus the average European fund is significantly smaller than the American. In addition, the typical US fund had a much greater percentage of assets invested in equities compared to the higher European dependence on bonds, although the last ten years has seen a growth in equity at the expense of money market funds. Thirdly, when comparing the size of the mutual fund equity holdings to the total market the US percentage was over twice that of Europe.

In terms of performance of the European mutual funds, the main findings were as follows. Firstly, small cap funds outperformed their benchmark, secondly, four out of five countries generated positive alphas, (Germany being the exception) but only the UK achieved significant out-performance and thirdly there was little evidence of persistence in performance, again except for the UK. The conclusion by OB is that "contrary to most US evidence, the majority of European funds seems to be able to find and implement new information to offset their expenses, and therefore add value for the investor" (p. 99). Possible reasons for this may lie with the smaller size and lower importance of the European mutual fund market.

2.3.2 Performance persistence

The above conclusions generally support two earlier papers. Brown et al (1997) examined performance persistence in UK pension fund management. Having adjusted for any survivorship, and using risk adjusted returns, they considered whether "… above average performance should be a major criterion for appointing and retaining fund managers" (p. 175) or whether "consistent performance … is a chimera that is unlikely to be realised" (p. 176). Their conclusion lay between these two extremes, highlighting "limited evidence of persistence" (p. 176) although it should be noted that they identified only one large fund manager as consistently successful. A similar paper from Allen and Tan (1999) mirrored this work but examined unit trusts rather than pension funds. They also adjusted for risk, albeit only recognising two categories of high and low variance, giving some doubt about their conclusion's validity that there was evidence of performance persistence.

OB's results, particularly the success of the UK mutual fund managers in out-performing the market, are out of step with a 2003 survey by the Investment Management Association (IMA). Although this looked at all funds under management rather than just unit trusts, the startling (in terms of OB's conclusions) result was that nearly 80% of funds were managed under contracts "requiring index tracking or a close approximation of it" (p. 1). There may be many reasons for the 80% but it is interesting that the UK mutual funds are shown to outperform the market by OB but the aggregated picture shows very large reliance on tracking with the underlying assumption that either the trustees ask for tracking or the managers prefer tracking.

In addition to the above survey, the Investment Management Association (or Association of Unit Trust and Investment Funds, as was), commissioned reports on persistency to support their argument to the Financial Services Authority (FSA) that fund marketing should include past performance measures. These reports were produced by Charles River Associates Limited (CRA), the first (2002a) being a literature review and the second (2002b) an empirical analysis of persistence in the UK equity based unit trust funds. The data for their analysis was extensive, possibly the largest utilised in persistency tests with UK funds, and was used to revisit conclusions on prior surveys for the FSA. These were Bacon and Woodrow (1999) and Rhodes (2000). The Bacon and Woodrow paper had concluded that, on the basis of its review of the literature, past performance should not be a FSA recognised performance indicator. The analysis by Rhodes similarly concluded that there was no requirement for past performance measures, stating that "...the conclusion ...is that repeat performance (if there is any) is both small in effect and short-lived" (cited in CRA p. 13).

The empirical analysis of CRA (2002b) concluded the opposite, stating:

> Performance broadly persisted in UK equity based unit trusts between 1981 and 2001.
>
> ...it is possible...to use this information to aid...investment decision-making.
>
> (Persistency is) strongly significant only in the short term for funds in the Equity (and) Bond Income and Smaller Companies sectors. However it is significant over all time horizons for the UK All Companies and UK Equity Income funds.
>
> Choosing a top quartile fund...will, on average, add to an investor's potential return. (p. 1)

Their overall conclusion being that "there appears to be very little doubt that investors can derive useful evidence from past performance data" (p. 52).

In response to the CRA paper's conclusions, the FSA commissioned an analysis of the CRA research by Blake and Timmermann (2003). Whilst acknowledging the quality of the data collected by CRA, the report and its conclusions were viewed as flawed on a variety of grounds. Firstly, CRA calculated their performance statistics on a "raw" or non-risk-adjusted returns. Blake and Timmermann (BT) viewed this approach as unjustified. In fact it is surprising that CRA had chosen that raw approach, considering that risk adjusted returns are so common in academic research on performance, if not so common in the market place. Secondly, given that persistent high raw returns would be published, BT felt that investors could achieve the same result with a geared tracker fund. Thus raw returns need not be published. Thirdly, BT were critical of the lack of cross-dependence in the analysis. This lack casting doubt on much of the statistical significance of CRA's findings. Although they recognised that the analysis should be repeated on a risk-adjusted basis, BT felt that persistence was experienced only in the poorly performing funds and that there was

> a good case for the FSA publishing risk-adjusted past-performance data in the comparative tables, not because we believe that superior risk-adjusted performance can be sustained over long periods, but because poorly managed funds can be exposed more quickly. (p. 40)

This has immediate implications for our view of UK market efficiency in that there is no case to support the view of consistent abnormal performance by investment professionals. Whilst there is persistent bad performance, this does not necessarily invalidate efficiency. In effect, for the UK market over the last thirty years there have been no 'hot hands' but several 'cold hands'.

An earlier US study of hot hands in mutual funds by Carhart (1997) was based upon a four factor asset pricing model. This was the Fama and French three factor model, as discussed previously, with an additional factor to adjust for the momentum effect. The conclusions are in step with the UK viewpoint of BT above. Using an extensive US database, adjusted for survivor bias, Carhart's paper demonstrated that persistence does not support the concept of hot hands or well informed managers, the only persistence being concentrated in the worst performing funds. His conclusions that are relevant to this discussion being strongly in line with Fama's (1991) review, namely:

> Overall, the evidence is consistent with market efficiency...
> The top decile funds earn back their investment costs...
> Most funds earn back their investment costs...
> The bottom decile firms underperform. (p. 80)

In extending the discussion to a wider indirect asset class he noted that "...these results are not confined to mutual funds...(others) reach qualitatively similar conclusions about pension fund performance" (p. 80).

Both Carhart's (1997) and Blake and Timmermann's (2003) conclusions were rejected by Tonks (2005) in examining pension fund manager persistence. Using a large sample and with a different approach to survivorship from earlier studies, and basing abnormal returns on three and four factor models of asset pricing, he concluded that "...the results...suggest that there appears to be a role for active fund management of pension funds" (p. 20). A conclusion that supports the Myners Review's suggestion of active management where a benefit can be gained. The research by Tonks ignored fund management costs but he observed that the benefit identified of 1.48% per annum exceeds the Myners Review estimate of fund management costs, thus suggesting lack of strong and also weaker efficiency. Although fund management costs will be followed up later, it should be noted that Malkiel (2003) assumes 140 basis points for active management. If this applies to the UK market then Tonks' 148 basis points makes the UK pension fund active management very close to being weakly efficient, with a benefit of only 0.08% per annum. In fact, even at 148 basis points, Tonks recognises that "...it is less clear how pension fund trustees could take advantage of this fact" (p. 21).

2.4 Strategic Asset Allocation

2.4.1 Background

Over the last fifty years much has been written on asset allocation in terms of the mean variance analysis as developed by Markowitz (1952). The same period has seen surprisingly little finance research produced on strategic asset allocation. The approach of the mean variance analysis is well known and is not covered here, other than to note that the production of an efficient portfolio and the combination of this with a riskless asset allows an investor (in theory) to be located at an appropriate position on the capital market line. The desired position on the market line for any investor is merely a function of their attitude to risk. One of the outcomes of the theory is that if all investors seek mean variance efficiency, then they will all hold the same risky portfolio. Their sole choice is to change the balance between the market portfolio and the riskless asset. Thus at its most simple level, the strategic asset allocation decision is merely a function of risk or utility of the investor. This was addressed by Tobin (1958) in his mean variance model of asset demands, where the investor is faced with the choice of just two assets, cash as the riskless asset and bonds as the risky asset. His mutual fund theorem being that for all investors, the proportions of risky assets are constant.

The following attempts to bring together much of the more recent work on strategic asset allocation. The first part considers nomenclature as this is not yet standardised. The second takes a retrospective view of strategic asset allocation via attribution analysis. The third part considers theoretical approaches to allocations and the fourth briefly reviews international asset allocations.

2.4.2 Nomenclature

The relatively low level of interest in the topic of strategic asset allocation has meant that nomenclature has taken some time to be established. Statman (2000) addressed this briefly and his use of terms will be used here. Strategic Asset Allocation is taken to be the absolute or percentage allocation or weights of a portfolio to individual asset classes. Similarly Dybvig (1999) sees asset allocation as a strategic decision of "how much … to place in various broad asset classes, such as domestic equities, foreign equities, and government bonds" (p. 49). This differs from early work on asset pricing models such as Black, Jensen and Scholes (1972) which either did not mention the issue or referred to it as grouped data. It was called fixed weight asset allocation by Jahnke (1997) and has often been referred to as tactical. In his extensive review of asset pricing at the millennium Campbell (2000) alludes to it once in that

> (long term investors) may seek to hedge their exposures to wealth productivity shocks and this gives rise to intertemporal hedging demands for financial assets. Brennan (et al) have coined the phrase 'strategic asset allocation' to describe this farsighted response to time-varying investment opportunities. (p. 1537)

This link between strategic asset allocation and the long term is supported by Grinold and Meese (2000) in that it "… captures the essence of long-term investment policy" (p. 53). Likewise, Davis (2002) sees strategic asset allocation in relation to pension funds as "the long term decision on the disposition of the overall portfolio" (p. 4). Possibly the first research based book on strategic asset allocation is that of Campbell and Viceira (2000) who do not define it but interpret it as "broad asset classes…and say nothing about the choice of individual assets within these broad classes" (p. 2). They do however also position strategic asset allocation as a long term concept.

Asset allocation is split by Jahnke (1999) into two main categories, fixed asset allocation and active asset allocation. The latter group being further split into the three sub-groups of active, dynamic and strategic. The rather tautological definition of that final sub-group being "the strategic school: those who invest mainly in index funds and engage in strategic active asset allocation" (p. 29). Alternatively, Brinson et al (1986) saw the need for performance measurement to decompose the investment management process into "investment policy, market timing and security selection" (p. 39) with investment policy being the strategic asset allocation process/decision.

The professional bodies do not add any great clarity to the discussion. For the UK, the Securities Institute's (1999) basic text sees asset allocation as "the process … of a top down approach to selecting investments, whereby a set of desired percentage holdings in various economies, sectors or industries are established at the outset" (p. 63). For the US, the Research Foundation of the Institute of Chartered Financial Analysis publication by Karnosky and Singer (2000) follows the same naming as Brinson et al (see below). Strategic asset allocation rarely warrants significant mention in finance texts, often totally ignored and occasionally alluded to under a variety of names. Lofthouse (2001) covers it well, identifying four main methods of establishing the long term allocations: firstly, by following asset pricing models and mirroring some form of world index; secondly, the use of benchmarking or following the median manager; thirdly, mean variance optimisation to select an efficient portfolio relative to the investors' risk profile; and finally there is the use of asset-liability modelling.

As is to be expected, there is a greater level of interest in strategic asset allocation within the actuarial profession, especially in relation to investment for pensions or life assurance. The actuarial approach will not be considered here as the focus is on finance and extensions to mean variance, asset pricing and market efficiency. The Myners

Review (2001) does however consider asset allocation, recognising that it is "by no means a precise term" (p. 51), but suggesting firstly it is the equities/bonds split, then sub-division by domestic and overseas, followed finally by geographic, sector and (interestingly) size and style.

Tactical asset allocation is generally seen as a short term shift in weights away from the strategic asset allocation levels and has an implicit assumption of lack of short term market efficiency. Again using Statman's (2000) definition "it involves shifts in allocations…in an attempt to benefit from divergence of current values asset classes from their correct or rational levels" (p. 129). This is termed market timing by Brinson et al (1986) but De Stefano (1999) takes a different view in that "tactical asset allocation, in combination with strategic asset allocation, is not market timing" (p. 168). This fairly extreme view is not generally accepted. For instance, Blake et al (1999) "distinguish between short-term market timing and long-term strategic-asset-allocation decisions" (p. 430). The short term focus is similarly supported by Jahnke (1999) and Brennan et al (1997) who see it as "a single-period or myopic strategy" (p. 1378) where the investor has "a mean-variance criterion defined over the one period rate of return on the portfolio" (p. 1377). They see its genesis in the development by Markowitz of portfolio theory such that

> tactical asset allocation (is) the systematic allocation of investment portfolios across broad asset classes such as bonds, stock and cash. (p. 1377)

There is no automatic conclusion that tactical shifts away from strategic allocations are a function of market inefficiency. This is considered below where Campbell and Viceira (2002) regard long term decision making as producing logical or rational allocations that differ from myopic ones.

Thus, if there is an emerging consensus of asset allocation nomenclature, then it would seem that strategic asset allocation is the process (if top down) or results (if bottom up) of allocating weights to a variety of asset classes. There is a tendency for it to be long term and there seems to be an implicit assumption of market efficiency, this later point being in terms of asset classes but not necessarily individual investments. Tactical asset allocation is generally viewed as short term shifts in allocations away from the strategic position, thus assuming lack of market efficiency in single periods. Security selection is the choice of individual investments within any asset class. As such this selection process will not discussed here.

2.4.3 Performance decomposition

Possibly the first attempt to assess strategic asset allocation by distinguishing it from tactical asset allocation and security selectionwas the 1986 paper of Brinson, Hood and Beebower (BHB). This was less of a theoretical model and more of a post hoc mathematical decomposition of a portfolio's returns. BHB's approach was to have the strategic asset allocation or the "passive portfolio benchmark" (p. 40) as:

$$\Sigma_i(W_{pi} \,.\, R_{pi}) \qquad \text{(I)}$$

such that the strategic asset allocation return is the sum of the products of the strategic weights (W_p) and their asset class returns (R_p). The effect of this and timing or tactical asset allocation was then:

$$\Sigma_i(W_{ai} \,.\, R_{pi}) \qquad \text{(II)}$$

where the strategic and tactical return is the sum of the products of the actual weights (W_a) and the strategic returns. Security selection is similarly derived as:

$$\Sigma_i(W_{pi} \,.\, R_{ai}) \qquad \text{(III)}$$

so that the combination of strategic asset allocation and security selection is the sum of the products of the strategic weights and the actual returns (R_a) of the asset classes. Finally, the actual return is:

$$\Sigma_i(W_{ai} \,.\, R_{ai}) \qquad \text{(IV)}$$

giving a portfolio return as the sum of the products of actual weights and security selection returns. BHB's "calculation of active contributions to total performance" (p. 41) then being various differences, namely:

"policy" or strategic asset allocation return	= I
"timing" or tactical asset allocation return	= II – I
"security selection" return	= III – I
"other" or residual return	= IV –(III+II-I)

Using US data, BHB analysed 91 large pension plans over the period 1974 to 1983 with mean annualised returns for each factor being 10.1% for (I) the passive benchmark or strategic asset allocation, -0.66% for timing or tactical asset allocation, -0.36% for security selection and –0.07% for other. The importance of the policy or strategic return was noted and was expected, but an interesting outcome was the variance with 93.6%% explained by the strategic asset allocation decision. A follow-up paper by Brinson et al (1991) repeated the exercise, with the following results.

	active return	% of variation explained
"passive" or strategic asset allocation	13.49%	91.5%
"timing" or tactical asset allocation	-0.26%	93.3%*
"security selection"	+0.26%	96.1%*
other	-0.07%	

(p. 45)

where * indicates percentage variation explained by strategic and tactical or strategic and selection.

This decomposition or attribution analysis was extended by Karnosky and Singer (1994). The same approach was followed, but in addition there were four equivalent returns based on currency selection and hedging. These were the base currency equivalent of passive weights and passive returns, active weights and passive returns, passive weights and active returns and active weights and returns. These four products giving the equivalent breakdown as set out above. When combined with the BHB decomposition the breakdown of a portfolio's added value is then:

Market allocation return = (active-passive market weight) x (passive – index return premium)

Currency allocation return = (active – passive currency weight) x (passive – active Eurodeposit return)

Market security selection = passive market weight x (active – passive market return premium)

Currency hedge selection = passive currency weight x (active– passive Eurodeposit return in base currency)

A behavioural finance orientated criticism of the BHB attribution analysis came from Statman (2001), who saw strategic asset allocation as "part of the management of investors, (whereas)... tactical asset allocation and security selection are part of the management of investments" (p. 132). Whilst this was not supported by alternative models or detailed analysis of data, there are interesting resonances with the Myners Review (2001) in that Statman argues "investors believe that investment management (tactical asset allocation, timing or selectivity) offers more value than investor management (strategic asset allocation)" (p. 133). Simultaneously the Myners Review in its outline of how a better (UK) pension fund system could work suggested that "recognising the importance of the (strategic) asset allocation decision to investment outcomes, trustees would devote greater attention and resources to it" (p. 16).

A much more critical evaluation of the BHB decomposition was applied to UK pension data by Blake et al (1999). Their concerns with the arithmetic identity of the model included: residual values being small but of the same scale as selectivity; ex post rather than ex ante information on weights giving "only noisy performance measurement" (p. 451); funds not being in a steady state and short time scales. Despite this, their results were not dissimilar to those of BHB, with "an economically small negative return from active portfolio management on average" (p. 456) whilst market timing was statistically insignificant. In comparison with the BHB strategic asset allocation explaining 93.6 % of US variation, the UK version (using two definitions for the normal weights (equation I)) produced 96%.

Central to Blake et al's (1999) discussion was the move away from the accepted interpretation that 93.6/96% indicates firmly the need to focus on the strategic asset allocation decision. Instead it was argued that this conclusion is wrong, the counter argument being that the high percentage of variation is merely a reflection in both tests of a very low level of active management by fund managers.

The same paper took an alternative view of decomposition, breaking down changes in portfolio weights into two components, that of return within an asset class and changes due to net cash inflows/outflows to/from that class. The decomposition took the form:

$$\Delta \log (\omega_{jt}) \cong r_{jt} - r_{pt} + NCF_{jt} - NCF_{pt} \qquad (2.12)$$

where ω_{jt} is the portfolio weight of asset class j at time t, r_{jt} and r_{pt} are the returns in period t of the asset class and the value weighted return of the portfolio as a whole respectively and NCF_{jt} and NCF_{pt} are the net cash flows in the period of the asset class and the value weighted portfolio. Implicit in this approach was the assumption that the net cash flows occur at the end of the period.

The application of this to UK pension fund data over 1986 to 1994 showed that "the only asset class for which differential returns contributed positively to its asset allocation was

UK equities" (p. 433), with all other changes attributable to net cash flows. Analysis on cross-sectional data suggested that:

> cash flows are used to stabilize the actual asset allocation around a common (and possibly dynamically changing) strategic asset allocation.... (such that funds) exhibit a tendency to rebalance toward their strategic asset allocations when relative asset returns move out of line. (p. 448)

Finally, the data would indicate that at an individual fund level there is evidence of mean reversion "towards a commonly changing strategic asset allocation" (p. 448). Blake et al make the important point (not reflected by BHB), that both approaches ignore the matching of assets and liabilities, an issue that is of importance in pension funds.

The Net Cash Flow variable in the previous model differs to the approach taken in work by Ferson and Schadt (1996). Although this paper looks at US mutual fund performance they note that "on average, funds invest about 62 cents of each new dollar in the concurrent month, while 38 cents goes into cash" (p. 456). In addition there seems to be a negative relationship between new funds (Blake et al's NCF) and fund betas. Whilst Ferson and Schadt make this observation it is not central to their main analysis, which is fund strategy in changing economic conditions. This is one of many papers that consider fund performance without any decomposition by asset class. The closest they come is brief discussion on performance linked to investment policy or strategic asset allocation, whereby naïve strategies used as a comparison commence with set allocations of "65% large stocks, 13% small stocks, 20% government bonds, and 2% low-grade bonds" (p. 442). Unfortunately there is no indication of the sources of this naïve allocation.

Similarly, fund managers' timing ability is examined by Bollen and Busse (2001). As with Ferguson and Schadt (op cit), they focus solely on efficiency issues but do generate synthetic funds with eight asset classes. In common with many papers of this type, such Treynor and Mazuy (1966), Henriksson (1984) or Graham and Harvey (1996), the strategic asset allocation is to a large extent ignored. Likewise, there are numerous studies of herding (for instance Wermers, 1999) where some papers find evidence of herding and others fail to confirm this. These are solely concerned with short term herding and do not regard commonality of strategic asset allocations as herding. Typical reasons for herding include reputational risk, correlation of information and its interpretation, following perceived well-informed trades and common demand. Interestingly it is often the case that such herding is seen as bad, whereas common approaches to strategic asset allocations, which could also be defined as herding, is either ignored or viewed as common sense.

Attribution analysis has to a considerable extent shifted from academic analysis to a commercial product. For instance, the Spaulding Group's 2002 survey of attribution products, contrasting various commercial providers' models. These encompass arithmetic and geometric approaches (additative and multiplicative) and logarithmic, optimised and smoothed. Links do however continue to exist with more academic approaches: as an example, Carino (1999) published the Frank Russell Company's proprietary model, setting out a multi-period approach utilising log normal returns to allocate residuals across the allocation, selection and interaction attributes, thus allowing addition of the components.

Slightly more recent was a paper by Bridgeland (2001) who described Bacon & Woodrow's product "SimIAn". This took attribution analysis further in that it attempted to "analyse the evidence of skill being employed in the different decisions involved in a portfolio construction process" (p. 247). Part of the proposal was the assumption that index tracking was the logical fund management style for a low risk fund (tracking being viewed as 'safe') whereas active management was the preferred approach if higher levels of risk could be tolerated. The latter case is seen as having 'hope' as the driving emotion. The model measures excess return (over the benchmark) and breaks this down into influence (e.g. style or research process), control (constraints which may limit active management) and stock selection.

Attribution analysis is a retrospective study of different causes of the performance of an investment portfolio. It does not suggest models for ex ante decision making. In developing a continuous time model of portfolio selection Merton (1969) showed how the decision is independent of utility and derived a formula for the optimal proportion of the risky asset, but this was in the world of just one risky asset. The model extended to many risky assets, but in common with several papers of this type there was no concept of asset groups. Although it could be argued that strategic asset allocation is just the aggregation by asset class of all the assets identified by such a process, Merton in a later paper (1971) assumed that "all assets are of the limited liability type" (p. 377), thus excluding this view.

Whilst Merton (1969) rejected the role of utility in portfolio selection, it was included in an interesting refutation of the BHB attribution by Kritzman and Page (2002). They set out to decide which was the more important, strategic asset allocation or stock selection, and came down firmly on stock selection. Their approach was two stage, initially using bootstrapping to build random equity portfolios to argue that "random variation among individual securities…causes substantially more return variation than does random asset allocation among (asset classes)" (p. 207). Unfortunately this conclusion was based on raw, non-risk adjusted returns so returns were then ranked by log utility and similar conclusions were drawn, although it should be recognised that logs is only one version of utility functions and utility is not the typical method for risk adjusting returns. Their second stage was to use a version of the Black Scholes option pricing model to value a theoretical option "to exchange median performance for top quartile performance" (p. 209). This was performed both for asset allocation and security selection and showed security selection always having the higher value!

2.4.4 Asset classes and strategic asset allocation

Whilst much has been written on asset allocation using mean variance analysis, little exists on the strategic asset allocation problem. One attempt to fill this gap is the 1997 paper of Brennan, Schwartz and Lagnado (BSL). For computational ease they focus on just three asset classes, namely bonds, shares and cash, although recognising that "extension to additional asset classes is straightforward so long as the expected returns …can be expressed in the same set of state variables" (p. 1379). The raison d'etre of their model is that mean variance analysis is single period or myopic and as such tactical asset allocation is flawed, firstly because the expected returns by class are typically internal rates of return estimated over long periods, with the assumption that the one period return is proportional to the long run rate; an assumption they reject. The second flaw is that evidence of predictable returns imply that single period allocations are "appropriate only if the investor has a logarithmic utility function" (p. 1378). In effect, the single period model cannot cope with a long term investor facing long term shifts in expected returns, variances and covariances.

The model of BSL is based on three state variables that predict expected returns, namely the short term interest rate for cash, the yield on consol bonds for bonds and the dividend yield on common stock for shares. The three state variables are assumed to follow a joint Markov process and form the first part of the model. Values for US data over the period 1972 to 1991 are used and expected returns are viewed as linear functions of the state variables. The resulting outputs from this first stage were "sufficiently well behaved to provide a useful input to our model" (p. 1390). The second stage was to allocate weights to the three asset classes based on the state variables and to maximise utility over three separate strategies: a myopic or one month strategy: a rolling 20 year strategy; and a declining period initially of 20 years but with a fixed time horizon.

The results showed a variety of proportions for the three asset classes and the three strategies. Myopia usually had a higher cash position than the other strategies, as cash was assumed to be riskless for the myopic investor but not in the long term. The equity proportion was much higher for the rolling 20 year strategy and always exceeded the myopic equity holding, assumed to be a function of share price volatility growing "less than proportionately with time, so that stocks are less risky for those with a long horizon" (p. 1395). For the bond holdings there was less consistency in the results, close to zero, then high, then low, and with no consistent bond weighting such that any one strategy was always different from the others. The conclusion being "the difference in the bond allocations is highly variable over time, suggesting that rules of thumb to adjust tactical asset allocation portfolios to account for a longer horizon are unlikely to be successful" (p. 1396).

The stochastic model of BSL has three domestic asset groups, a somewhat unrealistic view of the world. Broadening the asset class universe to include an international investment dimension is covered by Grinold and Meese (2000). Despite claiming the long term nature of their strategic asset allocation model they utilise a single period mean variance format, immediately falling foul of BSL's long term non-single period analysis. The fairly simple study compares allocations between domestic assets, unhedged international assets and hedged international assets and compares one step and two step approaches. Their one-step strategic asset allocation maximises the portfolio's expected return less its variance times a risk aversion parameter, subject to no short sales. The two-step procedure initially only allocates to domestic assets and unhedged international assets. The resultant domestic weight is then fixed and the second step allocates the balance between hedged and unhedged international assets. Their conclusion being that (with one exception) "the two-step procedure will always put as much or more in domestic assets as the one-step procedure" (p. 55). Similarly, "the one-step procedure will hedge more or at least the same as the two-step procedure" (p. 56). Their conclusions, which are applied also to liability matched portfolios, are a little oblique but in effect claim that most strategic allocation decisions made by funds are two-step, but that one-step would achieve better results.

A more rigorous and empirical paper by Blake and Timmermann (2002a) considers international asset allocation but is chiefly concerned with the market timing ability of UK pension funds rather than with longer term strategic asset allocations. Their data set consisted of the WM Company universe of 247 pension funds' investments in overseas shares allocated to Japan, North America, Europe (excluding UK) and Asia-Pacific (excluding Japan). Expected returns were modelled by region in relation to common state variables. Their focus was short term/tactical so they assumed:

> linear projections of portfolio weights on first and second conditional moments as an approximation to a relationship between portfolio weights and conditional moments that could be both more complex and vary over time. (p. 9)

As that paper was more concerned with short term tactical changes in international asset allocations it is not covered in any depth here, although some of the conclusions are of interest as a comparison to the BHB-type approach. Central is the conclusion that international asset allocation (be it strategic or more likely tactical) is "highly correlated with time-varying expected returns, volatilities and conditional covariances..." (p. 21). There was weak evidence of market-timing skills with an average of –0.2% per annum.

In a parallel paper Blake and Timmermann (2002b) extend their consideration of UK pension funds' activities in international markets. Although their main concern is again the success or failure of active management, they do base the analysis on four different suggested decompositions. The first is an extension of BHB:

$$\omega_{nijt} = \Sigma\, \omega_{aijt} \;/\, T \qquad (2.13)$$

with ω_{nijt} the weight of the i'th fund in region j at time t, a being actual and n the normal or strategic asset allocation. The second decomposition assumes:

$$\omega_{nijt} = \omega_{aij1} + (t/T)\,(\omega_{aijT} - \omega_{aij1}) \qquad (2.14)$$

thus allowing "benchmark portfolio weights (to) increase (or decrease) linearly in time" (p. 7). The third decomposition assumes normal weights at the average of the cross-section. With data on 247 funds this gave:

$$\omega_{nijt} = 1/247\, \Sigma\, \omega_{aijt}. \qquad (2.15)$$

The fourth was "simply...these equal to the world market weights" (p. 7). Whilst these decompositions give useful and additional insights to pension fund management and their efficiency in terms of international market timing (poor), they do little to suggest either the process of setting weights or a model of strategic asset allocation.

The papers discussed so far have an institutional investor focus. An alternative approach based on the individual investor is typified by Viceira (2001) where the asset allocation decision includes labour income. Extending the work of Bodie, Merton and Samuelson (1992), Koo (1995), Kimball (1993) and Gollier and Pratt (1996) amongst others, Viceira constructs a stationary model to show life-cycle impacts on asset allocation, with the two states of the life-cycle being receiving income as the yield on human capital whilst at work and receiving income from a portfolio of investments upon retirement. Although this is an asset allocation decision, the model has only two investment classes: a riskless asset with a constant log return and a risky asset with a one period log return. Despite these limitations the conclusions are informative. Once in retirement, Viceira argues that the asset allocation decision collapses to Merton's (1969) closed form solution (p. 439, see above) and is subject to "the myopic portfolio rule" (p. 442). During the employed state the model is more complex although some outcomes are intuitive. For instance "employed investors are willing to assume riskier portfolios than retired investors" (p. 442) as their employment income can compensate for shocks to financial asset returns. As an alternative to this, significant holdings by the employed investor in savings results in employment income being less important. In common with 'real world financial advice' the weight given to risky assets is relatively high early in the life-cycle. Finally, an increase in employment income risk tends to shift asset allocations away from the risky asset to the riskless one.

A totally different approach is taken in papers such as Trojani et al (2002). In this type of analysis the strategic asset allocation is taken as a given, or is selected via some type of discursive process. The issue is how to shift an extant portfolio with its own asset allocation weights to the proposed allocations with minimum costs, whilst also coping with specific or regulatory constraints. Referred to as the "Three-Portfolio Matching Problem" it provides an interesting insight for financial intermediaries but does not add to consideration of the establishment of the strategic weights, other than definitions. Trojani et al in this respect define an asset class as "specific sets of securities having at least one common characteristic" (p. 516). Although they do not support or expand on it, they claim that "if the asset classes are well diversified, a well diversified optimal asset allocation follows" (p. 516).

As briefly mentioned earlier, some asset allocation decisions may be taken in isolation, whereas others may be linked to the need to match liabilities (see below). Instead of liabilities, Dybvig (1999) considers the link between strategic asset allocation and the need to protect spending. Whilst being an extension of Merton's (1971) approach, it adds little to the strategic asset allocation discussion as it only considers the two basis classes of risky and riskless investments. The need for certain types of funds to relate assets to liabilities gives rise to portfolio insurance. For instance Constant Proportion Portfolio Insurance is considered by Black and Perold (1992) where asset classes are viewed as active and reserve. Active assets are those that are relatively risky and a reserve asset is safe to the extent that "it closely tracks a liability stream" (p. 404), thus it may fluctuate in value/return/volatility and as such cannot be classed as risk free in the traditional sense.

A different view of strategic asset allocation is taken in Blake and Timmermann (2002c) in a more general consideration of benchmarks. In this study:

> An appropriate benchmark recognises formally that the strategic assert allocation or SAA (i.e. the *long-run* division of the portfolio between the major categories of investment bassets, such as equities, bonds and property) is a risk decision relative to the liabilities, rather than an expected return decision. In other words, the SAA, properly interpreted, is not an investment decision at all: instead it is determined largely by reference to the maturity structure of the anticipated liability cash flows. In contrast, the stock selection and market timing (i.e. tactical asset allocation) decisions are investment decisions and it is the fund manager's performance in these two categories that should be judged against the benchmark provided by the SAA. (p. 110)

This is a very rigid picture of strategic asset allocation. It should be (or is partly) true in relation to certain pension funds, but the paper's title refers to institutional investors and it is difficult to tie down asset and liability matching so tightly to portfolios that are not pension funds. In fact this is recognised by Blake in a later paper (2003) where SAA will "depend on both the characteristics of individual schemes and those schemes' sponsors' attitude to surplus and contribution risk" (p. 3).

The Myners Review (2001) noted with some concern that UK institutional investors tended to ignore venture capital as an asset class in the strategic asset allocation process. Little research is available on this aspect, but Chen et al (2002) analyseUS data and recommend that "an allocation to venture capital of 2% to 9% is warranted for an aggressive portfolio" (p. 83). Unfortunately their process is less of a strategic asset allocation model and more akin to the inclusion of venture capital in the equities universe, albeit with a different method for calculating historic returns.

The role of international investment for pension funds is well reviewed by Davis (2002), although the existence of domestic liabilities can cloud the general application to all investors. This paper splits the initial strategic consideration into two activities, firstly "to choose the asset categories to be included in the portfolio" (p. 4) and secondly to make two strategic choices: active versus passive management and the strategic asset allocation. Part of this mean-variance based approach is to consider the impact of immunisation, such that greater emphasis is placed on the portfolio value at the end of a holding period. Thus for a pension scheme with liabilities in the domestic currency there is an immediate shift away from international or non-domestic asset allocation. Similarly there will be asset allocation issues based upon matching/duration and the need to balance the assets and liabilities risk/return profiles. One additional special case in relation to pensions is the issue of tax. Asset allocation for a pension fund may seek to maximise weights in asset classes where there is "the highest possible spread between pre-tax and post-tax returns" (p. 6).

The benefits of international diversification are well identified, not only by Davis (op cit) but also Solnik (1998), Baxter and Jermann (1997), Reisen (1997) and many others. Despite this there exists a home asset preference which may be due to domestic liabilities, inefficient overseas markets, currency risk, information and costs. Although the link is not made, one possible cause of the home bias may be found in sampling errors for mean variance efficient portfolios. Britten-Jones (1999), in trying to establish estimates of weights for an international portfolio concludes "These results provide no statistical support for the proposition that there are benefits to global diversification for a US investor" (p. 666). This contrasts with Solnik (1998) who sees strategic currency allocation as an important part of global asset management. The strategic currency allocation is akin to strategic asset allocation in that it is long term and linked to a suitable benchmark. Tactical currency allocation is short term variationto take advantage of fluctuations in expected returns and risks in the currencies.

Gratcheva and Falk (2003) link these issues together, with a model that attempts to apply mean variance theory to the strategic asset allocation decision when faced with aglobal portfolio. Using 14 asset classes (equity and bonds from seven countries) the model proposes the percentage allocations and suggests appropriate limits for tactical asset allocation. Based on optimisation and with many constraints it recognises that "Global asset markets offer significant opportunities to improve investment returns" (p. 1644). The model does however ignore efficiency or the results of various attribution analysis processes in that it assumes that:

> A tactical asset allocation process may offer good opportunities to enhance long-term portfolio return. The evidence suggests that active shifts of asset weights do lead to higher returns on average than with a static allocation. (Consequently)...the investor, however, should control the degree of risk the deviations produce by defining specific constraints. (p. 1645)

Solnik's paper virtually takes the benefit of international diversification as a given, unlike Britten-Jones, and instead considers the hedging decision, with the conclusion that:

> If the plan sponsor sets a benchmark for a very long-term horizon (say, fifty years) then it should probably be unhedged...(whereas)... if the plan sponsor has in mind a shorter strategic horizon (say, five to ten years), the ideal currency allocation is, and will remain, a question open to debate. (p. 51)

In their book based on the Clarendon Lectures at Oxford, Campbell and Viceira (2002) expand much of their research on strategic asset allocation. This tends to be focused on the individual investor (compared to much of Blake's work on pensions) and includes an extension of Viceira's already discussed paper on labour income. Unfortunately the work ignores international investment, although this does not detract from much of the interesting conclusions. Their initial consideration of myopia in strategic asset allocations is that under certain assumptions "the investment horizon is irrelevant for investors who have only financial wealth and who face constant investment opportunities" (p. 17). This view they recognise as being diametrically opposed to typical advice of long term investors having the scope to invest in a more risky portfolio. Relaxing some of the assumptions they argue that the shift from short to long term allocations significantly increases the importance of bonds. This is based on cash (i.e. money market investment) ceasing to be riskless due to future refinancing, with indexed bonds consequently becoming less risky. Not only this, but also nominal bonds should replace much of the equity holdings of risk averse investors if inflation risk is seen as low.

This view of the investor's optimal allocations contrasts, they argue, with Siegel (1994) who regards equity as giving reduced risk once the time horizon extends towards the long term. Their argument being based on Siegel assuming mean reversion in equities' returns supporting a buy and hold strategy, whereas if there is scope for market timing (a big "if" according to BHB, Blake, et cetera) then high equity holdings would be sub-optimal. Less contentious conclusions from their analysis include life cycle issues such as "risky investments should be extremely attractive to typical young households with many years to retirement" (p. 219). Finally there is the unsurprising conclusion that "time preference and risk attitudes can have large effects on optimal portfolios" (p. 220).

Their work on optimal consumption and portfolio choice is extended in Campbell et al (2003), with the investor being infinitely long lived and having Epstein-Zin utility. Although fairly esoteric, their extensions to the work of Campbell and Viceira (2002) conclude that:

> Dividend yields, interest rates, yield spreads, inflation and other variables that predict asset returns...have substantial effects on optimal portfolio allocations among bills, stocks and nominal and inflation indexed bonds. These effects are strategic...rather than merely tactical effects on myopic optimal portfolios. (p. 64).

Campbell and Viceira's use of intertemporal hedging is also considered by Graflund and Nilsson (2003) in relation to dynamic portfolio hedging. They find that "taking...specific regimes into consideration has a strong influence on the portfolio decision" (p. 199), when regimes are differing views of the state of the economy. This paper, like so many of those concerned with portfolios, has just two asset classes, is domestic in scope and does not add to discussion of strategic asset allocation.

It is often the case however that a fund has constraints on asset classes available to the manager. These can be regulatory or a choice of the plan sponsor. The impact of these constraints is considered by Kendal et al (1995) and Wang (1998). Wang observes that mean variance maximisation can generate short positions that "are difficult to implement in practice because finance professionals often face constraints on their portfolio holdings" (p. 360). The impact of this when analysed in relation to a NYSE-AMEX market portfolio is that the "...market portfolio is inefficient when portfolio weights are constrained...but the degree of inefficiency is found to be much smaller than in the case with unconstrained portfolio weights" (p. 373). This is a somewhat surprising conclusion in that the constraints increase the efficiency. It only applies however to one type of transaction, that of short sales, and so does not add much to the strategic asset allocation discussion.

The current UK perspective of strategic asset allocation is well set out in the Myners Review (2001). Although its title is concerned with institutional investment it is unfortunate that the main focus is on pensions, to the exclusion of other indirect investment vehicles. For self-administered (i.e. non-insured) schemes the allocation decisions are split between peer group total fund benchmarks, where the trustees delegate strategic asset allocation and security selection, and customised total fund benchmarks, where the trustees make the strategic decisions and then delegate security selection. Within defined contribution schemes an additional facility may exist whereby the member has a lifestyle-type choice in the allocation process. The peer group method of Strategic Asset Allocation is criticised in the Review as generating distorted allocations with "a [sic] historic industry consensus...serving the interests of the beneficiaries poorly" (p. 61). At the same time, the customised approach is over-reliant on trustees receiving allocation advice from a limited number of advisers. One of the principles therefore proposed by the Review is to increase the recognition of the importance of the strategic asset allocation decision, partly by measures to widen the range of asset classes under consideration and partly by reflection on the contribution that Strategic Asset Allocation can make.

2.5 Actual Strategic Asset Allocations

A comparison of weights for the pension funds in a variety of countries is set out in Table 2. The importance of domestic equities in the US and UK (greater than 50%) is immediately obvious and contrasts strongly with (say) Germany, Japan or Netherlands. Possibly reasons for the differences are cultural or regulatory or just the size of the domestic market. Foreign assets show a generally lower spread in allocations but are possibly less a function of portfolio choice and more linked to regulatory constraints.

Table 2 International comparison of pension fund percentage allocations 1998

	liquid	loans	domestic bonds	domestic equities	property	foreign assets
Australia	14	4	12	43	6	18
Canada	5	3	38	27	3	15
Chile	15	17	44	21	3	4
Denmark	1	0	59	23	6	11
Germany	0	33	43	10	7	7
Japan	5	14	34	23	0	18
France	0	18	65	10	2	5
Italy	0	1	35	16	48	0
Malaysia	24	27	32	18	1	0
Netherlands	2	10	21	20	7	42
Sweden	0	0	64	20	8	8
Finland	13	0	69	9	7	2
Singapore	28	0	70	0	0	0
Switzerland	11	0	29	17	26	17
UK	4	0	14	52	3	18
US	4	1	21	53	0	11

Source: National flows of funds balance sheets, cited in Davis 2002.

A comparison for mutual funds is set out in Table 3, although this is split not by the internal weights but by types of funds. The wide choice of types of fund (greater than shown in the table) raises the interesting question of efficiency. A tacit assumption of all of the above discussion is the need to produce an efficient portfolio, with an allocation process that will encompass all asset classes. If a fund company holds assets in all classes but parcels these up to sell funds that exclude certain classes, then the customer will by definition be holding an inefficient portfolio.

Table 3 International comparison of mutual fund percentage allocations 1998

	Equity	Bond	Balanced	Money	Other
US	55	15	7	23	
Europe	40	31	12	16	1
France	18	26	24	31	1
Italy	18	50	8	19	5
UK	84	8	8		
Spain	20	37	18	25	
Germany	43	40	3	14	
Netherlands	54	27	8	9	2

Source: FEFSI statistics, cited in Otten and Bams 2002.

The Investment Management Association's Fund Management Survey (2003) looked at assets managed in the UK. This gives a confusing picture as it includes member firms managing investments within and outside the UK and also member firms with clients within and outside the UK. Asset allocation aggregated from the 55 member firms who participated in their survey, as at June 2002 is set out in Table 4. Little can be concluded on strategic allocations from this survey. Of interest however, is the concern expressed in the survey that "nearly 80% of UK assets are managed on a 'passive' basis" (press release, page 1).

Table 4 Allocations of assets managed in the UK as at June 2002

Fixed Interest	%	%
Gilts and overseas government debt	12.7	
Corporate bonds	8.2	
Index-linked bonds	1.9	
High yield bonds	1.2	
Total-all bonds		24
Equities		
UK		20
Overseas		
North America	10.6	
European	5.8	
US	12.2	
Japan	3.0	
Emerging markets	1.7	
Other	0.7	
Total overseas		34
Money Market		12
Property, venture capital and other		10

Source: Investment Management Association, 2003. *Fund Management Survey 2002.*

To put these strategic or tactical weights in context, UK asset classes' actual weights by market capitalisation are shown in Table 5. Long term trends for UK pension fund weights are shown in Table 6. Significant changes over this 21 year period are the growth and then decline of domestic equity, contrasted with fairly regular growth of overseas equities. At the same time there has been a major reduction in domestic bonds in the first half of the period followed by some growth towards the latter end, which also coincides with the growth of overseas bonds.

Table 5 Market capitalisation of UK asset classes as at 31st December 2001

Asset class	Market capitalisation £bn	Market capitalisation %
UK money market securities	541	22
UK fixed-income government bonds	204	8
UK index-linked government bonds	71	3
UK index-linked non-government bonds	5	0
UK equity	1,482	61
UK investment property	130	6

Source: HM Treasury, Merrill Lynch, London Stock Exchange, Investment Property Databank, cited in Blake 2003.

One of the problems with these comparisons is the selective nature of the data. Table 6 is the WM Company pension fund universe, one of the two main UK providers of this type of information. The other main provider is CAPS, whose equivalent data is set out in Table 7 for comparison. As can be seen by comparing 2000, there are similarities between the two sets of information, but also some not insignificant differences.

Table 6 UK pensions WM All Funds Universe, asset allocations

	'82	'84	'86	'88	'90	'92	'94	'96	'98	'00	'02
UK equities	43	47	51	53	54	58	54	53	51	48	39
Overseas equities	14	16	20	16	18	22	22	22	21	23	25
UK bonds	19	17	13	10	6	4	6	6	9	10	12
Overseas bonds				1	3	4	3	3	4	3	4
UK indexed	3	3	3	3	3	3	4	5	6	6	9
UK property	18	13	8	10	8	6	6	5	5	5	7
Overseas property			1	1	1	1	0	0	0	0	0
Cash/other	3	4	4	6	7	4	4	6	6	4	3

Source: The WM Company.

Table 7 UK pensions CAPS asset allocations, 2000

Asset class	%
Cash	3
UK equities	48
UK property	2.8
UK index-linked	7.7
UK fixed income bonds	13.2
International equities	22.2
International fixed income bonds	3.1

Source: CAPS pension fund average portfolio, cited in Blake (2003)

A summarised version for US pension fund asset class weights is given in Table 8. Observations on comparisons between these and the UK position in Table 6 include: lower use of domestic equities and considerably lower use of overseas equities; much greater use of domestic bonds but slightly less use of overseas bonds; lower use of property, both domestic and overseas; and higher cash/other allocations.

Table 8 Aggregate portfolio weights for US pension funds.

	1986	1990	1994
Domestic equities	45.6	42.1	44.8
International equities	2.6	4.5	8.3
Domestic bonds	37.8	38.9	34.2
International bonds	.0	.0	2.0
Index bonds	.0	.0	.0
Cash/other	7.8	9.8	7.5
Domestic property	6.2	4.7	3.2
International property	.0	.0	.0

Source: Greenwich Associates, as cited in Blake et al (1999).

None of these actual allocations show a weight for overseas equities anywhere near those proposed by Britten-Jones (op cit) for US based investors. These are shown in Table 9.

Table 9 Estimated Global Tangency portfolio weights from viewpoint of US investor

	1977-1996	1977-1986	1987-1996
Australia	12.8	6.8	21.6
Austria	3.0	-9.7	22.5
Belgium	29.0	7.1	66.0
Canada	-45.2	-32.7	-68.9
Denmark	14.2	-29.6	68.8
France	1.2	-0.7	-22.8
Germany	-18.2	9.4	-58.6
Italy	5.9	22.2	-15.3
Japan	5.6	57.7	-24.5
U.K.	32.5	42.5	3.5
U.S.	59.3	27.0	107.9

Source: Britten-Jones (1999)

The concept of strategic asset allocation has been ignored to a large extent by the finance community. For over 50 years research has been undertaken on mean variance analysis, market efficiency and other areas of finance, but only in the last decade or so has long term asset allocation started to emerge. There would seem to be a growing consensus that SAA is a long term decision on weights of different asset classes for a portfolio. This has chiefly been driven by the need for asset-liability matching for pension funds, a requirement that is not so necessary, or not quite so overt for other types of investors. Actual allocations would seem to show high levels of convergence within a country or fund type, but there are major differences by country. The focus and recommendations of the Myners Review would indicate that greater attention in the UK will be placed on the strategic asset allocation decision, particularly in terms of pension funds.

2.6 Market Segmentation

2.6.1 Sectoral efficiency

This is the last of the sections that comprise the formal literature review. The first and second were a fairly descriptive "history" of the growth of the Efficient Market Hypothesis and some of its tests. The conclusion was somewhat vague or mixed, with a fairly general recognition that it is not perfectly efficient but at the same time there is no strong evidence that it is sufficiently inefficient so that investors can consistently make abnormal gains. Some polarization of views or opinions does take place, as many practitioners, academic researchers and regulators take fairly dogmatic views, with statements that the market is or is not efficient. These positions seem to be predicated on two extremes: firstly based on tests at the level of the equity market, resulting in the UK market as measured by the FTSE 100 index being described as efficient or not, (in effect a top down approach) and secondly a consideration, often using fictitious portfolios ranked by performance, that aggregate up from individual shares to the market as a whole, but again indicating efficiency or the lack of it.

The third, fourth and fifth sections of this literature review chapter looked at strategic asset allocation. Again there is no large body of literature that examines sectors. There is much on performance attribution and, as above, a range of views on efficiency, but no great focus on the role of the various sectors in the strategic asset allocation process.

The aim of this final section is to pull together the very limited number of research papers in the finance literature that sit somewhere between the two polarized positions described above. In terms of strategic asset allocation, it would be rare for a fund manager of a domestic fund personally having to decide the percentage strategic allocations to a single class called "equity". (Although this could be feasible with a well diversified international or global fund.) This view is supported by Francis (1986), Bing (1971) and Cuthbertson et al (1999) who take the view that it is more common for the allocations to be at the sector level. This section therefore considers the available literature that examines sector level efficiency.

2.6.2 Efficiency and market sectors

It is very common for research papers on efficiency, particularly with a method based on tests for randomness, to take a single index as the proxy for the market. Examples of this are numerous, including Chelley-Steeley (op cit), Dimson et al (2003), Clare and Thomas (1995), Dissanaike (2002), Ferson et al (2003), Milionis (2004), Mills and Jordanov (2003) and Summers et al (2004). For the UK the choice of appropriate index tends to depend on the time scale and/or frequency that is being examined, resulting in use of the Financial Times Industrial Ordinary Index or the FTSE All Share, the Barclays de Zoete Wedd equity stock price index or the FTSE 30; the alternative approach being to generate portfolios from the bottom up, usually based upon randomly selected shares.

Of particular interest and relevance is Groenwold and Fraser's 2001 study of IID-normal assumptions. For the UK (although the paper also considers the USA) the monthly data is from the Datastream Global Indices series but broken down by the Financial Times actuary classifications for constituent industry sectors, resulting in five sectors comprising Resources, General Industries, Consumption Goods, Services and Financials. The study is concerned with asset pricing models and the validity of the underlying assumption of IID-normal returns and so is only obliquely related to efficiency, but it does highlight a limited number of differences by sector, for example "...there was evidence of considerable ARCH in many of the sectors- both for the US and the UK" (p. 786). Similarly there was "...some evidence of AR in the Financial sector for the US and the General Industries sector for the UK and evidence of ARCH...in the Resources sector for the UK" (p. 788). In tests of Conditional CAPM they also show:

> For both markets, the money growth rate variable in the Resources and General Industries sectors...is statistically insignificantly different from zero. ... (T)he intercepts...are, individually, statistically significant at conventional levels, while in the UK case, only for the Financial sector are we able to reject the null hypothesis. (p. 791)

Thus, although not the concern of the paper, Groenwold and Fraser show that there are significant differences by sector. Differences that will be lost or unobserved when efficiency tests are performed on a single, market based index.

In an equivalent paper Fraser and Groenewold (2001) model mean variance efficiency in a GARCH format for the Australian market using sector portfolios based upon Mineral Extraction, General Industries, Consumption Goods, Services and finally Financial. They find evidence of ARCH effects in General Industries and Services, an "absence of higher order correlation in the residuals of Mineral Extraction and Consumption Goods" (p. 66) and residuals that are non-normal for all sectors except Services and Financials. Thus there is strong evidence that sectors have differing attributes.

A paper that was more concerned with sectors or market segmentation was that of Cuthbertson et al (1999). This was a multi-variate study of asset pricing models and so had some relevance to market efficiency, for instance "Clearly, rejection of the EMH based on aggregate data may be due to mispricing in only a sub-sector of the market" (p. 217) although the question was whether "...rejection of [CAPM] at the aggregate level [can be traced] to a failure of the CAPM to hold in specific sub-sectors of the market" (p. 218). Their industrial sector classification followed a similar structure to that of Groenwold and Fraser, examining five groups: Industrials (with and without Oil); Financial Services; Capital Goods; Consumer Goods; and the balance of the market defined as Other Sectors. No support was found for CAPM at the sector level but there was a range of results in covariances between the sectors. If each sector is defined as "the market", then there was a range of sectoral results with VAR parameters close to 5% rejection for Capital Goods and Consumer Goods and

> The null hypothesis that returns in excess of equilibrium cannot be rejected at the 5% level for Capital Goods, Consumer Goods and Other Sectors. However (sic), for the remaining sectors, the reduction in the Wald statistics is not sufficient to give unequivocal support to the own variance model. (p. 231)

Their conclusion is that "there seems to be some support for the... variance model within *certain* sub-sectors of the market" (p. 231), (their italics). As with Groenwold and Fraser, the very clear conclusion is that disaggregation of an index acting as a proxy to the market into a set of sector indices produces a range of results by sector. This immediately casts doubt on the many research papers that support or reject market efficiency at the market level, even though these two papers are not directly concerned with specific tests of the EMH.

The only research identified in the literature search that uses the same sector level segregation as proposed for this thesis is an unpublished conference paper by Yu and Stark (2004). This is chiefly concerned with the use of style strategies in the UK; style being viewed as value, growth, small/large capitalisation, momentum, contrarian and high-tec. Their analysis is a comparison of style in relation to micro-factors such as book to market value or leverage but part of the paper focuses on the same 29 sectors taken from Datastream as are utilised here. Some of their observations (p. 31) are:

- Growth stocks are overweight in Pharmacuticals & Biotechnology, Software, Media and IT
- Value style has a bias towards Steel, Utility and Diversified
- Small capitalisation tends towards Steel, Household Goods & Textiles and Diversified
- Small capitalisation favours Oil & Gas, Pharmacuticals & Biotechnology and Telecoms

Their conclusions are less sector-specific but it is interesting that different style investors tend to adjust their weights away from the market index weightings with a focus on sector. Of course, there is no suggestion that it is the sector itself that is selected, rather it is the aggregation by sector of the stocks selected on a style basis that produce the results.

Despite extensive searches, no other sector-level papers with a link to efficiency tests were identified, although there is a separate strand that seeks either cointegration, correlation, and transmission of shocks between markets at an international level or high level asset classes such as equity versus bonds or real estate within a domestic market. A good example of this type of methodology is Payne and Sahu (2004) who compare global real estate markets with the US equity market. They test the various markets for the random walk hypothesis using the unit root tests of Dickey Fuller and Phillips Perron and a variance ratio test. Cointegration is examined by means of the Johansen Juselius cointegration analysis and the transmission of shock is measured by a VAR model and Granger Causality tests. This methodology will be reviewed later, but at this stage their conclusions are of interest in that the three markets exhibited the behaviour of a random walk and they were not cointegrated. The conclusion is

> The random walk hypothesis and cointegration results suggest that investors can derive diversification benefits through the domestic and world real estate markets and the world stock market in both the short and long run….Moreover, the absence of cointegration provides support for the efficient market hypothesis… (p. 207)

The most common research on cointegration is that of comparison between different equity markets. Examples of this include Europe versus the US by Gerrits and Yuce (1999), central European markets by Gilmore and McManus (2003), African markets by Smith et al (2002) or eclectic mixes of countries by Heimonen (2002). Their conclusions, often based on different methodologies, are generally that there is conflicting evidence. For instance, Gerrits and Yuce find cointegration between some but not all market under examination; Heimonen identifies convergence of ex post returns between some but not all markets; Smith et al identify some African markets as efficient but not others; and Gilmore and McManus concludes that some markets do reject random walk behaviour whilst others do not.

This mix of results at an inter country comparison level, when combined with the domestic but sector level analysis provide strong support for the consideration of efficiency within the UK domestic equity market by sector.

2.6.3 Summary

Market efficiency, or the efficient market hypothesis or the rational market hypothesis, has been the subject of a vast amount of research in the past forty years. From its inception it very rapidly generated extensive work that was to a large extent highly supportive. Its growth coincided with the development of asset pricing models, so enabling tests of the hypothesis. Some time in its first two decades it became the dominant paradigm in this particular area of finance and gained wide acceptance within the academic community. This academic acceptance is evidenced by its almost compulsory inclusion in any text book on finance or financial management. Acceptance in the financial market place was slower. This was possibly due to active fund managers, analysts and the like possibly not wishing to admit their failure to beat the market.

The second two decades of its life has seen growth in evidence that the efficiency is not perfect. Issues such as the size effect, time effects, mean reversion and numerous other potential flaws have been identified and well documented. These have tended to coalesce under the heading of behavioural finance, but to date the lack of a single, unifying model has not completed a paradigm shift and market efficiency still appears in the text books of finance courses at all levels. At the same time the market place has tacitly accepted the impossibility of beating the market, as evidenced by the continued growth of overt and covert index tracking.

It is fairly evident that the efficient market hypothesis does not hold true for all investments in all asset classes in all market places all of the time. Despite this, it is recognised by many that the flaws or anomalies or mistakes, whilst existing, do not allow any great scope to achieve abnormal returns to be achieved. It is similarly evident that no successor to the efficient market hypothesis has yet been accepted by the academic community.

There are numerous areas for further research in strategic asset allocation. Firstly much of the current analysis has had pension fund allocation as its focus. This needs to be extended to encompass all indirect investment vehicles, including life assurance, unit trusts, investment trusts and also the direct investors, both commercial and individual. Secondly, where research does consider strategic asset allocation this tends to be a secondary issue with papers on efficiency or market timing or selectivity alluding to strategic allocations. There is much scope for the analysis to switch to consideration of the impact of asset class selection on portfolio performance. Thirdly, although it is growing, the use of international components (equities and bonds) is very low. There may be regulatory and behavioural reasons for this home bias and there equally may be implications for risk-return inefficiencies generated by the domestic preferences. Fourthly there is the possible concern that a finance house has, in aggregate, an efficient portfolio, but that by offering specific products other than balanced funds the clients' fund will be sub-optimal. Fifthly there seems to be no accepted approach either a) to hedging the overseas component of a fund or b) to including foreign currency as an asset class in its own right. Finally is the acceptance of the long term nature of strategic asset allocation versus the myopic portfolio choice of a mean variance approach.

CHAPTER THREE METHODOLOGY

3.1 Introduction

A research study based on one aspect of the Myners Review, namely strategic asset allocation, almost invariably has to address market efficiency. Had this study taken place in the 1970s or 1980s the topic would have been seen as highly current and the concept of the rational market hypothesis would have labelled the underlying research philosophy as accepting the then dominant paradigm. The last twenty years however, have seen a shift. Unexplained anomalies, combined with the growth in research into behavioural finance have moved market efficiency away from the limelight. At the same time, there has been a further shift, this time in research style, with qualitative research, case study based research and grounded theory being seen as the new dominant (or at least growing in popularity) approaches. These two shifts are addressed in this chapter on research methodology, as is a third issue: the growing trend in UK based finance research moving away from an American-centric quantitative empirical methodology towards a more pluralistic or less extreme/more central viewpoint.

The chapter outlines the growth in modern Western philosophical attitudes to research, places greater emphasis on the work of Hayek, due to its relevance to rational markets, gives an up-to-date summary of some current thinking in relation to finance, economics and accounting and concludes with the links between this history and the study of the rational market hypothesis.

3.2 Research Methodology: an overview

3.2.1 Early views

Many texts on (Western) research methodology and epistemology trace the origins of the philosophical approach to the Socratic method, as extended by Plato to the concept of the ideal forms method or alternatively to Aristotle's rejection of ideal form and the use of observation; Platonism being "the theory that abstract entities exist, ... (in fact they) are the only things that really or wholly exist..." (p. 665, Bullock and Trombley, 1999), whereas Aristotle visualised a set of general principles that could be interpreted or understood, based on observation (Mukherji, 2000). These two views are of some importance to any debate on epistemology, or the philosophical underpinning of how we define knowledge. Taking for example, the Capital Asset Pricing Model, Plato's ideal form might include CAPM; Aristotle's explanatory principles may have generated the relationship between risk and return; and epistemology may see knowledge about CAPM as having being derived by each user, or knowledge having been learnt from a text book or knowledge of how to use it without any understanding of the underlying theory of CAPM.

Over the centuries these debates have resulted in a tension or split between an empirical view of research and rationalism, an issue that still remains unresolved in discussions about the philosophical interpretation of knowledge to this day (Bernard, 2000). Rationalism (originally the disbelief in the supernatural) has its roots in the work of Rene Descartes (1596-1650) and regards knowledge as being achieved by individuals via a reasoning process. There are 'a priori truths' (hence the alternative name of apriorism) that become evident to the rational thinker, so rationalism can be seen to be the seventeenth century descendent of Plato's ideal form. It still "underpins much of modern continental philosophy (but) empiricism became dominant in Britain" (p. 12), (Ryan et al, 2002). The alternative epistemology of empiricism is that all knowledge is based on experience, hence David Hume's (1711-1776) conceit of a clean slate (tabula rasa) or Locke's blank sheet. Empiricism thus rejects rationalism and views it as transcendent or beyond physics and therefore metaphysical.

Immanuel Kant (1724-1804) suggested a middle way between rationalism and empiricism in proposing that the existence of a priori truths is due to the way the individual's brain is structured. His 'transcendental idealism' also addressed a further debate that was ontological rather than epistemological, namely that of idealism and realism. Realism being concerned with how do we know what is real?, compared to idealism where the mind or a mental state is the only thing that exists.

Rather than continuing the debate between the two competing views or epistemologies, the sixteenth century also saw the start of the scientific method, albeit having greater links with empiricism than rationalism. Known as positivism, it was the idea that "it is a philosophy which both proclaims the suitability of the scientific method to all forms of knowledge and gives an account of what that method entails"

(p. 14, Bryman, 1988). Positivism was extended by Comte (1798-1857) who proposed that all knowledge is scientific in terms of describing phenomena. Comte is regarded as the father of sociology, but many of his ideas gained wider acceptance in other disciplines, resulting particularly in the development of logical positivism, particularly via the Vienna Circle (chiefly in the 1930's).

3.2.2 Twentieth Century viewpoints

At its core, logical positivism assumes that knowledge is based on experience, that metaphysical issues could not be explained by science and that it is only answerable questions that should be asked. Coming out of this is the work of Hayek, which has strong resonances with the rational market hypothesis and as such will be discussed later. The Vienna Circle also gave a strong thrust towards quantitative research and was highly influential "in American social science which took the form of legitimizing empiricism in the sense that quantitative data could be used to test theories" (p. 122) (Mukherji, 2000). Karl Popper was critical of this position and advocated critical rationalism as a replacement to or extension of the then orthodoxy.

Popper's main argument was centered on his rejection of verification in the scientific method. Prior to his work, it was assumed that a theory or hypothesis could be verified by observation. Instead, critical rationalism turned this round, using his proposed principle of falsification, with the validity of a theory thus being 'measured' by how well it withstood tests to disprove it.

> I shall not require of a scientific system that it shall be capable of being singled out, once and for all, in a positive sense, but I shall require that its logical form shall be such that it can be singled out, by means of empirical tests, in a negative sense; *it must be possible for an empirical scientific system to be refuted by experience*. (p. 41, his italics, Popper, 1959).

There are obviously close links to the scientific method here, with theories always being conjectural in their nature and ultimately refutable, such that Ryan et al (2002) observe that "theories progress accumulating truth value through an almost Darwinian notion of survival of the fittest. Absolute truth is an almost unobtainable ideal but is the ultimate aim of all science" (p. 20). The early versions of this were such that a theory can or should be rejected as soon as there is evidence of falsification. This rather rigid or strong position was later replaced by Popper with a more relaxed version, in effect that although evidence of falsification may cast doubt on a theory, it should not be fully rejected until it was replaced by a new theory (Delanty, 1997).

Additionally, Popper's work was against the logical positivists' inductive approach, or the drawing of inferences based on observation, as there was no underlying hypothesis waiting to be falsified. Instead he suggested the hypothetico-deductive methodology as this obviated the inductive problem of not accepting the possibility of a theory being false. Popper's falsification and hypothetico-deductions were challenged in three ways, from Kuhn, Lakatos and Feyerabend. Positivism, logical positivism and falsification were rejected by Kuhn and replaced by what he called the prevailing intersubjective consensus of those researchers working, researching or teaching in that particular field (Mukherji, 2000). This is a more temporal approach, with the scientific community at times accepting normal science such that research and the development of new knowledge tends to accept the then current paradigms. Towards the end of the life cycle of the paradigm, persistent anomalies are identified and normal science is replaced by extraordinary research until a new paradigm achieves intersubjective consensus.

In a similar way Lakatos put forward the idea of research programmes (or aggregations of theories) and the commitment of the scientific community to that research programme. Over time the programme is seen as progressive if it identifies new discoveries and supports existing theories. Alternatively the programme is degenerative if it fails to achieve new developments and there is a new programme to replace it. In this respect, Barbour (1974) likens both Lakatos and Kuhn and their use of paradigms or research programmes in the scientific community as being equivalent to a religion. Feyerabend took this slightly further, with the view that when a theory/paradigm/research programme was losing general acceptance, then it is the language of observations that gains importance and that the theories become incommensurable. Research thus ceases to have any validity, all the various methodological approaches have flaws and there is anarchy.

Although approached from a different direction, Feyerabend's conclusions find resonances with postmodernism and post-structuralism; the latter being evident in the work of Derrida, where he argues that "there is no absolute foundation for beliefs and that no belief is more fundamental than any other" (p. 26) (Ryan et al, 2002); the former being a wide school, more aligned to the arts rather than science, but strongly against the philosophical debates on ontology, epistemology and methodology.

3.3 Friedrich A von Hayek

In the earlier overview of research methodology, brief mention was made of the work of Friedrich Hayek. Although not directly part of the Vienna Circle, and indeed not directly a philosopher proposing new paradigms on theories of knowledge, ontology, epistemology or methodology, his work is in fact of relevance to this doctoral thesis. Not all of his work is discussed here; instead, some of his reflections on the above are considered, particularly those that have a more specific link to markets, rational investors, price setting and the rationality of a market or its investors.

Hayek's view of society and how it worked lay between two polarised positions: on the one hand is the natural or organic structure and on the other is artificial or man-made structure (physical, or more particularly, organisational). For instance, a market for trading shares did not exist before the need for a market and neither was a market invented. In effect a market grew or evolved because it brought benefits to its users, so giving unplanned order through thought of minds and actions of society. From this position, that of unplanned complex structures, he argues that it is "this interplay of the rules of conduct and of the individuals with the actions of other individuals and the external circumstances in producing an overall order" (p. 71, Hayek, 1969). There must however be some regularity in individual behaviour to allow stable order, these being defined by Hayek as 'rules'. Against this, not all individuals need to follow all the rules. Thus we can immediately see the link between this philosophical position and two aspects of investment, namely that a stock market can perform not because it was invented, but due to its unplanned albeit useful structure, and that investors will trade following individual behaviour which generates stable order.

Although Hayek was putting forward a logical argument against planned economies his view of the market process was that market order was achieved precisely because it did not require planning or common aims or agreement on action. Again, this has resonances with market participants with differing goals and time horizons, various liabilities to match, attitudes to risk, expectations of the future and all other factors in investment decision making. He expressed this well in The Mirage of Social Justice, stating:

> That interdependence of all men, ... not only is the effect of the market order but could not have been brought about by any other means. What today connects the life of any European or American with what happens in Australia, Japan or Zaire are repercussions transmitted by the network of market relations. (p. 57, Hayek, 1976).

More specifically, his views applied to price setting, although he was writing about product prices rather than stocks and shares when, in Individualism and Economic Order, (1948) he referred to the price mechanism as a marvel. The price mechanism was based on all players' knowledge; knowledge which Hayek saw as subjective and which has to be found by and interpreted differently by all players. This is well explained by Butler (1983), where he discusses the ideas, beliefs or concepts that actually motivate people, a set of constructs that may be totally different from the explanation they give to the wider world for their motivations. In effect, individuals will react to new information about a share/company and reach different decisions or views about the impact of that news on their individual expectations. Hayek's work could therefore be seen as an adumbration of behavioural finance, with various theories of finance being the core to the 'ideas' whereas the new work on subjective behaviour being the underlying subjective explanation.

Hayek took this approach to greater detail in his "Studies in Philosophy, Politics and Economics" (1967), where he espoused Popper's hypothetico-deductive system (p. 4), taking it further to the idea that "science does not explain the unknown by the known, but, on the contrary, the known by the unknown" (p. 5). This assumes, according to Hayek, that individuals follow sets of rules (possibly an extension of Gestalt perception) that guide their actions, rules that are "known by none, and understood by all" (p. 85). This is extended to include sets of rules or patterns, which he calls rationalist constructivism, albeit recognizing that "reason is not the judge but an instrument" (p. 87). In this he is aware he is very much in line with Adam Smith's invisible hand, when he states:

> The distinction between a spontaneous order based on abstract rules which leave individuals free to use their own knowledge...and an organization...based on commands is of central importance for the understanding of the principles of a free society.....By using its (spontaneous order) we can achieve an order of a much more complex set of facts than we could ever achieve by deliberate arrangement. (p. 162)

Spontaneous unplanned order is referred to as catallaxy and applies equally to economic order as it does to justice or morality. Interestingly, this is tangential to comments by Maughan and Copp (2003) where they consider economic efficiency in relation to the role of law and the Old Testament, assuming that "(L)aws and rules, spiritual and temporal, implicit and explicit, are public goods" (p. 249).

Gray (1984) sees Hayek as very much a post-Kantian, with the view that social order develops or grows in a spontaneous and unplanned manner. He highlights the confusion between an economy and a catallaxy, such that "order which is the product of conscious direction...itself always depends on a larger spontaneous order" (p. 35). In fact, he supports one of the key components of Hayek's work with the assertion that

> Hayek's conception of social institutions as vehicles for the generation and dissemination of knowledge in fact represents one of the most important paradigm shifts his work brings about in social theory- a shift from the criticism and evaluation of social institutions by reference to preferred principles of morality to an assessment of them in terms of their capacity to generate, transmit and use knowledge.
>
> Hayek states his conception of social theory, and of the central importance in it of undesigned or spontaneous orders, programmatically and with unsurpassable lucidity. (p. 28)

Thus, at its most simple, Hayek's view of equilibrium in the marketplace is three-fold. Firstly there is the assumption that individuals follow a Gestalt-like set of rules, applying their own interpretation or views to new information. Secondly is the assumption that successful social institutions or organizations such as exchanges have evolved rather than been designed. Thirdly, is the difference between ideas of individual motivation and post-hoc ideas of explanation.

3.4 Finance and Economics

3.4.1 Positive and normative economics

This section reverts back to the earlier overview of research methodologies, bringing it more up to date and locating the main theme within the disciplines of finance and economics. It begins with consideration of Friedman's discussion of positive economics, then summarises the relevant parts of the most well known text on accounting methodologies by Ryan et al and concludes with Zingales' new theory of the firm.

One of the seminal papers on economic research methodology is Friedman's The Methodology of Positive Economics (1953, but taken from Breit and Hochman, 1968). As recognised earlier, logical positivism, or rather the interpretation of it set out by the Vienna Circle, was readily accepted in American social science research. It is not overly surprising therefore, that the underpinnings of logical positivism are reflected in Friedman's work. Similarly, Friedman's location at the University of Chicago has close physical connections with Fama's development of the Efficient Market Hypothesis, also at the University of Chicago. Indeed, much of the collaborative developments and the huge amount of research supporting EMH was generated at Chicago and follows closely the view of Friedman's positive economics.

The main themes of the paper were based round J M Keynes' view that 'positive economics' is the knowledge of what is, whereas 'normative economics' is knowledge of what ought to be. Two economic actors can thus agree on positive economics but disagree on what is the desired outcome of policy. Alternatively, two economic actors can agree on desired outcomes but disagree on the necessary positive theories needed to achieve those ends. Interestingly, Friedman used minimum wages as an example of this type of decision, and over fifty years later UK political parties still disagree on the positive economics of this, whilst agreeing on the normative aims.

Friedman argued that "the ultimate goal of a positive science is the development of a theory or hypothesis that yields valid and meaningful predictions about phenomena" (p. 26). The theory is a mixture of two components, a language or set of tautologies and a body of hypotheses which "abstract essential features of complex reality" (p. 26). Of the language, he recognizes the difficulty in application, using new information which may affect a share's price as an example. For instance, does rumour of increased profits operate on the supply of equity on the market, or on demand for them? Of the body of hypotheses, he states that "theory is to be judged by its predictive power for the class of phenomena which it is intended to explain" (p. 27). There is no direct concept of falsification here, tests of hypotheses are to be on the correctness of the predictions and a hypothesis is to be rejected if its predictions are wrong more often than those of an alternative hypothesis.

In terms of underlying assumptions, Friedman welcomed parsimony in theories, stating that "a hypothesis is important if it explains much by little" (p. 30). He was happy for a theory to be 'descriptively false' so long as it permitted valid predictions. As such, the role of assumptions is split into three different categories: description; to facilitate indirect testing of the theory; and a method of specifying the conditions within which the test of the theory should take place. This overall view of the philosophy, of the instrumentalist use of positivism was, according to Ryan et al (2002), the perception or definition of what constituted good research of the editors of The Journal of Accounting and Economics.

Thus, it can be seen that there are close links between the Vienna Circle and Hayek, between empiricism and the American philosophical approach to research, and between economics and accounting research traditions.

3.4.2 Critical and middle range thinking in the UK

Ryan et al (2002) discuss this in detail in their text on research methodology in accounting and put forward what they see as the traditions of research in finance. At the heart of finance research is the concept of rationality, although currently being questioned by the growth of behavioural school of finance.

Their main conclusion is that the dominant finance research framework is "the development of theoretical models which are then tested by … empirical data" (p. 51). The theory development is centered in "the neo-classical research programme in economics, (where):

> economic agents are, at the individual level, formally rational (and)
> financial markets are perfectly competitive (and)

information is freely available." (p. 51)

Additionally, investors are assumed to "have the ability to evaluate and rank choices" (p. 52) and individual investor behaviour is "often aggregated up to the market level" (p. 52). Rationality has often been questioned but "although the adoption of a different paradigm might alleviate some of the problems...a considerable body of knowledge could be lost" (p. 52).

There is a hint of criticism in their review, of an over-reliance on empiricism, of an American led rejection of other non-positivist approaches to finance research and a slowly developing move of UK accounting research away from that embodied by the University of Chicago and the Journal of Finance. This is evident in discussion of Habermas and the 'hermeneutic circle', addressing the theory dependence of observation and the feasibility of applying natural science methodology to the social sciences, the result being "problems which have become a major issue for accounting researchers" (p. 34). For instance, referring to Morgan and Smirich's 1980 classification of ontological assumptions, much of finance research is objective and at one end of the continuum comprising "reality as a:

> Concrete structure (naïve realism)
> Concrete process (transcendental realism)
> Contextual field of information (contextual relativism)
> Symbolic discourse (transcendental idealism)
> Social construction (socially mediated realism)
> Projection of human imagination (idealism)" (p. 36)

This is extended in Hopper and Powell's 1995 taxonomy of accounting research, where mainstream accounting research is defined as functionalist by being both objective and regulatory. This compares to interpretive research (subjective and regulatory) and critical accounting research (applicable if either objective or subjective, but radical rather than regulatory).

Ryan et al's (2002) text refers to Baker and Bettners' (1997) analysis of American accounting research. Using the above frameworks, plus that of Laughlin's 1995 classification of social research "they show that less than 1 per cent of (papers published in North American academic journals) can be classified as interpretive or critical research" (p. 48). Their conclusion is that accounting and finance researchers must adopt a much more pluralist approach to methodology. Laughlin does not actually prefer pluralism, with his paper's 'middle range'. He predicates his approach on "the developments in ... the generation of the efficient market hypothesis... (that have) created demands ... for accounting academics sympathetic to this thinking for empirical research" (p. 64); this being contrasted with a search for other methodologies by, inter alia, the behavioural school, resulting in increased diversity and tension in the literature. Research is, or rather, has been located in three dimensions of theory, methodology and change, with most attitudes being at one extreme of the various continuums. To reduce polarisation Laughlin therefore argues well for a general shift by all accounting researchers to a middle range in terms of theory and methodology and change.

If Ryan et al (2002) and Laughlin (1995) reflect current thinking of UK accounting and finance, then the 2000 paper of Zingales gives one current American perspective. Here the proposal is less philosophical and more pragmatic. The study of corporate finance, namely capital structure, valuation, efficiency, and corporate governance has been "deeply rooted in an underlying theory of the firm" (p. 1623). This underlying theory has been highly successful through the twentieth century in having "a tremendous impact on the way we think about corporate finance" (p. 1624). Against this background, Zingales posits that the nature of the firm is changing: firms were asset intensive, vertically integrated and had tight control over employees. He sees firms at the turn of the century as now being loose conglomerates, with human capital as the crucial asset and with dispersed investors.

Much of the discussion is based on power and authority and is not of direct relevance here, but one section is highly moot. Firstly, "what distinguishes the firm from the market is the web of specific investments" (p. 1645) and secondly the "fundamental difference between the working of the firm and the working of the markets" (p. 1646) which could result in the need for firms to specialise rather than diversify. One possible outcome from this viewpoint (not identified by Zingales) could therefore be for the investor to be less concerned with individual firms and instead achieve diversification by markets. This has immediate ramifications for strategic asset allocation.

3.5 Discussion

3.5.1 Efficiency and the work of Hayek

Research into the efficient market or the rational market hypothesis has taken place over the last forty years and has chiefly been based in the United States. Thus it is easy to see how it sits methodologically within that period's approach to research. At the most basic, the hypothesis is an abstract entity (Plato) and is subject to the scientific method and Compte's positivism. The influence of the Vienna Circle on the dominant research methodology of the United States is very evident and the vast amount of quantitative research on the hypothesis (with the commensurate almost total exclusion of other research styles) very much legitimized this non-qualitative testing of the hypothesis. Similarly, it is easy to see the early papers on rational market hypothesis testing as being verification, followed in later years by a greater acceptance of Popper and the growth in falsification tests using critical rationalism.

When early anomalies were identified there was an attempt to reject the hypothesis on the basis of one failure, but as Popper switched to his later replacement of an old theory by a new one in his attitude to falsification, so there was a growth in recognition that EMH may be flawed but did not have a successor and so could not be rejected. Both Kuhn's and Lakatos' concepts of intersubjective consensus of the scientific community and research programmes also sit well with the last forty years. Market rationality and efficiency have regularly been seen in conjunction with Modigliani and Miller's work on capital structure and dividend theory, with Sharpe, Linter and Ross' work on asset pricing, Markowitz's mean-variance space, Black and Scholes with option pricing or Merton on stochastic processes. These pillars of finance are readily seen and accepted as an intersubjective consensus or an overarching research programme.

The work of Hayek is particularly close to rationality, so it is surprising that in all the literature reviewed in the earlier chapters, it is only in one particular quote by Ray Ball that this link is made, namely the contrast between rational liberalism, "the belief in the ability of individuals to rationally determine outcomes" (cited in Doukas, 2002, p. 230) with his interpretation of Hayek's view that "order arises from spontaneous unplanned actions of individuals" (p. 230). This can be seen in much of Hayek's work: the use of rules in decision-making, but with individuals not all following all rules; with the price mechanism based on economic agents' subjective knowledge; with buy and sell investment decisions possibly linked to a Gestalt switch and "reason being not the judge but an instrument" (p. 230) (op cit). Indeed the decision to use indirect rather than direct investment sits well with Hayek, if not with the view that laws are a public good, given that indirect investment has its own costs. Similarly, price-setting and the market structure is very close to Hayek's catallaxy and spontaneous unplanned order and indeed institutions' generation/transmission/use of knowledge.

Further reinforcement of the centrality of research on efficiency is evident in the importance in American finance research of Friedman's view of methodology. Market rationality is positive not normative, EMH is a hypothesis that is parsimonious and yields valid and meaningful predictions. Whilst there are tests that cast doubt, and given that even its strongest supporters joke that it is (say) 85% efficient, it is still a central plank of finance. Within the UK there is probably more skepticism about investor rationality and market efficiency. This is despite the fact that its main contender, behavioural finance, has its origins in papers in America, the skepticism being based not only on quantitative and empirical tests of falsification/anomalies, but on the underlying methodologies. This is well evidenced in UK critical comments on the need for plurality in methodologies and the suggested move to middle range thinking.

Therefore it is very easy to position the efficient market hypothesis as being a dominant paradigm in Western finance over the last four decades. It is equally easy to view recent years as indicating a beginning of change in the dominant paradigm or consensus or research programme, but with no successor. One layer higher/lower, it is easy to position the ontology and epistemology and methodology employed by scientific study of the hypothesis as being the dominant research paradigm of the last four decades. It is equally easy to view the recent UK based comments as indicating a beginning of change in the dominant research paradigm. These shifts thus make the positioning of this thesis interesting, both in terms of the view taken of the hypothesis and the underlying general methodology. What is clear though, is that it will be an empirical, logical positivist, Friedmanesque, quantitative set of hypothesis tests that does not move towards the more pluralist centre ground of current UK finance research.

3.5.2 Approach to analysis

Much of this chapter has links with ontological and epistemological issues surrounding the growth of the Efficient Market Hypothesis, so it is worth ending with a consideration of the methodological debate surrounding the methods of testing theories. In Chapter Five the research method is set out, describing the extensive use of econometric techniques, numeric time series data and hypothesis tests. This locates the research epistemology within positivism and the allied views of deductivism (or the testing of a theory), rather than inductive (or the identification of a new theory).

The approach of using secondary data, the daily values of various share indices, means that the research is quantitative rather than qualitative but also is dependent on the suitability and more importantly, the accuracy of that data. Problems arising from use of secondary data in this research are various. The data may not be correct, but the working assumption is that the data is valid. The data may not be comprehensive, as borne out later in that not all industry sector indices have full data sets for the period under review, resulting in only a sub set of the sector indices being tested. There may be gaps in the data, as evidenced by lack of index values for Bank Holidays. Additionally, the analysis is univariate and so there is no scope to identify other factors that may have predictive power in modelling share indices.

All of the tests in the analysis chapters are of the hypothesis type, with a null and one or more alternatives. In all cases the 'decision' is based upon 5% significance, so the conclusions could be different if (say) 1% or 10% were used. Additionally, there is scope for Type I and Type II errors which could impact the conclusions arising from the analysis. The use of significance tests also has the scope to imply a spurious sense of accuracy, in that test results can be displayed to (say) ten decimal points

The analysis is performed on a sample of daily data over a period of one year. Long term trends may thus be lost and equally, short term relationships may be missed if the data is not segmented or of higher frequency. These issues are discussed in more detail in a later chapter.

One of the many criticisms of quantitative research is that it ignores the role of people or individuals in the theories under consideration. To an extent this is countered by Hayek's views discussed above and to an even greater extent, by the growth of behavioural finance which is currently attempting to address that issue. This criticism could be taken even further, in that the choice of univariate data analysis and hypothesis tests means that all other research approaches are being rejected. Aspects of the Myners Review could be examined by case study, panel data, with a regulatory focus, using grounded theory, via structured or unstructured interviews, experiments or almost any type of research method. The approach followed here does not address those methods, but follows in the methodological footsteps of the very many research papers that have been produced to consider market efficiency.

CHAPTER FOUR THE RESEARCH PROBLEM

4.1 Position to Date

4.1.1 Context

The preceding chapters could be seen as separate or unique and freestanding aspects of finance. Market efficiency, or rational markets, or the Efficient Market Hypothesis, or even the slow transmogrification of efficiency into behavioural finance is a central part of financial economics. It is well understood, extensively researched and has ramifications for all types of investor as well as linking to corporate finance and regulation of the market. Strategic asset allocation has had lower prominence in finance research, although this is possibly offset to an extent by both academic actuarial research and vocational research by market practitioners. It has developed a certain focus by its use in performance measurement in that much of the research activities tend to be post hoc rationalisation, such as attribution analysis, rather than as a decision making process. Both efficiency and strategic asset allocation are pulled together in the Myners Review (2001), with the implication that markets are not efficient, or rather than certain asset classes may not be efficient and that strategic asset allocation decisions are possibly dysfunctional or at least driven by consensus due to benchmarking. Finally it is apparent that the overarching methodological approach to much of the US-centric research in these areas tends to be post-Vienna Circle logical positivism, with the development of hypotheses that generate meaningful predictions.

This chapter sets out to conflate these various strands and in doing so, outline the research question. To an extent it is therefore a brief summary of the earlier chapters, but it is also an attempt to pull together the various themes that have been discussed.

4.1.2 Efficiency

The starting point of the synthesis of a research question or questions is market rationality. The Efficient Market Hypothesis has been the subject of innumerable research papers over the last forty years. For the first two decades there was growing acceptance of EMH's validity by the academic community, with the tacit assumption that developed capital markets were almost certainly weak-form efficient, were probably semi-strong form efficient and were possibly fairly strong-form efficient.

Tests of efficiency were even used to check on the progress of the capital markets of developing countries. At the same time, the hypothesis was rejected by the investment community. Fund management as a sector was growing in size and scale, there was an increase in the demand for pensions and indirect investment via mutual funds and investment trusts and unit-linked investment. Salaries for this sector were high and rising and the fund manager's competitive advantage was based around the concept that they could beat the market, or at least beat their competitors, by successful timing and stock picking. It would have been anathema for a fund manager to accept large bonuses whilst stating that their performance was based upon luck rather than skill.

The second two decades saw these polarized positions begin to break down. Research papers began to raise doubts about the Efficient Market Hypothesis. The identification of anomalies such as the size effect, time effects, unexpectedly high volatility, mean reversion and other issues started to raise doubts about market rationality. Some of the doubts were rejected in terms of the asset pricing models, blaming the models and adding new indirect variables to remove the efficiency anomalies. The growth of behavioural finance gave momentum to EMH's rejection and the last few years have shown classic signs of a paradigm shift. In the fund management sector, over the same period, the opposite has happened, although this has been covert rather than overt. Led by the US markets, but mirrored in the UK and other developed economies, there has been significant growth in passive investment generally, and in tracker or indexed funds and benchmarked funds specifically. A switch from active management to the passive management of funds is tacit recognition that the fund managers could not consistently beat the market, or their competitors. In the same way as academics now cover a spectrum from full rejection of EMH, through acceptance of weaker efficiency to full efficiency, the fund management sector now has 80% of funds based upon the unstated assumption of efficiency with the unwillingness to let go of active management completely evidenced by the use of core and satellite funds.

With few exceptions, the bulk of the research on market efficiency has been at the individual share level or with a share index that describes or acts as a proxy for the market. Where efficiency tests have been at a market or index level, they have still been performed with the intention to consider shares. Therefore, there has been very little research on asset classes and whether they are at the correct level. Even the consideration of attribution analysis, whilst using Strategic Asset Allocation as the focus, has ignored efficiency in relation to asset classes in that it has had actual performance as its focus. Similarly, consideration of portfolios in some of the later tests has been within an asset class. For example the use of (say) ten portfolios ranked by size and rebalanced each year has reached conclusions about company level efficiency or size effect or fund manager performance. In all of the papers included in the earlier literature review and strategic asset allocation chapters and also those read but not included, there has been no reference to or discussion of the efficiency of asset classes.

Within the fund management sector this asset class myopia is less evident. Many finance houses offer sector-specific funds (e.g. emerging economies, or Pacific Rim, or whatever). Additionally, many actively managed funds employ a structure where analysts specialize by sector. Despite this, the focus or intention would seem to be one of gaining more information about, and thus being better informed of individual companies, rather than asset classes.

If academic research and the fund management sector both tend to ignore efficiency in relation to asset classes, then Myners' suggestion of trustees letting managers have the space to be active in relation to certain classes may be perceptive. Thus the primary research question to be addressed has asset class efficiency as its locus.

The literature review has highlighted numerous approaches to testing stock markets for efficiency. These tests have been applied to a variety of 'meta' asset classes such as shares, bonds, derivatives, currencies, real estate, cash markets and others. The volume of testing and published research papers has probably been the most intense in relation to equity markets where the large variety of tests utilise one or more aspects of a multi dimensional approach. For instance, there is univariate analysis, based on early statistical techniques such as autocorrelation or runs tests, followed later by ARIMA and Box Jenkins and more recently using ARCH and GARCH and the various manifestations such as in mean or exponential. Alternatively there are multivariate methods: seeking links between prices or returns and either macro economic variables (Gross Domestic Product or interest rates or equivalent) or micro level independent variables (e.g. dividends). Much has been written on event study methodology as a test for semi-strong efficiency, with its extension into comparing speed of response and lead/lag relationships between underlying investments and their derivatives.

Market efficiency has also been a major consideration when related to asset pricing models, the growth of the latter becoming more sophisticated and going through cycles of supporting the concept of efficiency, then identifying possible anomalies and more recently identifying those anomalies as mistakes in asset pricing models. Although not formally labelled as studies in efficiency, the recent focus on more practical issues such as attribution analysis and performance persistency, often based on managed investment, has added a further approach. This reflects the shift in definition of strong form efficiency towards that of the professional versus the individual investor.

4.2 Area for Analysis

4.2.1 Myners Review and asset allocation

The report of the Myners Review is very clear on strategic asset allocation, as the following four paraphrased extracts show:

- peer group benchmarking has no satisfactory justification;
- only 1.5 basis points out of 47 in the value chain go to strategic asset allocation;
- commonality of investment policy amongst funds;
- asset allocation driven by historic convention.

This strongly held view is that the strategic asset allocation process is not working; insufficient attention (and as a consequence, expenditure) is paid to the process of systematically deciding what percentage allocations are to be made to each asset class; advice on the allocations to pension fund trustees is chiefly from two very similar sources and results in very similar or even identical percentage amounts; and the allocations are slow to change, with trends being long and stable. In effect, the strategic asset allocation process evidences herding, a term normally used to describe share level investment activity, and results in excessive benchmarking. Many observers have commented on the behavioural justification for this: the fund manager may wish to be different so as to beat competitors, resulting in increased market share, greater income, higher professional standing or increased profits, but the risk of getting it wrong, of being significantly worse than the herd from using some form of quasi-contrarian asset allocation has severe implications. The most common outcome of the fear of failure thus is the desire to stay in step with the crowd. The Myners Review recognized this, with its opening quotation from Keynes' General Theory of Employment, Interest and Money (1936), "Wordly wisdom teaches that it is better for reputation to fail conventionally than to succeed unconventionally" (prefix to submission letter).

Finance research shows that the strategic asset allocation process does not generate a great deal of interest, or rather it does generate huge interest but only at the meta asset class level of equities or currency or bonds. Thus the main area for consideration in this paper's research question will be to examine strategic asset allocation in relation to the concerns of the Myners Review.

There could be numerous approaches to considering how funds decide their percentage mixes between asset classes. This could look at:

- the role of advisors/consultants
- the various models linking risk and return
- a case study such as consideration of Boots' decision to put all of its pension fund assets into gilts
- the home country bias
- efficiency studies comparing shares, bonds, property, cash and other investment types.

A second method could be based around performance attribution, in that it is here that research, both academic and commercial, has studied the results of the allocation decisions. The problem with this however, is that it does not address the process of decision making. The research papers for both the UK and the USA show clearly that allocation decisions are of high importance, but are silent when it comes to looking forward rather than back.

A further focus could follow the well researched area of funds' performance persistence. This is topical, as seen in Charles Rivers Associates' conclusion that performance persists; Blake et al's conclusion that the performance persistence only applies to poorly performing funds; Tonks' most recent conclusion (2005) that fund performance does persist. It is also of relevance to policy makers, in that the Financial Services Authority seeks to decide whether past performance should be displayed on its web site. This area of research activity will not be considered here as it is retrospective in the same way that performance attribution is, the focus is on the outcomes of fund management. Additionally it does not consider the strategic asset allocation decisions, only the results.

4.2.2 Tests of efficiency

The area of research that is of interest is market efficiency. This is particularly so in that it would seem that the finance research community is undergoing a change in its attitude to or perception of the Efficient Market Hypothesis. This is a slow, long term shift as EMH was so entrenched and behavioural finance is not yet its complete successor chiefly because there is no single unifying theory, model or hypothesis that replaces efficiency, other than perhaps the rejection of rationality. The vast amount of research that has been produced over the last four decades has tended to look at a market as described by a share index, or has studied either individual shares or non-sectoral groupings of shares. There is little evidence of any great amount of finance research which examines industrial sector or sub-index efficiency. This lack could explain why there are so many mixed messages about efficiency. If the Myners Review's suggestion about active management for areas where active management is deemed more appropriate is valid, then this means that within the equity market there are some investments or rather sectors, that are efficient and some not.

There is no automatic or generally accepted definition within the investment community of what an asset class is. In a globally diversified portfolio the range of asset classes is very large, encompassing fixed interest stock, equity, cash and a wide range of fixed assets; all of these being a combination of domestic and overseas. The consideration of whether some asset classes are efficient and others not efficient should therefore examine all asset classes available to the global investor. Such a comprehensive examination would be so vast as to be well beyond the scope of this study but fortunately the purpose is not to identify each class that is or is not efficient. Instead, the approach is just to examine if there is a mixture of asset classes, some of which are efficient and others that are not, thus supporting or rejecting the view of the Myners Review that active management should be practiced where it could be of benefit.

For the majority of fund managers, we have already seen the issue of home country bias. Thus this study will just focus on one country's asset classes, with the domestic market being the UK. Within that marketplace this study will ignore markets in fixed interest stock, property, cash and near cash, currencies and other markets which are often studied as asset classes in their own right. The most common asset class considered by historic EMH tests in the finance journals tends to be equities. Thus the approach here will be to consider UK equities. Within that large asset class it is common for fund managers to see UK equities not as a single class but to break it down by industrial sectors. The best vehicle to examine equities by sector would therefore be a UK share index that splits the majority of the market by industrial sector. Hence the following analysis uses the FTSE All Share Index and its component sub-indices, with the desire to establish if some of the sectors are efficient whilst others are not.

The fund management sector puts much effort into industrial sector classification, but this has not been mirrored by the finance research community. Therefore the main analysis will be on strategic asset allocation in relation to industrial sectors, or rather sub-indices that aggregate up to a single market index. The UK equity market's sub indices will consequently be examined for efficiency. In selecting these sub indices as the focus for the examination, other levels of aggregation are by definition being rejected. For instance, the following could all be seen as equity asset classes, depending on the viewpoint or requirements of the user, given that the market portfolio could include all assets in the world:

- all equities in the world, as an asset class within a global managed fund that may also include bonds, etc from numerous countries;
- all equities in a region, as an asset class based on (say) the Pacific Rim or the European Union;
- all equities in a type of economy, such as emerging economies;
- all equities in an overseas country, e.g. a UK based USA fund;

- all equities in a domestic fund;
- all equities in a domestic fund by style, such as UK growth or UK income;
- all equities in a fund by sector, for instance High Tec.

It can therefore be seen that some focus, occasionally down to the sector level is utilised in the production of mutual fund products that target various niches, but tests for efficiency or persistence or application of asset pricing models tend to be common at the higher levels of aggregation and then reduce in popularity as areas of aggregation become more and more focused. Similarly, fund managers' use of benchmarked or indexed funds commonly have a satellite fund to take advantage of perceived inefficiencies in various areas, but again these are not extensively researched. The focus of this research at the lowest level of aggregation, that of the 29 sub indices within the UK market's FTSE All Share index, makes the analysis unique as far as the literature searches undertaken reveal.

For the purpose of this study, efficiency in relation to equity prices (or rather UK equity sub-indices) will be defined as set out in Fama's 1991 review; namely:

> The market efficiency hypothesis (is) the simple statement that security prices fully reflect all available information. (The) strong version is that information and trading costs are zero (and) the weaker or more sensible version (is) that prices reflect information to the point where the marginal benefits of acting on information do not exceed the marginal costs. (p. 1575)

There are many varied approaches to testing for efficiency. Original strong form tests are based around the ability of the professional manager and her performance, as shown in the current debate about performance persistency. If she can consistently beat the market or at least the competition, then there must be inefficiencies in pricing that are being used to achieve that superior performance that the competitor fund managers have failed to utilise. Unfortunately and as highlighted above, these tests are performed at the aggregate level and there is no consideration of the role of asset classes or sub-indices.

A second set of tests have built up around the concept of event studies. This would be difficult to use in relation to a set of share indices as the events normally used (e.g.

share splits) are company specific in terms of the event date. In order to follow this approach there would need to be events that impact on a variety of industrial sectors. That concept is feasible but the events themselves would most likely be macro economic in nature, such as unexpected changes in oil prices or interest rates. The accepted approach to this type of activity is usually a multi-factor analysis linked to some type of asset pricing model. There is no intention here to consider asset pricing and so that methodology is rejected.

Linked to the above, but also used in comparing different countries' indices at an aggregate level is the use of tests to examine if individual markets are cointegrated. This could be a plausible approach in that, for instance, performance of (say) the retail sector may depend on another sector. Earlier cross correlation tests and more recent sophisticated techniques could identify cointegration, but if that relationship is not lagged then, although interesting, it would not be of great help to the fund manager, other than assisting diversification. Of course, if there is a lagged relationship between two indices, then this could possibly imply inefficiency in the dependent sector. This type of approach could mirror research that compares prices of underlying assets with those of a derivative to establish lead-lag relationships.

4.2.3 Randomness in sector indices

The area that is possibly the most fruitful is that of studying trends in the various indices. Research in market efficiency has considered this approach in numerous papers. These seek autocorrelation, long term trends covering a century, short term trends with the growth of high frequency data, mean reversion, time series with memory and random walks. Of the variety of tests, it is the concept of random walks that would seem at this stage to be of the most use. If a time series is random, then the next period's value cannot be forecast. If it is not random, then there may be some data generating process that can be identified and used to forecast the next period's value. In effect, if the time series for a sub-index based on an industrial classification does follow a random walk, then there is no point in the fund manager using active management for that sector as the index is strong efficient and the strategic asset allocation should be passive. If the time series for a sub-index is not random, but the costs of taking advantage of this are greater than or equal to the benefit of having identified the data generating process, then there is no point in the fund manager using active management for that sector as the index is weakly efficient and the strategic asset allocation should be passive. Finally, if the index is not random and the benefits outweigh the costs, then that industrial sector may be inefficient and could be managed actively. Thus the three possible outcomes mesh well with the Myners Review's desire for active management where appropriate.

It must be recognized that randomness in the sub-index's time series would imply efficiency but that the opposite is not necessarily true. A series may not be random but the values or returns of that index may still be efficient. Given this, then the tests to be used are in theory tests for random walks, not efficiency. Despite this, the main research question will be to examine the UK equity market to examine if the various industrial sector share indices are random, warranting passive fund management for that sector, or non-random and either weakly efficient or not efficient, the latter warranting active management.

Tests for random walks are very much in step with the positivist or post-positivist school of thought described in the earlier discussion on methodology, in that the main tool for the various studies of randomness or data generating processes is the hypothesis test. The randomness or non-randomness will not be explained by the tests (although it might be interesting to consider if there are any common traits between the random indices, if any), a position that mirrors well the view of Hayek (1969) and his concept of the interdependence of men whose interreactions are "repercussions transmitted by the network of market relations" (p. 58).

The consideration of the random walk hypothesis has been central to tests of efficiency from the start. Initial research tended to have runs tests or autocorrelation at their core. The development in the nineteen eighties of chaos theory has given rise to additional tools that can supplement the early methods. Similarly, the development in the seventies of the Box Jenkins method for time series analysis and the recent growth of ARCH and its manifestations give a wide range of analytical techniques to assess the question of randomness. The intention is to address the main research question of randomness in sub indices by means of these tests. For each sector sub index, the index values will be converted into a log normal return and tests applied to establish if a data generating process can be identified. This will be in three stages. Firstly the time series of returns will be tested for stationarity and randomness. There are three forms of the random walk hypothesis: a pure random walk, where the next period is just white noise; a random walk with drift, where the next period is a non-zero constant plus white noise; and thirdly a random walk with trend, where the next period is a function of the previous period's value plus white noise. Obviously the final two may both be evident, resulting in a random walk with drift and trend.

The second stage will be to seek the appropriate data generating process if the time series is identified as non-random. This could be multivariate, but for the purpose of this study, the focus will remain univariate, depending therefore on the range of techniques available. This will be informed by other finance research undertaken at a market level and hence apply the techniques to the sub indices that have been utilized to examine the meta asset classes via a single market index.

The third stage will follow the method of Al Loughani and Chappel (1997) and test the residuals from either the random walk or the data generating process. If the residuals indicate that the process does not fully explain the time series, as evidenced by not being independent and identically distributed, then that process will be rejected and a further one sought. Only when randomness or an appropriate process is identified and the residuals are independent and identically distributed so that they contain no further unexplained dimensions will the particular sub index be regarded as being explained. To prevent duplication in later chapters 'explained' will be taken to mean that the sample evidence supports the hypothesis that the index's returns follow a suitable identified process which produces residuals that are independent and identically distributed.

There are two implications of this that require further reflection. One is that once a data generating process has been identified and has no 'message' in the residuals it will not be considered further. Despite the tests, it may be the case that there is another process that better describes the data. The sheer volume of the different processes is such that it allows production of an almost infinite number of tests, even without consideration of multivariate analysis. The second implication is that the method could be open to the criticism of data mining. To preclude this, the tests will follow a structured approach rather than a broadcast or scatter gun method. Secondly, as mentioned above, the choice of data generating processes will follow those identified in earlier finance research as being appropriate to the study.

It is envisaged that once all the sub indices have been analysed, there will be three broad groupings.

- Some will correspond to one of the three versions of a random walk and will be candidates for passive management as the randomness will infer efficiency.
- Some will have one of the various data generating processes that could be regarded as the maintained regression explaining the actual data.
- The remainder will not be random, but it may be the case that no suitable data generating process has been found. In which case nothing can be concluded as to their suitability for active or passive management.

For the second category, namely those where a data generating process has been identified, it will be necessary to compare the strength of the relationship with the excess costs of active fund management over and above the costs of passive management. This should establish whether, despite the non-randomness, the index is weakly efficient and therefore to be managed passively, or not efficient and hence a candidate for active management.

Research on efficiency has included short time horizons measured in days, through to long periods measured in tens of years. This paper will examine the daily sub indices over a period of one year. The choice of length of time will automatically have ramifications, for instance a twelve month period may be too short to establish memory of the type identified in rescaled range analysis. Thus a conclusion of randomness may be wrong. On the other hand, a time series may be chaotic in the sense of going through transitional phases from randomness to functional to behavioural to deterministic. The choice of one year may just pick up one of those phases and thus reach the wrong conclusion. Or the period may be too long: 250 days may 'hide' a shorter period when an industrial sector becomes deterministic and suitable for active management. Techniques exist in time series analysis for structural breaks but at this stage the size of the problem is much too large for a research study of that scale.

A second problem exists, linked to both the study of efficiency and some of Hayek's observations about free markets. If an industrial sector's index is identified as having some form of deterministic relationship, then the fact that it existed historically does not mean that the researcher, analyst or fund manager can infer that it will continue to exist into the future. This should not be a major problem as the identification by many funds of an inefficient sector would (if other aspects of efficiency are correct) result in their actions bringing that particular index back towards weak efficiency. This and the earlier comment about trends or relationships of less than one year are of course not fully relevant to a study of strategic asset allocation due to their shortness of time. Instead they have ramifications for the more short-term tactical asset allocation process and as such are not considered here.

If the previous chapters or the current chapter could be synthesized into a single research question, then this study's research problem would be as follows. To undertake univariate time series analysis examining one year's data on the various UK equity sector indices to establish if they are random or have a data generating process, so as to make inferences about their efficiency which could inform the strategic asset allocation decisions in terms of use of active or passive investment management.

CHAPTER FIVE METHOD

5.1 Tests for Random Walks

5.1.1 Randomness, efficiency and IID residuals

The second section of the literature review looked at some of the tests that have been developed for research into market efficiency. The purpose of this chapter is to examine in greater detail just a few aspects of this vast area of literature. This consideration will inform the analysis to be followed later and will be based solely on univariate analysis. Hence there will be no discussion of asset pricing models and no links with macro or micro economic factors. Similarly, the focus of attention will be on the random walk hypothesis, so there will be no discussion on other aspects of efficiency such as event study research or the various time or size effects.

One of the triggers for the method to be followed in this thesis is the paper by Al-Loughani and Chappel (1997). They test the FTSE 30 index for randomness; the tacit assumption being that if the index is random then it will be weak form efficient. Their conclusion is that the time series is explained by a GARCH (1,1) model, and as such is not a random walk and is therefore not efficient. Whilst this is not a unique approach, the interesting extension to their paper is the use of the BDS test of independent and identical distribution (IID) in the residuals of the model, as set out in Brock et al (1996). The purpose of this (then) fairly new test is to examine if one of the assumptions of randomness is satisfied, namely that of the regression's residuals being independently and identically distributed.

The random walk model is in the format

$$\log P_t = \log P_{t-1} + \varepsilon_t \qquad (5.1)$$

with P as the value of the FTSE 30 share index and ε_t a random error. Dickey Fuller and Augmented Dickey Fuller tests were used on the above format and its first difference (return equals a constant plus white noise) to establish that the series is non-stationary in the index value format but is stationary or I(0) in the first difference or return format. The first difference return format was then regressed and the constant found to be (only just) not significantly different from zero at 5% significance. Thus far the initial assumption is of a random walk, but Al-Loughani and Chappel then applied the BDS test which rejected at 5% the null of independently and identically distributed residuals within the regressed returns, suggesting "there is some further unexplained structure in the data" (p. 15). Use of a GARCH in Mean (1, 1) format gave the results:

$$\Delta \log P_t = .0002 - 16.028 h_i^2 + u_t \qquad (5.2)$$

$$h_i^2 = .00001 + .0816 u^2_{t-1} + .7386\, h^2_{t-1} \qquad (5.3)$$

with u as the residuals and h the conditional covariances. The constant in (5.2) was now significant and their conclusion was that the series was not a random walk. Finally, the residuals were again examined via the BDS test and this time found to be independently and identically distributed.

The use of unit root tests and GARCH was not a new approach, but application of the BDS tests was. Unfortunately there were issues in the approach that warrant further consideration. Firstly, as discussed in the previous section, the paper only considered a single index and did not extend the analysis to a sector level: their conclusions of non-randomness may not be valid for all industrial sectors. Secondly, the regression as set out in equation 5.2 was tested for a unit root on the assumption that the time series was a pure random walk (i.e. the constant does not differ significantly from zero): a more comprehensive analysis could have considered not only the pure random walk but also a random walk with drift and/or a random walk with trend. Thirdly there is the linkage between randomness and weak form efficiency: non-randomness does not necessarily mean non-weak form efficient (see for instance Milionis and Moschos (2000)), although it is generally accepted that the opposite is true, namely that if the series is random then it cannot be forecasted. This random versus efficient issue will be considered later in relation to the use of the 1991 definition of strong and weaker efficiency.

The use of the BDS test by Al-Loughani and Chappell was innovative and can be taken further. For instance, Opong et al (1999) apply this and the Hurst test to the FTSE All Share Index and the 100, 250 and 350 indices. Although this paper did not follow any unit root tests or run regressions for a random walk, the conclusions were that

> the FTSE Index series examined are not IID. The results indicate that the FTSE stock index returns series is not truly random since some cycle or patterns show up more frequently than would be expected in a true random series. A GARCH (1, 1) process appear to explain the behaviour of the index series. (p. 270)

Although not of direct relevance here, an additional conclusion which supports the use of the BDS test was that it was much more powerful than an alternative test based on Rescaled Range (or R/S) analysis, an earlier Chaos-derived forecast testing technique.

Blasco and Santamaria (1996) followed a similar path to Opong et al in testing the Spanish markets for independent and identical distributions in returns, but as discussed above, broadened their approach by breaking the market down into nine main sectors. Their BDS tests strongly rejected "the hypothesis that weighted-index returns are IID, therefore the possibility of predictable behaviour can be allowed" (p. 405). In effect, this and the Opong et al papers are using the BDS test differently from the Al-Loughani and Chappell method in that they are using the lack of IID as the evidence of predictability and thus non-randomness, compared to the former's application of the IID tests to the residuals after the regression of the random walk process. They did however acknowledge this in that:

> it is appropriate here to note that the rejection of IID, as Hsieh (1991) points out, does not contradict market efficiency directly because this fact does not imply the predictability of forecast errors. (p. 406)

The 2000 paper of Hamill et al to an extent duplicates the previous example, but applies the tests to the single Irish Stock Exchange index. The conclusions being that the BDS tests reject IID in the returns series and also reject IID in the residuals of a GARCH(1, 1) model. Rather than concluding a lack of efficiency they state that the evidence points to "a chaotic process, non-linear stochastic process or linear stochastic dependence" (p. 699).

5.1.2 The BDS test

There is therefore, a small body of research that is concerned with testing equity markets for efficiency via a random walk process, utilizing the BDS test for examination of the assumption of identical and independent distributions. Its relative newness and the reference by Hamill et al to chaos warrant further consideration of this technique. A summary is provided by Brock (2000) where chaos is defined as the "study of deterministic difference equations that display Sensitive Dependence on Initial Conditions to generate time paths that look like random behaviour" (p. 1). As part of that body of theory, not all of which has entered the main stream financial economics tool kit, the BDS test was developed to examine the residuals generated from a predictive model less the predictor variables. If the predictive model is valid "then the residuals should be unforcastable using histories based upon observables" (p. 3). Its designated focus on residuals thus makes the above work by Hamill et al or Blasco and Santamaria slightly at variance with the original concept as they apply it to the returns directly, rather than a set of residuals. Brock draws parallels between the BDS test and Q-tests for ARIMA models as a measure "of the adequacy of fitted models and evaluating whether the evidence warrants a more costly exploration of alternatives to the null hypothesis might be warranted" (p. 4).

The original test was set out by Brock, Dechert and Scheinkman in1987, hence the title the BDS test, but the version used in this research is based on Brock et al (1996). BDS is a non parametric test for serial dependence (or alternatively a non linear structure) in time series analysis, where the series must be stationary, with a null hypothesis that the data generating processes are independent and identically distributed (IID). The alternative hypothesis, central to its use here, is "an indication that the model is misspecified" (p. 198). Failure to accept the null is important for tests of market efficiency in that their "statistic (is) easy to interpret as a measure of the presence of 'pockets of predictability' over the whole space" (p. 200). Much research in finance shows that returns, even if using log normal returns, do not produce a normal distribution; this should not be an issue with the use of the BDS test as it does not require higher moments to exist. In fact "this is important in financial economics because of the problems that thick tailed distributions can cause for many test statistics" (p. 200). One of the first uses of the BDS test in relation to efficiency was that of LeBaron (1992, cited in Brock et al 1996)), based on traders being more concerned with finding pricing inefficiencies than econometricians, an approach that they refer to as a 'parameterised version of the Efficient Market Hypothesis'.

Application of the BDS test for IID is best explained by examination of its use. For instance, Chen and Yeh (2002) refer to "one of the most frequently used tests for non-linear dependence is the celebrated BDS test" (p. 228), defining the two parameters required as the distance parameter (or ε standard deviations) and the embedding dimension. This is explained in Blasco and Santamaria (1996) whereby the distance parameter ε is the distance between any pair of points in the data's time series, or rather the residuals. The probability that any pair are separated by less than or equal to that predefined distance is given by $C_{m,T}(\varepsilon)$, known as the correlation integral and based on Grassberger and Procaccia (1983) such that

$$C_{m,T}(\varepsilon) = \Sigma I_{\varepsilon}(x_t^{m}, x_s^{m})\ [2/T_m(T_m - 1)] \quad (5.4)$$

where m is the embedding dimension in the m-dimensional vectors $x_t^{m}=(x_t,\ldots x_{t+m-1})$. Al-Loughani and Chappel (op cit) view the correlation integral as "the fraction of all m-tuples in the series which are 'close' to (within ε of) each other" (p. 175).

Opong et al (1999) refer to this as "the probability that any two points are within a certain length, ε, apart in phase space" (p. 271). Thus as the researcher increases or selects higher values of ε, "the probability scales according to the fractal dimension of the phase space" (p. 271).
Equation 5.4 is reformulated by them to give

$$C_{m,T}(\varepsilon) = 1/N^2\ \Sigma Z(e - |X_i - X_j|),\ i \neq j \quad (5.5)$$

where "the function Z counts the number of points within a distance ε of one another" (p. 273), as described in the m-dimensional vector above.

The actual BDS statistic is defined as

$$W_{m,T}(\varepsilon) = T^{½}[\ C_{m,T}(\varepsilon) - C_{1,T}(\varepsilon)^{m}]/\ \sigma_{m,T}(\varepsilon) \quad (5.6)$$

which has a normal distribution if the series has at least 500 observations. Subsequent analysis in later chapters is based upon time series of 251 observations but that is not a major issue. For instance, Hseih (1991) expresses the concern that in long time series the BDS test may reject the null hypothesis of independent and identical distribution due to structural changes. Under this condition structural breaks are recommended so that sub-periods are tested instead. Sample size is also examined by Johnson and McCelland (2002) who compare results of BDS tests with a newer proposed version known as the GD test. Although the two tests are not identical in that GD "is insensitive to dependence among residuals that do not effect the regressors...(whereas)... BDS should have better power" (p. 3) they do show that GD outperforms BDS to the point that "for data sets with 250 observations, the BDS test detects the dependence in the residuals, while the GD test shows almost no power" (p. 12).

In using the BDS test to analyse residuals from a model for independent and identical distribution, the research has to identify the two parameters suggested above, namely the distance between pairs, or ε and the embedded dimension, or m. In their analysis of the sensitivity of the choice of ε, Kocenda and Briatka (no date available) conclude that:

- a range of (.25, 1.00) gives low power to the test
- for short time series the range (.50, 1.00) is preferred
- a range of (.50, 1.50) is better than (.25, 2.00) for dimensions m2 to 5
- a range of (.25, 2.00) is preferred for dimensions m= 6 to 9.

The later chapters which utilize the BDS test have a dimension of 4 so a range of 0.5 to 1.50 is identified as the best option. Many papers, including those referred to here, show the BDS test statistics for a variety of ε, e.g. 0.5, 1.0, 1.5 and 2.0 as in Opong et al (1999). The number of tests undertaken in the analysis of this paper invalidates that approach and so the default is set and statistics are only shown for ε of 0.7. The second parameter, that of the embedded dimension m, is normally identified by consideration of the time series' autocorrelation lengths. For subsequent calculations this paper will use a range of 2 to 4 for the embedded dimensions.

The BDS test statistic as generated by Equation 5.6 above approaches zero as the residuals' distribution tends towards IID, so the null hypothesis of a series of residuals being independently and identically distributed is based on the statistical significance of the statistic being zero for non rejection or not zero for rejection. Consensus amongst users is that rejection of the null means that the modelled data generating process has not been correctly specified and that there is a non-linear but unidentified relationship.

5.2 Other tests for randomness

5.2.1 Methods of testing

Although the technique will not be used here, it is interesting to compare the modern chaotic approach of BDS tests with Bartlett's goodness of fit test. This 1954 method is used by Lee et al (1998) to test efficiency of a variety of stock markets. The link to BDS is that Bartlett's test was "to examine whether the first difference of stock prices follows a white noise process" (p. 62). The process compares autocovariance functions and frequency domains, mapping a white noise model against outcomes from the actual time series. Thus there are resonances between Bartlett's and BDS tests, despite the difference of almost half a century and the major steps taken in univariate time series analysis. Out of interest, Lee et al studied indices in the nineteen twenties and found that the European markets more efficient (weak form) than those of North America. A conclusion possibly explained by "...the immaturity of the Canadian and US markets" (p. 63). Of more direct interest, they concluded that Bartlett's goodness of fit test for white noise "has some desirable intrinsic and operating properties, compared with other approaches such as the variance ratio test or the mean reversion test" (p. 63).

There are many other approaches to testing for random walks. For instance, Mills and Jordanov (2003) examine the UK market using Markov Chains. Their interest is on the size effect as an indicator of inefficiency. Fictitious portfolios are generated from the FTSE-Actuaries All Share index and are tested via the use of Markov Chains to allow for the return time series to be non-linear (a methodology that will not be examined here). Their results do show a size effect, with smaller sized portfolios generating the higher returns, but of the ten categories ranked by size:

> the returns of the two smallest and four largest size portfolios were predictable, but only the two largest were predictable in the direction suggested by the bubbles and fads alternatives to the random walk hypothesis...only the two largest portfolios rejecting the random walk hypothesis. (p. 813)

Hence they claim that there is a size effect in the UK market, but that this is for the largest firms only, with the eight smaller deciles following a random walk.

Alternatively, Summers et al (2004) examine weak form efficiency in terms of technical analysis by means of neural network models. Their choice of method being firstly, ease of programming and secondly, to allow "...for non linear relationships present in the data without intervention by the modeller" (p. 211). Their results show that trading rules from early periods can "be predictive at a later date and, rather unexpectedly, can even exceed the predictive power of rules derived from more contemporary data" (p. 214). Although unstated, this could mean the lack of strong efficiency, but they note that changes in particular an increase in volatility "results in a reduction in the signal to noise ratio, which masks the information content of the data" (p. 214), so a possible contender for weaker efficiency.

A third approach utilizes the Vector Autoregressive Model (VAR). Jung and Boyd (1996) compare this with the Error Correction Models and the use of Kalman Filters as a method of forecasting share prices in the UK, using a single composite index. They found that Error Correction Models tend to perform best but the multivariate approach "...using macro economic indicators as independent variables..." (p. 284) did not relate to their study's univariate methodology. Vector Autoregressive Models are also used by Cheung (2000) to explain the transmission of shocks across various markets (see earlier comments on cointegration). The findings of this paper suggest that "US stock volatility played a leading role in the transmission of stock volatility to other major stock markets like...the UK" (p. 771). Cointegration was also examined by Han (1996) in relation to present value models, finding that there was no cointegration between share prices and dividends. There was however, the possibility that "rational bubbles might exist in the deterministic component of [a] stock price" (p. 267).

5.2.2 Data generating processes

If it is the case that a time series of share prices or indices, or rather their returns, are not random, then there is a wide range of models that can be tested against the observable data to determine the appropriate data generating process. A useful summary of these is supplied by McMillan et al (2000) although it must be noted that the focus is on forecasting UK stock market volatility rather than returns or values. They analyse both the FTSE 100 and the UK FTA All Share indices (again the approach is at an aggregated market level rather than sectors) and compare the performance of a wide range of forecast methods: historic mean, moving average, the random walk (although only the pure version, i.e. ignoring drift and/or trend), exponential smoothing, exponentially weighted moving averages, regression and GARCH (including TGARCH, EGARCH and component-GARCH versions). The ability of the ten models to forecast volatility is tested by means of Mean Error, Root Mean Squared Error and Mean Absolute Error and additionally they apply Mixed Mean Error statistics to weight under-predictions more heavily than over-predictions.

Although the McMillan et al paper is concerned with forecasting volatility, their conclusions can inform the selection of appropriate models for this paper. Thus it is interesting to note the following paraphrased quotes from their results. (To prevent extensive quotations it should be noted that some conclusions may only apply to part of a series, or one level of data frequency or one measure of error testing. Despite this the outcomes are of much use.)

- All models over-predict volatility except the random walk.
- Random walk provides the smallest absolute Mean Error.
- The random walk model dominates
- The gain in performance of the random walk model over all other models is considerable.
- Simple regression and historical mean perform poorly.
- Performance of GARCH and smoothing models is similar.
- Good performance of recursive exponential smoothing.
- Poor performance of non-recursive GARCH and TGARCH.
- Poor performance of exponential smoothing.
- On the basis of Root Mean Squared Error there is far less divergence.

- For daily series all models are superior to historical mean and simple regression.
- Random walk performs poorly on Root Mean Squared Error.

It can be seen from this selection of results that there is no clear, unambiguous conclusion. Random walks perform well, unless tested via the Root Mean Squared Error, or if the data is of high frequency. GARCH type models are consistent and the simple models of historic mean and regression are poor. Parts of their conclusions state:

> For the symmetric loss case, the random walk model…is vastly superior. …For all frequencies the most consistent forecasting performance is provided by moving average and GARCH models. (p. 448)

The relevance of this work to the study of sector sub indices reinforces the use of the random walk model and indicates that the logical next step if a series is not random should be a member of the GARCH genre.

Within the following analysis chapters, GARCH will be the automatic assumption for a data generating process if the series is stationary but not random. The method is well typified by Siourounis (2002) in a study of the Athens Stock Exchange (ASE), where the following steps are followed:

- The ASE General Price Index itself, and expressed as a log return, is tested for a unit root;
- The error terms from a random walk process were found to be time dependent;
- A GARCH process was suggested to explain the lack of a constant variance in the errors;
- Consideration was given to EGARCH, Asymmetric GARCH and GARCH in Mean.

5.3 Summary of the proposed method

The previous chapter defined the research question as establishing whether sector indices are random or have a data generating process. This chapter can be summarized as utilizing a method which applies the research question to each industrial sector's index. This will be in four stages. Firstly, the time series will be tested for stationarity, initially as a level series of the index values expressed as a natural log and then, if not stationary, as a differenced series in the format of the log return. Secondly, for those series that are stationary, tests will be made to identify which, if any, of the series are random or near random walks (pure, or with drift and/or with trend). Thirdly, for the sector indices that are stationary but not random walks, tests will be followed to consider if the time series follows an autoregressive processes. Finally the remaining series will be examined to try and identify any other data generating processes: consideration of outliers (a common time series adjustment); a Moving Average process; ARMA; and finally cointegration.

Each of the above will be performed initially with a constant variance and then for an ARCH process. The first assumption will be of a basic GARCH, followed by an asymmetric version as this has close links with rational expectations. Failing this a GARCH in mean model will be applied, again due to the close relationship with finance and its link with asset pricing. Next will follow exponential GARCH, as many research papers find this successful. Finally component GARCH will be assumed, again due to its fairly widespread use in finance research.

In all cases, the search for the data generating process or maintained regression will end if that process has IID in the residuals, as verified by the BDS test, but will continue if that process shows that there is no IID.

All maintained regressions that seem to explain the data generating processes will then form the basis for forecasting out of sample values to establish if abnormal gains can be made from their predictive powers.

CHAPTER SIX STATIONARITY AND RANDOM WALKS

6.1 Introduction

This chapter forms the first of a set of three chapters that encompass the analysis of the equity sectors in the UK. The first examines all the series for stationarity and tests all time series to establish if they can be described or explained by a random walk process. The second of this set (Chapter 7) examines all stationary non random series to establish if one of the various univariate data generating processes explains the data. Finally Chapter 8 reviews all those series that can be explained and considers whether their maintained regressions identified in Chapters 6 and 7 have any predictive ability.

The intention of this analysis is to allocate each the various equity sectors into one of three possible 'states' of efficiency and thus identify possible investment management approaches. The successful outcomes will be as follows.

- A data generating process has been identified which has sufficient predictive power to make that sector not efficient in that the abnormal gains from the predictions outweigh the cost of trading on the predictions and so the sector should be actively managed.
- A data generating process has been identified which does have predictive power but the gain from those predictions is offset by the cost of trading on them, so that the sector is weakly efficient and should be passively managed.
- The process is a random walk, so the sector is strong efficient and should be passively managed.

Those series identified as being in the first of these three categories will be the ones alluded to in the Myners Review as giving scope to the investment managers to outperform their peers and add value via active management.

There is obviously a fourth category of sector, that where a suitable data generating process cannot be identified. No final decision will be possible for this type of sector, although the view could be taken that lack of a process would in itself mean that predictions were not possible and so passive management would be the order of the day.

6.2 Data and Summary Statistics

6.2.1 Sample data

The data relates to the FTSE All Share Index and its constituent industrial sector sub indices. All sectors were initially examined, but some were rejected where data was not available for the full period. For instance, FTSE A/S Steel & Other Metals and FTSE A/S Life Assurance Index values had gaps in the period under consideration. For the sector indices where all values were available, the basic data were obtained from Datastream* (with Sterling as the default currency), resulting in 263 observations of 30 variables. The choice of the period is based on current data over a time of no major UK political and economic change and with the UK equity market showing no major changes in trend. The data set is limited to one year as there is no consideration of seasonality (usually covered by tests for anomalies) and the number of observations more than satisfies the sample size requirements of the various statistical tests. (Some econometric texts alluding to a sample size of 200 being large.) In addition, there is no assumption of any relationship of great longevity. There is a body of finance literature that does examine long term trends, but that is not considered here.

The sample period is one year of daily data from 23rd April 2003 to 22nd April 2004. This differs from many research papers on stock market efficiency and pricing models which tend to use weekly or monthly data. The reason is summarized in the conclusion of Acker and Duck's (2004) paper:

> The choice of reference day does have important implications for key statistics such company betas (sic) and stock-market correlations and, as we have shown, it can reverse central conclusions of different types of study. (p. 18)

Their analysis shows that, using iterative calculations of variance or beta based successively on each of the 28 reference days available per month, when using

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* Original Datastream data was exported from Bankers TA to Excel where the natural log and returns transformations were made, prior to production of the E-Views worksheet. All calculations in this and subsequent chapters were performed in E Views Version 4, other than Table 11 where the runs tests were produced in SPSS.

monthly data a wide range of different statistical characteristics are achieved, depending on the day selected to represent the month. Their largest difference in calculated betas was a range from -0.41 through to + 3.0 and "even in the less extreme cases the difference across reference days was 'unsettlingly large'" (p. 5). Therefore, although much of the calculations in this chapter follow methods used extensively in finance research, the choice of daily data rather than the more common monthly format should remove this reference day problem. This is also in step with the gradual shift from monthly data to more high frequency analysis generally used in academic finance literature.

Daily returns at time t (DR_t) were calculated using the continuously compounded formula:

$$DR_t = \ln (P_t / P_{t-1}) \qquad (6.1)$$

where P_t is the value of the index at time t and ln is the natural logarithm. The use of log-price relatives is in step with the majority of academic literature in finance. The application of natural logs allows the result to be treated as a continuously compounded return. Further calculations are performed on excess returns, after deduction of the risk-free rate, such that:

$$R_t = DR_t - R_f \qquad (6.2)$$

where the risk free rate R_f, or its proxy, is the three month Treasury Bill rate, shown in Economic Trends (May 2004, number 606, TSO), converted to a daily equivalent. Where there were gaps in the data caused by bank holidays, the average of the indices one period each side of the 'gap' was inserted.

No account was taken of dividends, in line with Chortareas et al (2000), Nelson (1991) and others, on the basis that their omission does not result in any major error in analysis of this type. Had individual company data been analysed, then the omission of dividends could have given scope for error due to the differences between growth and value firms. The use of indices, however, when combined with the frequency of the data, means that exclusion of dividends should not invalidate the analysis.

6.2.2 Descriptive statistics

Table 10 sets out descriptive statistics of the various sub-indices and their daily returns. (For space reasons, subsequent tables may just use the reference number.) There are 29 industrial sector indices that have daily data available over the full period. These have a total of 644 constituent firms compared with the 695 firms in the whole of the FTSE All Share index. Thus 51 firms, or rather their sectors, are excluded from the analysis. Three of the sector indices each contain just one constituent firm so their subsequent analysis is simultaneously at the firm and sector level.

Although the focus of this research is on the sector indices, all calculations in this and the following chapters are also performed on the aggregate FTSE All Share index. This is for completeness rather than as a central part of the study. As a comparison with the sector indices in Table 10, the full index had daily return moments of 0.000505 (mean), 0.007250 (standard deviation), -0.210953 (skewness) and 3.642532 (kurtosis) and a Jarque-Bera (JB) normality test statistic of 6.450 (significant at 5%). The All Share index's kurtosis value is the closest of all the values to 3.0, indicating that it has the lowest skewness.

As can be seen from Table 10, the highest mean daily return (R_t) is 0.2729% for Electricity, with an associated standard deviation of over 6% (well above the second highest of 1.59). This sub-index has only one constituent, which possibly helps to explain the volatility, but is not the only series with a sole member. Two of the indices have a negative mean daily return, those of Forestry & Paper and Insurance, all others are positive over the twelve month period. All of the series indicate some level of skewness, with 11 being negative and 19 positive. Beverages has the largest skewness coefficient at 10.55, followed by Aerospace & Defence at over 7, but most have a value for the third moment of less than one. The fourth moment, that of kurtosis, would be expected to have a value of 3 if there is no kurtosis with returns normally distributed. Table 10 shows a wide range of values, from 145 for Beverages down to 4.03 for Speciality & Other Financials. Combining both the third and fourth moments, the JB test has the joint null hypothesis of no skewness and no kurtosis and is a test of the normality of the distribution. As can be seen, all of the indices' returns' time series reject this null at 5% significance; the highest statistic being (again) Beverages.

Table 10 Summary Data FTSE All Share sector indices

Name	Ref	Value £m +	Nu of firms	Daily return of index				
				Mean	Standard deviation	Skewness	Kurtosis	JB statistic
Aerospace & Defence	15577	363	3	.001890	.012450	7.296844	87.19092	79703.*
Auto & Parts	15579	728	9	.001772	.011771	.305219	8.179921	296.98*
Beverages	15581	148	1	.001861	.013176	10.55384	145.8802	227725.*
Chemicals	15585	643	8	.000282	.009238	.027135	5.49667	68.08*
Construction & Building Materials	15583	1,834	22	.001037	.005988	-1.035378	7.080078	228.54*
Electricity	19897	84	1	.002729	.060434	.139776	14.32934	1402.05*
Electro & Electrical Equipment	15593	2,082	21	.001090	.007706	.199570	4.183293	17.02*
Engineering & Machinery	15591	1,442	24	.001629	.007623	.043992	4.926966	40.62*
Food & Drug Retailers	15597	204	3	.002216	.015616	1.382192	19.19139	2945.35*
Food Production & Processors	15599	1,113	12	.000878	.006638	-.832228	7.583930	259.63*
Forestry & Paper	15595	13	1	-.000652	.015285	.100493	14.26520	1385.82*
General Retailers	15601	2,989	30	.001428	.005777	-.111151	4.158158	15.18*
Health	15603	1,673	19	.001457	.007474	-.677494	14.68717	1511.15*
Household Goods & Textiles	15605	918	17	.001701	.009752	.552424	4.915711	53.39*
Insurance	15609	1,618	12	-.000002	.007648	-2.834151	26.41625	6336.59*
Investment Companies	15610	16,624	189	.001293	.005508	-.267152	4.780903	37.74*
IT hardware	15607	1,387	20	.002732	.015900	.546147	4.552908	39.35*
Leisure & Hotels	15613	1,966	16	.001245	.007265	-.365619	9.295040	438.44*
Media & Entertainments	15615	2,757	32	.001604	.006639	-.277262	8.342336	314.93*
Mining	15617	588	6	.000879	.012965	.241733	5.367888	63.76*
Oil & Gas	15619	1,166	8	.001335	.009047	-.180058	6.061961	103.77*
Pharmaceuticals & Biotec	15623	1,299	16	.001760	.011991	.683814	4.930607	61.11*
Personal Care & Household Products	15621	269	3	.002446	.015733	1.189468	5.855835	150.82*
Real estate	15627	1,776	20	.001794	.003750	.469006	4.716184	41.76*
Software & CPU Services	15630	3,614	43	.002054	.009265	.339410	5.162296	56.07*
Speciality & Other Financials	15633	2,089	24	.001424	.005661	.435580	4.031362	19.52*
Support Services	15635	6,619	63	.001163	.005330	-.502881	5.074650	58.03*
Telecommunication Services	15641	579	6	.002173	.017238	.751319	6.882306	189.18*
Transport	15639	1,858	15	.000960	.008782	.167542	6.192041	112.46*

+ value as at 25th July 2005   * significant at 5%

Lack of normality can have severe adverse impact in econometric analysis, but this may be reduced by removal of outliers, consideration of ARCH, or sample size:

> …for sample sizes that are significantly large, violation of the normality assumption is virtually inconsequential. Appealing to a central limit theorem, the test statistics will asymptotically follow the appropriate distribution even in the absence of error normality. (Brooks, p 182. 2002)

6.2.3 Early tests for randomness

Early tests of the original weak form efficiency often used runs tests. These are produced here, but not as part of the main analysis, so the results do not inform later discussion. Table 11 sets out the results of the runs tests, although it should be noted

Table 11 Non-parametric Runs Test

Name	Ref	Number of Runs	Z	Asymp. Sig. (2-tailed)
FTSE All Share	5921	138	1.689	.091
Aerospace & Defence	15577	100	-3.074	.002 *
Auto & Parts	15579	107	-1.98	.048*
Beverages	15581	104	-2.844	.004 *
Chemicals	15585	97	-3.731	.000 *
Construction & Building Materials	15583	102	-2.241	.025*
Electricity	19897	128	.587	.557
Electro & Electrical Equipment	15593	120	-.557	.577
Engineering & Machinery	15591	103	-2.544	.011*
Food & Drug Retailers	15597	113	-1.516	.13
Food Production & Processors	15599	109	-1.829	.66
Forestry & Paper	15595	59	-1.605	.109
General Retailers	15601	92	-3.482	.000*
Health	15603	87	-4.449	.000 *
Household Goods & Textiles	15605	116	-.968	.333
Insurance	15609	107	-2.465	.014*
Investment Companies	15610	100	-2.567	.010 *
IT hardware	15607	113	-1.488	.137
Leisure & Hotels	15613	116	-.845	.398
Media & Entertainments	15615	107	-1.625	.104
Mining	15617	113	-1.702	.089
Oil & Gas	15619	103	-2.863	.004 *
Pharmaceuticals & Biotec	15623	101	-3.030	.002 *
Personal Care & Household Products	15621	98	-3.362	.001 *
Real estate	15627	94	-2.24	.025*
Software & CPU Services	15630	89	-3.996	.000 *
Speciality & Other Financials	15633	86	-4.495	.000 *
Support Services	15635	91	-3.777	.000 *
Telecommunication Services	15641	122	-.362	.717
Transport	15639	118	-.927	.354

*= non random at 5%

that these have been performed not on the index values, but on the daily returns. A change in the sign of the return is indicative of a new run. At 5 % significance, 17 of the returns' series reject the null hypothesis of randomness and 13 indicate that the data series' runs are not inconsistent with that of a random walk.

Table 12 Pearson Correlation with lag

Ref	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6	Lag 7	Lag 8	Lag 9	Lag 10
5921	-.168*	.032	-.040	.047	-.015	-.084	.069	-.080	-.009	-.163*
15577	.054	-.075	.010	.029	-.019	-.064	-.001	-.005	-.007	-.002
15579	.139*	.153*	.096	.108	.026	.170*	-.024	.127	-.005	.094
15581	.112	.034	.174*	.017	-.013	.007	.016	-.063	-.005	-.010
15585	.206 *	.218 *	.082	.049	-.026	-.040	-.029	.063	.018	.040
15583	.222 *	.142 *	.111	.025	.089	.044	.105	-.083	-.020	-.025
19897	.075	-.121	-.041	.055	.003	-.096	-.083	.022	-.007	-.021
15593	.242 *	.100	.194*	.149	.034	.111	.061	.005	.032	.056
15591	.187 *	.035	.092	.065	-.011	-.001	-.009	.028	.093	-.032
15597	.064	-.112	.028	-.014	-.086	.083	-.032	-.008	-.010	-.014
15599	.236 *	-.055	-.096	-.050	-.033	-.071	-.052	.045	-.005	-.062
15595	.099	-.005	-.106	-.007	-.025	-.029	-.066	-.011	.035	-.046
15601	.269*	.086	.094	.092	.065	.081	.154*	.061	.027	.122
15603	.220*	.123*	.081	.054	.022	-.022	.013	-.006	-.029	-.042
15605	-.021	.091	.044	.050	.089	-.074	.003	-.032	-.032	.090
15609	.163*	.106	.027	-.022	.106	.122*	.001	.087	-.064	.035
15610	.174 *	.082	.110	.088	-.007	.011	.034	-.112	-.107	-.090
15607	.169*	-.002	-.008	.118	.062	-.044	.025	-.034	-.017	-.090
15613	.144*	-.044	.001	.029	.031	-.018	.041	.013	-.045	-.054
15615	.156*	.028	-.019	.018	.101	.097	.099	.073	.084	.121*
15617	.043	.007	.047	.058	.056	-.032	-.015	-.080	.026	.028
15619	.165 *	.061	-.009	.076	.019	.024	.008	-.012	.027	-.002
15623	.128 *	-.016	.115	-.051	-.031	.008	-.057	-.088	.042	.029
15621	.117*	-.012	-.040	-.012	-.046	-.072	-.107	-.022	-.060	.108
15627	.173*	.069	.099	.070	.090	.030	-.018	-.090	-.025	.011
15630	.282*	.126*	.114	.120 *	.015	-.036	.017	-.040	-.039	-.001
15633	.417 *	.144*	.046	.010	.030	-.019	.042	.043	.001	.002
15635	.341 *	.102	.176 *	.122 *	.159 *	.089	.051	.021	.001	.049
15641	.052	.022	.132 *	.100	-.142*	-.058	-.054	-.129	-.018	.051
15639	.173 *	.054	.047	-.007	.065	.068	-.047	-.075	-.021	-.010

*correlation coefficients not equal to zero at 5% significance.

Table 12 shows the lagged correlations for the indices' returns as another fairly simplistic measure of randomness. Using 5% significance it is seen that 22 out of the

30 series show significant non-zero correlation (with a two sided test) with one day's lag. All but one of these correlations are positive. As the lag length increases, so the number of significant correlations reduces. Again the comments can only be superficial, but evidence of autocorrelation could be an indicator of non randomness in some of the indices.

Table 13 Ljung Box Test of Autocorrelation

Name	Ref	Ljung Box Statistic
FTSE All Share	5921	20.8*
Aerospace & Defence	15577	3.4
Auto & Parts	15579	32.6 *
Beverages	15581	4.2
Chemicals	15585	34.3 *
Construction & Building Materials	15583	33.0 *
Electricity	19897	12.5
Electro & Electrical Equipment	15593	50.9 *
Engineering & Machinery	15591	18.0
Food & Drug Retailers	15597	6.1
Food Production & Processors	15599	20.9*
Forestry & Paper	15595	6.9
General Retailers	15601	54.7
Health	15603	23.2 *
Household Goods & Textiles	15605	8.25
Insurance	15609	23.0*
Investment Companies	15610	28.9 *
IT hardware	15607	16.1
Leisure & Hotels	15613	12.7
Media & Entertainments	15615	22.4*
Mining	15617	6.82
Oil & Gas	15619	11.6
Pharmaceuticals & Biotec	15623	12.1
Personal Care & Household Products	15621	11.9
Real estate	15627	14.6
Software & CPU Services	15630	41.3 *
Speciality & Other Financials	15633	57.0 *
Support Services	15635	66.7 *
Telecommunication Services	15641	20.5*
Transport	15639	18.8*

*=5% significance, 10 degrees of freedom.

The lagged correlations in Table 12 give some support to the constancy of the covariances in some of the returns of the indices, but this can be tested more formally using a test of joint hypotheses that all appropriate correlation coefficients are zero. (For 'appropriate', this is assumed to be the ten lags encompassing two weeks of data.) The Ljung Box statistic assumes a chi-squared distribution with ten degrees of freedom (the number of lags) and has a 5% critical value of 18.307. The results of this test (which are part of a set of statistics known as portmanteau tests of time series linear relationships) are set out in Table 13 where it can be seen that 16 indices reject the null hypothesis that all ten lags have no autocorrelation and could require differencing. (See later sections for an explanation of differencing.)

A comparison of Tables 11 and 13 (using 5% significance) produces: ten series that do not reject the null hypothesis that the series is random, as indicated by the runs test and also do not reject the null hypothesis of no serial correlation according to the Ljung Box test; seven series that are not random in runs and have auto-correlation; and 13 with mixed messages where just one of the two tests indicates some degree of randomness.

Runs test indicates randomness and LB suggests no auto-correlation

Auto & Parts	Insurance
Chemicals	Investment Companies
Construction & Building Materials	Software & CPU Services
Food Production & Processors	Speciality & Other Financials
Health	Support Services

Runs test indicates not random and LB suggests auto-correlation

Electricity	IT Hardware
Food & Drug Retailers	Leisure & Hotels
Forestry & Paper	Mining
Household Goods & Textiles	

Mixed Message

FTSE All Share	Oil & Gas
Aerospace & Defence	Pharmaceuticals & Biotec
Beverages	Personal Care & Household Products
Electro & Electrical Equipment	Real Estate
Engineering & Machinery	Telecommunication Services
General Retailers	Transport
Media & Entertainments	

A simple or naïve interpretation of this could be that the first group (not rejecting either of the two null hypotheses of randomness and zero correlation) show weak form efficiency, whereas the second group (rejecting both of the two nulls) does not seem efficient. The third group (rejecting one of the two nulls) give mixed messages. It was this type of approach that formed the early tests of efficiency. Whilst its range of outcomes more than validates the continuation of this analysis to establish if some of the FTSE All Share component indices are random, its usage has been superceded by more modern and sophisticated tests, hence its inclusion here in the review of descriptive statistics.

The remainder of this chapter and the subsequent analytical chapters move away from basic descriptive statistics and have a univariate time series econometric focus. This depends on or is derived from a variety of econometric texts, namely: Brooks (2002); Gujarati (2003); Patterson (2000); Shiryaev (1999): and Quantitative Micro Software (2001). These are supplemented by a variety of quantitative texts shown in the Bibliography. Although specific quotations will be referenced, general interpretation will not.

6.3 Random Walks

6.3.1 Autoregressive processes

There are many tests of the Efficient Market Hypothesis, but this chapter's analysis will focus just on one test, that of randomness. Various forms of the random walk will be applied to the returns of the 30 indices to establish whether any are random. The overarching assumption is that if a series does follow a random walk, then it is efficient. Of course, the opposite does not generally apply, in that if a series is not random that would not automatically mean that the series was not efficient. This case will be followed up in the next chapter, to establish if the non-random series can be described by an AR(p) process of the type in equations 6.3 or 6.4 below.

A univariate linear deterministic model is of the form:

$$Y_t = \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \ldots\ldots + \varphi_p Y_{t-p} \quad (6.3)$$

This is autoregressive AR(p) and can be converted from deterministic to stochastic by the addition of a stochastic term such that

$$Y_t = \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \ldots\ldots + \varphi_p Y_{t-p} + \varepsilon_t \quad (6.4)$$

An autoregressive process such as equation 6.4 with one lag is

$$Y_t = \varphi_1 Y_{t-1} + \varepsilon_t \quad (6.5)$$

where the value of Y at time t depends on the prior period's value plus a stochastic error term. This data generating process is therefore AR(1). If the parameter φ_1 is equal to one then equation 6.5 becomes a pure random walk

$$Y_t = Y_{t-1} + \varepsilon_t \qquad (6.6)$$

The interpretation of the pure random walk in relation to a share index would be that the best estimate of the value of the index tomorrow is today's value and that there is no scope for making abnormal gains.

The pure random walk is not the only time series that can be random. A second case is where it is a random walk with drift, namely

$$Y_t = \mu + Y_{t-1} + \varepsilon_t \qquad (6.7)$$

where μ is the drift term. A third case is that of a random walk with a deterministic trend

$$Y_t = Y_{t-1} + \beta t + \varepsilon_t \qquad (6.8)$$

where β is the time series trend. All versions could be combined such that

$$Y_t = \mu + Y_{t-1} + \beta t + \varepsilon_t \qquad (6.9)$$

This final version will form the basis of the tests for randomness in relation to the indices' time series, with particular reference to various formats, each exhibiting various random walk characteristics or non-random data generating processes which produce trends similar to an index time series. For convenience the three versions of the random walk will be referred to as formats one, two and three, namely:

format	**drift**	**φ**	**trend**	**type**
One	μ=0	φ_1=1	β=0	pure random walk
Two	$\mu \neq 0$	φ_1=1	β=0	random walk with drift
Three	$\mu \neq 0$	φ_1=1	$\beta \neq 0$	random walk with drift and deterministic trend

It may be the case that the maintained regressions produce a value for the parameter φ_1 which is close to unity but significantly different to 1.00 (assumed below, or else the series would be explosive). In this situation the process could be viewed as a near random walk and the error term is best described as coloured noise. There could be no automatic conclusion in these cases as to randomness or efficiency.

6.3.2 Stationarity

A concept closely linked to auto regressive processes is that of stationarity. A time series that is not stationary suffers from prior error term values (ε_t) having an infinite impact on future values (in effect an infinite memory) and can give rise to spurious regressions This is not immediately attractive in terms of studying share indices in relation to forecasting or testing for efficiency, so it is desirable to test the series for stationary before proceeding with any analysis. Examination of all of the 30 indices shows a gradual growth over the year: positive for 28 and negative for two. This contradicts the requirements of stationarity, namely that stationary processes must have a constant mean. This condition is known as first order stationarity and can be extended to include variance and covariance. For a time series to be second order stationary, in addition to a constant mean, both the variance and all the covariances must also be constant.

If this concept is applied to (say) the FTSE All Share index, with the assumption that it is a random walk with drift, then the index is equivalent to equation 6.7 such that:

$Y_{24/4/05} = \mu + Y_{23/4/05} + \varepsilon_{24/4/05}$ and additionally

$Y_{25/4/05} = \mu + Y_{24/4/05} + \varepsilon_{25/4/05}$ which is equivalent to

$= \mu + \mu + Y_{23/4/05} + \varepsilon_{24/4/05} + \varepsilon_{25/4/05}$

$= 2\mu + Y_{23/4/05} + \varepsilon_{24/4/05} + \varepsilon_{25/4/05}$

It can now be seen that if the index's starting value on 23rd April 2003 is the constant μ, then the mean (expected value) of 24th April is different from that of the 25th: i.e. the starting value plus one μ compared to the starting value plus two μ. Likewise the variance will be different for the two days. Similarly, although a larger example would be required, the covariances will not be constant. With this fairly simple example the conclusion would be that although the All Share index is random it is not stationary. If the pure random walk of equation 6.7 is differenced once it can be written as

$$Y_t - Y_{t-1} = \varepsilon_t \qquad (6.10)$$

Performing this operation in relation to the example results in:

$$Y_{25/4/05} - Y_{24/4/05} = \mu + \varepsilon_{25/4/05}$$

which, as can be seen, will now have a constant mean, variance and covariance. This process is known as differencing to stationarity. Given that the random walk goes to stationarity after one differencing it is known as integrated of order one. (A series such as equation 6.3 above may require d differencings to achieve stationarity and would be referred to as integrated of order d, or I(d).) A time series that becomes stationary after one differencing, I(1), is defined as having a unit root. All three versions of the random walk can be differenced as for equation 6.10 above, resulting in the following formats.

Format One $R_t = Y_t - Y_{t-1} = \varepsilon_t$ (6.11)

Format Two $R_t = Y_t - Y_{t-1} = \mu + \varepsilon_t$ (6.12)

Format Three $R_t = Y_t - Y_{t-1} = \mu + \beta t + \varepsilon_t$ (6.13)

The importance of the series in this analysis being stationary is such that the first step is to test this condition. The conversion of the index values to natural logarithms, (as set out above) results in the difference Y_t-Y_{t-1} being the log normal return on the index. The next section of this chapter undertakes formal tests on the 30 index time series to examine if they are stationary, either in the level version of the indices, or more likely when converted to log normal returns after first differencing. These tests are based on those of Dickey Fuller, although there are other methods that could be used. The tests examine the value of φ_1, given that for a random walk it should be equal to one, i.e. the series has a unit root. It should also be emphasized that although the Dickey Fuller tests are based on regressing the time series in one of the three random walk formats, at this stage the resulting regression equations are of no interest: it is only the value of φ_1 that is of importance.

(As an aside it should be noted that a trend stationary process, unlike those considered here, cannot be differenced to stationarity; instead they require de-trending. This issue will be readdressed if the various data generating processes identified in subsequent analysis warrant it.)

6.4 Dickey Fuller test structure

6.4.1 Approach

Within time series analysis, there is much reflection on the approach to identifying the appropriate data generating process. Early work was heavily dependent upon visual consideration of graphs of the time series and autocorrelation and partial autocorrelation graphs. Subsequent approaches often followed the Univariate Box Jenkins methodology. The growth in use of time series analysis in economics and finance generally has also more recently produced many statistical tests and other tools to review a time series. For this analysis, the consideration of whether or not an index's time series follows a random walk model means that much of the time series tests are not necessary. Instead the main approach will be the use of Dickey Fuller tests for unit roots. An alternative approach could be to use (say) the Phillips and Perron test, but this suffers from additional problems in simulating critical values.

The earlier generation of equation 6.6 to produce a pure random walk assumed that φ_1 equals one. The test of this assumption is the basis of the Dickey Fuller tests for unit roots. Their purpose is not to establish via regression the detailed parameters for the data generating process but merely to identify if that process, when using one of the various formats of the random walk model has a unit root. Hence the goal is to discover if φ_1 equals one. For formats one, two and three of the random walk model, there is no single test for the value of φ_1. Different nested tests can be used to reject or not reject various null hypotheses about the value of the parameters. Time series analysis usually assumes a starting point at the "complex" end of any proposed data generating process and gradually reduces down to achieve a regression that is the most simple or parsimonious. This will form the basis of the tests on the indices' time series.

The following section describes the various tests, specifically in relation to the differenced formats, i.e. the returns. The actual tests in the later section are performed on both the level, undifferenced indices as well as the differenced returns, but the approaches are the same so the description is just given for differenced formats.

6.4.2 The Φ_3 and τ_β tests

The first test will be based upon the Dickey Fuller Φ_3 statistic which is designed to examine format three, does the series have a unit root if the maintained regression is a random walk with drift and trend? Equation 6.13 is used, but to allow the null hypothesis to state that the autoregressive parameter equals zero, it is redefined with $\gamma = \varphi_1 - 1$ such that

$$R_t = Y_t - Y_{t-1} = \mu + \gamma Y_{t-1} + \beta t + \varepsilon_t \qquad (6.14)$$

For the Φ_3 test, which is two sided, the null hypothesis is: H_0: $(\mu,\gamma,\beta) = (\mu,0,0)$ but with three alternatives encompassing either or both γ and $\beta \neq 0$. The alternative hypotheses being H_{a1}: $(\mu,\gamma,\beta) = (\mu,\gamma,\beta)$ or H_{a2}: $(\mu,\gamma,\beta) = (\mu,0,\beta)$ or H_{a3}: $(\mu,\gamma,\beta) = (\mu,\gamma,0)$. Non rejection of the Φ_3 null will infer a unit root and a series that could be a random walk with drift (Format Two) or a pure random walk (Format One) as $\gamma=0$ so $\varphi_1 = 1$ and $\beta=0$. Rejection does not identify which of the alternative hypotheses is valid. Thus, in the case of rejection of the Φ_3 test, the one-sided τ_β test will be used with the null that $\gamma=0$ and alternative $\gamma<0$. Non rejection of this null will give a unit root and a non-stationary series that is a random walk with drift and trend as if $\gamma=0$ then the Φ_3 rejection must have been based on $(\mu,0,\beta)$, (Format Three), although at this stage the drift may or may not be zero. Rejection of the τ_β null will infer that $\gamma<0$, so that $\varphi_1 < 1$.

6.4.3 The Φ_1 and τ_μ tests

The second round of tests applies to those series where the Φ_3 test's null was not rejected. The trend can now be dropped as $\beta = 0$ and the test is based on Format Two, but again with $\gamma = \varphi_1 - 1$ so that equation 6.12 becomes

$$R_t = Y_t - Y_{t-1} = \mu + \gamma Y_{t-1} + \varepsilon_t \qquad (6.15)$$

Here, the two sided Φ_1 test is used with the null H_0: $(\mu,\gamma)=(0,0)$, again with three alternatives being either or both μ and $\gamma \neq 0$. Thus H_{a1}: $(\mu,\gamma)=(\mu,0)$ or H_{a2}: $(\mu,\gamma)=(0,\gamma)$ or H_{a3}: $(\mu,\gamma)=(\mu,\gamma)$. Non rejection of the null results in the conclusion that the time series is consistent with having a unit root and could be Format One, a pure random walk. If the null is rejected it is necessary to establish which of the three alternatives apply. In this case the one-sided τ_μ test is employed with the null H_0: $\gamma=0$ and the alternative $\gamma<0$. Non rejection of the null will infer that the series has a unit root and is Format Two, whilst rejection means there is no unit root and the series is not I(1).

6.4.4 The τ test

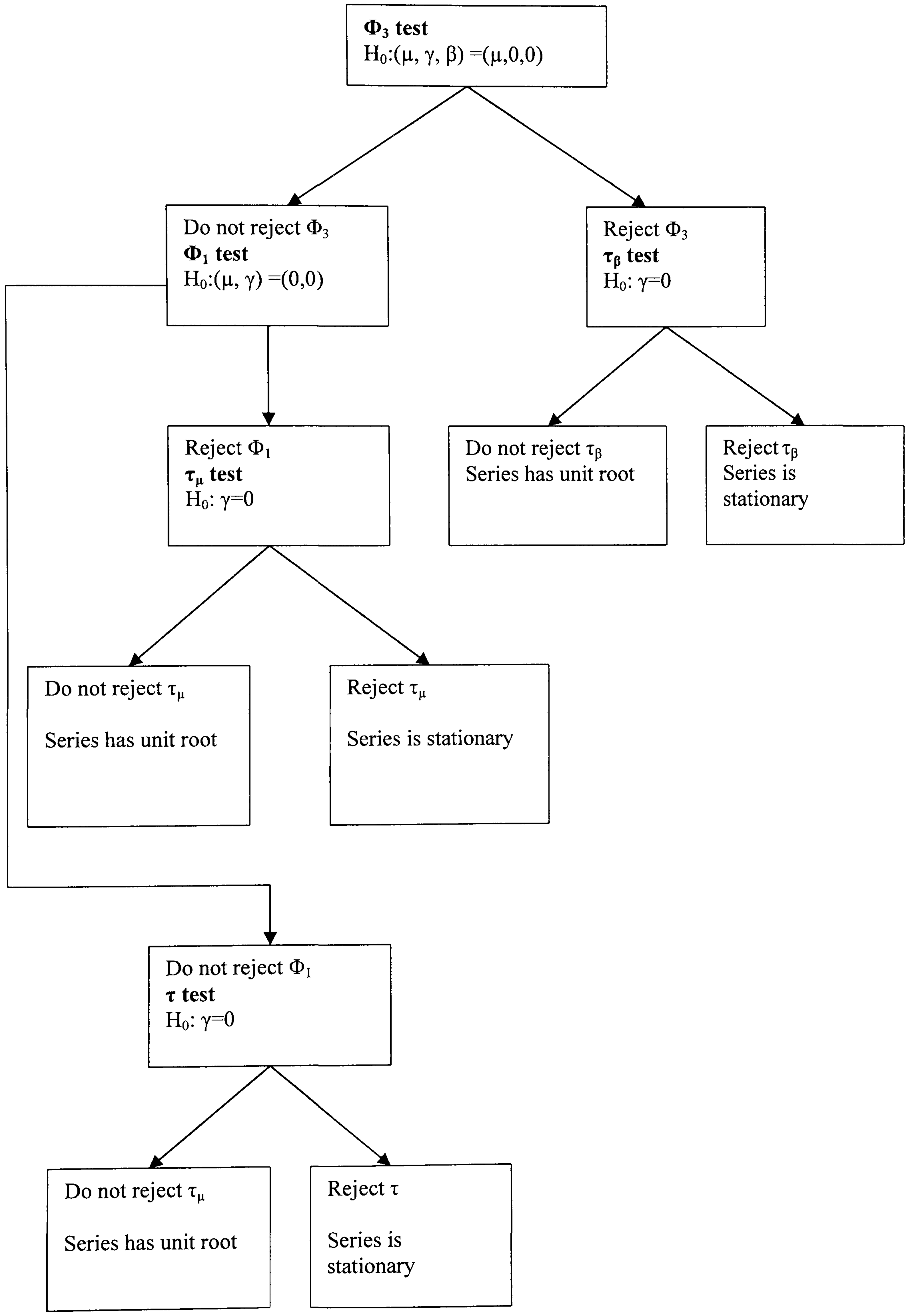
The final round of the Dickey Fuller tests applies if the series did not reject the Φ_1 test. This could be regarded as unnecessary duplication in that non rejection of Φ_1's null assumes a pure random walk with no drift. Unfortunately, the test is not overly powerful: three alternative hypotheses, a joint null and two-sided. To compensate for this the framework proceeds to the third level, the τ test. The data generating process is viewed as:

$$R_t = Y_t - Y_{t-1} = \gamma Y_{t-1} + \varepsilon_t \qquad (6.16)$$

In this case the τ test is used, with a null H_0: $\gamma=0$. Non rejection gives a unit root and a non-stationary random walk of Format One, rejection means stationarity.

This framework of testing for unit roots is displayed for simplicity in Figure 1.

Figure 1 Test Framework



6.4.5 Augmented DF tests

It is sometimes the case that non-stationarity may be caused by correlation within the error term rather than the main parameters. The basic Dickey Fuller test does not take account of this, but the errors can be examined by use of the Augmented Dickey Fuller (ADF) test. For each of the three versions of the model, an additional factor is added to the regression, namely the lagged R_t. Thus the three random walk formats become:

R_t is a random walk: $Y_t-Y_{t-1}=R_t=\delta y_{t-1}+ \Sigma\alpha i\ R_{t-i} +\varepsilon_t$ (6.17)

R_t is a random walk with drift: $Y_t-Y_{t-1}=R_t=\beta_1+\delta y_{t-1}+ \Sigma\alpha i\ R_{t-i} +\varepsilon_t$ (6.18)

R_t is a random walk with drift and a stochastic trend : $Y_t-Y_{t-1}=R_t=\beta_1+ \beta_2 t+\delta y_{t-1}+ \Sigma\alpha i\ R_{t-i} +\varepsilon_t$ (6.19)

where i is the number of lags.

This augmented test can be applied to the three forms of the model as before, with the same critical values. Various tests can be applied to the data to recommend or give an indication of the appropriate number of lags to apply to the ADF test. These can include various information criteria or LM tests for serial correlation. Rather than these, the lagged correlations set out in Table 12 will be used. Where the lag is replicated in the second week (6-10) these will be ignored as they could be an 'echo' of the first week, e.g. significant correlation at days one and six. Of course, where there is no significant lag in periods one to ten, then the ADF(0) collapses to the basic Dickey Fuller test.

There is one final point which requires elaboration. All of the various versions of the random walk model discussed above assume a stochastic error term ε_t. For a series to be random, this error term or white noise must satisfy various conditions, namely:

$E(\varepsilon_t) = 0$ for all t;

variance is constant and independent of time;

autocorrelations equal to zero.

Under these conditions the stochastic error term itself is seen as stationary. A more rigorous definition is for it to be an independent and identically distributed variable, referred to as IID. The conditions for IID are similar to white noise, namely:

$E(\varepsilon_t)$ a constant that may or may not =0;

variance is constant and independent of time;

ε_t is independent of ε_s for all s,t, $s \neq t$.

For the various time series to be tested for randomness via the Dickey Fuller and Augmented Dickey Fuller tests, the error terms must also be examined for IID. This will be undertaken using the Brock, Dechert and Scheinkman (BDS) statistic, the null hypothesis being that the residuals from the regression of the appropriate random walk format are IID. The implications of the rejection of this hypothesis will be considered later. Chapter 5 described earlier the background to the BDS test.

6.5 Results of Unit Root Tests on level series

6.5.1 Φ_3 tests on level series

The first round of tests will be on the level time series of index values expressed as their natural logarithm. The underlying assumption or expectation is that the series will have a unit root and will not be stationary. The maintained regressions will be undifferenced versions of the equations shown in 6.6 to 6.8.

Critical values for Φ_3 are obtained from tables available in the public domain, typically generated by simulations as the distributions are not normal or other common formats. The need for simulations restricts the accuracy and no table is available for this particular sample size, however it can be seen from the following extract in Table 14 that this should not be particularly problematic. The initial (two sided) test is for Φ_3 and the results from the tests are shown in Table 15 below.

Table 14 **Φ_3 Critical Values**

	1%	5%	10%
Sample			
200	8.542	6.397	5.433
500	8.326	6.238	5.321

(Source: Patterson, Critical values of the DF test statistic Φ_3)

Given that E Views 4 is used to calculate the test statistics, then it should be feasible to use the critical values generated by the software, rather than relying on the above, but their lower values and lack of supporting explanation infer that these critical values may be for a single sided test, so the extract from Patterson is a safer value and a 'view' will be taken if any test statistic lies between 6.397 and 6.238.

Examination of Table 15 shows that none of the 30 indices reject the null hypothesis H_0: $(\mu,\gamma,\beta)= (\mu,0,0)$ at 5% significance, indicating that at this early stage all the time series could be consistent with a random walk but have a unit root and are not stationary. The fact that there were no rejections additionally means that there is now no requirement for the Dickey Fuller τ_β test.

Table 15 Dickey-Fuller Tests for Stationarity in the level index series Format Three, Φ_3 test

	Ref	Lags for ADF	Test statistic
FTSE All Share	5921	1	-3.613
Aerospace & Defence	15577	0	-1.701
Auto & Parts	15579	2	-1.400
Beverages	15581	3	-2.809
Chemicals	15585	2	-2.943
Construction & Building Materials	15583	2	-2.171
Electricity	19897	0	-2.618
Electro & Electrical Equipment	15593	3	-2.457
Engineering & Machinery	15591	1	-1.086
Food & Drug Retailers	15597	0	-2.264
Food Production & Processors	15599	1	-2.300
Forestry & Paper	15595	0	-2.840
General Retailers	15601	1	-3.078
Health	15603	2	-3.587
Household Goods & Textiles	15605	0	-2.590
Insurance	15609	1	-1.827
Investment Companies	15610	1	-2.349
IT hardware	15607	1	-1.543
Leisure & Hotels	15613	1	-2.538
Media & Entertainments	15615	1	-0.956
Mining	15617	0	-0.815
Oil & Gas	15619	1	-1.540
Pharmacuticals & Biotec	15623	1	-1.823
Personal Care & Household Products	15621	1	-2.353
Real estate	15627	1	-2.568
Software & CPU Services	15630	4	-2.403
Speciality & Other Financials	15633	2	-1.771
Support Services	15635	4	-2.681
Telecommunication Services	15641	5	-2.568
Transport	15639	1	-2.865

* significant at 5%

6.5.2 Φ_1 tests on level series

Non rejection of the Φ_3 null tells us nothing about the drift parameter μ as in the test it was unrestricted, so it is now necessary to move to the second round. Critical values for the Φ_1 two sided test are shown in Table 16. The calculated values of the test statistic are set out in Table 17. None of the indices reject the null of H_0: $(\mu,\gamma)=(0,0)$ even at 1% significance, so the third version of the test, that of τ is required.

Table 16 **Φ_1 Critical Values**

	1%	5%	10%
Sample			
200	6.730	4.696	3.835
500	6.387	4.646	3.803

(Source: Patterson, Critical values of the DF test statistic Φ_1)

Table 17 Dickey-Fuller Tests for Stationarity in level index series

Format Two, Φ_1 test

Name	Ref	Lags for ADF	Test statistic
FTSE All Share	5921	1	-1.788
Aerospace & Defence	15577	0	-0.819
Auto & Parts	15579	2	-2.904
Beverages	15581	3	-1.667
Chemicals	15585	2	-2.608
Construction & Building Materials	15583	2	-2.825
Electricity	19897	0	-1.680
Electro & Electrical Equipment	15593	3	-3.440
Engineering & Machinery	15591	1	-3.193
Food & Drug Retailers	15597	0	-1.285
Food Production & Processors	15599	1	-2.008
Forestry & Paper	15595	0	-1.874
General Retailers	15601	1	-4.268
Health	15603	2	-3.481
Household Goods & Textiles	15605	0	-3.624
Insurance	15609	1	-1.570
Investment Companies	15610	1	-2.807
IT hardware	15607	1	-1.423
Leisure & Hotels	15613	1	-2.231
Media & Entertainments	15615	1	-3.147
Mining	15617	0	-1.741
Oil & Gas	15619	1	-0.994
Pharmacuticals & Biotec	15623	1	-2.700
Personal Care & Household Products	15621	1	-1.781
Real estate	15627	1	-2.582
Software & CPU Services	15630	4	-2.855
Speciality & Other Financials	15633	2	-2.842
Support Services	15635	4	-3.036
Telecommunication Services	15641	5	-3.497
Transport	15639	1	-3.073

* significant at 5%

6.5.3 τ tests on level series

The critical values for this are set out in Table 18.

Table 18 **τ Critical Values**

sample	1%	5%	10%
200	-2.581	-1.938	-1.619
500	-2.536	-1.943	-1.610

(Source: Patterson, Critical values of the DF test statistic τ)

Table 19 Dickey-Fuller Tests for Stationarity in level index series

Format One, τ test

Name	Ref	Lags for ADF	Test statistic
FTSE All Share	5921	1	1.865
Aerospace & Defence	15577	0	2.678
Auto & Parts	15579	2	1.881
Beverages	15581	3	2.975
Chemicals	15585	2	0.684
Construction & Building Materials	15583	2	2.199
Electricity	19897	0	0.859
Electro & Electrical Equipment	15593	3	1.665
Engineering & Machinery	15591	1	3.013
Food & Drug Retailers	15597	0	2.395
Food Production & Processors	15599	1	1.870
Forestry & Paper	15595	0	-0.565
General Retailers	15601	1	3.203
Health	15603	2	2.379
Household Goods & Textiles	15605	0	3.062
Insurance	15609	1	0.311
Investment Companies	15610	1	3.410
IT hardware	15607	1	2.336
Leisure & Hotels	15613	1	2.606
Media & Entertainments	15615	1	3.403
Mining	15617	0	1.265
Oil & Gas	15619	1	2.282
Pharmaceuticals & Biotec	15623	1	2.286
Personal Care & Household Products	15621	1	2.277
Real estate	15627	1	6.181
Software & CPU Services	15630	4	2.087
Speciality & Other Financials	15633	2	2.643
Support Services	15635	4	1.998
Telecommunication Services	15641	5	1.907
Transport	15639	1	1.788

*= significant at 5%.

The calculated test statistics are set out in Table 19 above. The results indicate that no indices reject the τ test's null hypothesis H_0: $\gamma=0$ and are thus consistent with Format One, a non stationary series with a unit root.

6.5.4 ADF tests on level series: summary

It is no surprise that for all three versions of this test none of the indices have rejected the null hypotheses of the Φ_3 test, the Φ_1 test or the τ test. The time series were for the natural logarithm of the index values and it is very common for these types of series to be non-stationary. To summarise this process (see also Figure 1):

- The Φ_3 test had the null and alternatives H_0: $(\mu,\gamma,\beta)= (\mu,0,0)$ and
  H_{a1}: $(\mu,\gamma,\beta) = (\mu,\gamma,\beta)$ or H_{a2}: $(\mu,\gamma,\beta) = (\mu,0,\beta)$ or H_{a3}: $(\mu,\gamma,\beta) = (\mu,\gamma,0)$
  Non rejection of the null results in the conclusion that the time series is consistent with having a unit root, that there is no trend but there is no indication of the drift, hence the need for the Φ_1 test. None of the 30 indices rejected this test so none are stationary.

- The Φ_1 test had the null and alternatives H_0: $(\mu,\gamma)=(0,0)$ and
  H_{a1}: $(\mu,\gamma)=(\mu,0)$ or H_{a2}: $(\mu,\gamma)=(0,\gamma)$ or H_{a3}: $(\mu,\gamma)=(\mu,\gamma)$.
  Non rejection of the null results in the initial conclusion that the time series is consistent with having a unit root and no drift and from Φ_3 there is no trend. None of the thirty indices rejected this test so none are stationary.

- The τ test had the null and alternative H_0: $\gamma=0$ and Ha: $\gamma<0$.
  Non rejection gives a unit root and a pure random walk of Format One, rejection means no unit root and not random. None of the thirty indices rejected this test so none are stationary.

6.6 Dickey Fuller Tests for first difference

6.6.1 Φ_3 tests on first differences

The tests in this section follow exactly the same structured approach as for the tests on levels, the only change is that the tests are now performed on the first differences of the natural logarithms of the index values, in effect the returns. Prior to commencing the Dickey Fuller tests, a small adjustment to the data is necessary. Asset pricing models assume that investors' expected return is a combination of the risk free rate and a premium for taking risk. The risk free rate could possibly 'interfere' with the drift term of a random walk and therefore has been deducted from the raw data Y_t - Y_{t-1}. (See also section 6.2 above.)

Critical values for the Φ_3 test of first differences are the same as for the level or undifferenced series (Table 14 above) but are reproduced here as Table 20.

Table 20 **Φ_3 Critical Values**

	1%	5%	10%
Sample			
200	8.542	6.397	5.433
500	8.326	6.238	5.321

(Source: Patterson, Critical values of the DF test statistic Φ_3)

All but two of the indices shown in Table 21 reject the null hypothesis and are therefore stationary using a maintained regression of random walk with drift and trend. (In the same way that financial econometrics normally expects a level time series not to be stationary, there is a similar expectation that a first differenced series will be stationary.) The two exceptions that did not reject the null and are not stationary in format three are Electrical Equipment (15593) and Support Services (15635).

Table 21 Dickey-Fuller Tests for Stationarity in the first differenced index series Format Three, Φ_3 test

Name	Ref	Lags for ADF	Test statistic
FTSE All Share	5921	1	-12.157*
Aerospace & Defence	15577	0	-15.248*
Auto & Parts	15579	2	-7.783*
Beverages	15581	3	-10.896*
Chemicals	15585	2	-7.488*
Construction & Building Materials	15583	2	-7.480*
Electricity	19897	0	-14.527*
Electro & Electrical Equipment	15593	3	-6.126
Engineering & Machinery	15591	1	-10.704*
Food & Drug Retailers	15597	0	-14.850*
Food Production & Processors	15599	1	-11.116*
Forestry & Paper	15595	0	-14.602*
General Retailers	15601	1	-9.795*
Health	15603	2	-7.817*
Household Goods & Textiles	15605	0	-16.759*
Insurance	15609	1	-9.440*
Investment Companies	15610	1	-9.896*
IT hardware	15607	1	-10.710*
Leisure & Hotels	15613	1	-11.321*
Media & Entertainments	15615	1	-10.882*
Mining	15617	0	-15.477*
Oil & Gas	15619	1	-9.865*
Pharmacuticals & Biotec	15623	1	-20.590*
Personal Care & Household Products	15621	1	-10.997*
Real estate	15627	1	-10.064*
Software & CPU Services	15630	4	-6.421*
Speciality & Other Financials	15633	2	-8.086*
Support Services	15635	4	-5.489
Telecommunication Services	15641	5	-7.240*
Transport	15639	1	-10.203*

* significant at 5%

6.6.2 Φ_1 tests on first differences

The two time series that did not reject the null in the previous test continue to follow the framework for testing used earlier and having not rejected the Φ_3 test proceed to the Φ_1 test. Critical values are as before, namely 4.696 for a sample of 200 and 4.646 for a sample size of 500.

Table 22 Dickey-Fuller Tests for Stationarity in first differenced index series Format Two, Φ_1 test

Title	Ref	Lags for ADF	Test statistic
Electro & Electrical Equip	15593	1	-5.721*
Support Services	15635	0	-5.169*

* significant at 5%

Both the series in Table 22 reject the null of a unit root, but as this test was on both a constant and the lagged value of format two there is no immediate conclusion, thus they follow the structure set out in Figure1 and move on to the τ_μ test.

6.6.3 τ_μ tests on first differences

This is a one sided test and has critical values shown in Table 23 that vary with the regressed value of μ.

Table 23 **τ_μ Critical Values**

5% critical values

sample.	μ= 0.00	0.05	0.10	0.25	0.50	1.00	10.00
200	-2.878	-2.837	-2.717	-2.156	-1.888	-1.763	-1.647
500	-2.851	-2.763	-2.461	-1.933	-1.811	-1.719	-1.659

(Source: Patterson, Critical values of the DF test statistic τ)

As can be seen from Table 24 below, both the series reject the null and are therefore assumed to be stationary when using format two of a pure random walk with drift as the maintained regression.

Table 24 Dickey-Fuller Tests for Stationarity in first differenced index series Format Two, τ_μ test

Title	Ref	Lags for ADF	Regressed μ	Critical Value	Test statistic
Electro & Electrical Equip	15593	1	0.0007	-2.878	-5.721*
Support Services	15635	0	0.0005	-2.878	-5.169*

* significant at 5%

6.6.4 τ_β tests on first differences

The 28 series that rejected the Φ_3 test are now retested using the τ_β test, as set out in Figure 1. This has a one sided alternative hypothesis and critical values (Table 25) that not only depend on the sample size but also on the value of the regressed coefficient β.

Table 25 **τ_β Critical Values**

5% critical values

sample.	β= 0.00	0.05	0.10	0.25	0.50	1.00	10.00
200	-3.433	-1.729	-1.715	-1.655	-1.653	-1.667	-1.636
500	-3.424	-1.683	-1.646	-1.625	-1.643	-1.615	-1.671

(Source: Patterson, Critical values of the DF test statistic τ)

The results of this test are shown below in Table 26.

Table 26 Dickey-Fuller Tests for Stationarity in the first differenced index series, τ_β test

	Ref	Lags for ADF	Regressed β	Critical value	Test statistic
FTSE All Share	5921	1	0.00	3.433	-12.157*
Aerospace & Defence	15577	0	0.00	3.433	-15.248*
Auto & Parts	15579	2	0.00	3.433	-7.783*
Beverages	15581	3	0.00	3.433	-10.896*
Chemicals	15585	2	0.00	3.433	-7.488*
Construction & Building Materials	15583	2	0.00	3.433	-7.480*
Electricity	19897	0	0.00	3.433	-14.527*
Electro & Electrical Equipment	15593	Not applicable			
Engineering & Machinery	15591	1	0.00	3.433	-10.704*
Food & Drug Retailers	15597	0	0.00	3.433	-14.850*
Food Production & Processors	15599	1	0.00	3.433	-11.116*
Forestry & Paper	15595	0	0.00	3.433	-14.602*
General Retailers	15601	1	0.00	3.433	-9.795*
Health	15603	2	0.00	3.433	-7.817*
Household Goods & Textiles	15605	0	0.00	3.433	-16.759*
Insurance	15609	1	0.00	3.433	-9.440*
Investment Companies	15610	1	0.00	3.433	-9.896*
IT hardware	15607	1	0.00	3.433	-10.710*
Leisure & Hotels	15613	1	0.00	3.433	-11.321*
Media & Entertainments	15615	1	0.00	3.433	-10.882*
Mining	15617	0	0.00	3.433	-15.477*
Oil & Gas	15619	1	0.00	3.433	-9.865*
Pharmaceuticals & Biotec	15623	1	0.00	3.433	-20.590*
Personal Care & Household Products	15621	1	0.00	3.433	-10.997*
Real estate	15627	1	0.00	3.433	-10.064*
Software & CPU Services	15630	4	0.00	3.433	-6.421*
Speciality & Other Financials	15633	2	0.00	3.433	-8.086*
Support Services	15635	Not applicable			
Telecommunication Services	15641	5	0.00	3.433	-7.240*
Transport	15639	1	0.00	3.433	-10.203*

* significant at 5%

All 28 of the first differenced series reject the null hypothesis and are therefore assumed to be stationary. Thus when combined with the two series that were identified as stationary earlier, all 30 of the FTSE All Share indices' return time series are stationary

6.7 Random Walk as the Data Generating Process

6.7.1 BDS tests for IID in the residuals from a random walk process

The previous section has shown that the natural logarithmic values of the indices' time series are not stationary in levels but are stationary in first difference (i.e. as a log return). This section now considers whether the data generating process is a random walk. Regressions are run for each time series in the format of equation 6.14 above:

$$R_t = Y_t - Y_{t-1} = \mu + \gamma Y_{t-1} + \beta t + \varepsilon_t$$

with the exception of Electrical Equipment (15593) and Support Services (15635) where the Augmented Dickey Fuller tests showed that there was no trend and thus β is assumed to be zero.

The results of these regressions are not shown here, instead the BDS test is undertaken on the residuals from the 30 regressions. Table 27 sets out the results. The test is two sided and the null hypothesis is that the residuals are IID. In small samples the distribution of the BDS test statistic is often not normal, but with a sample of over 250 this is not seen as a problem. Thus a normal distribution can be assumed with critical values of: 1%, 2.5757; 5% 1.96; and 10% 1.6449. Rejection of the null of IID means that the data generating process is possibly not linear, that the residuals contain evidence of additional processes that as yet are not included in the regression and thus the regressed form is not fully explaining the data generating process. The BDS test statistics have been calculated for two, three and four dimensions, in line with earlier indications of possible autocorrelation of up to five days.

At 5% significance it can be seen that 24 of the series reject the null of the residuals being IID, but that six require further consideration as the BDS test statistics indicate that the data generating processes produced residuals that were IID (or rather did not reject the null). These six indices are: FTSE All Share (5921); Aero (15577): Chemicals (15585); Forestry (15595); Oil (15619); and Personal (15621). For the remaining 24 time series, the lack of IID in the residuals means that the various random walk formats are not appropriate as they do not explain the data generating process satisfactorily. These will be examined for other processes in the next chapter.

Table 27 BDS tests on a random walk as the DGP

Name	Ref	Dimension 2		Dimension 3		Dimension 4	
		Statistic	Z	Statistic	Z	Statistic	Z
FTSE All Share	5921	.000610	.127354	.002968	.390047	.003639	.401903
Aerospace & Defence	15577	-.000029	-.063093	.000088	-.085314	-.000176	-.102764
Auto & Parts	15579	.012241	2.181529*	.019872	2.224146*	.016671	1.563758
Beverages	15581	.019878	3.261489*	.029987	3.081461*	.038654	3.319257*
Chemicals	15585	-.006273	-1.035528	-.002101	-.217177	.000282	.024319
Construction & Building Materials	15583	.011907	2.117750*	.020107	2.247378*	.026720	2.504565*
Electricity	19897	.030648	5.039662*	.053518	5.522386*	.072117	6.230757*
Electro & Electrical Equipment	15593	.010417	2.185787*	.018752	2.477933*	.031143	3.459436*
Engineering & Machinery	15591	.018003	3.072637*	.024045	2.576349*	.034065	3.057621*
Food & Drug Retailers	15597	.032070	4.089148*	.062319	4.970121*	.077635	5.165011*
Food Production & Processors	15599	.018467	3.282143*	.025455	2.837344*	.026237	2.447549*
Forestry & Paper	15595	.007887	.904041	.014253	1.019826	.023663	1.409194
General Retailers	15601	.011850	2.115268*	.021080	2.359165*	.028593	2.677290*
Health	15603	.014406	2.698370*	.021711	2.551479*	.024457	2.406536*
Household Goods & Textiles	15605	.016054	3.170560*	.028491	3.531979*	.036982	3.841011*
Insurance	15609	.021138	3.341858*	.038309	3.803387*	.050111	4.168447*
Investment Companies	15610	.014732	2.570734*	.026453	2.891379*	.034912	3.213908*
IT hardware	15607	.028913	5.538803*	.047019	5.664692*	.054857	5.547019*
Leisure & Hotels	15613	.023882	4.271881*	.036849	4.138971*	.039563	3.723671*
Media & Entertainments	15615	.012656	2.278745*	.021931	2.483574*	.034643	3.292830*
Mining	15617	.034924	5.966999*	.056166	6.020431*	.067959	6.098194*
Oil & Gas	15619	-.002172	-.404703	-.004147	-.485913	-.006650	-.653916
Pharmaceuticals & Biotec	15623	.005282	1.097581	.015140	1.980811*	.025058	2.754924*
Personal Care & Household Products	15621	.000054	-.007520	-.007578	-.656797	-.002364	-.171269
Real estate	15627	.019577	3.728815*	.033220	3.973959*	.043339	4.345464*
Software & CPU Services	15630	.021468	3.578631*	.029247	3.060871*	.032666	2.863766*
Speciality & Other Financials	15633	.024992	4.625650*	.036877	4.290028*	.040316	3.933975*
Support Services	15635	.011852	2.342277*	.019099	2.368436*	.025468	2.644899*
Telecommunication Services	15641	.012871	2.477628*	.031677	3.832319*	.042548	4.317468*
Transport	15639	.022929	4.169214*	.045992	5.255945*	.056168	5.383531*

* significant at 5%

6.7.2 Time series with IID residuals

The six indices that do produce IID residuals when regressed in a random walk format are set out below, with details of the regressions and allied statistics.

FTSE All Share (5921)

$R_t = \mu + \gamma Y_{t-1} + \beta t + \varepsilon_t$

$R_{t,\,5921} =$ $-0.747066 + 0.098786 Y_{t-1,\,5921} - 0.000065t$

t statistics -3.624993* 3.629444* -3.614008*

F statistic (probability) 6.736811* (0.001405)

R^2 0.049449

JB (probability) 3.118787 (0.210264)

LM test (probability) 3.570853 (0.058802)

All three t statistics are significant at 5%, indicating that they reject the null hypotheses of individually being zero. This is confirmed by the F statistic, (a simultaneous test that all slope coefficients (i.e. excluding the constant) are zero) which is also significant at 5%. The JB statistic is not significant at 5%, thus the null of residuals being normal is not rejected. Finally, the LM test is not significant at 5%, so the null of no serial correlation is not rejected. The BDS statistics from Table 27 above show that the residuals are IID. Hence it is concluded that the FTSE All Share index (5921) is explained by the above data generating process of a near to random walk with drift and trend. (See Chapter 4 for discussion on an index being "explained".)

Aerospace & Defence (15577)

$R_{t,\,15577} =$ $-0.169078 + 0.022591 Y_{t-1,\,15577} - 0.000034t$

t statistics -1.743082 1.763187 -1.575579

F statistic (probability) 1.554866 (0.213183)

R^2 0.011864

JB (probability) 71334.91* (0.000000)

LM (probability) 1.068216 (0.301349)

None of the regression's coefficients' t statistics are significant, a conclusion supported by the F statistic. The JB statistic does however reject the null of normality. The LM is not significant and the BDS statistics from Table 27 above indicate that the null is not rejected, so the residuals are IID. Hence it is concluded that the Aerospace & Defence index (15577) is explained by the above data generating process of a random walk with drift and trend (but with the coefficients not significantly different from zero).

Chemicals (15585)

$R_{t,\,15585} =$	$0.16757 - 0.002004Y_{t-1,\,15585} - 0.000016t$		
t statistics	.310289	-.265690	-2.173304*
F statistic (probability)	2.361677 (0.096289)		
R^2	0.017910		
JB (probability)	61.89220* (0.000000)		
LM (probability)	17.047598* (0.000181)		

Within the regressed data generating process only the coefficient for the trend is significantly different from zero, a result contradicted by the F statistic which shows both slopes as not significant. (It is not uncommon for the F statistic to contradict the t or z statistics and in these cases is sometimes an indicator of collinearity.) The LM test for serial correlation is significant at 5%, as is the JB test for normality. Table 27 shows no rejection of the null of IID in the BDS test. Hence it is concluded that the Chemicals index (15585) is explained by the above data generating process of a random walk with drift, although lack of normality and possible serial correlation casts some limited doubt and the contradiction between the t and F statistics gives mixed messages as to the process being a pure random walk or a random walk with trend.

Forestry & Paper (15595)

$R_{t,\,15595} =$	$-0.412467 + 0.059901Y_{t-1,\,15595} + 0.000027t$		
t statistics	-2.821274*	2.821498*	1.616456
F statistic (probability)	4.060905* (0.018341)		
R^2	0.030406		
JB (probability)	1285.766* (0.000000)		
LM (probability)	4.108235 (0.042675)		

Lack of normality is evidenced by the JB statistic but the LM is not significant. The F statistic rejects the null that both slope coefficients are significantly different from zero, rather than just the one shown by the individual t scores. The BDS statistics all show that the residuals are IID. Hence it is concluded that the Forestry & Paper index

(15595) is explained by the above data generating process of a near to random walk with drift and possibly trend.

Oil and Gas (15619)

$R_{t,\,15619} =$	-0.092434 +	$0.011884Y_{t-1,\,15619}$	- 0.000012t
t statistics	-1.205177	1.223587	-1.000857
F statistic (probability)	0.750933 (0.472951)		
R^2	0.005765		
JB (probability)	93.71542* (0.000000)		
LM (probability)	7.609340* (0.005807)		

All coefficients in the regression are concluded to be zero, based on both the F statistic and the individual t statistics. The residuals are not normal and show evidence of serial correlation. The BDS tests from above show the residuals to be IID. Hence it is concluded that the Oil and Gas index (15619) is explained by the above data generating process of a random walk with drift and trend, (but both are insignificantly different from zero).

Personal Care & Household Products (15621)

$R_{t,\,15621} =$	-0.277770 +	$0.039704Y_{t-1,\,15621}$	- 0.000122t
t statistics	-2.436796*	2.475185*	-2.693107*
F statistic (probability)	3.701514* (0.026002)		
R^2	0.027789		
JB (probability)	116.3135* (0.000000)		
LM (probability)	4.326653 (0.114942)		

F and t statistics confirm that all the regression coefficients are significantly different to zero. There is no serial correlation, but the JB statistic shows lack of normality. The BDS statistics in Table 27 do not reject the null hypothesis of IID residuals. Hence it is concluded that the Personal Care & Household Products index (15621) is explained by the above data generating process of a near to random walk with drift and trend.

The three time series that are identified as having their data generating processes consistent with a random walk are such that their next period's values cannot be forecasted. Thus initially they can be regarded as exhibiting strong efficiency. These particular sub indices of the FTSE All Share index could therefore warrant a passive investment strategy, but that conclusion is however too soon to be valid. The three indices that have a maintained regression that is a near random walk may or may not be efficient. The six indices will be further tested in Chapter 8 to assess their forecasting ability. It is of interest that the aggregate index is near to random, as this vague conclusion is in step with several efficiency studies, some finding the market efficient whilst others cast doubt. The difference here is that those studies did not examine the sub indices and tacitly assumed that if the aggregate was efficient, then so were the sub indices.

6.7.3 Summary for stationarity and random walk processes

The conclusions of this chapter are that: firstly, no series are stationary in levels (i.e. the log normal index) ; secondly, all series are stationary in first difference (the log return) and so the indices are integrated of order one; thirdly, that three indices are random and three near random with residuals that are IID and as such they are now regarded as being fully explained.

Near random	FTSE All Share	5921
Random	Aerospace & Defense	15577
Random	Chemicals	15585
Near random	Forestry & Paper	15595
Random	Oil and Gas	15619
Near random	Personal Care & Household Products	15621

At this stage, although they are possibly random, but their residuals are not IID, nothing can be inferred about the efficiency of the remaining 24 indices. These will be examined in the next chapter.

CHAPTER SEVEN OTHER DATA GENERATING PROCESSES

7.1 ARCH in the Data Generating Processes

7.1.1 Outline

The analysis in Chapter 6 showed that all 30 time series were stationary when differenced once. Six indices had a data generating process identified which gave residuals from the maintained regression that were IID and so are now assumed to be explained. The remaining 24 exhibited the characteristics of stationarity, but were not IID in their residuals when using one of the random walk formats for the regression, an indication of possible serial correlation which makes either Autoregressive Conditional Heteroscedastic (ARCH) or Generalised Autoregressive Conditional Heteroscedastic (GARCH) type models an obvious next contender for examination of these as yet unidentified processes.

Central to ARCH processes is conditional variance, so that a basic model could be

$$y_t = x_t\gamma + \varepsilon_t \qquad (7.1)$$

and

$$\sigma_t^2 = \omega + \alpha\varepsilon^2_{t-1} \qquad (7.2)$$

Extending this simple model, an increase in the number of lags produces:

$$\sigma_t^2 = \omega + \alpha_1\varepsilon^2_{t-1} + \ldots\ldots + \alpha_q\varepsilon^2_{t-q} \qquad (7.3)$$

which is an ARCH(q) model, where q is the number of lagged values.

Its conversion to a GARCH type model is to change equation 7.2 so that

$$\sigma_t^2 = \omega + \alpha\varepsilon^2_{t-1} + \beta\sigma_{t-1}^2 \qquad (7.4)$$

In the same way that equation 7.2 was extended to 7.3 by increasing the number of lags, the basic GARCH model can likewise be extended by increasing the lags on σ_t^2, so that

$$\sigma_t^2 = \omega + \alpha_1\varepsilon^2_{t-1} + \ldots\ldots + \alpha_q\varepsilon^2_{t-q} + \beta_1\,\sigma_{t-1}^2 + \ldots + \beta p\,\sigma_{t-p}^2 \qquad (7.5)$$

resulting in a GARCH(p, q) format.

For subsequent GARCH modelling, the equations will use R_t as the dependent variable in the data generating process, with the prior evidence of stationarity giving the basic regression equations of drift and trend, apart from the two that were just drift.

7.1.2 Tests for ARCH

Two of the main tests for evidence of ARCH are the LM and the F. The LM test has the null of H_0: $\alpha_1 = \alpha_2 = \ldots = \alpha_q = 0$ and the alternative of at least one $\neq 0$. The F test is analogous to the test for serial correlation. Results for both of these tests are shown in Table 28, where the regressions include constant and trend for all series other than Electrical Equipment (15593) and Support (15635) where the unit root tests indicated no trend.

Table 28 ARCH Tests on random but not IID time series

Name	Ref	F stat	p	LM test	p	ARCH?
Auto & Parts	15579	.004274	.947924	.004307	.947674	
Beverages	15581	.001207	.972310	.001216	.9722177	
Construction & Building Materials	15583	1.602923	.206627	1.605366	.205144	
Electricity	19897	29.14542*	.000000	26.39970*	.000000	Yes
Electro & Electrical Equipment	15593	2.743814	.098842	2.736017	.098109	
Engineering & Machinery	15591	1.413490	.235567	1.416673	.233952	
Food & Drug Retailers	15597	.082291	.774446	.082900	.773406	
Food Production & Processors	15599	7.283744*	.007416	7.139216*	.007542	Yes
General Retailers	15601	.898404	.344094	.902212	.342189	
Health	15603	.047055	.828404	.047430	.827597	
Household Goods & Textiles	15605	8.383284*	.004110	8.183149*	.004228	Yes
Insurance	15609	.017340	.895338	.017473	.894838	
Investment Companies	15610	1.876233	.171949	1.877123	.170661	
IT hardware	15607	25.56094*	.000001	23.44456*	.000001	Yes
Leisure & Hotels	15613	7.888333*	.005355	7.714293*	.005479	Yes
Media & Entertainments	15615	.013259	.908418	.013360	.907980	
Mining	15617	15.49420*	.000106	14.73250*	.000124	Yes
Pharmacuticals & Biotec	15623	.918959	.338642	.922782	.336746	
Real Estate	15627	7.623987*	.006172	7.463172*	.006297	Yes
Software & CPU Services	15630	6.707431*	.010145	6.588599*	.010263	Yes
Speciality & Other Financials	15633	6.864950*	.009309	6.739331*	.009431	Yes
Support Services	15635	.089273	.765342	.089932	.764264	
Telecommunication Services	15641	.904610	.342435	.908422	.340533	
Transport	15639	24.40465*	.000001	22.47533*	.000002	Yes

*=significant at 5%

Examination of the probabilities shows that for both tests, the null of no ARCH effect in the residuals is rejected very strongly for Electricity (19897), Food Production & Processors (15599), Household Goods & Textiles (15605), IT Hardware (15607), Leisure & Hotels (15613), Mining (15617), Real Estate (15627), Software & CPU Services (15630), Speciality & Other Financials (15633) and Transport (15639).

GARCH has become very common in recent research in time series in finance and it must be admitted that prior to this test, the expectation was that a majority would reject the null. To find only ten rejections at 5% significance is somewhat unexpected!

With the ten series that indicate an ARCH effect, the following analysis will assume a GARCH(1, 1) format unless the evidence suggests otherwise. Most research in finance indicates that p=q=1 is the most common and this can be observed in the following example, based on Electricity (19897), where the ARCH LM test is repeated for one to four lags.

Lag	**LM**	**p**
4	26.95030	.000000
3	26.88417	.000000
2	26.76843	.000000
1	26.39970	.000000

As can be seen, there is virtually no change in the test value for evidence of ARCH, so for the sake of parsimony the lags will be set at one.

7.2 Results of GARCH regressions

7.2.1 Basic GARCH format

There are many different types of GARCH models and, as with the Dickey Fuller test framework of the previous chapter, there is the risk of data mining unless a structured approach is taken. Consequently the first consideration will be that the basic GARCH model applies, but it may be necessary at a later stage to expand this to encompass other versions. The following sets out the results of running the basic random walk with drift and trend in a GARCH format. The statistics follow the earlier format although use of GARCH precludes the LM test for serial correlation. In each regression the residuals are tested for IID via the BDS test. Lack of IID will mean that the regression does not explain the time series.

Electricity (19897)

$R_{t,\,19897} = -0.306218 + 0.046245Y_{t-1,\,19897} - 0.000133t$

z statistics	-2.388231*	2.446029*	-2.484873*
F statistic (probability)		1.297686 (0.265297)	
R^2		0.024719	
JB (probability)		232.9736* (0.000000)	

$\sigma_t^2 = .0000733 + .336702\varepsilon^2_{t-1} + .427575\sigma_{t-1}^2$

z 3.725058* 3.783790* 4.242197*

Dimension	2	3	4
BDS statistic	.008182	.010655	.013723
Z	1.497891	1.226280	1.324845

The mean regression has z statistics that are significant, conflicting with the F statistic. (Earlier regressions in Chapter 6 showed t statistics, but E-Views reports z rather than t where normality is asymptotic. Use of z and t does not invalidate the analysis.) The JB test indicates lack of normality. All the variance regression coefficients are significant and the BDS test does not reject the null of IID. Thus Electricity (19897) is assumed to be explained (as described in Chapter 4).

Food Production & Processors (15599)

$R_{t,\,15599} = -0.099766 + 0.013629Y_{t-1,\,15599} - 0.000023t$

z statistics	-.962845	.985437	-1.557010
F statistic (probability)		.736955 (0.596362)	
R^2		0.014189	
JB (probability)		182.9011* (0.000000)	

$\sigma_t^2 = .000032 + .291369\varepsilon^2_{t-1} - .015981\sigma_{t-1}^2$

z 3.950991* 4.343171* -.089262

Dimension	2	3	4
BDS statistic	.002624	.003088	.002866
Z	.481690	.356078	.277018

None of the mean's regressed coefficients are significant, as supported by the F test, whereas the first two variance regression coefficients reject the null of being zero. The JB test indicates a lack of normality and the BDS test indicates that the residuals are IID. So Food Production & Processors (15599) is assumed to be explained.

Household Goods & Textiles (15605)

$R_{t,\,15605} =$	$-0.072584 + 0.010699Y_{t-1,\,15605}$		$- 0.000038t$
z statistics	-1.014359	1.074199	-2.027170*
F statistic (probability)		1.691018 (0.137138)	
R^2		0.031972	
JB (probability)		13.24871* (0.001328)	

$\sigma_t^2 = .000068 + .267432\varepsilon^2_{t-1} + .014625\sigma_{t-1}^2$

z	5.938228*	4.205914*	.118150

Dimension	2	3	4
BDS statistic	-.000313	.003528	.008426
Z	.064249	.454937	.910969

The trend's coefficient is significant in the mean equation, but is countered by the F test. The JB statistic indicates a lack of normality. Within the variance regression the GARCH component is not significant. BDS statistics do not reject the null of the residuals being IID. Household Goods & Textiles can therefore be assumed to be explained.

IT Hardware (15607)

$R_{t,\,15607} =$	$-0.288330 + 0.040534Y_{t-1,\,15607}$		$- 0.000140t$
z statistics	-3.053892*	3.066880*	-2.884916*
F statistic (probability)		1.307346 (0.261215)	
R^2		0.024898	
JB (probability)		12.39836* (0.002031)	

$\sigma_t^2 = .000061 + .210341\varepsilon^2_{t-1} + .518603\sigma_{t-1}^2$

z	2.763824*	2.440487*	3.416067*

Dimension	2	3	4
BDS statistic	.006669	.003664	-.001523
Z	1.459005	.505051	-.176534

All coefficients in the mean's regression are significant, but the F test is not significant. The JB's statistic indicates a lack of normality. All three variance regression coefficients are significant and the BDS statistics indicate IID in the residuals. IT Hardware is thus assumed to be explained.

Leisure & Hotels (15613)

Dimension	2	3	4
BDS statistic	.015269	.020249	.018589
z	2.866961*	2.388053*	1.837524

The BDS test statistics for dimensions two and three reject the null hypothesis that the residuals from the mean regression are IID. Using the random walk with drift and trend with GARCH does not explain Leisure & Hotels.

Mining (15617)

$R_{t,\,15617} = -0.236758 + 0.034326Y_{t-1,\,15617} - 0.000078t$

z statistics	-2.566576*	2.610596*	-3.557156*

F statistic (probability) 1.661666 (0.144314)

R^2 0.031434

JB (probability) 52.7626* (0.000000)

$\sigma_t^2 =$	.000117 +	$.395104\varepsilon^2_{t-1}$ -	$.074930\sigma_{t-1}^2$
z	6.600005*	4.176194*	-.627213

Dimension	2	3	4
BDS statistic	.002783	.005493	.010214
z	.505031	.626297	.976373

Coefficients in the mean regression are all significant, but the F test indicates that the slope coefficients are not significantly different from zero. The JB test indicates a lack of normality in the residuals and the BDS test statistics for dimensions two to four indicate IID. Thus Mining is assumed to be explained.

Real Estate (15627)

$R_{t,\,15627} = -0.014584 + 0.002296Y_{t-1,\,15627} - 0.000011t$

z statistics	-.188440	.221307	-.546970

F statistic (probability) 1.272626 (0.276135)

R^2 0.024253

JB (probability) 17.87338* (0.000131)

$\sigma_t^2 =$	.000004 +	$.207697\varepsilon^2_{t-1}$ +	$.534437\sigma_{t-1}^2$
z	2.552200*	2.778255*	3.974037*

Dimension	2	3	4
BDS statistic	.004587	.008236	.010640
Z	.885277	1.000953	1.086662

All of the mean's coefficients are zero (z statistics and F test). The JB test shows no normality in the residuals but BDS indicates IID. Real Estate is assumed to be explained.

Software & CPU Services (15630)

Dimension	2	3	4
BDS statistic	.013427	.017795	.019775
Z	2.313574*	1.927411	1.796621

The BDS test shows that the residuals from the mean regression, combined with GARCH in the variance, reject the null of IID. Thus Software & CPU Services is not explained.

Speciality & Other Financials (15633)

$R_{t,\,15633} =$ -0.093910 + $0.014218Y_{t-1,\,15633}$ - 0.00038t

z statistics -1.225264 1.267496 -2.080317*

F statistic (probability) 3.071981* (0.010347)

R^2 0.056603

JB (probability) 7.187624* (0.027493)

$\sigma_t^2 = .000017 + .197315\varepsilon^2_{t-1} + .215849\sigma_{t-1}^2$

z 2.835528* 2.356265* .909282

Dimension	2	3	4
BDS statistic	.009974	.013417	.012743
Z	1.891305	1.599620	1.274662

A lack of normality in the residuals is indicated by the JB test. In the mean regression only the trend coefficient is significant, compared to the lack of significance in the F test, which infers that none of the coefficients are significantly different from zero. The BDS tests show no rejection of the null of IID, so Speciality & Other Financials is assumed to be explained.

Transport (15639)

$R_{t,\,15639} =$	$-0.142468 + 0.019342Y_{t-1,\,15639} - 0.000040t$		
z statistics	-1.749238	1.789275	-2.900383*
F statistic (probability)	1.530154 (0.180787)		
R^2	0.029019		
JB (probability)	14.80795* (0.000609)		

$\sigma_t^2 =$	$.000010 +$	$.227160\varepsilon^2_{t-1} +$	$.644619\sigma_{t-1}^2$
z	2.199725*	3.434064*	6.880248*

Dimension	2	3	4
BDS statistic	-.001017	.000139	-.002704
z	-.196636	.016866	-.275485

As with the other indices, there are mixed messages for the regression coefficients in the mean, but all are significant in the variance. Residuals do not reject the BDS null of IID. Transport is therefore considered to be explained.

7.2.2 Extended or enhanced versions of GARCH

Of the ten indices that showed potential for ARCH in their generating process, eight are now explained but two remain unexplained; those of Leisure & Hotels and Software & CPU Services. There are many types of GARCH models and, as with the Dickey Fuller test framework, there is the risk of data mining unless a structured approach is taken. Consequently the first model to be considered will be that where the conditional variance is asymmetric, i.e. there is a tacit assumption that investors will increase expectations of volatility if returns fall rather than rise. A fairly recent asymmetric model is Glosten, Jagannathan and Runkle's GJR model (also known as Threshold GARCH or TGARCH) based upon:

$$\sigma_t^2 = \omega + \alpha\varepsilon^2_{t-1} + \beta\sigma_{t-1}^2 + \gamma\,\varepsilon^2_{t-1}I_{t-1} \qquad (7.6)$$

where $I_{t-1} = 1$ if $\varepsilon_{t-1} < 0$, else $=0$ and with the expectation that γ will be positive. Table 29 shows the results of the GJR regressions, but only in relation to the BDS statistics to establish if this model is applicable

Table 29 BDS Statistics with Threshold GARCH

Name	Ref	BDS Dimension 2		BDS Dimension 3		BDS Dimension 4	
		Statistic	z	Statistic	z	Statistic	z
Leisure & Hotels	15613	.020616	3.802245*	.028122	3.261100*	.027401	2.666238*
Software & CPU Services	15630	.002557	.443717	.005577	.617456	.008520	.777377

*=significant at 5%.

Leisure & Hotels is still rejecting the BDS null of IID and remains unexplained, but Software & CPU Services does not reject the BDS test and is detailed below.

Software & CPU Services (15630)

$R_{t,\,15630} =$ -0.034905 + $0.006527Y_{t-1,\,15630}$ - 0.000033t

z statistics -.726781 .830499 -1.917724

F statistic (probability) 1.764701 (0.106747)

R^2 0.039867

JB (probability) 55.20982* (0.000000)

$\sigma_t^2 = .000074 + .301052\varepsilon^2_{t-1} - .165564\sigma_{t-1}^2 + .044184\,\varepsilon^2_{t-1}I_{t-1}$

z 2.199725* 3.434064* 6.880248*

Dimension	2	3	4
BDS statistic	.002557	.005577	.008520
z	.443717	.617456	.777377

None of the mean's regressed coefficients are significant, nor is the F statistic. Residuals are not normal and all the variance coefficients are significant. As would be expected, the asymmetric component's coefficient in the variance regression is positive. The BDS test statistics show the residuals are IID so Software & CPU Services is explained.

Another version of ARCH models that finds frequent application in finance and has a financial rationale is that of GARCH in mean. This can be tested with the standard GARCH(1, 1) variance equation but with the data generating process having an additional term (the standard deviation) reflecting the impact of risk on return (in step with most asset pricing models). The process thus becomes:

$$y_t = x_t\gamma + \delta\sigma_{t-1} + \varepsilon_t \qquad (7.7)$$

so that the conditional σ_{t-1} is now one of the dependent variables in the expression for the data generating process. Results of the BDS test with the regression in this GARCH in mean format are in Table 30.

Table 30 BDS Statistics with GARCH in mean

Name	Ref	BDS Dimension 2		BDS Dimension 3		BDS Dimension 4	
		Statistic	z	Statistic	z	Statistic	z
Leisure & Hotels	15613	.019917	3.706153*	.029831	3.482934*	.032100	3.138292*

*=significant at 5%.

Leisure & Hotel's index yet again produces residuals from the regression that reject the null hypothesis of independent and identical distribution.

The third version of GARCH to be tested is Exponential GARCH or EGARCH. In this version the variance equation is

$$\log\sigma_t^2 = \omega + \beta\log \sigma_{t-1}^2 + \alpha|(\varepsilon_{t-1}/ \sigma_{t-1})| + \gamma(\varepsilon_{t-1}/ \sigma_{t-1})$$

Results of the BDS test with the regression in this format are in Table 31.

Table 31 BDS Statistics with EGARCH

Name	Ref	BDS Dimension 2		BDS Dimension 3		BDS Dimension 4	
		Statistic	z	Statistic	z	Statistic	z
Leisure & Hotels	15613	.011608	2.217220*	.015688	1.882469	.017142	1.724593

*=significant at 5%.

Leisure & Hotels yet again fails to achieve IID in its residuals, although use of EGARCH produces only one dimension that is significant.

The fourth version to be applied is Component GARCH. This includes a time varying volatility q which is assumed to converge in the long run to a constant ω. The variance is expressed as

$$\sigma_t^2 - q_t = \omega + \alpha(\varepsilon^2_{t-1} - \omega) + \beta(\sigma_{t-1}^2 - \omega)$$

$$q_t = \omega + \rho(q_{t-1} - \omega) + \Phi(\varepsilon^2_{t-1} - \sigma_{t-1}^2)$$

In this format the BDS test on the residuals of the mean's regression does not reject the null of IID. Leisure & Hotels is set out below.

Leisure & Hotels (15613)

$R_{t,15613} =$ -0.090928 + $0.013537Y_{t-1,15613}$ - 0.000030t

z statistics -.906880 .093871 -1.662146

F statistic (probability) .489524 (0.841840)

R^2 0.013311

JB (probability) 504.4241* (0.000000)

$\sigma_t^2 - q_t = \omega + .159871(\varepsilon^2_{t-1} - \omega) - .306077(\sigma_{t-1}^2 - \omega)$

z 1.177270 -.878711

$q_t = .000051 + .562594(q_{t-1} - \omega) + .028027(\varepsilon^2_{t-1} - \sigma_{t-1}^2)$

z 11.39760* .556996 .263397

Dimension	2	3	4
BDS statistic	.010068	.015366	.015852
z	1.911966	1.835024	1.588659

The regressed mean has no significant coefficients. The residuals are not normally distributed but are IID. Only one of the component GARCH coefficients is significant. Thus Leisure & Hotels is now explained.

The ten indices that exhibited ARCH effects are now explained. These plus the six explained by a random walk type process in Chapter 6 mean that out of the original 30 indices there remains a further 14 sub indices that are not yet explained.

7.3 Auto Regression as the Data Generating Processes

7.3.1 Basic AutoRegressive regressions

This section begins with all the 30 indices that were stationary according to Augmented Dickey Fuller tests, less six time series that were showing evidence of a random or near random walk as the maintained regression and ten that had a form of a GARCH process. These 16 industrial sector indices are now considered to be explained. Thus the 14 unexplained time series must now be re-examined to consider the explanatory powers of other data generating processes. As with all processes so far explained, the residuals will be tested for IID via the BDS test.

One of the most common univariate time series models is auto regression, or AR(p) where p is the number of lags. This is now utilized, rather than say exponential or moving average as there is some financial justification. The basic AR(1) process is:

$$R_t = c + \varphi_1 R_{t-1} + \varepsilon_t \qquad (7.8)$$

where the inclusion of the lagged return could be viewed as a momentum factor. The statistics from the BDS tests on the residuals from running the regressions in this AR(1) format against the 14 time series are shown in Table 32 below.

Table 32 BDS statistics for an Autoregressive Processes

Name	Ref	BDS Dimension 2		BDS Dimension 3		BDS Dimension 4	
		Statistic	z	Statistic	z	Statistic	z
Auto & Parts	15579	.010765	1.970915*	.016394	1.888127	.014794	1.430376
Beverages	15581	.020523	3.286680*	.023766	2.384202*	.027492	2.305138*
Construction & Building Materials	15583	.003797	.671947	.006163	.685474	.009290	.866754
Electro & Electrical Equipment	15593	.004643	1.014312	.008298	1.140202	.020579	2.373925*
Engineering & Machinery	15591	.014085	2.422590*	.017851	1.926895	.028691	2.593579
Food & Drug Retailers	15597	.032495	3.963120*	.061524	4.683642*	.075335	4.773762*
General Retailers	15601	.008417	1.509559	.011788	1.326308	.017901	1.686182
Health	15603	.016166	2.976619*	.023872	2.763214*	.031392	3.048350*
Insurance	15609	.025464	4.040348*	.045051	4.473580*	.059047	4.895856*
Investment Companies	15610	.011511	1.976841*	.017585	1.896259	.029704	2.683705*
Media & Entertainments	15615	.007297	1.372153	.012706	1.504036	.022209	2.208404*
Pharmaceuticals & Biotec	15623	.000291	.057381	.006783	.840828	.015965	1.661308
Support Services	15635	.002773	.551389	.006269	.781594	.012520	1.306462
Telecommunication Services	15641	.014778	2.818408*	.030247	3.627031*	.039399	3.964481*

*= 5% significance

Four of the time series do not reject the BDS null when the residuals are generated by an AR(1) process and are examined below.

Construction & Building Materials (15583)

$R_{t,\,15583} =$	0.000965 +	$0.222377R_{t-1,\,15583}$
t statistics	2.094213*	3.714901*
F statistic (probability)		13.80049* (0.000249)
R^2		0.050588
JB (probability)		197.3507* (0.000000)
LM (probability)		2.540652 (0.280740)

F and t statistics confirm that the regression coefficients are significantly different from zero. There is no serial correlation, but the JB statistic shows lack of normality. Table 32 above shows that the residuals do not reject the null of being IID. Hence it is concluded that the Construction & Building Materials index (15583) is explained by the above data generating process of an autoregressive process.

General Retailers (15601)

$R_{t,\ 15601} =$	0.001415 +	$0.268872R_{t-1,\ 15601}$
t statistics	2.993489*	4.494382*
F statistic (probability)		20.19947* (0.000011)
R^2		0.072348
JB (probability)		11.27486* (0.003562)
LM (probability)		.196377 (0.657661)

F and t statistics confirm that the regression coefficients are significantly different from zero. There is no serial correlation, but the JB statistic shows lack of normality. Table 32 above shows that the residuals do not reject the null of being IID. Hence it is concluded that the General Retailers index (15601) is explained by the above data generating process of an autoregressive process.

Pharmaceuticals & Biotec (15623)

$R_{t,\ 15623} =$	0.001665 +	$0.127899R_{t-1,\ 15623}$
t statistics	1.978297*	2.088910*
F statistic (probability)		4.363544* (0.037692)
R^2		0.016569
JB (probability)		69.06013* (0.000000)
LM (probability)		.731079 (0.693822)

F and t statistics confirm that the regression coefficients are significantly different from zero. There is no serial correlation, but the JB statistic shows lack of normality. Table 32 above shows that the residuals do not reject the null of being IID. Hence it is concluded that the Pharmaceuticals & Biotec index (15623) is explained by the above data generating process of an autoregressive process.

Support Services (15635)

$R_{t,\,15635} =$ $0.001112 + 0.340638R_{t-1,\,15635}$

t statistics 2.367604* 5.864501*

F statistic (probability) 34.39237* (0.000000)

R^2 0.117223

JB (probability) 73.79352* (0.000000)

LM (probability) 4.425275 (0.109412)

F and t statistics confirm that the regression coefficients are significantly different from zero. There is no serial correlation, but the JB statistic shows lack of normality. Table 31 above shows that the residuals do not reject the null of being IID. Hence it is concluded that the Support Services index (15635) is explained by the above data generating process of an autoregressive process.

7.3.2 AutoRegression with GARCH

Four further time series are now explained. In the same way as section 7.2 above applied GARCH processes in those cases where there was non-linearity in the residuals, this has also been undertaken with the auto regressive data generating process and applied to the time series contained in Table 31 but excluding the four that were explained by AR(1) without any modification. The results of the BDS tests on these are set out in Table 33 below.

Table 33 BDS statistics for an Autoregressive Processes with GARCH

Name	Ref	BDS Dimension 2		BDS Dimension 3		BDS Dimension 4	
		Statistic	z	Statistic	z	Statistic	z
Auto & Parts	15579	.005924	1.074323	.006671	.758243	.003481	.330969
Beverages	15581	.016499	2.608086*	.014935	1.477849	.019390	1.602521
Electro & Electrical Equipment	15593	-.003949	-.887658	-.007816	-1.104448	-.001877	-.222620
Engineering & Machinery	15591	-.000086	-.014310	-.006698	-.701951	-.000791	-.069329
Food & Drug Retails	15597	.026988	3.329464*	.057140	4.402659*	.072860	4.675791*
Health	15603	.005737	1.140969	.009515	1.188315	.016942	1.771308
Insurance	15609	-.009992	-1.622480	-.018156	-1.849639	-.020587	-1.755801
Investment Companies	15610	-.000820	-.163001	-.004254	-.531750	-.003561	-.373685
Media & Entertainments	15615	.000675	.132449	-.002341	-.288468	.006055	.624840
Telecommunication Services	15641	.005948	1.285907	.011258	1.530137	.012357	1.409396

*= 5% significance

Of the ten indices, two reject the null of IID in the residuals. The remaining eight are expanded below.

Auto & Parts(15579) AR(1) and GARCH(1, 1)

$R_{t,\,15579} = .001806 + .165311R_{t-1,\,15579} + \varepsilon_t$

z 1.827521 2.334336*

F 1.221291 (.302183)

$R^2 = .037958$

JB 216.4582* (.000000)

$\sigma_t^2 = .000016 + .060666\varepsilon^2_{t-1} + .829523\sigma_{t-1}^2$

z (2.559848*) (3.276289*) (16.79411*)

In the mean generating processes the constant coefficient is not significant, but all the coefficients in the variance are significant. There is a lack of normality as shown by the JB statistic. Results from the BDS test are shown in the table above and are not significant, indicating IID. Auto & Parts is therefore explained.

Electro & Electrical Equipment (15593) AR(1) and GARCH(1, 1)

$R_{t,\,15593} = .000940 + .24554R_{t-1,\,15593} + \varepsilon_t$

z 1.624598 3.134275*

F 4.032724* (.003444)

$R^2 = .059276$

JB 3.890909 (.142922)

$\sigma_t^2 = .000005 + .203432\varepsilon^2_{t-1} + .727884\sigma_{t-1}^2$

z (1.496077) (3.171054*) (8.782747*)

In the mean generating processes the constant coefficient is not significant whereas the auto regressive slope is. This later conclusion is supported by the F test. The residuals are shown by the JB statistic to be normal. All the slope coefficients in the variance are significant, but not the constant. Results for the BDS test are shown in the table above and are not significant, indicating residuals that are IID. Electro & Electrical Equipment is therefore explained.

Engineering & Machinery(15591) AR(1) and GARCH(1, 1)

$R_{t,\,15591} = .001316 + .235637R_{t-1,\,15591} + \varepsilon_t$

z 2.171594* 3.295522*

F 2.703740 (.069043)

$R^2 = .033287$

JB 40.98675* (.000000)

$\sigma_t^2 = .000017 + .163103\varepsilon^2_{t-1} + .539561\sigma_{t-1}^2$

z (1.665579) (2.390939*) (2.512002*)

In the mean generating processes the constant coefficient is significant, as is that of the slope. This is not supported by the F test. The JB statistic shows the residuals not to be normally distributed. All the slope coefficients in the variance are significant, but not the constant. Results for the BDS test are shown in the table above and are not significant, indicating residuals that are IID. Engineering & Machinery is therefore explained.

Health (15603) AR(1) and GARCH(1, 1)

$R_{t,\,15603} = .001717 + .328685R_{t-1,\,15603} + \varepsilon_t$

z 2.279932* 4.305996*

F 2.409369 * (.049803)

$R^2 = .036281$

JB 2385.7070* (.000000)

$\sigma_t^2 = .000059 + .126017\varepsilon^2_{t-1} - .230828\sigma_{t-1}^2$

z (4.121450*) (1.066804) (-.818278)

In the mean generating processes the constant coefficient is significant, as is that of the slope. The latter is supported by the F test. The residuals are shown by the JB statistic not to be normal. Only the constant's coefficient in the variance are significant. Results for the BDS test are shown in the table above and are not significant, indicating residuals that are IID. Health is therefore explained.

Insurance (15609) AR(1) and GARCH(1, 1)

$R_{t,\ 15609} = .000835 + .291945R_{t-1,\ 15609} + \varepsilon_t$

z 1.880535 4.997219*

F .217578 (.928512)

$R^2 = .003388$

JB 257.1803* (.000000)

$\sigma_t^2 = .000015 + 1.317049\varepsilon^2_{t-1} + .042453\sigma_{t-1}^2$

z (6.715601*) (9.461652*) (.836820)

In the mean generating processes the constant coefficient is not significant, but that of the slope is. This is not supported by the F test. The JB statistic shows the residuals not to be normal. The constant and the ARCH slope coefficients in the variance are significant, but not the GARCH. Results for the BDS test are shown in the table above and are not significant, indicating residuals that are IID. Insurance is therefore explained.

Investment Companies (15610) AR(1) and GARCH(1, 1)

$R_t = .000934 + .261451R_{t-1} + \varepsilon_t$

z (2.092969*) (3.987443*)

F 1.448235 (.218559)

$R^2 = .022128$

JB 53.06800* (.000000)

$\sigma_t^2 = .000000 - .026261\varepsilon^2_{t-1} + 1.006336\sigma_{t-1}^2$

z (5.406668*) (-3.272240*) (122.2961*)

Both of the mean generating process's coefficients are significant, (but not the F) as are all coefficients in the variance. The JB indicates a lack of normality in the residuals but BDS shows IID. It can therefore be concluded that Investment Companies is now explained.

Media & Entertainments (15615) AR(1) and GARCH(1, 1)

$R_{t,\ 15615} = .001385 + .171305R_{t-1,\ 15615} + \varepsilon_t$

z 3.151765* 2.621229*

F 1.645258 (.163338)

$R^2 = .025063$

JB 25.28089* (.000003)

$\sigma_t^2 = .000003 - .004329\varepsilon^2_{t-1} + .909410\sigma_{t-1}^2$

z (3.865358*) (-.262976) (35.33143*)

In the mean generating processes the constant coefficient is significant, as is that of the slope. This is not supported by the F test. The JB statistic rejects the null of a normal distribution. The constant and the GARCH slope coefficients in the variance are significant, but not the ARCH. Results for the BDS test are shown in the table above and are not significant, indicating residuals that are IID. Media & Entertainments is therefore explained.

Telecommunication Services (15641) AR(1) and GARCH(1, 1)

$R_{t,\ 15641} = .000434 + .006077R_{t-1,\ 15641} + \varepsilon_t$

z .454926 .113806

F not available

$R^2 = -.008524$

JB 2.225295 (.328688)

$\sigma_t^2 = .000003 - .026301\varepsilon^2_{t-1} + 1.0015429\sigma_{t-1}^2$

z (6.362058*) (-2.489175*) (98.66585*)

In the mean generating process neither the constant nor the slope's coefficient is significant. (E-Views could not calculate the F statistic but there is no apparent reason for this lack. Neither the manuals nor the help desk cast any light on this.) The residuals are shown by the JB statistic to be normal. All the coefficients in the variance are significant. Results for the BDS test are shown in the table above and are not significant, indicating residuals that are IID. Telecommunication Services is hence assumed to be explained.

It can be seen that of the remaining ten indices, eight have been explained by an AR process with GARCH. Two indices remain unexplained.

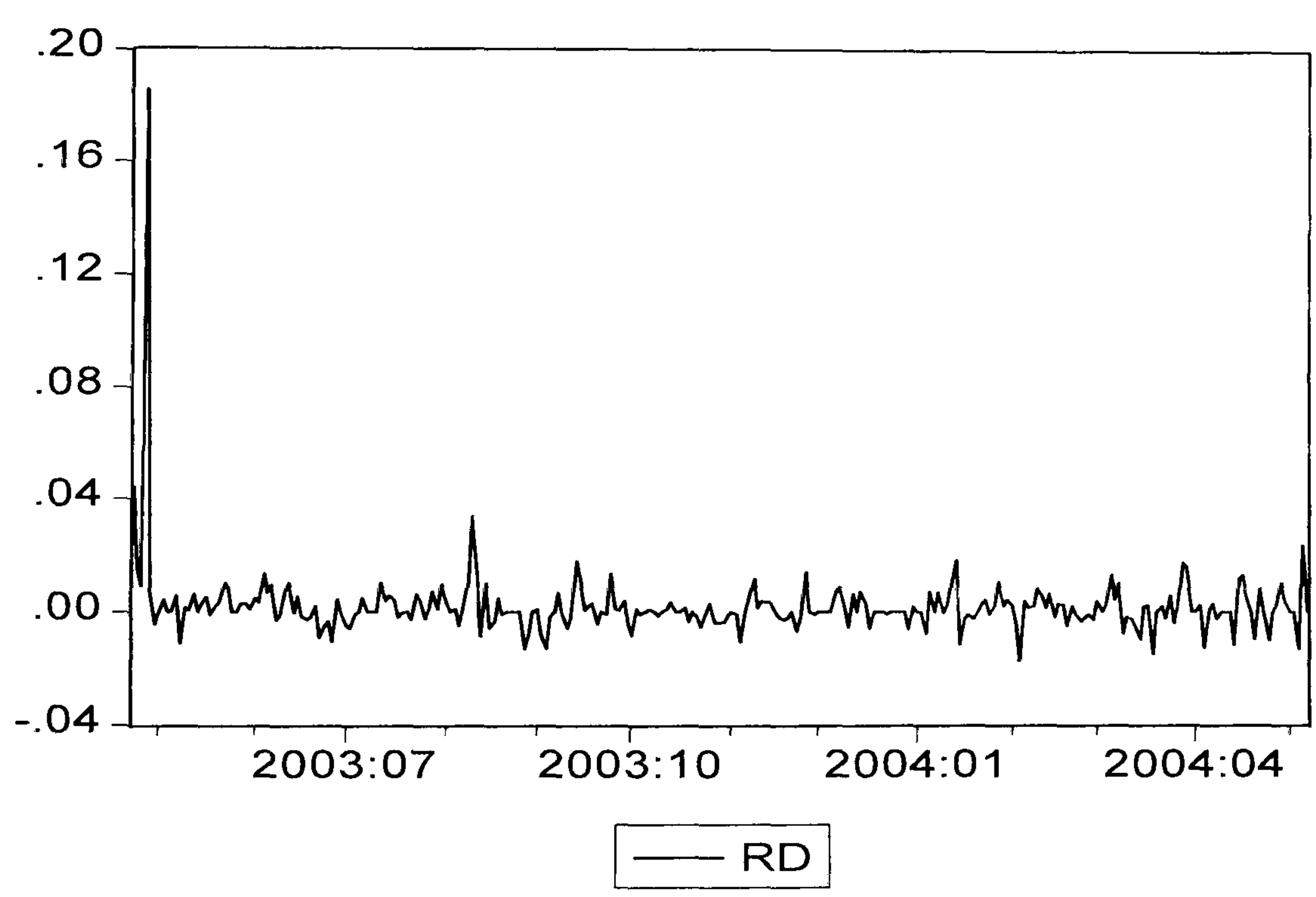
Thus far 28 of the indices have been explained, with two remaining unexplained; those of Beverages (15581) and Food & Drug Retailers (15597). Tests on these two have repeated the earlier use of modified versions of GARCH with an AR process, but to no avail in that the residuals were not IID. Test results are not shown here.

7.4 Other Approaches

7.4.1 Outliers

A possible cause of the failure to identify a suitable univariate model could be the existence of outliers. This is common in time series analysis. Graphs of these two series of returns are set out below.

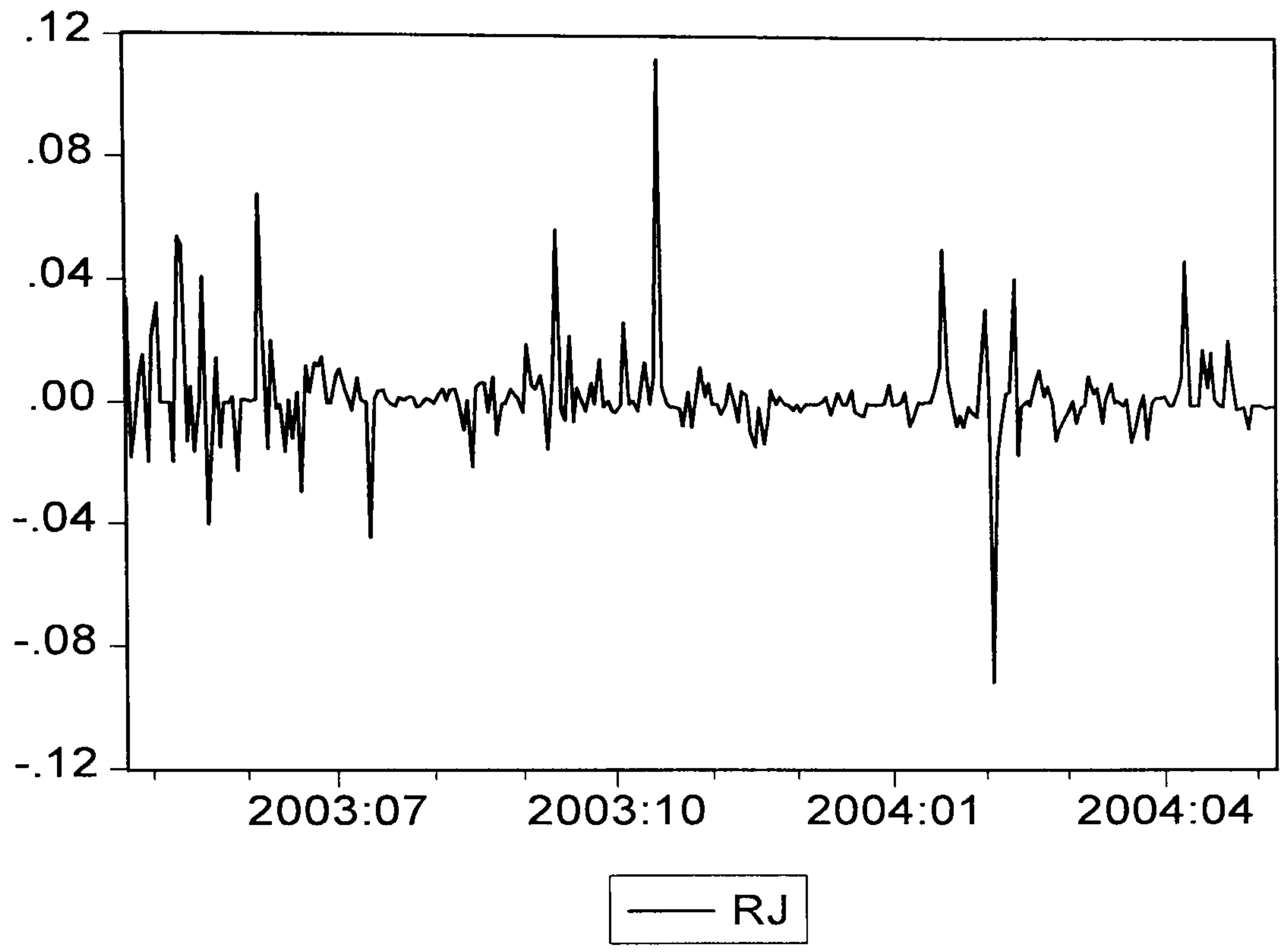
Figure 2 Return on Beverages



The natural log return on Beverages shows abnormally high returns immediately at the start of the series. By reducing the sample frame to exclude the first four days' values there should be no great impact on the validity of the various statistical tests, nor should their removal invalidate any potential forecasts as these occur after the series ends, almost a year away.

Unlike Beverages, there is no obvious adjustment to make for outliers with Food & Drug Retailers.

Figure 3 Return on Food & Drug Retailers



The application of a random walk with drift and trend to the reduced sample frame of Beverages produces a regression equation (detail not shown here) that strongly rejects the BDS null hypothesis of IID. Use of GARCH however, does produce valid results.

Beverages (15581) GARCH(1, 1) with outliers removed

$R_{t,\,15581} =$ .356941 - 0.047434$Y_{t-1,\,15581}$ + 0.000044t

z statistics 3.932400* -3.922683* 3.779138*

F statistic (probability) 1.580636 (0.165980)

R^2 0.030408

JB (probability) 50.92742* (0.000000)

$\sigma_t^2 =$ .000031 + .408421ε^2_{t-1} - .223337σ_{t-1}^2

z 11.20059* 6.638863* -6.820539

Dimension	2	3	4
BDS statistic	-.007234	-.012900	-.010278
z	-1.155630	-1.292070	-.861257

Coefficients in the mean regression are all significant, but the F test indicates that the slope coefficients are not significantly different from zero. The JB test indicates a lack of normality in the residuals and the BDS test statistics for dimensions two to four indicate IID. Thus Beverages is assumed to be explained, albeit with a slightly reduced sample.

7.4.2 MA or ARMA as the maintained regression

One index remains unexplained, that of Food & Drug Retailers. There are two fairly basic time series approaches that have not yet been fully tested, namely those for Moving Averages and Auto Regressive Moving Averages. There is no indication that these should be for greater than one lag, so the results of the BDS test with regressions that are respectively MA(1) and ARMA(1, 1) are shown in Tables 34 and 35 below.

Table 34 MA(1) Process

Name	Ref	Constant	MA(1)	BDS(2) prob	BDS(3) prob	BDS(4) prob	BDS(5) prob
Food & Drug Retailers	15597	.002233	.088296	.0000*	.0000*	.0000*	.0000*

*=significant at 5%.

Using a simple MA(1) process, the remaining index does not display acceptance of the BDS null hypothesis of the residuals being IID. The BDS probabilities are shown here rather that the more usual statistic, just to emphasise how far from non-rejection all the dimensions are.

Table 35 ARMA(1, 1) Process

Name	Ref	Constant	AR(1)	MA(1)	BDS(2) prob	BDS(3) prob	BDS(4) prob
Food & Drug Retailers	15597	.002137	-.403401	.517583	.0022*	.0000*	.0000*

*=significant at 5%.

As with just MA(1), the ARMA(1, 1) results indicate that again there is extreme rejection in the BDS probabilities of IID. Hence there still remains the last unexplained index.

7.5 Cointegration

7.5.1 The Engle Granger method

Cointegration is not so much a data generating process as a relationship between two separate stochastic processes. Typically it would be used in a multi-variate analysis between two variables (if bivariate) which share a fairly common long term trend but deviate in the short term. The application of cointegration in this case would logically be to examine the sub index for cointegration with the main FTSE All Share Index, although the approach must be suspect in that the sub index is by definition a part of the main index. A more normal use would be to examine the relationship between (say) spot and future rates in currency, earnings and share price or similar pairs (or more than two variables) where some type of equilibrium might be hypothesized.

Cointegration can be considered or defined as when the variables are I(1) and their combination is I(0) or stationary. This is not a full definition as it could equally apply to variables integrated to order greater than 1, but the previous chapter's Augmented Dickey Fuller tests show that all the indices are I(1) in the time series of the index and I(0) in the first differenced return series. Thus the series of pairs, if cointegrated, are of the order CI(d,b), where d is the integration order (in this case 1) and b is the differencing, so giving CI(1, 1).

Tests for cointegration often follow the Engle Granger approach (EG) which has as its null the hypothesis of non-cointegration between the two variables. In much financial analysis based on cointegration it is not important which of the variables is/are dependent or independent, but in this case it would be logical for the sub index to be a function of the All Share Index and thus the EG regression can be normalized on the time series for the sub index. A constant may be included so the basic EG regression is:

$$y_{ti} = \varphi_1 + \varphi_2 \, y_{ta} + E_t \qquad (7.9)$$

where y_{ti} is the log normal value of the currently unexplained sub index, y_{ta} the equivalent for the All Share Index and E_t the error term. The EG approach assumes that φ_2 will equal zero if there is no relationship between the two series and tests if the residuals E_t are also I(1). In step with the Dickey Fuller method for testing for unit roots, the residuals are formatted such that:

$$\Delta E_t = \gamma E_{t-1} + u_t \qquad (7.10)$$

In this case there is no constant and, as in the Dickey Fuller process, $\gamma = \Phi_1 - 1$. Rather than following the full framework for testing for unit roots, the assumption will be that the tests are all Augmented Dickey Fuller, so that equation 7.10 becomes:

$$\Delta E_t = \gamma E_{t-1} + \Sigma \alpha i \, \Delta E_{t-1} + u_t \qquad (7.11)$$

a format referred to as the Cointegrating Augmented Dickey Fuller regression or CRADF. ADF lags will follow those of earlier tests.

Critical values for the one sided hypothesis tests will be based on the MacKinnon response surface, derived from the following:

$$C(\alpha, T) = k_\infty + k_1/T + k_2/T^2 \qquad (7.12)$$

where T is the sample size and k_∞, k_1 and k_2 are the 5% response surface estimates (Patterson 2000, reprinted from Long Run Economic Relationships, edited by RF Engle and CWJ Granger, 1991, OUP). Resulting values are T=261, (after allowing for the ADF lags), $k_\infty = -2.8621$, $k_1 = -2.738$ and $k_2 = -8.36$ with the test statistic more negative than $C(\alpha, T) = -2.8621 - 2.738/245 - 8.36/245^2 = -2.874$ indicating rejection of the null of no cointegration.

7.5.2 Test results for cointegration

As mentioned above, the results of the initial tests for unit roots show that the sole remaining unexplained time series is I(1), as is the All Share Index, so the next step is to run the EG regression in the Equation 7.9 format. Results of this are set out in Table 36, although the statistics for R^2 and t are 'suspect' as no knowledge of

Table 36 EG Basic Regression of Equation 7.9

Name	Ref		Coeff	t	P	R^2 / dw
Food & Drug Retailers	15597	Φ_1	-15.06906	-25.82854	.0000	.860134
		Φ_2	3.047629	39.98649	.0000	.168676

cointegration or its lack is available at this stage. Following the basic regression, the residuals are saved, converted into differences and regressed in the form of equation 7.11 above. These results are displayed in Table 37.

Table 37 EG Auxiliary Regression of Equation 7.11, statistics for γ

Name	Ref	coeff	t	P	R^2	dw
Food & Drug Retailers	15597	.915812	36.71003	.0000	.83820	2.063222

*=significant at 5%

The conclusion from Table 37's results for the auxiliary regression of the residuals is that the index time series does not reject the null of no cointegration at 5% significance, hence Food & Drug Retailers is not consistent with cointegration in relation to the FTSE All Share Index. This is not the end of the process however, as the EG approach has a final stage via an Error Correction Model (ECM), (also known as Equilibrium Correction) in that the basic EG regression in equation 7.9 is assumed to be a long term equilibrium. The typical ECM for equation 7.9 is:

$$\Delta y_{ti} = \Theta_1 \Delta y_{ta} + \Theta_2 E_{t-1} + \varepsilon_t \qquad (7.13)$$

where use of Δ converts the relationship back from log series of index values to returns and E_{t-1} is equation 7.9's error term, factored by an error correction coefficient Θ_2. Although this is not required, as Food & Drug Retailers are not cointegrated with the FTSE All Share index, the process is continued just for completeness, so this final stage is now run for the non cointegrated sub index, followed by the BDS test for IID of the residuals ε_t.

Food & Drug Retailers (15597) Cointegrated (1, 1) with the All Share Index

$R_{t,15597} = .337978R_{t,5921} + .020249E_{t-1} + \varepsilon_t$

s.e. (.135871) (.015938)

t (2.487754*) (1.270455) $R^2 = .005712$

P (.0135) (.2051) dw=1.790671

Dimension	2	3	4
BDS statistic	.028723	.05540	.071335
z	.0002	.0000	.0000

The BDS statistics are not significant so the residuals could be assumed to be IID. Despite this, Food & Drug Retailers is not explained due to the absence of cointegration.

7.6 Summary of Data Generating Processes

These two chapters have applied many of the more finance-specific data generating processes to all 30 of the time series. The results show that 29 are explained in that there is both a statistically significant data generating process and residuals from that process that are independent and identically distributed. Additionally it has not been possible to identify a suitable process that explains Food & Drug Retailers. In summary the processes are:

- IID with Random or Near Random Walk

FTSE All Share Index	(5921)
Aerospace & Defence	(15577)
Chemicals	(15585)
Forestry & Paper	(15597)
Oil & Gas	(15619)
Personal Care & Household Products	(15621)

- IID with Random Walk format and GARCH

Electricity	(19897)
Food Production & Processors	(15590)
Household Goods & Textiles	(15605)
IT Hardware	(15607)
Mining	(15617)
Speciality & Other Financials	(15633)
Telecommunication Services	(15641)
Transport	(15639)
Real Estate	(15627)
Software & CPU Services (TGARCH)	(15630)
Leisure & Hotels(C GARCH)	(15613)
Beverages (less outliers)	(15581)

- IID with Auto Regression

Construction & Building Materials	(15587)
Pharmaceuticals & Biotec	(15623)
Support Services	(15635)
General Retailers	(15601)

- IID with Auto Regression and GARCH

Auto & Parts	(15579)
Electro & Electrical Equipment	(15593)
Engineering & Machinery	(15591)
Health	(15603)
Insurance	(15609)
Investment Companies	(15610)

Media & Entertainments (15615)

- Unexplained
  Food & Drug Retailers (15597)

The next chapter uses the 29 maintained regressions that produce IID in the residuals to forecast values of the indices to establish if any deterministic components generate abnormal gain.

CHAPTER EIGHT FORECASTING

8.1 Introduction

The results from Chapters 6 and 7 are set out in Table 38.

Table 38 Coefficients from IID regressions

Name	Ref	F sig?	Data Generating Process coefficients			
			constant	**Y_{t-1}**	**Trend**	**R_{t-1}**
FTSE All Share	5921	yes	**-.747066**	**.098786**	**-.000065**	
Aerospace & Defence	15577		-.169078	.022591	- .000034	
Auto & Parts	15579		.001806			**.165311**
Beverages	15581		**.356941**	**- .047434**	**.000044**	
Chemicals	15585		.167570	-.002004	-.000016	
Construction & Building Materials	15583	yes	**.000965**			**.222377**
Electricity	19897		**-.306218**	**.046245**	**-.000133**	
Electro & Electrical Equipment	15593	yes	.000940			**.245540**
Engineering & Machinery	15591		**.001316**			**.235637**
Food & Drug Retailers	15597	unexplained				
Food Production & Processors	15599		-.099766	.013629	-.000023	
Forestry & Paper	15595	yes	**-.412467**	**.059901**	.000027	
General Retailers	15601	yes	**.001415**			**.268872**
Health	15603	yes	**.001717**			**.328685**
Household Goods & Textiles	15605		-.072584	.010699	**-.000038**	
Insurance	15609		.000835			**.291945**
Investment Companies	15610		**.000934**			**.261451**
IT hardware	15607		**-.288330**	**.040534**	**-.000140**	
Leisure & Hotels	15613		-.090928	.013537	-.000030	
Media & Entertainments	15615		**.001385**			**.171305**
Mining	15617		**-.236758**	**.034326**	**-.000078**	
Oil & Gas	15619		-.092434	.011884	-.000012	
Pharmacuticals & Biotec	15623	yes	**.001665**			**.127899**
Personal Care & Household Products	15621	yes	**-.277770**	**.039704**	**-.000122**	
Real estate	15627		-.014584	.002296	-.000011	
Software & CPU Services	15630		-.034905	.006527	-.000033	
Speciality & Other Financials	15633	yes	-.093910	.014218	**-.000038**	
Support Services	15635	yes	**.001112**			**.340638**
Telecommunication Services	15641		.000434			.006077
Transport	15639		-.142468	.019342	**-.000040**	

Bold = coefficients are significant as measured by z or t statistic (intercept) or F (slopes).

The previous two chapters have identified regressions of various types that explain the time series relationships for 29 of the 30 indices and have used the BDS test to confirm that the residuals from the regression do not carry any further messages or relationships. The potential random walks derived from that process are summarized below. Where the various coefficients are significant at the 5% level (F statistic for slopes, t statistic for intercept) these are indicated by *.

Random Walk Format:

FTSE All Share Index	$R_t = -.747066^* + .098786^* Y_{t-1} - .000065^* t$
Aerospace & Defence	$R_t = -.169078 + .022591 Y_{t-1} - .000034t$
Chemicals	$R_t = .16757 - .002004 Y_{t-1} - .000016t$
Forestry & Paper	$R_t = -.412467^* + .059901^* Y_{t-1} + .000027t$
Oil & Gas	$R_t = -.092434 + .011884 Y_{t-1} - .000012t$
Personal Care & Household Products	$R_t = -.277770^* + .039704^* Y_{t-1} - .000122^* t$

As can be seen, Aerospace & Defence, Chemicals and Oil & Gas have no coefficients significantly different from zero, so these can be dropped and the processes become pure random walks. Thus:

Aerospace & Defence	$R_t = \varepsilon_t$
Chemicals	$R_t = \varepsilon_t$
Oil & Gas	$R_t = \varepsilon_t$

In these three cases there is no point in attempting to forecast the next period's return as it is just white noise. These can therefore be classed as strong efficient, their management should be solely passive, there is no scope for active management.

8.2 Goodness of Fit and the Cost of Active Management

8.2.1 Coefficients of determination

The 26 indices that may be considered as possibly of use in forecasting are set out in Table 39 below, showing the coefficients of determination or R^2. In theory R^2 can be viewed as a measure of goodness of fit, as it is the square of the correlation coefficient between the index's actual return and the values generated by the regression. Its typical use is to give a view of how 'good' the data generating process is.

Table 39 Coefficients of determination

Name	Ref	R^2	Constant	ARCH	Coint
FTSE All Share	5921	.049449			
Aerospace & Defence	15577	Not applicable as random walk			
Auto & Parts	15579		No	Yes	
Beverages	15581	.030408		Yes	
Chemicals	15585	Not applicable as random walk			
Construction & Building Materials	15583	.050588			
Electricity	19897	.024719		Yes	
Electro & Electrical Equipment	15593	.059276	No	Yes	
Engineering & Machinery	15591	.033287		Yes	
Food & Drug Retailers	15597	No explained process			
Food Production & Processors	15599	.014189	No	Yes	
Forestry & Paper	15595	.030406			
General Retailers	15601	.072348			
Health	15603	.036281		Yes	
Household Goods & Textiles	15605	.031972	No	Yes	
Insurance	15609	.003388	No	Yes	
Investment Companies	15610	.022128		Yes	
IT hardware	15607	.024898		Yes	
Leisure & Hotels	15613	.013311	No	Yes	
Media & Entertainments	15615	.025063		Yes	
Mining	15617	.031434		Yes	
Oil & Gas	15619	Not applicable as random walk			
Pharmacuticals & Biotec	15623	.016569			
Personal Care & Household Products	15621	.027789			
Real estate	15627	.024253	No	Yes	
Software & CPU Services	15630	.039867	No	Yes	
Speciality & Other Financials	15633	.056603	No	Yes	
Support Services	15635	.117223			
Telecommunication Services	15641	-.008524	No	Yes	
Transport	15639	.029019	No	Yes	

Const No = regression does not have a significant (5%) constant
ARCH Yes = R^2 possibly not valid as ARCH and no regressors
Coint Yes = cointegrated with another index

As an example, from Table 39 it can be seen that the equation for Support Services (15635) has an R^2 of 0.117223, or that the regression equation in theory explains 11.7% of the value of Support Service's return.

In a simple world any of the 26 identified equations' coefficients of determination could be compared with the cost of active management and where the R^2 is greater, then there is possibly scope for active management to make abnormal gains.

Unfortunately the coefficient suffers from a variety of problems that preclude use of the coefficient as an identifier of management styles.

Issue One: R^2 is the sample's coefficient, not that of the population. It may be invalid for out-of-sample forecasts.

Issue Two: Even if the population's coefficient of determination is known, its decomposition into signal and noise could invalidate a superficially strong relationship.

Issue Three: R^2 is not valid if the regression equation does not have a constant. 11 of the above have a constant that is not significantly different from zero at 5% and so the R^2 must be replaced with the series' uncentred R^2, which makes inter-index comparison difficult. The uncentred R^2 can be derived by dividing the serial correlation LM test value by the number of observations, however there is no real point in this adjustment for the affected indices as they are GARCH regressions with no regressors and suffer from Issue Seven below. This adjustment is therefore not appropriate for any of the indices.

Issue Four: As with regression coefficients, the value of R^2 can vary if x is regressed on y rather than y on x, although this is not of particular relevance in time series analysis.

Issue Five: R^2 will be random if a variable is not stationary. This does not apply here as all return series were shown to be stationary.

Issue Six: Use of additional variables in a regression can spuriously increase R^2 with no recognition of loss of parsimony. This can be countered by use of Adjusted R^2 but the approach taken in this analysis, of accepting the first and most parsimonious equation that is IID removes this problem.

Issue Seven: If the process is ARCH and there are no regressors, then the R^2 may be meaningless, hence the negative or missing values in the table above and the query against those that are not negative. This applies to 19 of the indices.

Issue Eight: Food & Drug Retailers was not identified as being cointegrated with the FTSE All Share Index. Even if it had been cointegrated, with IID residuals, the resulting effective coefficient of determination would be the product of the two individual coefficients. A value that would be so low as to be of no use.

The net effect of the above is that using R^2 as a measure of how good a forecast might be can only apply (and then with many caveats) to the seven indices in Table 40 where their coefficient of determination is acceptable.

Table 40 Applicable Coefficients of determination

Name	Ref	Original R^2
FTSE All Share	5921	.049449
Construction & Building Materials	15583	.050588
Forestry & Paper	15595	.030406
General Retailers	15601	.072348
Pharmacuticals & Biotec	15623	.016569
Personal Care & Household Products	15621	.027789
Support Services	15635	.117223

8.2.2 Fund management costs

If the cost of active management, or rather its excess over the cost of passive management is known, then the indices with a percentage coefficient of determination above the excess cost could be classed as not efficient. Knowledge of the data generating process will allow the investor to make profits in excess of the cost of trading actively. Likewise those where the percentage coefficient of determination is less than or equal to the excess costs will be weakly efficient. The Myners Review (2001) suggests that average annual costs in the investment value chain are:

Activity	**Basis Points**
Consultant	1.5
Investment Manager	27.0
Broker	15.0
Custodian	3.0
Performance Measurer	0.5
Total	47.0

In trying to establish those costs that are specific to active management (excess cost) it can be assumed that Custodian and Performance Measurer apply to both active and passive management styles and as such can be ignored. That leaves 43.5 basis points or 4.35% per annum as the excess cost of active management within fund management. In addition, Myners (p. 82) suggests that Fund Managers' costs in the UK for equities are:

Upper quartile 48 basis points per annum

Median 40 basis points per annum

Lower quartile 30 basis points per annum.

These costs are for a £100 million mandate and can be assumed to be relatively lower for a larger fund and commensurately higher for a smaller fund. Taking the median value could be excessive as the costs are an average covering both styles. If one assumes the 30 point lower quartile value is for passive and 48 is for active, then active management accounts for an additional 18 basis points. Combining these two elements (43.4 and 18) then active management's excess costs are 6.15% per annum, or approximately 0.023% per trading day.

An alternative view is taken by Barber et al (2001) who suggest "an estimated round-trip transactions cost of 4.12 percent" (p. 553). Barber et al's data is for the US market, but a similar study by Goodacre et al (1999) for the UK market utilizes round-trip costs of up to 2%. Taking the 2% for the UK as the average round-trip costs and halving it for typical non-round trip, single way transactions and assuming that these would only apply to active management, then the excess cost over and above passive management is .023% per day plus 1% trading costs. The regressions are on a daily basis, so if all indices are traded every day (an extreme case) the costs would be 1.023% per day for one way transactions. If these estimates of costs have any validity, then a superficial conclusion might be that the excess of the coefficient of determination over the estimated excess costs of active management indicate excess return from active management. This is shown in Table 41.

Table 41 Potential Excess Return from Active Management

Name	Ref	Applicable R^2	Excess Costs	Excess Return
FTSE All Share	5921	.049449	.01023	.039219
Construction & Building Materials	15583	.050588	.01023	.040358
Forestry & Paper	15595	.030406	.01023	.020176
General Retailers	15601	.072348	.01023	.062118
Pharmacuticals & Biotec	15623	.016569	.01023	.006339
Personal Care & Household Products	15621	.027789	.01023	.017559
Support Services	15635	.117223	.01023	.106993

None of the excess returns are negative but that of Pharmacuticals & Biotec is virtually zero. This index could be classed as weakly efficient, in that although there is scope for forecasting an abnormal return, the cost will approximately equal the potential gain. The other six indices that have a valid coefficient of determination could be viewed as not efficient and warrant active management. This type of conclusion is of course subject to errors generated firstly by the issues surrounding the interpretation of the coefficient of determination and secondly by the estimates of the excess costs of active management. In addition, the conclusion can only be applied where the index's regression produces a valid R^2. Consequently, no further consideration of the coefficient of determination will take place. Instead an alternative approach will be followed, one often promulgated in economic forecasting, where the success or usefulness of the forecasts from a model is examined. If the forecasts produce benefit, then the model can be regarded as useful, irrespective of issues surrounding statistics or logic that may cast doubt on the model.

8.3 Forecastable Regressions

8.3.1 Forecast error statistics

In-sample forecasts, i.e. the filling in of gaps in the actual data, is of little or no use in the world of forecasting share or index values as the whole point is to estimate tomorrow's values. Thus for this exercise the forecasts are out of sample. Similarly, given that an investor can make a buy, sell or hold decision each day, based on the latest data, then the forecasts will be one step ahead (i.e. t+1) rather than multi step. For the following, a rolling window will be used, allowing ten recursive forecasts where t+1 is forecast at time t, t+2 is forecast at time t+1 using actual t+1 values rather than the forecast value of t+1 from time t. The use of ten forecast periods is partly pragmatic (equivalent to two weeks) but is not dissimilar to other work on stock price forecasting. For instance, Jung and Boyd (1996) forecast 18 periods out of sample, based on 288 sample periods. McMillan et al (2000) study the FTSE and use:

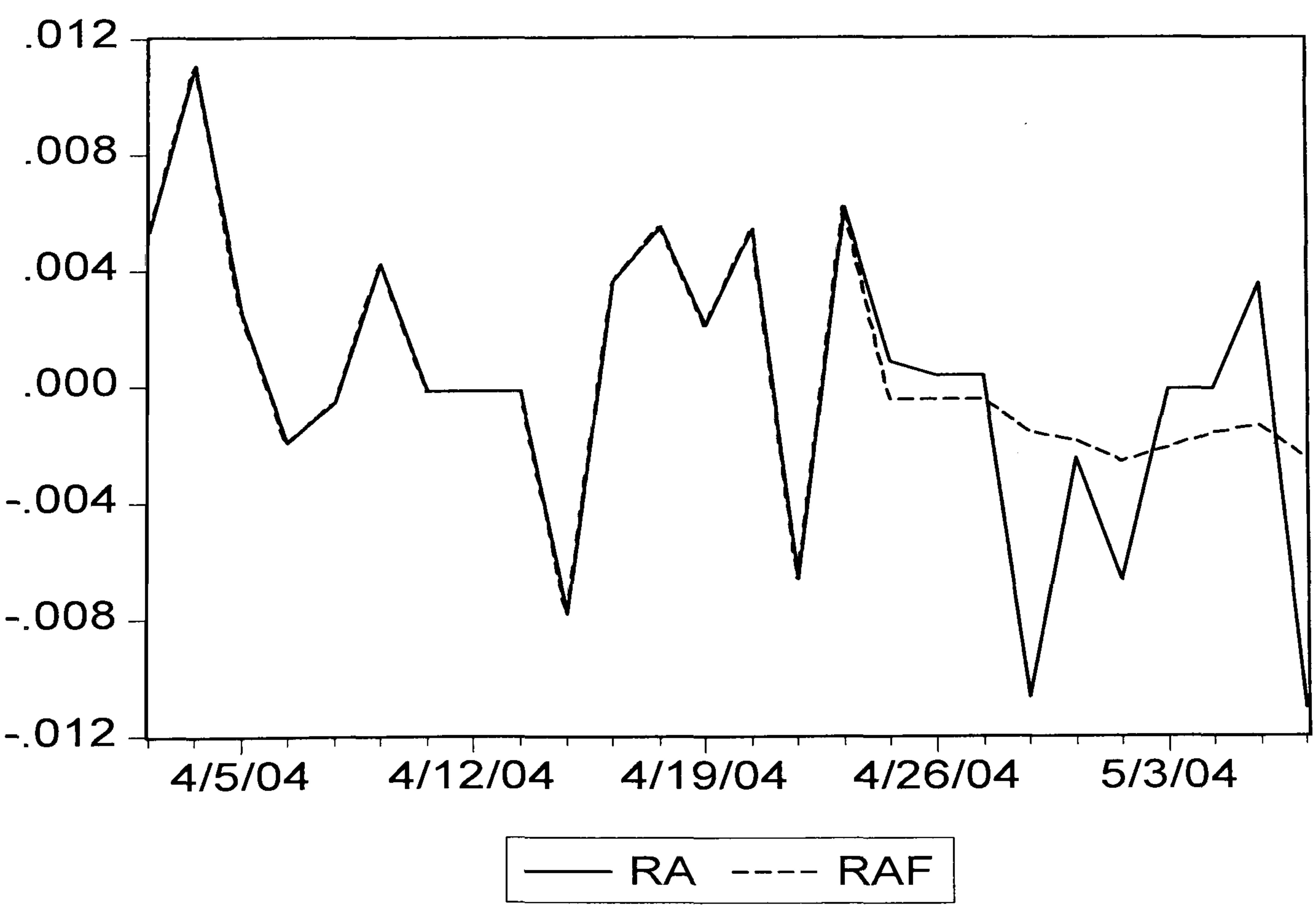
	Months	Weeks	Days
Sample	132	574	2869
Forecast	20	83	413.

In tests of the Finnish Option Index, Maukonen (2002) utilized monthly data such that "the length of the rolling window…varied between 99 and 130 observations" (p. 818).

Thus the use of 250 observations in this study to generate ten forecast periods is fairly cautious. The regressions were based on daily observations for the year 23rd April 2003 to 22nd April 2004, so the forecasts are for the ten days 23rd April 2004 to 6th May 2004.

The forecasts will be based on the regression equations that produced IID in the residuals, as confirmed by the BDS tests. As an example, returns for the FTSE All Share Index series are regressed using the equation format above, for the survey period of one year ending on 23rd April 2004. The forecast is performed and Figure 4 below shows April 2004, with the actual returns through to 23rd followed by the out of sample actual returns and the forecast returns. As can be seen, the forecast correctly follows that period's downward trend but fails to display the volatility experienced by the actual series. A visual comparison of the actuals and forecast gives some indication of the success of the model but is somewhat subjective. A more accurate or objective method of appraising the success of the forecast is by means of a variety of forecast error statistics.

Figure 4 Forecast (RAF) and Actuals (RA), April 2004, FTSE All Share Index



There are four main measures of a forecast:

Root Mean Squared Error (RMSE) (also referred to as Mean Squared Error) is the square root of the average of the squared forecast errors. A benefit specific to RMSE is that it can be split into three component parts: bias, variance and covariance.

Mean Absolute Error (MAE) is the average of the absolute forecast errors.

Mean Absolute Percentage Error (MAPE) is an extension of MAE where the absolute forecast differences are each divided by the actual value and expressed as a percent. This can be adjusted by dividing by the forecast plus the actual, to give the Symmetric MAPE to correct for asymmetry in the differences. Unfortunately this measure cannot be used here as it cannot cope with changes in signs: it could be a test of forecasting the index but not the return.

Thiel's U statistic (also referred to as Thiel's Inequality Coefficient) which compares the model in question with a naïve benchmark (typically a random walk). The lower the value, the better the forecast, which allows an inter index forecast comparison as it is not relative

Although all but MAPE will be considered in subsequent forecasts, RMSE and MAE tend to be of more benefit in relative comparisons of the same data across various models, whereas this analysis is solely a single model per time series. Actual forecast error statistics are given in Table 42. Of particular benefit is the breakdown of RMSE where the (albeit) relative error is decomposed into its component parts of: bias, or difference between means of actual and forecast; variance, or difference between variances of actual and forecast; and covariance, which is really a balancing item. The covariance proportion is thus a measure of the success of a forecast and should be as large as possible.

8.3.2 Error statistics from identified data generating processes

Initial observations on these error statistics are:

i) as expected, MAE is of little use;

ii) all of the U values from the TIC are less than one, indicating that the regression is more useful than a naïve model, but in many cases only just so. Using the Thiel Inequality Coefficient, the five most successful forecasts are: IT Hardware, Transport, Mining, the All Share and Forestry & Paper.

iii) the breakdown of the RMSE into its three components shows poor ability of the regressions to forecast the mean, with the highest being 38% and a third below 20%. The largest errors are in the variance with many over 90%. Covariance, where a high value is desirable, only has General Retail and Health above 50%.

Table 42 Forecast Error Statistics

Name	Ref	MAE	TIC	RMSE	of which		
					bias	var	covar
FTSE All Share	5921	.003378	.625168	.004539	.056722	.796001	.147277
Aerospace & Defence	15577	Pure random walk so not applicable					
Auto & Parts	15579	.007097	.918848	.009930	.287758	.461522	.250720
Beverages	15581	.006335	.918052	.009550	.013805	.964970	.021225
Chemicals	15585	Pure random walk so not applicable					
Construction & Building Materials	15583	.002294	.866997	.002940	.337340	.388309	.274351
Electricity	19897	.074249	.839905	.102877	.070594	.812060	.117346
Electro & Electrical Equipment	15593	.004588	.872400	.005946	.040807	.954089	.005104
Engineering & Machinery	15591	.002142	.689393	.003045	.015366	.645680	.338954
Food & Drug Retailers	15597	Unexplained so not applicable					
Food Production & Processors	15599	.002007	.659126	.002656	.137598	.805167	.057235
Forestry & Paper	15595	.004527	.648779	.005417	.126181	.783308	.090511
General Retailers	15601	.002618	.801215	.004152	.075257	.415208	.509535
Health	15603	.003605	.753024	.004409	.077941	.401920	.520139
Household Goods & Textiles	15605	.004924	.818562	.005792	.312951	.658689	.028361
Insurance	15609	.004873	.839162	.005845	.324130	.339117	.336753
Investment Companies	15610	.003375	.760607	.003847	.381913	.434181	.183905
IT hardware	15607	.014625	.550704	.017573	.186124	.690784	.123092
Leisure & Hotels	15613	.003588	.779006	.005621	.077993	.893094	.028914
Media & Entertainments	15615	.002813	.838935	.004708	.219653	.546927	.233421
Mining	15617	.009506	.619027	.010443	.450672	.484236	.065092
Oil & Gas	15619	Pure random walk so not applicable					
Pharmacuticals & Biotec	15623	.013514	.937687	.018488	.339831	.453512	.206657
Personal Care & Household Products	15621	.013792	.682786	.016190	.000294	.833316	.166391
Real estate	15627	.002149	.759404	.002828	.001268	.995912	.002820
Software & CPU Services	15630	.007131	.910379	.010480	.064616	.922769	.012615
Speciality & Other Financials	15633	.003855	.665405	.004784	.092326	.894159	.013515
Support Services	15635	.002455	.859718	.003177	.289079	.247646	.463274
Telecommunication Services	15641	.009851	.982082	.012722	.300103	.695021	.004876
Transport	15639	.003751	.595512	.004260	.254117	.695664	.050219

Whilst there are mixed messages from these error statistics, there is no strong indication that the forecasts would be successful and it is not possible to draw inferences about efficiency.

8.3.3 Maintained regressions with just significant coefficients

The forecasts were performed on the 26 regression equations, using all regressed coefficients, irrespective of their significance. An alternative approach would be to drop those coefficients that are not significantly different from zero. For forecasting purposes the equations can be grouped as: Near Random Walks; a variety of formats but all with GARCH; and Auto Regressive.

- Near Random Walks

FTSE All Share Index	$R_t = -.747066 + .098786Y_{t-1} - .000065t + \varepsilon_t$
Forestry & Paper	$R_t = -.412467 - .059901Y_{t-1} + \varepsilon_t$
Personal Care & Household Products	$R_t = -.277770 + .039704Y_{t-1} - .000122t + \varepsilon_t$

where all three have drift, but only Forestry & Paper has no trend.

- GARCH

For those processes that had GARCH in the variance, removal of the non-significant coefficients gives the following mean equations (at this point the variance regression is not given), irrespective of whether a) the mean process was based on a random walk or AR(1) and b) ignoring various versions of GARCH. The GARCH process means that the error term ε_t no longer has a constant variance, so adding an additional factor to the forecasting.

Food Production & Processors	$R_t = \varepsilon_t$
Household Goods & Textiles	$R_t = \varepsilon_t$
Real Estate	$R_t = \varepsilon_t$
Transport	$R_t = \varepsilon_t$
Software & CPU Services	$R_t = \varepsilon_t$
Leisure & Hotels	$R_t = \varepsilon_t$
Auto & Parts	$R_t = \varepsilon_t$
Insurance	$R_t = \varepsilon_t$

Telecommunication Services	$R_t = \varepsilon_t$
Electricity	$R_t = -.306218 + \varepsilon_t$
IT Hardware	$R_t = -.288330 + \varepsilon_t$
Mining	$R_t = -.236758 + \varepsilon_t$
Beverages	$R_t = .356941 + \varepsilon_t$
Engineering	$R_t = .001316 + \varepsilon_t$
Investment Companies	$R_t = .000934 + \varepsilon_t$
Media & Entertainments	$R_t = .001385 + \varepsilon_t$
Speciality & Other Financials	$R_t = -.000038t + \varepsilon_t$
Electro & Electrical Equipment	$R_t = .245544\ R_{t-1} + \varepsilon_t$
Health	$R_t = .001717 + .328685\ R_{t-1} + \varepsilon_t$

Apart from the last two which are autoregressive, the others have the basic 'look' of a random walk, with or without drift and trend, but the conditional variance of the error term precludes the conclusion that they cannot be forecast and so they cannot be viewed as being efficient at this stage.

- Auto Regressive

The four non-GARCH AR(1) series all have significant coefficients, but a constant variance in the error term.

Construction & Building Materials	$R_t = .000965 + .222377\ R_{t-1} + \varepsilon_t$
General Retailers	$R_t = .001415 + .268872\ R_{t-1} + \varepsilon_t$
Pharmacuticals & Biotec	$R_t = .001665 + .127899\ R_{t-1} + \varepsilon_t$
Support Services	$R_t = .001112 + .340638\ R_{t-1} + \varepsilon_t$

- Unexplained

The final index Food & Drug Retailers is unexplained.

8.3.4 Forecast error statistics with just significant coefficients

Seventeen of the above are now seen as random walks, the majority pure random walks, one a random walk with trend and a further seven being a random walk with drift. As with the earlier removal of the first three, these can now be dropped as there is no benefit from attempting to forecast random walks. Of the remaining nine, seven have not changed their coefficients as all were significant, but two have dropped coefficients and are reforecast to assess the impact on the forecast error statistics of dropping the non-significant coefficients. A comparison of the results is shown in Table 43, with the proportions expressed as percentages for ease of comparison.

Table 43 Comparative Forecast Error Statistics for non-random regressions

Name	Ref		TIC	Bias %	Var %	Covar* %
Electro & Electrical Equipment	15593	With all coefficients	.872400	4	95	1
		Just significant coeffs	.707470	45	37	19
Forestry & Paper	15595	With all coefficients	.648779	13	78	9
		Just significant coeffs	.269527	78	18	6

*May not sum to 100% due to rounding.

The error statistics are now of marginally more use as a comparison can be made between the errors with all regression coefficients in the forecast and those with just the 5% significant coefficients. With Electro & Electrical Equipment there is some improvement in both the TIC and the increased covariance proportion: for this index the reduced equation would be more suitable for forecasting. Secondly, in the case of Forestry & Paper there is a large improvement in the TIC but the covariance proportion has fallen slightly and is at a very low level; based on the TIC the reduced form may be a slightly better forecast equation. Therefore the subsequent forecasts will use the following formats:

FTSE All Share Index	$R_t = -.747066 + .098786Y_{t-1} - .000065t$
Construction & Building Materials	$R_t = .000965 + .222377\ R_{t-1}$
Electro & Electrical Equipment	$R_t = .245544\ R_{t-1}$
Forestry & Paper	$R_t = -.412467 + .059901Y_{t-1}$
General Retailers	$R_t = .001415 + .268872\ R_{t-1}$
Health	$R_t = .001717 + .328685\ R_{t-1}$
Pharmacuticals & Biotec	$R_t = .001665 + .127899\ R_{t-1}$
Personal Care & Household Products	$R_t = -.277770 + .039704Y_{t-1} - .000122t$
Support Services	$R_t = .001112 + .340638\ R_{t-1}$

All other indices' return time series are pure random walks, random walks with drift and/or trend or, in one case, unexplained, albeit the majority have GARCH.

8.4 Forecasts

8.4.1 Forecasting approach

It is unfortunate that Monday 3rd May 2004 was a Bank Holiday in England and Wales, as this is within the ten day period for forecasting. Earlier analysis, as discussed, 'filled' gap days with average index values. An alternative would be to forecast just for the six days to 30th April 2004, giving limited data for consideration. The following calculations of forecasts will continue with ten day forecasts but will not fill the gap on the Bank Holiday, so avoiding any spurious results from treatment of days when the London Stock Exchange was closed. The initial comments are made just for one of the nine forecastable regressions, in this case the FTSE All Share index, so as to consider various factors relating to forecasts. This is then extended to the other eight.

Table 44 shows the basic data resulting from the regression equation

$$R_t = -.747066 + .098786Y_{t-1} - .000065t$$

Over the ten working day forecasting period a passive manager who held the whole index would have achieved a return of the sum of the daily returns (log normal returns are additive), giving the sum for 23rd April to 7th May of -.031063 or -3.1063%. An active manager with a one day forecasting horizon, at the end of each day having run the next day's forecast, and holding the index, would logically go liquid if the next day's forecast indicated a negative return. This could be adjusted using Goodacre et al's (1999) 1% costs, so the forecast of a return more negative than -1% would be a sell indicator. Similarly, a liquid active manager would buy the index if the forecast return was greater than 1%.

Table 44 FTSE All Share Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	-0.000483	0.000797		0
6th April 2004	-0.000454	0.000327		0
27th April 2004	-0.000471	0.000331		0
28th April 2004	-0.000487	-0.010727		0
29th April 2004	-0.001596	-0.002551		0
30th April 2004	-0.001897	-0.006722		0
4th May 2004	-0.002610	-0.000160		0
5th May 2004	-0.001591	0.003472		0
6th May 2004	-0.001297	-0.011122		0
7th May 2004	-0.002445	-0.004708		0
Total	-0.013331	-0.031063	0	0

Examination of the forecasts shows that, on 22nd April, a liquid manager would stay liquid for the 23rd and also on each of the subsequent nine days as the next day's forecast was always negative. The net return would thus be 0%, compared to a fully invested passive manager's loss of 3.1063%. Alternatively, a fully invested active manager would logically decide each day to stay invested as the negative forecast was always less than the 1% dealing cost, producing a loss of 3.1063%. If, however, the trading costs are ignored, then the decision would be to liquidate immediately and stay liquid, giving a return of 0%. This approach suffers from the use of one day forecasts: if on 22nd April a ten day forecast is performed, with a negative return of .1% per day, then the decision may be made to go liquid, based on two weeks rather than the more incremental daily decision. There are two immediate problems with this: firstly, the longer the forecast period the greater the forecast error; secondly, why ten days rather than (say) five, or 20? To get round this, subsequent assumed decisions will be based on gross return, i.e. ignoring trading costs, and will be on a daily basis irrespective of the size of the forecast return. To narrow the number of outcomes it will also be assumed that any manager is fully liquid or not invested in the index at the end of 22nd April 2004. On this basis the active manager will outperform the passive manager by 3.1063% by being liquid at the start and staying liquid for all ten days.

8.4.2 Forecasts of non random sectors' data generating processes

For the Construction & Building Materials index, the passive manager would lose 1.3455% (Table 45). The initially liquid active manager would buy the index at the end of 22nd, sell for 29th, buy for 30th, sell for 4th May and then buy and hold for the rest of the period. The effect being to achieve the actual return on days of positive forecasts and nil returns on days of negative forecasts, irrespective of the actual return. A return over the ten days of -1.0532% which is better than the passive result by 0.2933 percentage points due to removal of the actual losses on the two days of negative forecasts, but achieved at the cost of five trades.

Table 45 Construction & Building Materials Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	0.001117	-0.001889	Buy	-0.001889
6th April 2004	0.000545	0.002241		0.002241
27th April 2004	0.001463	0.002040		0.002040
28th April 2004	0.001419	-0.004607		-0.004607
29th April 2004	-0.000060	-0.002763	Sell	0
30th April 2004	0.000351	-0.005124	Buy	-0.005124
4th May 2004	-0.000174	-0.000160	Sell	0
5th May 2004	0.000929	-0.001688	Buy	-0.001688
6th May 2004	0.000590	-0.000001		-0.000001
7th May 2004	0.000965	-0.001504		-0.001504
Total	0.007145	-0.013455	5	-0.010532

The same approach for Electro & Electrical Equipment is more successful, with the active manager being liquid for five days, four of which experienced negative actual returns. Table 46 shows that the passive strategy generates a loss of 0.8759% compared to an active gain of 1.1741%, after trading three times, a gross abnormal return of 2.05%. It is the case, in this and all other of the nine forecastable indices, that the assumed trade happens seconds before close on the day the forecast is undertaken. Thus changes in the index post trade are ignored in the decision making process, an assumption that could be seen as casting doubt on the validity of the process. The tables show this buy or sell decision on the day it takes effect, i.e., at the end of 22nd April the next day's forecast is positive so the Trade colum shows "buy" for the 23rd.

Table 46 Electro & Electrical Equipment Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	0.000374	0.008329	Buy	0.008329
6th April 2004	0.002045	0.010074		0.010074
27th April 2004	0.002474	0.001278		0.001278
28th April 2004	0.000314	-0.001442		-0.001442
29th April 2004	-0.000354	-0.005256	Sell	0
30th April 2004	-0.001291	-0.006328		0
4th May 2004	-0.001554	-0.000160		0
5th May 2004	-0.000039	-0.009958		0
6th May 2004	-0.002445	0.001203		0
7th May 2004	0.000295	-0.006498	Buy	-0.006498
Total	-0.000181	-0.008759	3	0.011741

For Forestry & Paper, Table 47 sets out the forecast and actual returns. The forecast performed late on 22nd April shows an expected negative return for 23rd so the active manager would stay liquid. All other forecasts are negative so there are no further trades. Over the ten days the passive manager would show a loss of 0.1601% compared to a nil return by the active manager. Ignoring costs, active management outperforms passive.

Table 47 Forestry & Paper Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	-0.009606	-0.000160		0
6th April 2004	-0.009606	-0.000160		0
27th April 2004	-0.009606	-0.009697		0
28th April 2004	-0.010178	-0.000160		0
29th April 2004	-0.010178	-0.000160		0
30th April 2004	-0.010178	-0.009789		0
4th May 2004	-0.010754	-0.000160		0
5th May 2004	-0.010754	-0.000160		0
6th May 2004	-0.010754	0.009469		0
7th May 2004	-0.010178	0.009377		0
Total	-0.101793	-0.001601	0	0

For the General Retailers index, Table 48 shows the active manager undertaking three transactions, so as to be liquid just for 30th April. This was a correct decision as that day's actual performance was negative and resulted in an excess return over the passive manager of 0.1665%.

Table 48 General Retailers Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	0.002062	0.002896	Buy	.002896
6th April 2004	0.002194	0.001867		.001867
27th April 2004	0.001917	0.000427		.000427
28th April 2004	0.001530	0.007276		.007276
29th April 2004	0.003371	-0.007972		-.007972
30th April 2004	-0.000729	-0.001665	Sell	0
4th May 2004	0.000967	-0.000160	Buy	-.000160
5th May 2004	0.001372	-0.001716		.001716
6th May 2004	0.000954	-0.000977		-.000977
7th May 2004	0.001152	0.003675		.003675
Total	0.014791	0.003651	3	.005316

Table 49 indicates that with Health, the active manager will go liquid for two non-adjacent days, resulting in four trades and an excess return over passive management of 0.0791%.

Table 49 Health Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	0.004228	0.000101	Buy	.000101
6th April 2004	0.001750	-0.002496		-.002496
27th April 2004	0.000896	0.000007		.000007
28th April 2004	0.001719	-0.000133		-.000133
29th April 2004	0.001673	-0.003747		-.003747
30th April 2004	0.000486	-0.006952		-.006952
4th May 2004	-0.000568	-0.000160	Sell	0
5th May 2004	0.001664	0.000254	Buy	.000254
6th May 2004	0.001800	-0.005429		-.005429
7th May 2004	-0.000067	-0.000631	Sell	0
Total	0.013582	-0.019186	4	-.018395

Table 50 shows that for Pharmacuticals & Biotec the active manager is very active, trading on seven of the ten days to generate a return above that of the passive manager of .007993 or 0.7993%.

Table 50 Pharmacuticals & Biotec Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	0.002104	-0.011952	Buy	-.011952
6th April 2004	0.000126	-0.044779		-.044779
27th April 2004	-0.004072	0.007841	Sell	0
28th April 2004	0.002658	-0.004205	Buy	-.004205
29th April 2004	0.001117	-0.015625		-.015625
30th April 2004	-0.000343	-0.015542	Sell	0
4th May 2004	-0.000333	-0.000160		0
5th May 2004	0.001635	-0.021682	Buy	-.021682
6th May 2004	-0.001118	-0.000132	Sell	0
7th May 2004	0.001638	0.005787	Buy	.005787
Total	0.003411	-0.100448	7	-.092455

The penultimate forecastable index is that of Personal Care & Household Products. Forecast and actual returns are given by Table 51. As can be seen, the active manager stays liquid for the whole period, giving a zero return which is 6.0739 percentage points better than the tracker.

Table 51 Personal Care & Household Products Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	-0.003769	-0.003481		0
6th April 2004	-0.004023	-0.016933		0
27th April 2004	-0.004811	0.009938		0
28th April 2004	-0.004532	-0.023882		0
29th April 2004	-0.005596	-0.027983		0
30th April 2004	-0.006822	-0.025985		0
4th May 2004	-0.007970	-0.000160		0
5th May 2004	-0.007656	0.024584		0
6th May 2004	-0.006796	-0.000160		0
7th May 2004	-0.006918	0.003325		0
Total	-0.058893	-0.060739	0	0

Support Services, the final index under question, also has a fairly active manager (Table 52), avoiding two negative returns but missing out on one day with a positive return. The net effect being to outperform the passive manager by 0.035 percentage points.

Table 52 Support Services Index Forecasts

Date	Forecast Return	Actual Return	Trade	Active Manager
23rd April 2004	0.001322	0.002405	Buy	.002405
6th April 2004	0.001931	-0.000614		-.000614
27th April 2004	0.000903	-0.001629		-.001629
28th April 2004	0.000557	-0.004160		-.004160
29th April 2004	-0.000305	-0.000272	Sell	0
30th April 2004	0.001019	-0.003725	Buy	-.003725
4th May 2004	-0.000157	-0.000160	Sell	0
5th May 2004	0.001057	-0.006274	Buy	-.006274
6th May 2004	-0.001025	0.000082	Sell	0
7th May 2004	0.001140	-0.001815	Buy	-.001815
Total	0.006442	-0.016164	7	-.015814

8.4.3 Use of historic regressions in forecasting

These forecasts must be viewed with some caution. Earlier in this chapter concern was expressed about the accuracy or validity of the coefficient of determination and its applicability in deciding whether a regression was of any use. A similar concern exists with use of historic regressions in forecasting. These are best expressed by two papers. The first is that of Gordon and Kammen (1996) who argue that models where there is some form of assumption as to normality of distribution of forecast errors suffer from leptokurtosis. This can be particularly so in the case of overconfidence which in some cases they view as being systemic in the forecasting of returns. For ease of presentation, the forecasts in this chapter have been point rather than interval, i.e. they have not been accompanied by confidence intervals. Gordon and Kammen suggest that had interval forecasts been made, then "processes correcting for stationarity may describe stock levels and variances, but the resulting confidence intervals (will) continue to underestimate the probability of shocks to returns to a significant degree" (p. 196). This could, for example, be a reason why in forecasts of the All Share Index shown in Figure 4 the trend is correctly identified, but extreme values are not forecast. Their proposed solution (not followed up here) is that a correction should be applied based upon the Shlyakhter, Kammen et al model (1994, cited in Gordon and Kammen, 1996) which uses compound exponential distributions to generate confidence intervals.

The second area of concern in relation to forecasting sector index returns is that expressed by Timmermann and Granger (2004). This paper is less to do with forecasting per se and is more focused on issues surrounding market efficiency, in particular, issues surrounding model specification, non stationarity in the return series and choice of approach. The problems of 'model specification' are well exemplified by the method used in this thesis, namely a univariate time series with or without GARCH, which has by definition ignored all other model types (event studies, high frequency data, exponential modelling, long term mean reversion, panel data, cross sectional analysis and many others). Selection of any one model (which raises further questions about the selection method) leads to their suggestion of "a market...being efficient locally in time" (p. 20). Linked with the identification of new forecasting models is the concept of a 'honeymoon period' where, for a short time, the model is successful prior to its wider use, at which point the temporary inefficiency is arbitraged away. In support of the Efficiency Hypothesis, they posit that even if a model had predictive powers, but was one of several competing models, then its ex post success would not have been evident ex ante and as such does not invalidate EMH.

The second problem of Timmerman and Granger is that use of a model may cause a stationary series to break down and become non stationary, thus invalidating the model. This is viewed as the market 'learning' how to use a new model such that predictable returns models will probably have their parameters updated on a rolling basis, generating ex post serial correlation and loss of stationarity. Thirdly there are issues surrounding the 'choice of approach' including: size of the time series (which may not be opimal for stationarity); thick versus thin modelling (where decisions are based on the outputs of many models, not just the best) or use of one modelling technique versus "all techniques…applied to all returns at all times" (p. 23) (a method identified as costly).

Whatever the view of these two papers, it is obviously the case that forecasting with univariate time series regression should be viewed with caution.

CHAPTER NINE SUMMARY AND CONCLUSIONS

9.1 The Sector Regressions and their Forecasts

9.1.1 Industrial sectors where passive management is appropriate

The sample evidence supports the conclusion that three of the sector indices are pure random walks. These are:

Aerospace & Defence (15577),
Chemicals (15585),
Oil & Gas (15619).

If they are random walks, then it is not possible to forecast the next day's return or index value, their best estimate for time t+1 is that of the value at time t, in that the error term is white noise. Earlier mention has been made of the point that lack of randomness does not automatically mean inefficiency, but there is general acceptance that evidence of randomness does indicate efficiency. The conclusion for these three UK equity industrial sector indices is that they are strong efficient and as such there is no point in using active management; they should be managed passively.

9.1.2 Industrial sectors with GARCH and no management conclusion

The previous chapter on forecasting dropped the non significant regression coefficients. This showed that nine indices became pure random walks in the mean equation but had GARCH in their variance processes. These are:

Auto & Parts (15579),
Food Production & Processors (15599),
Household Goods & Textiles (15605),
Insurance (15609),
Leisure & Hotels (15613),
Real Estate (15627),
Software & CPU Services (15630),
Telecommunication Services (15641),
Transport (15639).

It is tempting to conclude that their random processes result in the same conclusion as above. Unfortunately the GARCH process in their variances could theoretically give scope for trading decisions based on the regressions. For instance, an increase in variance may be a sell signal for a low risk investor. Alternatively, changes in variance may feed into a derivatives model, indicating a price change in the derivative that could have a commensurate impact on the underlying. On the other hand, the current UK derivatives market does not have industrial sector products, so any actions would need to be via the over the counter market, a process that would increase both risk and transaction costs. There can be no formal conclusion as to efficiency and likewise there can be no formal conclusion with regard to management style.

Similarly there were seven sector indices where their logarithmic returns were random walks with drift and there was GARCH. These are:

Beverages (15581),

Electricity (19897),

Engineering (15591),

Investment Companies (15610),

IT Hardware (15607),

Media & Entertainments (15615),

Mining (15617).

Three of these regressions' constants were negative and four positive. Had all of the random processes had consistently positive or negative coefficients, then it could have been the case that the earlier adjustment for the market's risk premium was at the wrong value. This is not so here, but it may be considered that these seven series have 'unique' equity sector risk premiums with their constants being the 'adjustment' to the full market equity risk premium. Whatever the cause, they are random walks, but the drift in all three of the negatives and one of the positives is of a size such that, when combined with the GARCH points from above, could cast doubt on their efficiency in that the drift may be greater than the white noise of the error term. The conclusion is as above, or rather there is no conclusion, but the possible existence of a sector risk premium makes inefficiency more likely and thus active management more feasible.

One index was a random walk, not with drift but with trend. This also had GARCH in the residuals. The index was:

Speciality & Other Financials (15633).

The trend is negative and small but significantly different from zero. Whilst its negative trend could act as a deterrent to a risk averse investor and the existence of

GARCH raises the same issues as above, its conclusion is as above, that inefficiency is probably more likely and active management is possibly feasible.

9.1.3 Industrial sectors with management style based on forecasts

Two sector indices are close to random walks. These are:

Forestry & Paper (15595),

Personal Care & Household Products (15621).

Although lack of randomness does mean there is no automatic conclusion of efficiency, it does not have the corollary that they are not efficient. The Thiel Inequality Coefficient error statistics are 0.269527 and .682786 respectively, indicating that Forestry & Paper is possibly more likely to be inefficient than Personal Care & Household Products. The forecasts result in active management's abnormal gains over passive management of 0.1601% for Forestry & Paper and a much larger 6.0739% for Personal Care & Household Products. A contrary and stronger conclusion is that Personal Care & Household Products is possibly more likely to be inefficient than Forestry & Paper.

Four indices are autoregressive without GARCH and two with GARCH (indicated by G). The index, Thiel Inequality Coefficient and forecast abnormal gains from active management are:

Construction & Building Materials (15583):	0.864482	0.2933%
General Retailers (15601):	0.801215	0.1665%
Pharmacuticals & Biotec (15623):	0.937687	0.7993%
Support Services (15635):	0.859718	0.035%
Electro & Electrical Equipment (15593) G:	0.707470	2.05%
Health (15603) G:	0.753024	0.0791%

For the processes without GARCH, the existence of such data generating processes in theory means rejection of the conclusion of efficiency but the Thiel Inequality Coefficients are all relatively high and the results of the forecasts show either negative or very low positive gains. Strong efficiency must be rejected, but the sector indices are either weakly efficient or not efficient. The same view cannot be taken for Health, as the existence of GARCH makes inefficiency more likely, so no immediate conclusion. For Electro & Electrical Equipment the forecast shows scope for a fairly large gain that is likely to be above excess costs of active management. This sector index cannot therefore be viewed as strongly efficient.

These last two groups of two and eight industrial sectors respectively may be weakly efficient or not efficient. The previous chapter suggested that the excess cost of active management over passive was 0.023% per day plus 1% for each trade and Tables 44 to 52 indicated the number of trades over a ten day period. Table 53 below uses this to calculate the excess costs if these forecasts are acted on, where excess cost equals 1% times number of trades plus tens days' active management costs at .023% per day (.2302%).

Table 53 Net Gains from Active Management

Name	Ref	Trades	Forecast's Excess Return %	Excess Costs %	Net Gain %
Construction & Building Materials	15583	5	.2933	5.2302	-4.9369
Electro & Electrical Equipment	15593	2	2.05	2.2302	-.1802
Forestry & Paper	15595	0	.1601	0.2302	-0.0701
General Retailers	15601	2	.1665	2.2302	-2.0637
Health	15603	3	.0791	3.2302	-3.1511
Personal Care & Household Products	15621	1	6.0739	1.2302	4.8437
Pharmacuticals & Biotec	15623	6	.7993	6.2302	-5.4309
Support Services	15635	6	.0350	6.2302	-6.1952

Only Personal Care & Household Products has a positive net gain and can be viewed as not efficient and therefore suitable for active management. The other seven have costs in excess of the gain and can be viewed as weakly efficient and not suitable for active management.

Finally there is one index that is unexplained, namely:

Food & Drug Retailers (15597).

No conclusion can be drawn with regards to efficiency, but the lack of a forecastable data generating process would make active management problematic. Thus it should be passively managed.

9.1.4 Summary of management style by sector

Sectors where the log normal index returns are pure random walks or the mean process is unexplained and there is thus no scope for forecasting, so the sectors can be assumed to be efficient are:

Aerospace & Defence (15577)

Chemicals (15585)

Oil & Gas (15619)

Food & Drug Retailers (15597).

Sectors where the log normal index returns have a deterministic mean process but the costs of active management outweigh the benefits, making them weakly efficient are:

Construction & Building Materials (15583)

Support Services (15635)

Health (15603)

Pharmacuticals & Biotec (15623)

Forestry & Paper (15595)

General Retailers (15601)

Electro & Electrical Equipment (15593).

The only sector where the log normal returns are not efficient and there is scope for a net gain from active management is:

Personal Care & Household Products (15621)

The other sectors do not have a conclusion. The existence of GARCH means that they may or may not be efficient and they may or may not be forecastable. Thus, from the 29 individual industrial sector share indices: four are efficient and candidates for passive management; five are weakly efficient and candidates for passive management; one is inefficient and could be managed actively; and 19 are such that a decision cannot be made. Figure 5 displays these results graphically.

The majority of the sector indices fall under the diagram's heading of "No decision as GARCH" where they can be viewed as being in one of two categories. Firstly, a pure random walk for the mean process, but with GARCH in the variance, in which case it is difficult to reach a firm conclusion as to their suitability for active or passive management. Secondly, those where there is a random walk with drift or trend for the means' data generating processes but the variances are again conditional.

Figure 5 **Suggested Management Styles**

Maintained regression	Passive Management	No decision as GARCH	Active Management
Unexplained	Food & Drug		
Pure random walk	Aero Chemicals Oil & Gas	Auto Food PP Household Insurance Leisure Real Estate Software Telecom Transport	
Random walk with drift/trend		Beverages Electrical Engineering Investment IT Media Mining Speciality	
Autoregressive	Construction Support Services General Retail Pharm & Bio	Health Electro	
Close to random walk	Forestry		Personal Care

9.2 The FTSE All Share Index

Section 9.1 above discusses the results of the tests on the sector specific sub indices. It is worth considering the All Share index in more detail, even though this is not the main focus of this research. The outcomes from the analysis for the main index are that the data generating process is a near random walk with drift and trend, there is no evidence of GARCH, the coefficient of determination is 4.9%, the Thiel Inequality Coefficient is 0.6 and the excess return from active management over passive management is calculated as 3.1063%. With the regression explaining almost 5% of the relationship, and a gross excess return of over 3%, then the All Share cannot be described as efficient and is a logical candidate for active management.

The main index contains some sub indices that are random, some with GARCH, some that are deterministic and one that is unexplained. This is not paradoxical, nor unexpected. The random indices have white noise as the error term, as have the deterministic processes, so their aggregation will still produce a white noise error term with a deterministic process. Similarly, the aggregation of various different deterministic processes may be expected to produce a new deterministic process. The interesting case is that many of the sub indices exhibit GARCH but this is not aggregated up to the main index. Although this has not been examined, it is assumed that the various impacts of the individual conditional variance processes either 'cancel' each other out, or are of sufficiently small magnitude so as not to reject the null of no ARCH at the market level, even though the null is rejected at the sector level.

This does give the investor an additional factor to consider, in that the Myners Review is recommending active management where appropriate. Should a fund manager therefore be active in just a few sectors, whilst being passive in the other sectors (e.g. a tracker fund with satellites) or should the whole market be defined as applicable for active investment? It is assumed that costs would suggest the former and not the latter.

The same issue, but viewed from a different angle, casts doubt on much research into efficiency. The Literature Review chapter highlighted many papers where a wide range of efficiency tests have been applied to markets as measured by their aggregate or market index. It is highly possible that the same position as applies in this research applies to those papers; namely that certain sectors of those markets are efficient (weakly or strong) and the non-efficiency of the market index as a whole is a function of some of the sectors being inefficient.

9.3 Conclusions

The 'trigger' for this thesis was the Myners Review of Institutional Investment in the United Kingdom (2001), in particular the suggestion that passive management is a free ride, that more effort/cost should be put into strategic asset allocation and that each asset class should have "sufficient freedom for active management to occur" (p. 22) if active management is appropriate. The definition of that 'appropriateness' has been based upon the concept of market efficiency; specifically, the format which assumes that prices fully reflect all available information, either strongly in the case where information and trading costs are zero, or weakly where benefits do not exceed costs. The concept of asset class has been viewed as the 29 FTSE All Share Index industrial sector sub indices. Finally, the tests of market efficiency on these sectors have been based upon univariate time series analysis, attempting to establish if they are random or not, forecastable or not, and if forecastable, capable of excess returns from active management.

The use of univariate time series analysis is not new, it is a well established method of finance and economics research. The factors that do make this thesis unique and a contribution to our understanding of finance are threefold. Firstly, the study of industrial sector indices is a very under-researched area; the literature review shows many studies at the firm level or market level, but only a small number that give some limited consideration at the sector level, and even then there is a fairly high aggregation into just a few sectors. Secondly, the use of the BDS tests to establish whether a possible data generating process produces residuals that are IID is a rarely utilized technique in the vast majority of papers on tests of efficiency. Failure to apply this test must cast doubt on many conclusions in papers that have sought to identify a mean process, but not established if there were further 'messages' in the residuals. Thirdly, the tests for stationarity and random walks have been comprehensive, considering all three types of random walks. This contrasts with many papers where the tests are solely on a pure version with neither drift nor trend.

The immediate conclusion of this thesis is that the Myners' suggestion is valid. There is scope for active management to take place in terms of strategic asset allocation. Unfortunately that is only appropriate for one of the 29 sectors, that of Personal Care & Household Products. The other sectors are shown as being efficient (in either form) or not capable of being identified as 'appropriate'.

number of non-efficient sectors appropriate for active management	1
number of strong efficient sectors appropriate for passive management	4
number of weakly efficient sectors appropriate for passive management	5
number of sectors where no decision can be made	19

The UK equity market, as measured by the All Share Index, is also shown to be inefficient, so it can be concluded that if this level of aggregation is used to define an asset class, then it should be actively managed. The logical way to proceed, however, would be to manage it passively as a 'core' apart from a 'satellite' which focused on Personal Care & Household Products.

A further conclusion is that if the UK market is inefficient in aggregate, but many of the sectors are strong or weakly efficient, then previous research on market level efficiency should have considered sectoral differences. The literature on efficiency is vast, with hundreds of published papers addressing market efficiency for many countries, over many different periods, using a variety of tests, so it is possibly the case that some of these macro level tests hide the sector level differences. The aggregation of sectors up to a total market, when some are efficient and some are not could be hypothesised as the cause of the tension in the intersubjective consensus in relation to efficiency: the debates about mistakes versus anomalies or the 'yes performance persists' versus 'no it doesn't' discussions could be viewed as manifestations of testing the sum of the sectors rather than each one in turn. Causes of the sectors' impacts on the differences in total market efficiency test conclusions are likely to be varied but three are proposed. It may be that a sector is "efficient locally in time" (p. 20) rather than the market as a whole, as suggested by Timmerman and Granger (2004), so that over one period the efficient sectors combine to produce an efficient market whereas in a later period shifts in certain individual sectors produce an inefficient 'whole'. Secondly, the cause could be more pragmatic, with just different returns by sector increasing the weighting of an inefficient sector to the point where its size then dominates the aggregation, so tipping the market from efficiency to inefficiency. Thirdly, although the method used in this thesis has been univariate, there may be state variables or cross-sectional data indicating common attributes among the efficient sectors, so that as the independent variables change, they drive certain sectors to change their efficiency status. These three possible causes could of course be interlinked: an inefficient sector may be identified, resulting in trading activity which over time arbitrages away the inefficiency.

There are obviously many caveats that should be considered in relation to the conclusions. Some of these are considered below, as areas for further research, but it is worth some final reflection of Type I and II errors. As discussed in the chapter on methodology, the approach taken in this thesis is quantitative, derived indirectly from the Austrian School and utilised extensively in American finance research generally, and at the University of Chicago particularly. Virtually all of the analysis is dependent upon hypothesis testing and so the conclusions must be viewed in the light of Type I errors, the situation where the null hypothesis was true but the test statistic indicated its rejection and Type II errors, the case where the null hypothesis was not true but test statistic did not indicate its rejection.

In common with much research in this area, the hypothesis tests have been performed using 5% significance. This could have been replaced with (typically) 10% or 1%, with a commensurate impact on the conclusions and the power of the tests. Unfortunately there is no specific process for setting the level of significance or confidence limits. The power of the tests could also have been increased by using a larger sample size, compared to the 252 used here. This could be achieved by a longer period or higher frequency data. The former would then suffer from loss of accuracy if the time series had short term trends and the latter was not possible as the appropriate data was not available at a frequency greater than daily. Thus, as with all hypothesis test-based research the process is a compromise and the results or conclusions suffer from Type I and II errors.

9.4 Further Research

The use of BDS tests and the breakdown of a country's equity market into industrial sectors give very wide scope to the application of this approach to other equity markets, but that would be a huge exercise encompassing most of the world's capital market places. Its use would be relevant, however, not only to fund managers and consultants in advising on strategic asset allocation decisions, but also to capital market regulators who seek to ensure that their markets are efficient.

Similarly, the approach could be used with other types of efficiency tests. The focus here has been on a time series being random or deterministic, whereas the Literature Review shows numerous different types of tests. A sectoral analysis using filters (trading rules) or mean reversion or speed of reaction between derivatives and underlyings or time effects or size effects all could be revisited at the sub index level. It would be problematic to attempt event study analysis with sectors, as the need to identify the 'event' would preclude any meaningful study.

In the realms of this thesis, there are a variety of areas for consideration in taking the research further. Firstly, the analysis has been univariate, which is possibly acceptable for those indices where the results showed randomness in the log returns. For the non random sectors the extension of the regressions to multivariate analysis could be a fruitful area. This could be at the macro level, where the variables are economic indicators such as GDP growth or inflation, or a more micro-based review. The latter would be interesting for all sectors, to test if there are various attributes that determine randomness or its lack. A second consideration may be to revisit the many sector indices where the mean generating regression was random but the variance was conditional, as evidenced by GARCH. Chapters 7 and 8 on the analysis did briefly utilise the various forms of GARCH, but greater consideration could be given to tests for (say) GARCH in mean. The algorithm followed in the analysis has been to stop when a data generating process has been identified that has nothing left in the residuals, hence the numerous GARCH solutions that make firm conclusions difficult. It may be the case that further examination shows a later version of GARCH also not rejecting the BDS null but having a much greater forecasting ability, so allowing a conclusion of inefficiency and scope for active management. Alternatively, the forecast method could be amended so as to estimate changes in volatility, which could be of benefit to the active manager.

The third major consideration for further research is of course to revisit the size and location of the sample. This could be extended to include many years, so seeking those sectors where efficiency is a long term attribute. It could be duplicated on (say) an annual basis, but over a long period to establish if, as time passes, the various sectors 'drift' into and out of efficiency and if indeed this is forecastable. Fourthly, it could be interesting to follow up the possibility of sector specific equity risk premiums. This would logically seek factors, both macro and micro, that attempt to explain the premium.

9.5 Endnote

Chapter 3 on methodology gave some consideration to the work of Hayek, in particular the subjective interpretation by economic players of new information and the unknown rules about how it should be interpreted. This is central to discussion on the efficient market hypothesis and had interesting adumbrations for the growth of behavioural finance. The following reflections are based on "Roads to Freedom: essays in honour of Friedrich A von Hayek" (1969); all references are to its contributors.

Hayek viewed growth in economic understanding as subjectivism (in contrast to formalism). Lachmann saw this as "Spontaneous action …(being)… transformed into a response to stimulus" (p. 96). This viewpoint meshes well with efficiency, in that it is new information that triggers a possible change in investors' expectations about index values. If the market or rather a sector is efficient, then it is only changes in those expectations that generate movement away from the mean value, so generating the random walk. Lachmann took this further, linking Hayek's thoughts with those of Keynes whereby it is "the unfathomable subtlety, complexity and mutability of the influences which bear upon the decision to invest" (p. 99). The strategic asset allocation decision of fund managers, when examined from this philosophical viewpoint, makes passive investment much more attractive than attempting to cope with unfathomable subtlety. This can become paradoxical however, for he argues that:

> The market is a process of continuous change, not a state of rest. It is clear that what keeps this process in continuous motion is the occurrence of unexpected change as well as the inconsistency of human plans (but) ...it is likely that plans would gradually become consistent as men come to learn more about their environment." (p. 91)

If this is the case, then the move towards passive management due to strong or weakly efficient markets will remove one of the causes of the market's continuous change. If this study has found only one sector that warrants active management, and if all investors took the view to manage passively in all other sectors, then the UK equity market would slowly move towards this (undesirable?) state of rest.

Buchanan similarly discusses Hayek's use of subjectivism in relation to economic behaviour, where "in the logic of choice, choosing becomes a subjective experience" (p. 52). The Myners Review discusses the role of the trustee and the trustees' reliance on consultants or peer benchmarking in the strategic asset allocation decision. In effect, reliance on peer grouping or consultants is a way of removing the subjective experience by transferring the choice to someone else. If the majority of the sectors in the UK equity market should not be actively managed because they are strong or weakly efficient, then this removes the domestic equity market decision's subjectiveness and the trustee can recommend passive management. Yet again, as with Lachmann's logic, this removes one of the drivers that make the equity market dynamic. It may therefore be the case that even if the market were to be totally efficient, the strategic asset allocation decision should be encouraged towards active management, if only to prevent stultification and to make it dynamic, changing and vibrant.

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